Report
Focused Soil Vapor Investigation
North Lot Development
Seattle, Washington

November 19, 2010

Prepared for

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1.0 INTRODUCTION

This report presents the results of focused soil vapor investigation activities that were completed at the North Lot Development property (Property) on October 15, 2010. The Property is located at the southeast corner of the intersection of South King Street and Occidental Avenue South in Seattle, Washington (Figure 1). Soil vapor investigation activities were performed by Landau Associates at the request of North Lot Development, LLC (NLD) to collect data to document benzene concentrations in soil vapor at selected locations in the northwest portion of the Property in the area formerly occupied by gasoline stations and where benzene and gasoline have been detected in soil. Soil vapor investigation activities were performed in accordance with the *Soil Vapor Investigation Work Plan, North Lot Development* (Work Plan; Landau Associates 2010a). The Work Plan was approved by the Washington State Department of Ecology (Ecology) per the Opinion Letter dated October 5, 2010 (Ecology 2010). The nature and extent of the soil and groundwater contamination at the Property is summarized in the Ecology Review Draft Report: *Feasibility Study, North Lot Development* (Draft FS; Landau Associates 2010b).

The Draft FS includes focused excavation and offsite treatment or disposal of benzene- and gasoline-contaminated soil from the northwest portion of the Property as a remedial element to reduce the potential for vapor intrusion into buildings planned as part of future development of the Property. A remediation level for benzene in soil was developed in the Draft FS using the Johnson and Ettinger (J&E) Model for Subsurface Vapor Intrusion into Buildings (Johnson and Ettinger 1991) and the benzene concentrations detected in soil in the northwest portion of the Property. The modeling showed that removal of soil with benzene concentrations greater than the proposed remediation level [2,450 micrograms per kilogram (µg/kg)] would be protective of indoor air to an incremental cancer risk less than the regulatory level of $1x10^{-6}$.

Following its review of the Draft FS, Ecology requested that focused soil vapor sampling be conducted at the two locations where the highest benzene concentrations were detected in soil to calibrate the J&E modeling results and to allow for adjustment of the remediation level, as warranted based on the soil vapor data and additional modeling results, to ensure that the selected remediation level will be sufficiently protective of indoor air. The comments received from Ecology regarding the Draft FS and responses from the NLD team are documented in the response letter to Ecology dated September 7, 2010 (Landau Associates 2010c).

The objective of this report is to document soil vapor sampling activities, present and evaluate the analytical results for the soil and soil vapor samples, and support a remediation level for benzene in soil. The subsurface investigation included the collection and laboratory analysis of soil vapor and soil samples from the two locations requested by Ecology and one additional location selected to aid in evaluation of the data (Figure 2).

2.0 SOIL VAPOR AND SOIL SAMPLING

Soil and soil vapor samples were collected from the same locations to help identify the relationship between contaminant concentrations in soil and soil vapor and to aid in the justification of the site-specific model input parameters to make the J&E model results more representative for predicting site-specific benzene concentrations in soil that are protective of the vapor intrusion pathway. Soil and soil vapor samples were collected from the same locations and approximate depths where soil sampling in 2008 indicated the highest benzene concentrations at the Property or about 6 inches above the elevation of the groundwater table, whichever was shallower at the time of sampling. Each specific sampling location was selected from areas near the previous sample location where the asphalt showed minimal signs of cracking or deterioration.

The three 2008 sampling locations (B-23, B-26, and B-17) are shown on Figure 2. Two of the sample locations were located close to [i.e., within 1 foot (ft) of] the two previous soil boring/sampling locations that indicated the highest detected benzene concentrations in soil at the Property in 2008, B-23 and B-26, as requested by Ecology. The third soil sample location was located close to the 2008 soil boring/sample location (B-17) where the benzene concentration detected in soil (1,900 μg/kg) was close to the remediation level proposed in the Draft FS (2,450 μg/kg).

2.1 PREPARATORY ACTIVITIES

Prior to sample collection, preparatory activities included update and review of the project health and safety plan (HASP), locating and marking underground utilities, and the measurement of groundwater elevations at nearby monitoring wells. Underground utilities were marked by public and private utility locating services in the area of the investigation activities. All borings were located a minimum of 4 ft from any marked utility. Water levels were measured at nearby monitoring wells MW-2, MW-8, and MW-10 (Figure 2). Depth to groundwater was used for planning purposes to ensure that soil vapor and soil sample collection depths were above the water table.

2.2 SAMPLING METHODOLOGY

Per the Work Plan, the soil vapor samples were to be collected from the same depth at each location where the maximum benzene concentrations were previously detected in soil. During drilling, field screening with a photoionization detector (PID) indicated that the most concentrated presence of volatile contamination was in the depth range approximately 1 ft above the elevation of the groundwater table. Therefore, the soil and soil vapor samples were collected in a narrower range from depths between 6.5 and 8 ft below ground surface (BGS) versus the 2008 soil sampling depths of between 5 and 7.5 ft

BGS. Soil and soil vapor sampling activities were performed in accordance with the procedures identified in Section 2.2 of the Work Plan and are summarized in the sections below.

2.2.1 SOIL SAMPLING

Soil samples were collected using direct-push drilling and sampling techniques. Soil sampling was conducted prior to soil vapor sampling to facilitate the use of field-screening data (i.e., visual observations and PID measurements) to collect soil vapor samples at depths corresponding to the highest levels of contamination.

Soil samples were obtained from direct-push borings using a closed-piston sampling device with a 48-inch long, 1.5-inch inside-diameter core sampler. An environmental professional from Landau Associates was on site to supervise all drilling and sampling activities, prepare a descriptive log of each soil boring, and field-screen samples for possible contamination. All soil samples were collected in conformance with the Work Plan. Field-screening results (i.e., obvious signs of contamination, PID headspace analysis) are recorded on the boring logs (Appendix A). Headspace analysis was conducted by placing a representative portion of the soil in a sealable plastic bag, allowing the soil to vaporize inside the sealed container for 5 minutes, then inserting the PID tip into the bag to measure total volatile organic compounds (VOCs). All samples collected were visually described in the field in general accordance with the American Society for Testing and Materials (ASTM) D 2455, *Standard Recommended Practice for Description of Soils (Visual-Manual Procedure).*

One soil sample was collected for laboratory analysis from the deepest 1-ft interval above the water table at each boring; this was also the interval in which the maximum observed PID reading was observed in the field. All samples were collected using a laboratory-supplied coring device for collection of soil for VOC analysis [gasoline-range total petroleum hydrocarbons (TPH-G) and benzene] per U.S. Environmental Protection Agency (EPA) Method 5035A. Each VOC sampling device was preset by the sampler to collect approximately 5 grams of soil. The sample was collected directly from the soil of interest (i.e., an undisturbed portion of the soil core) using the coring device. The soil was transferred from the coring device to pre-weighed, laboratory-supplied vials. After the sample was collected, it was placed in a cooler on ice, cooled to 4ºC, and recorded on the chain-of-custody form. Samples were submitted to Analytical Resources in Tukwila, Washington for laboratory analysis under the appropriate chain-of-custody procedures. The soil samples were analyzed for TPH-G by Method NWTPH-G and benzene by EPA Method 8021B.

A soil sample was also collected at each boring location and analyzed for physical parameters, including organic carbon fraction, porosity, wet and dry bulk density, and grain size analyses, to document Property-specific soil conditions.

2.2.2 SOIL VAPOR SAMPLING

Soil vapor samples were collected using the direct-push drilling rig and a post-run tubing (PRT) system setup. Soil vapor sampling was also supervised and performed by an environmental professional from Landau Associates, and all vapor sampling was completed in accordance with the Work Plan. Field parameters measured during soil vapor sampling are detailed in Table C-1 in Appendix C.

The PRT setup allows polyethylene tubing to be inserted through the direct-push rod and connected to the bottom of the rod after the rod has been advanced to the selected sampling depth. The surface end of the tubing is connected directly to the purge and sampling pump. The PRT setup reduces the potential for leakage through the rod connections and eliminates the need to evacuate/purge air from the rods prior to sample collection. The sampling procedures are as follows:

- The direct-push rod was fitted with a PRT drive point holder.
- The direct-push rod was advanced to the location-specific sampling depth, which was selected based on the previous soil sampling depth and adjusted based on field observations and the depth of groundwater.
- Dedicated sample tubing and a PRT adapter were inserted down the sampling rods and connected to the point holder. The surface end of the tubing was fitted with a valve to allow the flow of air to be controlled.
- The direct-push rods were pulled back about 1 ft to allow the drive point to drop off and expose the tubing for sample collection.
- A surface seal of hydrated bentonite was placed around the top of the drill rods at the surface.
- A helium tracer leak test was conducted to evaluate leakage through the surface seal by comparing the concentration of the helium tracer contained in a shroud placed over the sampling equipment setup with the tracer concentration in vapor collected through the sample tubing. The general procedures for the leak test included: 1) Covering the sampling setup with a gas shroud (bucket) fitted with a notch (sealed with an inert modeling putty) to allow the end of the sample tubing to remain outside the shroud and be connected to a helium gas detector; 2) Pumping helium into the shroud; 3) Using a helium detector to measure helium gas concentrations in the air within the shroud to establish a baseline helium concentration; and 4) Measuring the helium concentration in vapor drawn through the sample tubing. The comparison of the helium concentration in vapor collected from the sample tubing with the baseline concentration was used to evaluate leakage through the surface seal to the sample tip below the ground surface. Helium was not detected in the vapor collected from the sample tubing at any of the soil vapor sampling points, indicating that no leaks were present throughout soil vapor sampling activities.
- The sample tubing was slowly purged for 5 to 10 minutes using a vapor purge pump to evacuate air from the sampling system.
- During purging, the flow rate was monitored, and a PID and multi-gas meter were used to evaluate the presence of VOCs within the air being evacuated along with the concentrations of oxygen and methane and the percent lower explosive limit (%LEL).

Measurements were taken immediately after the purging had begun and near the middle and end points of purging.

- Following purging, the valve was closed to prevent backflow of air into the sample tubing.
- The soil vapor sample was then collected by connecting the sample tubing to an individually certified, laboratory-provided, 1-liter Summa canister using an airtight fitting. The valves were opened and the canister was allowed to fill until the pressure valve on the canister indicated that the canister was full.
- After the canister was filled, an identification label was affixed to the canister with a zip-tie, the sample was recorded on the chain-of-custody form, and the sample canister was placed back into the cardboard shipping container for shipment to the laboratory.

As noted above, the laboratory-supplied Summa canisters arrived under a vacuum such that when the orifice was opened the canister filled with soil gas from the attached tubing. Each canister was outfitted with a critical orifice assembly that allowed the canister to fill gradually over the course of approximately 4 minutes. Field personnel ensured that the Summa canister seal was maintained and the valves were kept completely closed until the canister had been fully connected to the sample tubing so that ambient air was not allowed to enter the canister. The samples were packed and shipped to Columbia Analytical Services for analysis of benzene using EPA Method TO-15 low level analysis.

3.0 DATA RESULTS AND EVALUATION

This section presents an evaluation of the potential for vapor intrusion to result in benzene concentrations in indoor air greater than the Model Toxics Control Act (MTCA) modified Method B indoor air cleanup level for benzene of 1.4 micrograms per cubic meter ($\mu g/m^3$) in future buildings on the Property. The buildings to be constructed at the Property will not have first-floor residential use. Plans call for the on-Property buildings to have a ground-floor parking garage and commercial development; all residential units would be constructed on the third story and higher. The 1.4 $\mu g/m^3$ benzene cleanup level is protective of an occupational exposure scenario, modified from the standard Method B indoor air cleanup level (0.32 $\mu g/m^3$) to account for an occupational exposure frequency of 8 hr/day, 250 days/yr, as provided for when considering alternative exposure scenarios under Washington Administrative Code (WAC) 173-340-750(3)(d).

Table 1 presents the chemical concentrations and physical parameter values reported by the laboratory for the soil samples collected from the three borings. The three soil samples were collected from borings completed as near as possible to 2008 soil borings B-17, B-23, and B-26 (Figure 3). Soil samples from those three borings contained the highest benzene concentrations detected during the 2008 investigation. The 2010 benzene concentrations in soil (ranging from non-detect at a laboratory reporting limit of 24 μg/kg to a detection of 78 μg/kg) were approximately 20 to 1,000 times less than the concentrations detected at the same locations in 2008 (1,900 to 57,000 μg/kg). Although some reduction in concentrations may be expected from chemical degradation or natural attenuation over time, the magnitude of the reductions observed at the Property is likely the result of a high degree of spatial variability in the soil contamination.

The benzene concentrations detected in the soil vapor samples are presented in Table 2 and shown on Figure 3; the concentrations ranged from 10 to 58 $\mu g/m^3$. The observed soil vapor concentrations are lower than those predicted by the J&E model, and result in estimates of acceptable risk ($9.5x10^{-9}$ to $2.8x10^{-8}$) using the J&E model (Table 3 and Appendix B). These same concentrations, however, exceed screening levels developed in accordance with MTCA and Ecology's draft soil vapor intrusion guidance document (Ecology 2009). Evaluations of potential risk in the context of both approaches—the J&E model and Ecology's draft guidance—are discussed below.

3.1 JOHNSON AND ETTINGER MODEL

Whether using the lower 2010 benzene concentrations in soil or the greater 2008 concentrations, the J&E model predicts higher soil vapor concentrations than the actual soil vapor concentrations measured during soil vapor sampling (by factors ranging between two and five orders of magnitude). The

J&E model provides a conservative overestimate of the anticipated soil vapor concentrations and, therefore, a conservative overestimate of the risk associated with the proposed soil cleanup level of 2,450 µg/kg for benzene. The data from the 2010 sampling event support the conclusion that the previously proposed cleanup level (2,450 µg/kg) is protective of the vapor intrusion pathway at the Property.

Without knowing the degree to which the more elevated benzene concentrations in soil (e.g., 57,000 µg/kg at B-23 in 2008) are impacting the soil vapor concentrations at a location versus the lower concentrations (e.g., 58 µg/kg at B-23 in 2010), it is difficult to accurately model the partitioning from the soil contamination into the vapor phase using the J&E model.

Although the J&E model overestimates the benzene concentrations in soil vapor at the Property based on the observed concentrations in soil, the model does provide a conservative estimate of the predicted soil vapor concentrations. If the model were to be used to estimate indoor air benzene concentrations in a commercial building based on measured soil vapor concentrations, then the corresponding risks would be between $9.5x10^{-9}$ and $2.8x10^{-8}$, all less than the acceptable risk level of $1x10^{-6}$.

3.2 ECOLOGY'S GUIDANCE METHODOLOGY

Although the J&E model predicts acceptable levels of risk associated with vapor intrusion when benzene concentrations in soil are at or below 2,450 µg/kg, NLD also recognizes that Ecology has identified screening levels and vapor attenuation factors (VAFs) in its draft soil vapor intrusion guidance document (Ecology 2008). This section presents an evaluation of the soil vapor data in the context of the Ecology soil vapor guidance document.

Ecology recommends that a VAF of 0.1 be used for soil vapor samples collected to a maximum depth of 15 ft BGS. Ecology's recommended VAF is intentionally conservative and has been established to be protective of residential exposure in single-family dwellings. Several site-specific factors at the Property combine to make the VAF of 0.1 overly conservative:

- The VAF of 0.1 represents the 95th percentile of the EPA database for VAFs relating soil vapor to indoor air contaminant concentrations (EPA 2008). Even if the data set were completely representative of site-specific conditions, the 95th percentile would be a strong upper-bound estimate of the VAF (i.e., providing a high confidence that indoor air cleanup levels would not be exceeded). Use of the 95th percentile to establish the VAF when the data set is representative of site-specific conditions will yield a large percentage of "false positives" (i.e., erroneous conclusions that soil vapor contaminant concentrations are not protective of indoor air).
- Most of the buildings included in the EPA (2008) database for VAFs are residential. Residential buildings typically have lower indoor air exchange rates and, therefore, higher VAFs than commercial buildings. Future development at the Property will have ground-level

parking facilities and first-floor commercial use. Vapor intrusion risks, therefore, will be much less than those predicted for residential scenarios.

- Older concrete slabs have higher crack fractions than newer slabs; new concrete slabs have fewer cracks and less potential for vapor intrusion. Any building construction at the Property will be new and will have less risk for vapor intrusion than that characterized by the EPA database.
- Benzene is a highly degradable chemical and prone to more degradation in the subsurface than many of the chemicals included in the EPA database.

Given the range of VAFs in the EPA database and the site-specific conditions described above, a VAF of 0.01 is expected to be a reasonably conservative value for vapor attenuation at the Property. If applied to the Property, a VAF of 0.01 would correspond to a soil vapor screening level of 140 $\mu g/m^3$. All of the benzene soil vapor concentrations detected at the Property were less than 140 $\mu g/m^3$; the maximum detected concentration of benzene in soil vapor at the Property was 58 $\mu g/m^3$. A comparison of the benzene concentrations detected in soil vapor at the Property to the screening level based on the modified VAF of 0.01 results in the conclusion that no further action is warranted at the Property with respect to vapor intrusion as a pathway of concern.

4.0 SUMMARY AND RECOMMENDATIONS

As demonstrated in Section 3.0, using the benzene concentrations in soil vapor observed during the October 2010 sampling event, the J&E model predicts that the potential risks associated with vapor intrusion in an occupational worker scenario would be acceptable (up to $2.8\text{x}10^{-8}$), not requiring any active remedial action at the Property. Using the soil vapor screening level developed in accordance with Ecology's draft guidance with a modified VAF of 0.01 (i.e., soil vapor screening level of 140 μg/m^3), all of the benzene soil vapor concentrations detected at the Property are less than the screening level and, therefore, remedial action would not be required.

The results of the recent soil and soil vapor sampling indicate that the benzene contamination in soil at the Property does not pose a potential vapor intrusion risk. However, in an effort to avoid prolonged technical discussions with Ecology that could impact the schedule for development of the Property, NLD proposes to move forward with the proposed hotspot excavation of soil from the northwest portion the Property, and proposes a remediation level of 780 micrograms per kilogram (μg/kg; (see below) based on the overly conservative soil vapor screening level established in the Ecology draft soil vapor intrusion guidance document (14 μg/m^3; as calculated using a VAF of 0.1). The remedial action proposed in the FS includes excavation of soil to the depth of the groundwater table at locations where the highest concentrations of soil and soil vapor have been detected (B-17, B-23, and B-26), and continued excavation until benzene concentrations in soil are reached that are considered conservatively protective of the vapor intrusion pathway. The minimum proposed excavation area is shown on Figure 4.

The soil vapor samples were collected within 1 ft of the soil borings completed in 2008. Although the benzene concentrations in soil were highly variable, the close proximity of the soil vapor samples to the 2008 soil sample locations allows for a direct correlation between the 2008 benzene concentrations in soil and the 2010 benzene concentrations in soil vapor. Even though the same discrete soil contamination was not encountered in 2010, the soil vapor samples were collected close enough to the 2008 sample locations that the higher contaminant concentrations in soil would be expected to influence the soil vapor samples. The most conservative correlation between soil and soil vapor concentrations is observed at B-17:

$$Ratio_{s-sv} = \frac{C_{sv}}{C_s} = \frac{34\,\mu\text{g/m}^3}{1{,}900\,\mu\text{g/kg}} = 0.018\,\frac{\mu\text{g - kg}}{\text{m}^3\text{ - }\mu\text{g}}$$

Applying this ratio to the benzene soil vapor screening value of 14 μg/m^3 yields a benzene concentration in soil of 780 μg/kg. NLD recommends that this concentration—780 μg/kg benzene—be established as the remediation level for benzene in soil, which is protective of the vapor intrusion pathway, at the Property. Compliance with this remediation level would be demonstrated by confirmation sampling in the field at the time of excavation. The remediation level will be included in the revised FS and pending Cleanup Action Plan (CAP).

NLD requests a timely review and approval of this conservative remediation level for benzene in soil to facilitate finalization of the FS and preparation of the CAP.

5.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of North Lot Development, LLC, and applicable regulatory agencies, for specific application to the North Lot Development property, including review by the public. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau Associates. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau Associates, shall be at the user's sole risk. Landau Associates warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

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6.0 REFERENCES

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Data Source: *ESRI 2008*

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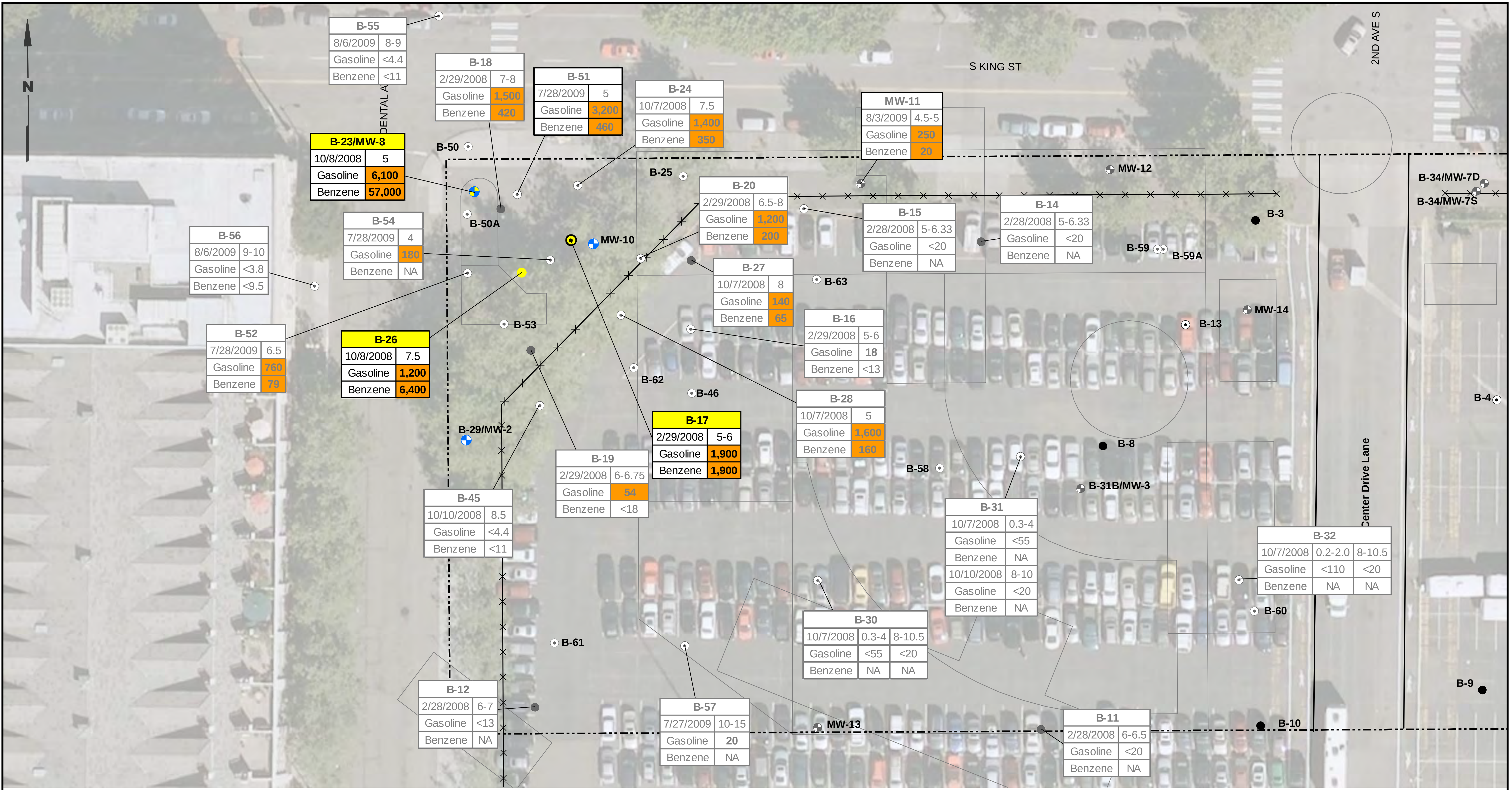
North Lot Development Seattle, Washington	**Vicinity Map**	Figure 1



Legend

- ◕ Direct-Push Soil Boring and Monitoring Well Location
- ⊙ Direct-Push Soil Boring Location
- ● Direct-Push Soil and Groundwater Sample Location
- ── Historical Building Outlines
- ×─× Fence Line
- -·-· Property Boundary
- 🟨 Soil Vapor and Soil Sampling Location
- 🟦 Water Level Measurement Location

Location ID	
Date	Depth (ft)
Gasoline	Result mg/kg
Benzene	Result µg/kg

Notes

1. Gray symbol indicates sample was not analyzed for the constituent at this depth.
2. Depths are in feet below ground surface.
3. Gasoline soil cleanup level is 30 mg/kg, Benzene soil cleaup level is 4.5 µg/kg.
4. **Bold** values indicate compound was detected at the reported concentration. Orange highlight indicates compound exceeds cleanup level.
5. <1.00 = The analyte was not detected at the reported concentration.
6. Refer to Figure 3 for Historical Property Features Legend.
7. NA = Not Analyzed.
8. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 40 80
Scale in Feet

Data Source: Triad Boundary Survey, King County

Landau Associates

North Lot Development
Seattle, Washington

Sampling Locations

Figure
2

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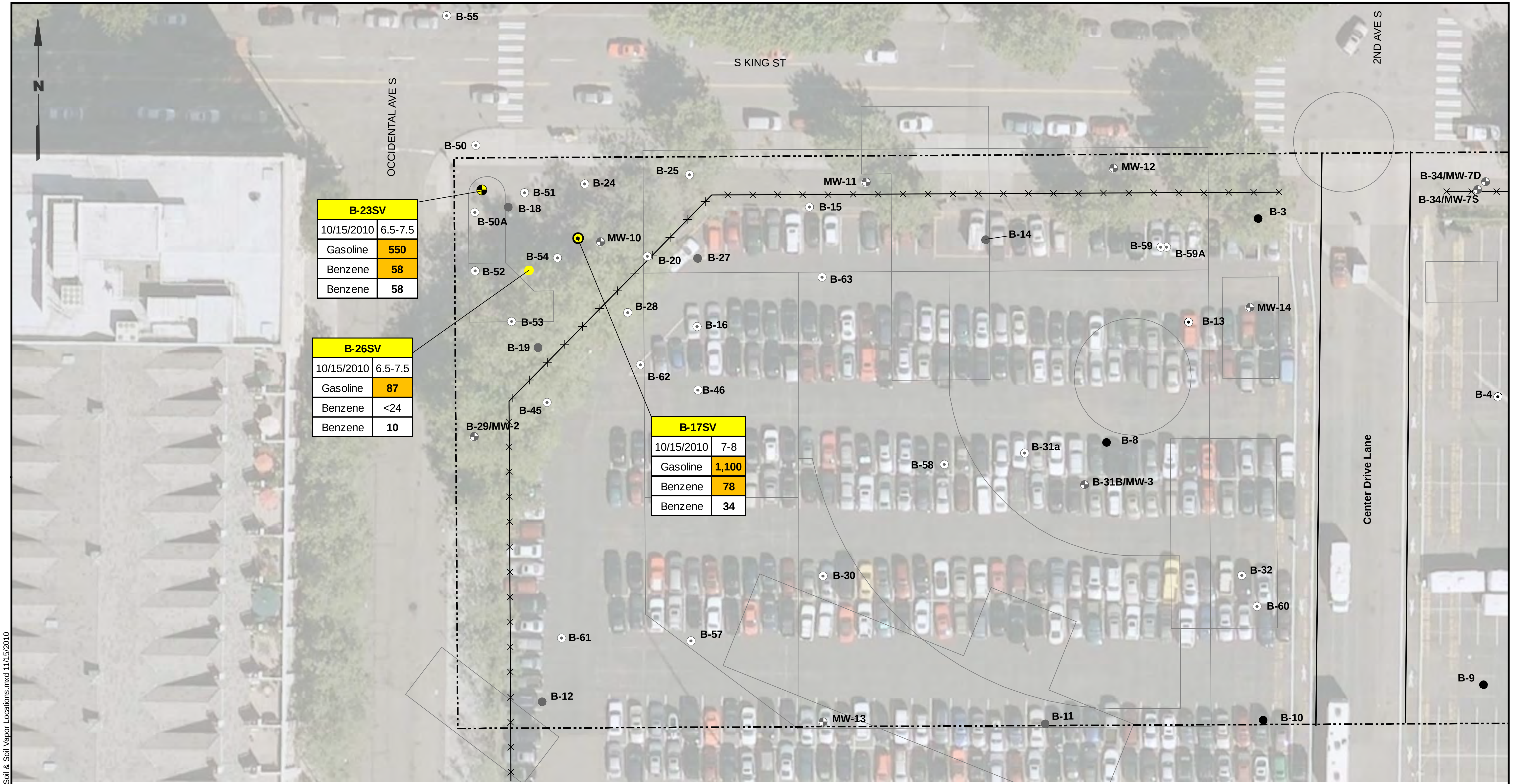

B-23SV	
10/15/2010	6.5-7.5
Gasoline	**550**
Benzene	**58**
Benzene	**58**

B-26SV	
10/15/2010	6.5-7.5
Gasoline	**87**
Benzene	<24
Benzene	**10**

B-17SV	
10/15/2010	7-8
Gasoline	**1,100**
Benzene	**78**
Benzene	**34**

Legend

- ◐ Direct-Push Soil Boring and Monitoring Well Location
- ⊙ Direct-Push Soil Boring Location
- ● Direct-Push Soil and Groundwater Sample Location
- Historical Building Outlines
- ×—× Fence Line
- - - - Property Boundary
- 🟨 Soil Vapor and Soil Sampling Location

Location ID	
Date	Depth (ft)
Gasoline (Soil)	Result mg/kg
Benzene (Soil)	Result µg/kg
Benzene (Soil Vapor)	Result µg/m³

Notes

1. Depths are in feet below ground surface.
2. Gasoline soil cleanup level is 30 mg/kg, Benzene soil cleanup level is 4.5 µg/kg.
3. **Bold** values indicate compound was detected at the reported concentration. Orange highlight indicates compound exceeds cleanup level.
4. <1.00 = The analyte was not detected at the reported concentration.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 40 80
Scale in Feet

Data Source: Triad Boundary Survey, King County

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North Lot Development
Seattle, Washington

Soil and Soil Vapor Results

Figure
3

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Legend

⊕ Direct-Push Soil Boring and Monitoring Well Location

◉ Direct-Push Soil Boring Location

● Direct-Push Soil and Groundwater Sample Location

×—× Fence Line

-·-· Site Boundary

▨ Approximate Boundary of Minimum Proposed Excavation; Actual Area to be Based on Confirmation Samples

0 80 160

Scale in Feet

Data Source: Triad Boundary Survey, King County

Note

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

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North Lot Development
Seattle, Washington

Proposed Excavation Area

Figure
4

TABLE 1
SOIL ANALYTICAL RESULTS
NORTH LOT DEVELOPMENT
SEATTLE, WASHINGTON

	LAI-S-B17(7-8) RR78B 10/15/2010	LAI-S-B23(6.5-7.5) RR78A 10/15/2010	LAI-S-B26(6.5-7.5) RR78C 10/15/2010
BTEX/TPHG			
Benzene (SW8021Mod) (µg/kg)	78	58	24 U
Gasoline Range Organics (NWTPH-G) (mg/kg)	1,100	550	87
CONVENTIONALS (%)			
Total Solids (EPA 160.3)	69.80	93.40	71.50
Total Organic Carbon (PLUMB81TC)	16.4	2.27	10.5
GEOTECHNICAL ANALYSIS			
Wet Density (ASTM D 2937) (lb/ft^3)	97.5	92.8	88.4
Dry Density (ASTM D 2937) (lb/ft^3)	87.9	87.1	80.1
Porosity (SW9100) (Std Units)	0.45	0.49	0.48
GRAIN SIZE (ASTM D422)			
Particle/Grain Size, Gravel	25.7	14.3	30.6
Particle/Grain Size, Sand	63.5	76.4	57.4
Particle/Grain Size, Silt	9.0	7.0	9.1
Particle/Grain Size, Clay	1.8	2.3	2.8

U = Indicates the compound was undetected at the reported concentration.
µg/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
lb/ft^3 = Pounds per cubic feet

TABLE 2
SOIL VAPOR ANALYTICAL RESULTS
NORTH LOT DEVELOPMENT
SEATTLE, WASHINGTON

			Benzene EPA Method TO-15	
Sample Location	Lab ID	Date Collected	µg/m³	ppbV
LAI-SV-B17(7-8)	P1004034-002	10/15/2010	34	11
LAI-SV-B23(6.5-7.5)	P1004034-001	10/15/2010	58	18
LAI-SV-B26(6.5-7.5)	P1004034-003	10/15/2010	10	3.1

µg/m^3 = Micrograms per cubic meter

ppbV = Parts per billion by volume

TABLE 3
DATA COMPARISON
NORTH LOT DEVELOPMENT
SEATTLE, WASHINGTON

Sample ID	Original Samples (2008)				Confirmation Samples (2010)				
	Date	Soil Source (µg/kg)	Modeled Source Vapor (µg/m^3)	Modeled Risk	Date	Soil Source (µg/kg)	Modeled Source Vapor (µg/m^3)	Measured Source Vapor (µg/m^3)	Modeled Risk (from Source Vapor)
B17	2/29/2008	1,900	1.30E+06	6.5E-07	10/15/2010	78	7.18E+03	3.40E+01	2.8E-08
B23	10/8/2008	57,000	3.90E+07	2.4E-05	10/15/2010	58	5.32E+03	5.80E+01	2.3E-08
B26	10/8/2008	6,400	4.38E+06	2.0E-06	10/15/2010	24	2.19E+03	1.00E+01	9.5E-09
Cleanup Level		2,450	1.68E+06	1.0E-06					

µg/kg = Micrograms per kilogram
µg/m^3 = Micrograms per cubic meter

APPENDIX A

Boring Logs

Soil Classification System

MAJOR DIVISIONS			GRAPHIC SYMBOL	USCS LETTER SYMBOL (1)	TYPICAL DESCRIPTIONS (2)(3)
COARSE-GRAINED SOIL (More than 50% of material is larger than No. 200 sieve size)	GRAVEL AND GRAVELLY SOIL (More than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVEL (Little or no fines)	▨	**GW**	Well-graded gravel; gravel/sand mixture(s); little or no fines
			▨	**GP**	Poorly graded gravel; gravel/sand mixture(s); little or no fines
		GRAVEL WITH FINES (Appreciable amount of fines)	▨	**GM**	Silty gravel; gravel/sand/silt mixture(s)
			▨	**GC**	Clayey gravel; gravel/sand/clay mixture(s)
	SAND AND SANDY SOIL (More than 50% of coarse fraction passed through No. 4 sieve)	CLEAN SAND (Little or no fines)	▨	**SW**	Well-graded sand; gravelly sand; little or no fines
			▨	**SP**	Poorly graded sand; gravelly sand; little or no fines
		SAND WITH FINES (Appreciable amount of fines)	▨	**SM**	Silty sand; sand/silt mixture(s)
			▨	**SC**	Clayey sand; sand/clay mixture(s)
FINE-GRAINED SOIL (More than 50% of material is smaller than No. 200 sieve size)	SILT AND CLAY (Liquid limit less than 50)		▨	**ML**	Inorganic silt and very fine sand; rock flour; silty or clayey fine sand or clayey silt with slight plasticity
			▨	**CL**	Inorganic clay of low to medium plasticity; gravelly clay; sandy clay; silty clay; lean clay
			▨	**OL**	Organic silt; organic, silty clay of low plasticity
	SILT AND CLAY (Liquid limit greater than 50)		▨	**MH**	Inorganic silt; micaceous or diatomaceous fine sand
			▨	**CH**	Inorganic clay of high plasticity; fat clay
			▨	**OH**	Organic clay of medium to high plasticity; organic silt
	HIGHLY ORGANIC SOIL		▨	**PT**	Peat; humus; swamp soil with high organic content

OTHER MATERIALS	GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
PAVEMENT	■ ▨	**AC** or **PC**	Asphalt concrete pavement or Portland cement pavement
ROCK	▨	**RK**	Rock (See Rock Classification)
WOOD	▨	**WD**	Wood, lumber, wood chips
DEBRIS	▨	**DB**	Construction debris, garbage

Notes:
1. USCS letter symbols correspond to symbols used by the Unified Soil Classification System and ASTM classification methods. Dual letter symbols (e.g., SP-SM for sand or gravel) indicate soil with an estimated 5-15% fines. Multiple letter symbols (e.g., ML/CL) indicate borderline or multiple soil classifications.
2. Soil descriptions are based on the general approach presented in the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), outlined in ASTM D 2488. Where laboratory index testing has been conducted, soil classifications are based on the Standard Test Method for Classification of Soils for Engineering Purposes, as outlined in ASTM D 2487.
3. Soil description terminology is based on visual estimates (in the absence of laboratory test data) of the percentages of each soil type and is defined as follows:

Primary Constituent: > 50% - "GRAVEL," "SAND," "SILT," "CLAY," etc.
Secondary Constituents: > 30% and ≤ 50% - "very gravelly," "very sandy," "very silty," etc.
> 15% and ≤ 30% - "gravelly," "sandy," "silty," etc.
Additional Constituents: > 5% and ≤ 15% - "with gravel," "with sand," "with silt," etc.
≤ 5% - "with trace gravel," "with trace sand," "with trace silt," etc., or not noted.

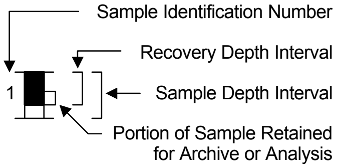
4. Soil density or consistency descriptions are based on judgement using a combination of sampler penetration blow counts, drilling or excavating conditions, field tests, and laboratory tests, as appropriate.

Drilling and Sampling Key

SAMPLER TYPE

Code	Description
a	3.25-inch O.D., 2.42-inch I.D. Split Spoon
b	2.00-inch O.D., 1.50-inch I.D. Split Spoon
c	Shelby Tube
d	Grab Sample
e	Single-Tube Core Barrel
f	Double-Tube Core Barrel
g	2.50-inch O.D., 2.00-inch I.D. WSDOT
h	3.00-inch O.D., 2.375-inch I.D. Mod. California
i	Other - See text if applicable
1	300-lb Hammer, 30-inch Drop
2	140-lb Hammer, 30-inch Drop
3	Pushed
4	Vibrocore (Rotosonic/Geoprobe)
5	Other - See text if applicable

SAMPLE NUMBER & INTERVAL



Field and Lab Test Data

Code	Description
PP = 1.0	Pocket Penetrometer, tsf
TV = 0.5	Torvane, tsf
PID = 100	Photoionization Detector VOC screening, ppm
W = 10	Moisture Content, %
D = 120	Dry Density, pcf
-200 = 60	Material smaller than No. 200 sieve, %
GS	Grain Size - See separate figure for data
AL	Atterberg Limits - See separate figure for data
GT	Other Geotechnical Testing
CA	Chemical Analysis

Groundwater

▽	Approximate water level at time of drilling (ATD)
▼	Approximate water level at time other than ATD

LANDAU ASSOCIATES

North Lot Development
Seattle, Washington

Soil Classification System and Key

Figure
A-1

B-17

Drilling Method: Geoprobe™

Ground Elevation (ft):

Drilled By: Cascade Drilling Inc.

SAMPLE DATA					SOIL PROFILE		GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	PID (ppm)	USCS Symbol	Description	Water Level
0					AC	Asphalt	
					SM	Brown, silty, fine to medium SAND with gravel (medium dense, damp) (no odors) (fill)	
					AC	Asphalt	
2	S-1	d3		0.0	SP/ SM	Black, fine to coarse SAND with silt and gravel (medium dense, damp) (no odors)	
4				0.0			
6	S-2	d3			AC	Concrete debris from 6.0 to 6.5 ft	
					SP/ SM		
8		d3		23.4	SP	Black, medium to coarse SAND with gravel (loose, wet) (strong hydrocarbon odors, sheen present)	∇ ATD

Boring Completed 10/15/10
Total Depth of Boring = 8.0 ft.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

LANDAU ASSOCIATES

North Lot Development
Seattle, Washington

Log of Boring B-17

Figure
A-2

B-23

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	PID (ppm)	Graphic Symbol	USCS Symbol	Drilling Method: Geoprobe™ Ground Elevation (ft): Drilled By: Cascade Drilling Inc.	Water Level
0					■	AC	Asphalt	
					▥	SM	Gray, silty, fine to medium SAND with gravel (medium dense, damp) (no odors) (fill)	
2	S-1	d3		0.0	■	AC	Asphalt	
					░	SP	Dark gray to black, fine to medium SAND with trace silt and gravel (medium dense, damp to wet) (no odors)	
4				0.0				
	S-2	d3						
6								
		d3		29			Hydrocarbon odors observed at 7 ft	▽ ATD
8								

Boring Completed 10/15/10
Total Depth of Boring = 8.0 ft.

10

12

14

16

18

20

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

1014001.05 11/15/10 N:\PROJECTS\1014001.050.GPJ SOIL BORING LOG

LANDAU ASSOCIATES

North Lot Development
Seattle, Washington

Log of Boring B-23

Figure
A-3

B-26

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	PID (ppm)	Graphic Symbol	USCS Symbol	Drilling Method: Geoprobe™ Ground Elevation (ft): Drilled By: Cascade Drilling Inc.	Water Level
0						AC	Asphalt	
						SM	Brown, silty, fine to medium SAND, trace gravel (medium dense, damp) (no odors) (fill)	
2	S-1	d3		0.0		SP	Black, fine to coarse SAND with gravel (medium dense, damp) (no odors)	
						SM	Brown, silty, fine to medium SAND with gravel (medium dense, moist) (no odors)	
						SP	Black, medium to coarse SAND with gravel, lenses of silt, wood fragments (loose, damp) (no odors)	
4								
	S-2	d3						
6								
							Red brick fragments at 7 ft	
		d3		0.0			Hydorcarbon odors at 8 ft	∇ ATD
8								
10								
12								
14								
16								
18								
20								

Boring Completed 10/15/10
Total Depth of Boring = 8.0 ft.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

LANDAU ASSOCIATES

North Lot Development
Seattle, Washington

Log of Boring B-26

Figure
A-4

APPENDIX B

Johnson & Ettinger Model Files

Appendix B1: B-17 Soil Vapor-to-Soil Modeling

Appendix B2: B-23 Soil Vapor-to-Soil Modeling

Appendix B3: B-26 Soil Vapor-to-Soil Modeling

APPENDIX B1
JOHNSON ETTINGER MODEL FILE
B-17 SOIL VAPOR-TO-SOIL MODELING
DATA ENTRY SHEET

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
71432	7.80E+01			Benzene

MORE ↓

			Totals must add up to value of Ls (cell F24)					
ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^{o}C)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	213	12.5	213	0	0	S		

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.41	0.45	0.054								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)		ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1.5		

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
75	30	30	250

END

APPENDIX B1
JOHNSON ETTINGER MODEL FILE
B-17 SOIL VAPOR-TO-SOIL MODELING
INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	198	0.396	ERROR	ERROR	0.003	9.97E-08	0.999	9.95E-08	4,000	7.80E+01	1.02E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, $D^{eff}{}_A$ (cm^2/s)	Stratum B effective diffusion coefficient, $D^{eff}{}_B$ (cm^2/s)	Stratum C effective diffusion coefficient, $D^{eff}{}_C$ (cm^2/s)	Total overall effective diffusion coefficient, $D^{eff}{}_T$ (cm^2/s)	Diffusion path length, L_d (cm)
1.06E+06	3.77E-04	15	8,096	3.04E-03	1.30E-01	1.76E-04	1.99E-02	0.00E+00	0.00E+00	1.99E-02	198

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	7.80E+01	0.10	9.96E+01	1.99E-02	4.00E+02	2.42E+54	5.06E-04	3.95E-02	7.8E-06	3.0E-02

END

APPENDIX B1
JOHNSON ETTINGER MODEL FILE
B-17 SOIL VAPOR-TO-SOIL MODELING
RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.8E-08	3.0E-04

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL DOWN TO "END"

END

APPENDIX B2
JOHNSON ETTINGER MODEL FILE
B-23 SOIL VAPOR-TO-SOIL MODELING
DATA ENTRY SHEET

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER	ENTER		ENTER	
Chemical CAS No. (numbers only, no dashes)	Soil gas conc., C_g ($\mu g/m^3$)	OR	Soil gas conc., C_g (ppmv)	Chemical
71432	5.80E+01			Benzene

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER		ENTER
			Totals must add up to value of Ls (cell F24)					
Depth below grade to bottom of enclosed space floor, L_F (cm)	Soil gas sampling depth below grade, L_s (cm)	Average soil temperature, T_S (^oC)	Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)	Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	User-defined stratum A soil vapor permeability, k_v (cm^2)
15	198	12.5	198	0	0	S		

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Stratum A SCS soil type Lookup Soil Parameters	Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	Stratum A soil total porosity, n^A (unitless)	Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	Stratum B SCS soil type Lookup Soil Parameters	Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	Stratum B soil total porosity, n^B (unitless)	Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	Stratum C SCS soil type Lookup Soil Parameters	Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	Stratum C soil total porosity, n^C (unitless)	Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.4	0.49	0.054								

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Enclosed space floor thickness, L_{crack} (cm)	Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	Enclosed space floor length, L_B (cm)	Enclosed space floor width, W_B (cm)	Enclosed space height, H_B (cm)	Floor-wall seam crack width, w (cm)	Indoor air exchange rate, ER (1/h)	Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1.5	

ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_C (yrs)	Averaging time for noncarcinogens, AT_{NC} (yrs)	Exposure duration, ED (yrs)	Exposure frequency, EF (days/yr)
75	30	30	250

END

APPENDIX B2
JOHNSON ETTINGER MODEL FILE
B-23 SOIL VAPOR-TO-SOIL MODELING
INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	183	0.436	ERROR	ERROR	0.002	9.97E-08	0.999	9.95E-08	4,000	5.80E+01	1.02E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, $D^{eff}{}_A$ (cm^2/s)	Stratum B effective diffusion coefficient, $D^{eff}{}_B$ (cm^2/s)	Stratum C effective diffusion coefficient, $D^{eff}{}_C$ (cm^2/s)	Total overall effective diffusion coefficient, $D^{eff}{}_T$ (cm^2/s)	Diffusion path length, L_d (cm)
1.06E+06	3.77E-04	15	8,096	3.04E-03	1.30E-01	1.76E-04	2.31E-02	0.00E+00	0.00E+00	2.31E-02	183

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	5.80E+01	0.10	9.96E+01	2.31E-02	4.00E+02	6.45E+46	5.62E-04	3.26E-02	7.8E-06	3.0E-02

END

APPENDIX B2
JOHNSON ETTINGER MODEL FILE
B-23 SOIL VAPOR-TO-SOIL MODELING
RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.3E-08	2.5E-04

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL DOWN TO "END"

END

APPENDIX B3
JOHNSON ETTINGER MODEL FILE
B-26 SOIL VAPOR-TO-SOIL MODELING
DATA ENTRY SHEET

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
71432	2.40E+01			Benzene

MORE ↓

			Totals must add up to value of Ls (cell F24)					
ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^{o}C)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	198	12.5	198	0	0	S		

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.28	0.48	0.054								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)		ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1.5		

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
75	30	30	250

END

APPENDIX B3
JOHNSON ETTINGER MODEL FILE
B-26 SOIL VAPOR-TO-SOIL MODELING
INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	183	0.426	ERROR	ERROR	0.002	9.97E-08	0.999	9.95E-08	4,000	2.40E+01	1.02E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, $D^{eff}{}_A$ (cm^2/s)	Stratum B effective diffusion coefficient, $D^{eff}{}_B$ (cm^2/s)	Stratum C effective diffusion coefficient, $D^{eff}{}_C$ (cm^2/s)	Total overall effective diffusion coefficient, $D^{eff}{}_T$ (cm^2/s)	Diffusion path length, L_d (cm)
1.06E+06	3.77E-04	15	8,096	3.04E-03	1.30E-01	1.76E-04	2.23E-02	0.00E+00	0.00E+00	2.23E-02	183

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	2.40E+01	0.10	9.96E+01	2.23E-02	4.00E+02	3.35E+48	5.53E-04	1.33E-02	7.8E-06	3.0E-02

END

APPENDIX B3
JOHNSON ETTINGER MODEL FILE
B-26 SOIL VAPOR-TO-SOIL MODELING
RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
9.5E-09	1.0E-04

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL DOWN TO "END"

END

APPENDIX C

Soil Vapor Sampling Parameters

TABLE C-1
SOIL VAPOR SAMPLING PARAMETERS
NORTH LOT DEVELOPMENT
SEATTLE, WASHINGTON

				Pre-sample Collection			Mid-sample Collection			Post-sample Collection		
Sample ID	Date	Average Barometric Pressure (mbar) (a)	Sampling Flow Rate (min/L)	Total Organic Vapors with PID (ppm)	%Oxygen	%LEL (Methane)	Total Organic Vapors with PID (ppm)	%Oxygen	%LEL (Methane)	Total Organic Vapors with PID (ppm)	%Oxygen	%LEL (Methane)
LAI-SV-B23 (6.5-7.5)	10/15/2010	1023	4.0	2.0	19.7	20.0	40.2	3.7	66.0	55.6	34.0	3.4
LAI-SV-B17 (7-8)	10/15/2010	1023	3.75	3.0	0.3	36.0	21.7	0.9	88.0	31.5	0.3	NM
LAI-SV-B26 (6.5-7.5)	10/15/2010	1023	3.25	0.6	0.7	82.0	1.3	0.5	92.0	1.8	0.7	73.0

Notes:

PID = Photoionization Detector
NM = Not Measured
(a) Barometric pressure for the Seattle area was recorded in morning, afternoon, and evening on the day prior to, day of, and day after sampling.
Average of recorded values over the three day span is shown in the table above.