TECHNICAL MEMORANDUM

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

TO: James Bet, The Boeing Company

CC: Dennis Dowdy and Chris Anderson, City of Auburn
Jim Swortz, The Boeing Company
Robin Harrover, Washington State Department of Ecology

FROM: Chip Halbert, P.E. and Jennifer Wynkoop

DATE: October 16, 2013

RE: SEWER WORKER EXPOSURE ASSESSMENT AND SEWER AIR SAMPLING RESULTS
BOEING AUBURN FACILITY
AUBURN, WASHINGTON

INTRODUCTION

The Boeing Company (Boeing) is investigating volatile organic compounds (VOCs) in groundwater related to releases from the Boeing Auburn Fabrication Division facility (facility) located at 700 15th Street SW in Auburn, Washington (Figure 1)[1]. Groundwater VOC impacts extend north of the facility into Auburn and in some areas the high groundwater table has the potential to come in contact with underground sanitary sewer infrastructure. The primary constituents of concern in these plumes are trichloroethene (TCE) and vinyl chloride (VC). The extent of shallow zone TCE and VC plumes are presented on Figures 2 and 3, respectively. The City of Auburn (City) expressed concerns about whether contaminated groundwater could cause buildup of VOC vapors within the sewer system and present an exposure risk to workers who perform routine sewer jetting operations. Based on the City's concerns, Ecology requested that Boeing collect VOC air samples in the sewers to allow evaluation of worker safety during sewer cleaning (Ecology 2013).

This technical memorandum presents the results of the sewer air testing and Boeing's evaluation of the sewer worker exposure scenario. It includes a discussion of sewer air screening levels protective of sewer workers, describes the procedures for sewer air sampling that was completed in May 2013, and presents the results of that sampling event. The sampling locations are shown on Figures 2 and 3. Table Analytical results are summarized in Table 1.

[1] Boeing is currently undergoing corrective action at the facility. Corrective action requirements are documented in an Agreed Order (No. DE 01HWTRNR-3345) dated August 14, 2002 and the First Amended Agreed Order dated February 21, 2006, both with Washington State Department of Ecology (Ecology).

DEVELOPMENT OF SEWER AIR SCREENING LEVELS

The sewer worker exposure scenario is not specifically described in Washington State guidance documents; however, risk-based concentrations were developed using equations and exposure factors (where applicable) provided in Ecology's Model Toxics Control Act [MTCA; Washington Administrative Code (WAC) 173-340; Ecology 2007]. Site-specific values for some exposure factors were selected based on discussions with the City about the frequency, duration, and type of activities performed related to sanitary sewer jetting.

Based on previous evaluations of groundwater data, the primary chemical risk drivers for the inhalation exposure pathway (to the extent sewer workers may be exposed to air in the sewer lines) are TCE, and VC; tetrachloroethene (PCE) was also analyzed at Ecology's request[2]. Based on discussions with Dennis Dowdy, City Public Works Director, we understand that the following represents the expected exposure scenario for sewer workers:

- Sewer maintenance is conducted twice per year;
- Each maintenance event occurs over a period of 4 weeks;
- The typical work day for a sewer worker is 8 hours per day.

The risks associated with non-carcinogenic and carcinogenic effects of PCE, TCE, and VC were evaluated. Modified MTCA Method B sewer air screening levels protective of non-carcinogenic and carcinogenic effects were calculated as described below.

Modified MTCA Method B cleanup levels (sewer air screening levels) were calculated to be protective of the risk level that is established as "acceptable" based on state regulations. Under MTCA, the acceptable level of carcinogenic risk for an individual chemical is $1x10^{-6}$ (1 in 1 million). For non-carcinogenic effects, a hazard quotient of 1 indicates that no adverse health effects are expected as a result of exposure.

The equation used to calculate the cleanup levels protective of a sewer worker for potential non-carcinogenic effects is as follows (Equation 750-1, Ecology 2007):

$$Air\ Cleanup\ Level\ (\mu g/m3) = \frac{RfD \cdot ABW \cdot UCF \cdot HQ \cdot AT}{BR \cdot ABS \cdot ED \cdot EF}$$

where:

RfD	=	Reference dose as specified in WAC 173-340-708(7) (chemical specific; see table)
ABW	=	Average body weight (70 kilograms)

[2] Although PCE is generally not detected in shallow groundwater, Boeing agreed to have the laboratory report PCE per Ecology's request (Ecology 2013), but with the understanding that detections of PCE may be related to the sewer waste stream rather than groundwater intrusion.

UCF	=	Unit conversion factor (1000 micrograms per kilogram)
HQ	=	Hazard quotient (1; unitless)
AT	=	Averaging time – [equal to expected exposure duration (20 years)]
BR	=	Breathing rate [20 cubic meters per day (adult)]
ABS	=	Inhalation absorption fraction (1.0; unitless)
ED	=	Exposure duration (20 years)
EF	=	Exposure frequency [0.037 (40, 8-hour days per year)]

The equation used to calculate the cleanup levels protective of a sewer worker for potential carcinogenic risk is as follows (Equation 750-2, Ecology 2007):

$$Air\ Cleanup\ Level\ (\mu g/m3) = \quad = \frac{RISK \quad \cdot ABW \quad \cdot UCF \cdot AT}{CPF \cdot BR \cdot ABS \cdot ED \cdot EF}$$

where:

RISK	=	Acceptable risk level – carcinogens ($1x10^{-6}$; unitless)
AT	=	Averaging time (75 years)
CPF	=	carcinogenic potency factor (chemical specific; see table)
ED	=	Exposure duration (20 years)

The following table identifies the calculated sewer air screening levels protective of sewer workers under the identified exposure scenario.

Constituent	Inhalation Reference Dose (mg/kg/day)	Inhalation Cancer Potency Factor (kg-day/mg)	Air Cleanup Level for Non-carcinogenic Effects (µg/m^3)	Air Cleanup Level for Carcinogenic Risk (µg/m^3)	Selected Air Cleanup Level (µg/m^3)
TCE	0.00057	0.014[3]	54	25	25
PCE	0.011	0.00091	1,000	390	390
VC	0.029	0.031[4]	2,700	11	11

For each of the constituents evaluated, the screening levels protective of risk associated with carcinogenic effects are less than those associated with non-carcinogenic effects; therefore, the concentrations protective of carcinogenic risks were selected as the sewer air screening levels. These concentrations are also protective of non-carcinogenic risks.

SEWER AIR SAMPLING PROCEDURES

On May 20, 2013 and May 21, 2013, Landau Associates collected air samples from five sewer manholes located north and northwest of the facility. Rationale for selection of sampling locations is

[3] Sum of inhalation cancer potency factors for kidney cancer, non-Hodgkin lymphoma, and liver cancer.
[4] Cancer potency factor protective of pregnant women.

presented in the sewer air sampling work plan (Landau Associates 2013). As described in the work plan, sampling locations were identified to represent areas over a range of shallow groundwater TCE and VC concentrations, including background conditions. The only deviation from the work plan was that the sample collected to represent background conditions was collected from manhole 909-01 rather than manhole 908-27. Manhole 908-27 is not owned by the City or King County sewer departments and access was not available on the day of sampling. The City sewer department assisted Landau Associates field staff in the selection of the alternate background sewer manhole location. The sewer air sample locations are presented on Figures 2 and 3.

Sewer air samples were collected below sanitary sewer manhole covers. Three of the sanitary sewer manholes (907-17, 907-19, and 909-01) were located within street right-of-way (ROW), the remaining two manholes (907-27 and 907-28) were located on a private access road at The Outlet Collection. A construction permit was obtained from the City for manholes in street ROW. Permission was obtained from The Outlet Collection to collect samples in the private roadway (Hensley 2013). Traffic control measures were performed when accessing sanitary sewer manhole locations 907-17, 907-19, 907-27, and 907-28; sewer manhole location 909-01 did not require traffic control.

Sewer air samples were collected over an 8-hour time period using 6-liter laboratory-certified evacuated Summa canisters. Each Summa canister was equipped with a pressure gauge and a calibrated critical orifice air flow controller set by the laboratory at a flow rate of 11.5 milliliters per minute. In order to sample sanitary sewer air, canister inlet valves were installed approximately 1 to 2 feet below ground surface underneath sewer manhole access covers. Canisters were fastened to the sewer access ladder using a plastic zip tie. Canisters were clearly labeled with identification tags indicating the purpose of the canisters and that the canisters were not to be disturbed. The sewer access ladders were accessible from above ground so sewer entry was not required to place the canisters. The manhole lids were replaced during the 8-hour sample period.

The Summa canisters were evacuated to a vacuum pressure of 28 to 30 inches mercury (Hg) by the laboratory. Canister closure occurred at vacuum pressures ranging from 6 to 8 inches Hg. Subsequent to sample collection the canisters were shipped using the original shipping packaging under chain-of-custody procedures to Boeing's contracted laboratory, Eurofins Lancaster Laboratories, Inc. West Coast Regional Air Toxics branch in Folsom, California. Samples were submitted for analysis for total concentrations of PCE, TCE, and VC by U.S. Environmental Protection Agency Method TO-15. Upon receipt of the samples, Air Toxics recorded vacuum pressures ranging from 4.9 to 6.5 inches Hg, which is indicative of valid samples.

SEWER AIR SAMPLING ANALYTICAL RESULTS

The analytical results for the sewer air samples are provided in Table 1 along with a comparison to the screening levels, and are summarized as follows:

- TCE was detected at concentrations greater than the laboratory reporting limits in two of the five sewer air samples. The detected concentrations of TCE at manholes 907-27 (14 $\mu g/m^3$) and 907-28 (7 $\mu g/m^3$), are less than the modified MTCA Method B sewer air screening level for TCE of 25 $\mu g/m^3$. Sample 907-27 (14 $\mu g/m^3$ TCE) was located in the highest concentration zone, where TCE is greater than 5 micrograms per liter ($\mu g/L$) in groundwater. Sample 907-28 (7 $\mu g/m^3$ TCE) was located in an area with TCE groundwater concentrations between 2.4 $\mu g/L$ and 5 $\mu g/L$.
- VC was detected at a concentration greater than the laboratory reporting limit in one of the five sewer air samples. The detected concentration of VC at manhole 907-27 (3.9 $\mu g/m^3$) is less than the modified Method B sewer air screening level for VC of 11 $\mu g/m^3$. VC concentrations in groundwater near this manhole are between 0.5 $\mu g/L$ and 2.4 $\mu g/L$.
- PCE was not detected at concentration greater than the laboratory reporting limits in any of the five samples.

CONCLUSIONS

The sewer worker exposure assessment was conducted to evaluate human health risks associated with potential exposure of sewer workers to VOC vapors in sewer air. Modified MTCA Method B sewer air screening levels protective of sewer workers during routine maintenance activities were developed for comparison to results from the sewer air samples. Sewer air samples were collected from five sewer manholes representative of a range of shallow groundwater TCE and VC conditions, including background conditions at one location, to evaluate the potential presence of TCE and VC at concentrations greater than the sewer air screening levels.

The maximum detected concentrations of TCE and VC in sewer air are below the calculated screening levels. This evaluation is considered to be conservative; sewer maintenance workers reportedly do not enter the sewers during maintenance activities and concentrations of VOCs will be diluted as air exits the sewer. The concentrations observed in the sewer air sampling event support the conclusion that existing conditions are protective of the sewer worker scenario. Boeing will follow up with the City and Ecology regarding any needs for additional sampling to verify protection of worker safety.

JWW/CPH/jrc

REFERENCES

Ecology. 2013. Email message from Robin Harrover, Hazardous Waste and Toxics Reduction Program, Washington State Department of Ecology to Jennifer Wynkoop, Landau Associates, Associate Scientist,

Landau Associates and James Bet, Environmental Affairs, The Boeing Company. Re: *Preparing for Air Sampling of plume-related VOC's in Algona Sanitary Sewer Lines*. April 1.

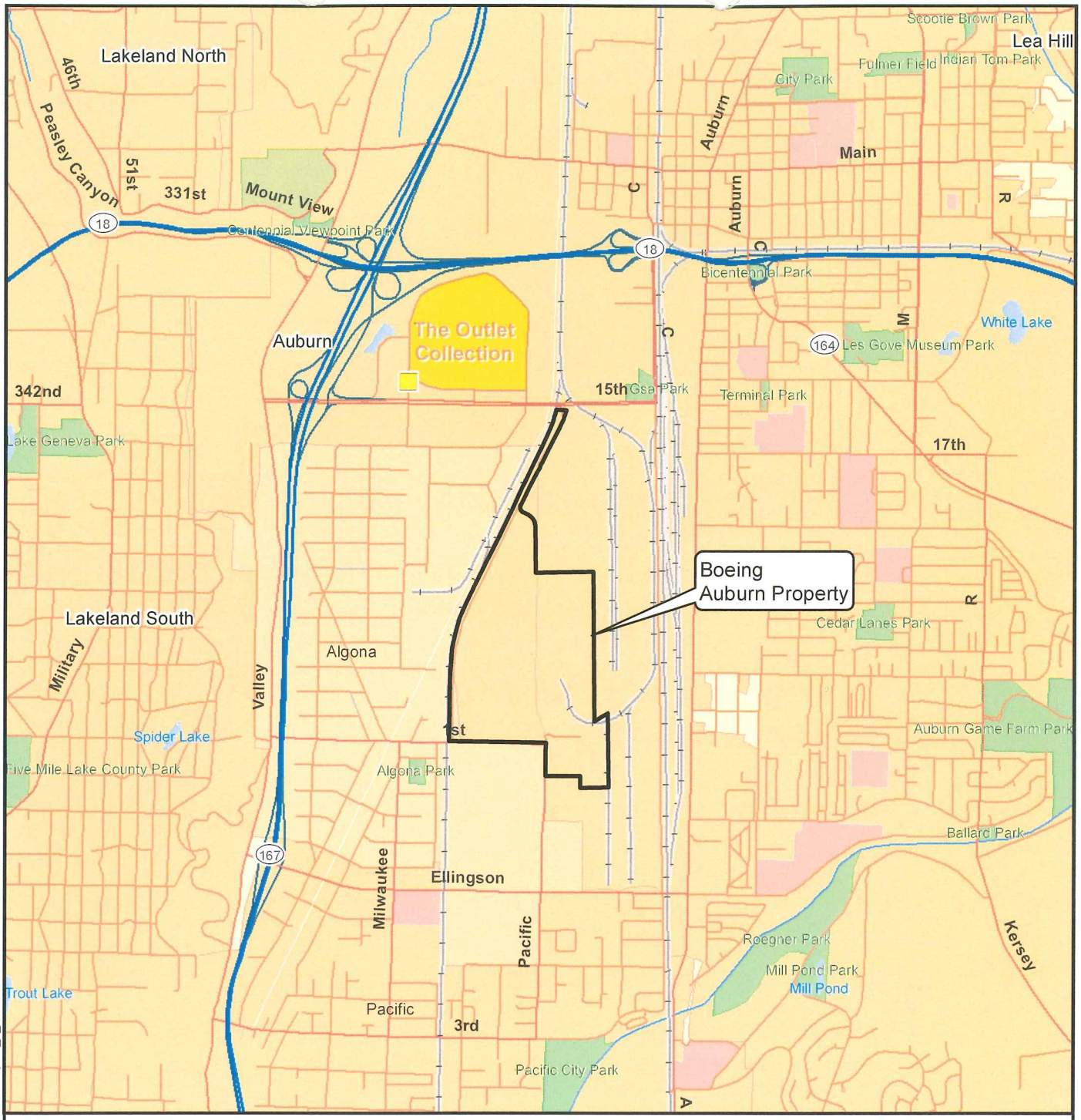
Ecology. 2007. *Model Toxics Control Act Statute and Regulation*. Publication No. 94-06. Washington State Department of Ecology. November.

Landau Associates. 2013. Report: *Work Plan Sewer Vapor Sampling, Boeing Auburn Facility, Auburn, Washington.* Prepared for the Boeing Company. April 24.

Hensley, P. 2013. Email message from Paul Hensley, Operations Director, The Outlet Collection, to Jennifer Wynkoop, Associate Scientist, Landau Associates. Re: *Auburn Sewers*. May 15.

ATTACHMENTS

Figure 1: Vicinity Map
Figure 2: Shallow Zone TCE Concentrations
Figure 3: Shallow Zone VC Concentrations
Table 1: Sewer Air Analytical Results



N

0 0.5 1

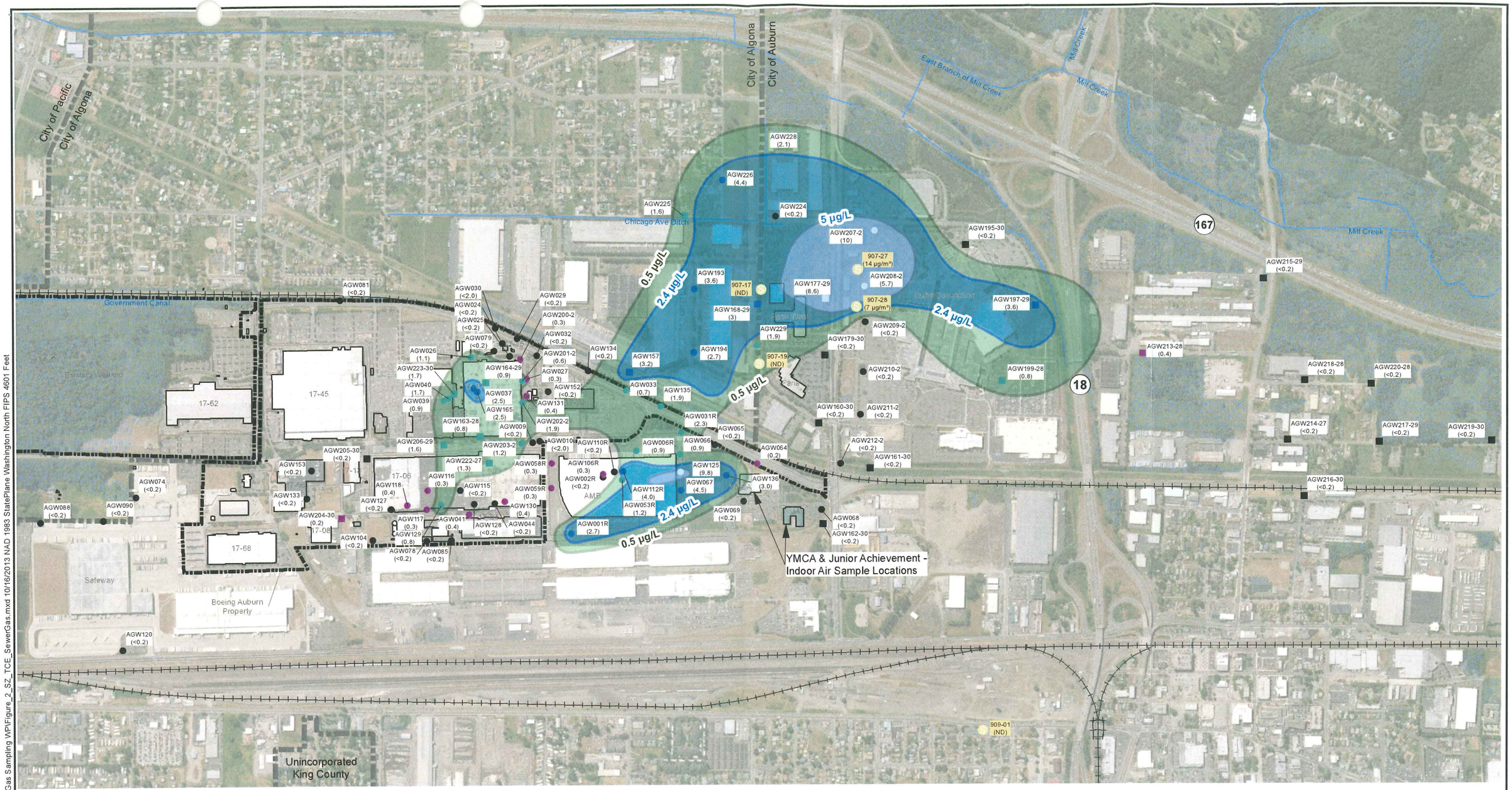
Miles

Data Source: ESRI 2008

Y:\Projects\025164\MapDocs\100\109\Direct Push Work Plan\Figure_1_R2.mxd 3/21/2013

LANDAU ASSOCIATES

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



Notes

1. All concentrations shown in µg/L. The screening level for TCE is 0.49 µg/L.
2. <0.2 = Compound not detected at indicated reporting limits.
3. TCE was collected during December 2012, borehole grab samples were collected at the time of drilling.
4. Multilevel wells have seven well channels. Channel designations are included in the well ID (ex: AGW208-1). Channels 1 and 2 are in the shallow aquifer zone.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Sewer Gas Sampling Location
- Monitoring Well Location
- Borehole Grab Sample Location
- Last TCE Detection = > 5 µg/L
- Last TCE Detection = > 2.4-5 µg/L
- Last TCE Detection = 0.5-2.4 µg/L
- Last TCE Detection = < 0.5 µg/L
- Non-Detect
- TCE Contour = ≥ 5.0 µg/L
- TCE Contour = > 2.4 µg/L
- TCE Contour = > 0.5 µg/L
- 14 µg/m³ Vapor Concentration
- Waterways
- Wetland Areas

N

0 1,000 2,000

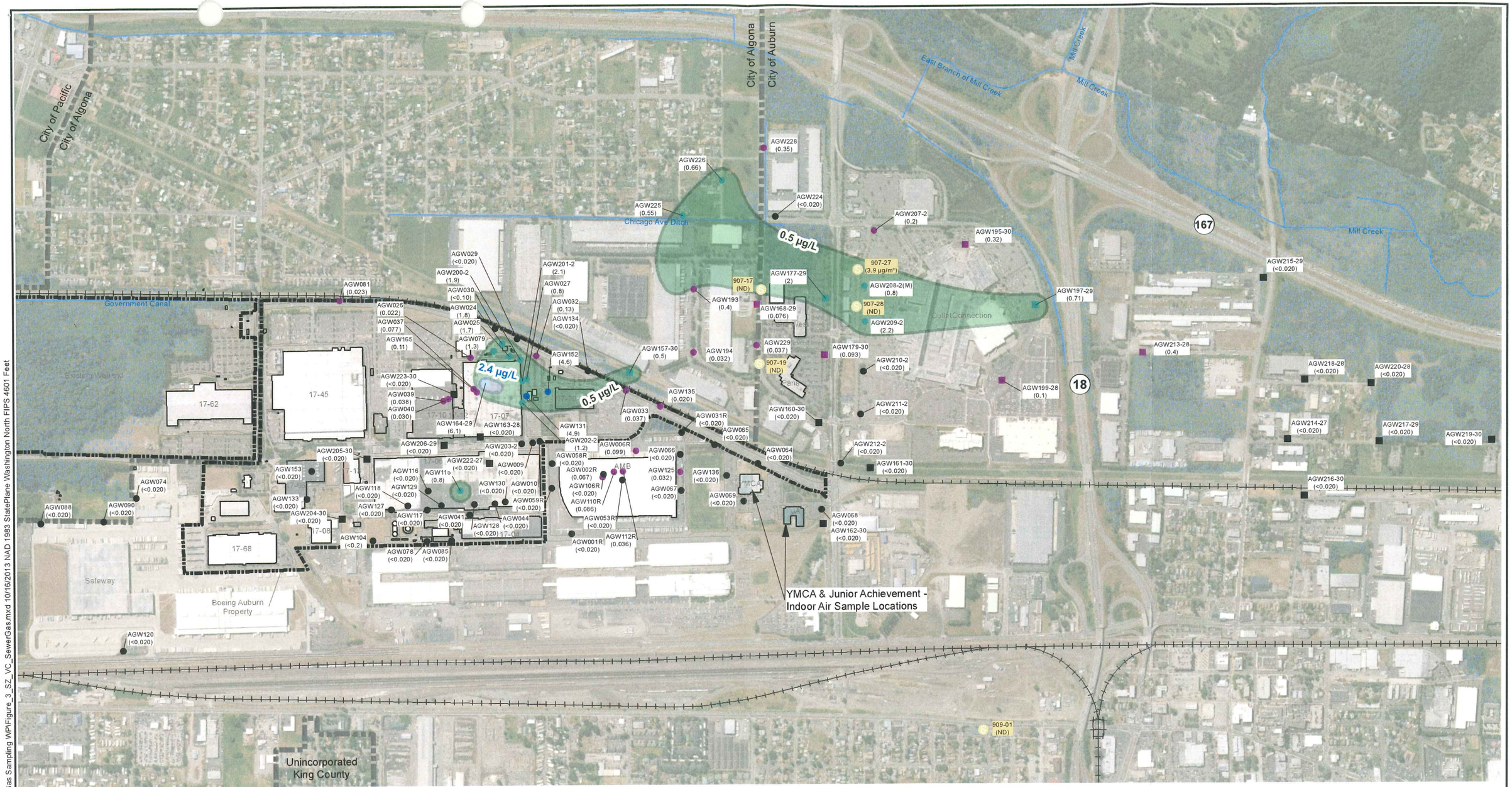
Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2010

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Shallow Zone TCE Concentrations Most Recent**	Figure 2

G:\Projects\025\164100\105\Sewer Gas Sampling\WP\Figure_2_SZ_TCE_SewerGas.mxd 10/16/2013 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. All concentrations shown in µg/L. The screening level for VC is 0.029 µg/L.
2. <0.020 = Compound not detected at indicated reporting limits.
3. Vinyl Chloride was collected during December 2012, borehole grab samples were collected at the time of drilling.
4. Multilevel wells have seven well channels. Channel designations are included in the well ID (ex: AGW208-1). Channels 1 and 2 are in the shallow aquifer zone.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Sewer Gas Sampling Location
- Last TCE Detection = > 5 µg/L
- Last TCE Detection = > 2.4-5 µg/L
- Last TCE Detection = 0.5-2.4 µg/L
- Last TCE Detection = < 0.5 µg/L
- Non-Detect
- VC Contour = ≥ 5.0 µg/L
- VC Contour = > 2.4 µg/L
- VC Contour = > 0.5 µg/L
- 3.9 µg/m³ = Vapor Concentration
- Waterways
- Wetland Areas

N

0 1,000 2,000

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2010

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Shallow Zone Vinyl Chloride Concentrations Most Recent**	Figure 3

G:\Projects\025\164\100\105\Sewer Gas Sampling \MP\Figure_3_SZ_VC_SewerGas.mxd 10/16/2013 NAD 1983 StatePlane Washington North FIPS 4601 Feet

TABLE 1
VAPOR ANALYTICAL RESULTS
SEWER MANHOLES
BOEING AUBURN FACILITY
AUBURN, WASHINGTON

VOLATILES (µg/m3)
Method TO-15

Location	Lab Id	Date Collected	Vinyl Chloride	Trichloro ethene	Tetrachloro ethene
	Air screening level:		*11*	*25*	*390*
SV-907-17-20130520	1305479-05A	5/20/2013	2.1 U	4.4 U	5.5 U
SV-907-19-20130521	1305479-01A	5/21/2013	2.0 U	4.3 U	5.4 U
SV-907-27-20130521	1305479-02A	5/21/2013	**3.9**	**14**	5.7 U
SV-907-28-20130521	1305479-03A	5/21/2013	2.2 U	**7.0**	5.8 U
SV-909-01-20130520	1305479-04A	5/20/2013	2.1 U	4.5 U	5.7 U

U = Indicates the compound was not detected at the reported concentration.

Bold = Detected compound.