2011-2012 Annual Report
SWMU-17 Remedial Action
Enhanced Anaerobic Bioremediation
Boeing Developmental Center
Tukwila, Washington

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Prepared for

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TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 INTRODUCTION

This document presents a 2011-2012 annual report for the anaerobic bioremediation remedial action performed at Solid Waste Management Unit (SWMU)-17 of The Boeing Company's (Boeing) Developmental Center (DC) in Tukwila, Washington (Figure 1). This is the first annual report following the start of the remedial action. The DC is a regulated facility under the Resource Conservation and Recovery Act (RCRA) with a facility identification number of WAD-09363-9946. The Washington State Department of Ecology (Ecology) is authorized by the U.S. Environmental Protection Agency (EPA) to implement RCRA corrective action through its Model Toxics Control Act (MTCA) regulations. Boeing is performing remedial actions at the DC under Ecology's voluntary cleanup program (VCP).

Remedial action at SWMU-17 is performed to enhance reductive dechlorination of tetrachloroethene (PCE) and trichloroethene (TCE) present in groundwater. SWMU-17 wells and site features are shown on Figure 2. Anaerobic bioremediation remedial action was performed in general accordance with the *SWMU-17 Remedial Action Work Plan* (Work Plan, Landau Associates 2011).

This annual report summarizes the activities and results for June 2011 through November 2012. During this reporting period, new injection wells (IWs) and monitoring wells (MWs) were installed, a single electron donor injection event was conducted at 11 wells in August 2011, and baseline and performance monitoring was conducted.

1.1 BACKGROUND

SWMU-17 comprises the general area of a former 67-gallon sump and associated 4,000-gallon steel underground storage tank (UST; designated DC-05) located west of Building 9-64 (Figure 2). Waste oil generated by hydraulic testing shops, automotive maintenance shops, and various other operations at the DC was discharged to the sump, which flowed into the UST. Periodically, waste oil was pumped from the UST for offsite treatment and disposal (SAIC 1994). The sump and UST were installed in 1957 and removed in late March or early April 1986 (Landau Associates 1987).

Following removal of the sump and UST and initial phases of the investigation (Landau Associates 2004), groundwater monitoring has focused on chlorinated volatile organic compounds (CVOCs) and selected metals (copper and arsenic). CVOCs of interest include PCE, TCE, and reductive dechlorination breakdown products cis-1,2-dichloroethene (*c*DCE) and vinyl chloride (VC). Preliminary screening levels (Landau Associates 2002) were exceeded for PCE and intermittently for dissolved metals (copper only) and total metals (both copper and arsenic); total metals concentrations have historically been substantially higher than dissolved concentrations. Through May 2008, prior to bioremediation pilot testing, the highest concentrations of PCE and TCE were detected at wells BDC-05-02 and BDC-05-07

(Landau Associates 2008). Groundwater concentrations of PCE ranged from approximately 5 to 33 micrograms per liter (µg/L) at BDC-05-07 and BDC-05-02; TCE at these two wells ranged from 7 to 45 µg/L. Preliminary screening levels for total and dissolved copper and total arsenic were exceeded in groundwater at multiple wells. Cumulative data for these constituents are presented for SWMU-17 wells in Table 1. Screening levels presented in Table 1 are those screening levels proposed for the DC site in the 2002 *Corrective Action Summary Report* (Landau Associates 2002). Proposed cleanup levels for the DC (Landau Associates 2013) are also presented in Table 1.

Bioremediation pilot testing of electron donor amendment to enhance biological degradation of PCE and TCE began in October 2008. The pilot test began with installation of an additional downgradient MW (BDC-05-08) and a baseline monitoring event. On October 28, 2008, water amended with electron donor substrates, nutrients, and ferrous sulfate (included in the injection solution in an attempt to stimulate removal of dissolved copper and arsenic from groundwater and abiotic degradation of PCE and TCE through reaction with formed iron sulfides) was injected to well BDC-05-02. Details on the pilot test can be found in the *Pilot Test Report* (Landau Associates 2010a) and the subsequent Response to Ecology Comments (Landau Associates 2010b).

Bioremediation stimulated by electron donor injection was successful in substantially reducing PCE and TCE at the injected well and, with time, at the nearest downgradient well. At the end of pilot testing (February 2010), PCE and TCE were reduced to below detection limits at IW BDC-05-02 and were reduced to approximately 25 percent of baseline at well BDC-05-07, located 20 ft downgradient (Landau Associates 2010b). Through the pilot testing period (October 2008 to February 2010), *c*DCE concentrations increased at BDC-05-02 and BDC-05-07. *c*DCE was not further dechlorinated to subsequent breakdown product VC, or to innocuous end products ethene or ethane. There was no evidence of substantial abiotic degradation of PCE or TCE, nor was there enhanced decrease in the concentrations of dissolved or total metals.

A supplemental direct-push investigation (Landau Associates 2010b) indicated a limited extent of treatment from the pilot test, very slow downgradient transport of injected electron donor, and a smaller than anticipated radius of influence (ROI), indicating that full-scale treatment would be most effective by injecting at multiple wells located on relatively close spacing throughout the contaminated area, to achieve adequate treatment coverage. The supplemental investigation also indicated that the extent of contamination was larger than previously understood, which led to additional characterization efforts.

In order to further characterize the SWMU-17 plume, groundwater was sampled from 67 additional direct-push borings in 2010 and 2011. Both the horizontal and the vertical extents of contamination were characterized (Landau Associates 2011). Results from the deeper borings confirmed that contamination is restricted to the shallow interval. However, the horizontal boundaries of PCE and

TCE contamination were found to extend farther downgradient toward the west than previously understood. The observed west to southwesterly contaminant distribution is attributed to groundwater flow generally toward the Duwamish River, with some preferential flow paths and variability in localized flow directions. Isoconcentration contours representing SWMU-17 concentrations of PCE and/or TCE are presented on Figure 3. Both PCE and TCE are parent products targeted for remediation.

Anaerobic biodegradation end products of PCE and TCE were also detected. TCE breakdown product *c*DCE was detected in most borings where PCE and/or TCE were present. The distribution of *c*DCE also confirmed the general west to southwest alignment of the contaminant plume. Relatively low concentrations of VC were detected in some of the direct-push borings, indicating that aquifer micro-organisms are capable of further degradation beyond *c*DCE and suggesting that innocuous end products ethene and ethane may be achieved through biotreatment. Further details on plume characterization and evaluation of contaminant distribution are provided in the Work Plan (Landau Associates 2011).

1.2 REMEDIAL APPROACH

Anaerobic bioremediation at SWMU-17 is accomplished through stimulation of micro-organisms present in the aquifer to enhance biodegradation of chloroethenes. Vegetable oil and ethyl lactate (electron donor substrate) were injected through the higher-concentration core of the plume to stimulate biotic reductive dechlorination of PCE and TCE (electron acceptors).

Reductive dechlorination of PCE and TCE occurs through microbially mediated (biotic) reactions whereby micro-organisms obtain energy through oxidation-reduction (redox) reactions. Electron donors (hydrogen, fatty acids, etc.) are used by microbes together with various electron acceptors [oxygen, nitrate, manganese (IV), ferric iron, sulfate, and carbon dioxide]. These redox reactions can be compared to the process whereby humans obtain energy through consumption of food (electron donor) and oxygen (electron acceptor). Bacteria obtain the greatest energy yield by using oxygen as an acceptor, as it is highly oxidized and, therefore, can be reduced easily and to a large degree. When oxygen is depleted in an uncontaminated aquifer, bacteria sequentially use the less oxidized electron acceptors in the following order: nitrate, manganese (IV), iron (III) (i.e., ferric iron), sulfate, and carbon dioxide.

Chloroethenes can also be used as electron acceptors by specific micro-organisms and degraded to harmless end products. Through biodegradation, chlorine ions present on the chlorinated hydrocarbon molecule are replaced with hydrogen (electron donor), resulting in the formation of successively less chlorinated molecules. By this process, PCE and TCE are degraded to less chlorinated breakdown products *c*DCE, and VC, and then to innocuous end products ethene and ethane. PCE is the most oxidized electron acceptor in groundwater systems after oxygen (Vogel et al. 1987) and, therefore, can be reduced as soon as oxygen is depleted. TCE, *c*DCE, and VC, however, require successively more reducing aquifer conditions for degradation. TCE can be degraded under iron-reducing conditions (Chapelle 1996); *c*DCE can be degraded under sulfate-reducing or methanogenic conditions (Chapelle 1996; Vogel et al. 1987); and VC can be degraded only under highly reducing carbon dioxide (CO_2)-reducing (methanogenic) conditions (Ballapragada et al. 1997; Freedman and Gosset 1989; Maymó-Gatell et al. 1995; Vogel and McCarthy 1985).

Reductive dechlorination is enhanced through injection of electron donor substrates (e.g., vegetable oil and lactate) as a food source for the bacteria. Electron donor substrates are injected into the contaminated aquifer where indigenous bacteria ferment the substrate to volatile fatty acids and hydrogen, which are then used by micro-organisms for reduction of natural electron acceptors and chloroethenes. Depletion of natural electron acceptors (e.g., oxygen, iron, sulfate, CO_2) creates the highly reducing aquifer conditions (sulfate-reducing to methanogenic conditions) required for complete reductive dechlorination of PCE and breakdown products. Hydrogen is the required electron donor for VC and *c*DCE degraders [i.e., *Dehalococcoides* (DHC) strains] to degrade these PCE breakdown products to harmless non-chlorinated products. Other anaerobic dechlorinating organisms are typically common and widespread, and many can utilize the fatty acids directly as electron donor.

2.0 SUMMARY OF ACTIVITIES AND RESULTS

This section summarizes activities that took place during the reporting period, including installation of new groundwater wells in July 2011, an injection event in August 2011, and groundwater monitoring performed in July and November 2011, and in February, May, August, and November 2012.

2.1 WELL INSTALLATION

Sixteen groundwater wells (BDC-05-09 through BDC-05-24) were installed July 5 through July 11, 2011. Wells were installed using a truck-mounted, hollow-stem auger drill rig for most locations, and with a limited-access, hollow-stem auger drill rig used for locations BDC-05-18, BDC-05-21, and BDC-05-23. Well locations were as proposed in the Work Plan with the following modifications:

- BDC-05-13 - moved 2 feet (ft) to the north to be out of a parking stall.
- BDC-05-18 - moved 3 ft to the north due to a tree interfering with drill rig operation.
- BDC-05-20 - moved 9.5 ft southwest due to underground utility conflicts.
- BDC-05-22 - moved 5 ft east due to underground utility conflicts.
- BDC-05-23 - moved 4 ft east to avoid a utility conflict and be more centered in the contaminant plume.
- BDC-05-24 - moved 2 ft northeast to be closer to the direct-push boring location that had the highest concentration of VC.

None of these well location changes adversely affected the intended function of the wells. The as-built locations of both newly installed and previously existing wells are presented on Figure 2.

Although some of the new wells were intended only for monitoring, each was constructed to allow for both donor injection and groundwater monitoring. Each new groundwater well was installed to a total depth of just over 25.ft below ground surface (BGS), with screens extending from 15 to 25 ft BGS. Wells were constructed with 2-inch diameter, flush-threaded, schedule 40, PVC well casing and screen (0.020-inch slot size). A sand pack of 2/12 Monterey sand was placed from the bottom of the well to 2 ft above the screen, and a 2-ft deep seal of hydrated bentonite pellets was placed on top of the sand pack. A cement/bentonite grout was used to seal the well to within 4 ft BGS, and a traffic-rated flush-mount well monument was set in concrete. At BDC-05-20, which is near the edge of a roadway, a heavy-duty aluminum monument was used. A PVC male pipe thread adapter was glued to the top of each new IW to facilitate connection to the injection hose. At half of the 16 locations, soil cores were collected at 5-ft intervals during drilling for lithologic logging and to screen for the presence of non-aqueous phase liquid (NAPL) using a photoionization detector (PID). The soil cores were collected from approximately every other well boring located along the centerline of the PCE/TCE plume. Boring logs and well construction diagrams for the new wells are presented in Appendix A.

Following completion, wells were developed, top of casing elevations determined, and IWs were registered. Monitoring wells were developed July 12 and 13, 2011. The top of casing elevations of new wells were measured on August 22, 2011 using auto-level survey equipment and referencing previously surveyed MWs. Injection wells were registered with the Washington State Underground Injection Control (UIC) program, and confirmation of the registration is presented in Appendix B.

2.2 INJECTION

Electron donor solution was injected into 11 wells during the 4 days of August 15 through August 18, 2011, in general accordance with the Work Plan (Landau Associates 2011). Each of the 11 wells (BDC-05-02, BDC-05-07, and BDC-05-09 through BDC-05-17) was injected with approximately 5,600 gallons of donor injection fluid, consisting of approximately 5,300 gallons of potable water from an onsite hydrant, 6 drums (320 gallons) of LactOil™ donor substrate, and 2 lbs of yeast extract. LactOil is a combination donor substrate containing both soluble (fast-release) ethyl lactate and insoluble (slow-release) soybean oil. Injection at each well was preceded and followed by a flush of unamended, potable water to minimize biofouling. Exact injection volumes varied slightly from well to well. The order of well injection was generally staggered to avoid injecting adjacent wells sequentially. This approach allowed groundwater mounding caused by injection to dissipate before injecting the next adjacent well. A summary of injection data is provided in Table 2.

A gasoline-powered, centrifugal injection pump [3-inch, 8 horsepower (hp), 290 gallons per minute (gpm)] was used, and injection pressures and flow rates were monitored on regular intervals. It was anticipated that the injection pump would be operated at a reduced throttle to keep injection pressures below 15 to 20 pounds per square inch (psi), to minimize short-circuiting of injection fluid to the ground surface while maintaining a pressurized well screen for uniform application of injection fluid. However, little to no backpressure was observed when the pump was operating at full throttle. No discharge of injection fluid occurred to the ground surface. Nearby storm and sanitary sewer systems were observed repeatedly during injection, with no signs of infiltrating injection fluid.

2.3 MONITORING

Baseline and quarterly monitoring was performed during the reporting period in general accordance with the Work Plan. Baseline sampling was performed in July 2011 at all wells with the exception of five pre-existing wells (BDC-05-03 through BDC-05-05, BDC-05-07, and BDC-05-08) for which extensive historical data is available and May 2011 data was used as baseline. Post-injection semiannual sampling was performed in November 2011, and in May and November 2012. Quarterly sampling was performed in February and September 2012. Semiannual sampling was performed at all 22 wells, and included collection of groundwater elevations. Quarterly monitoring was performed at 10 select wells, including three representative IWs (BDC-05-02, BDC-05-12, and BDC-05-16), the three MWs located within the core of the plume between IWs (BDC-05-18 through BDC-05-20), and the four downgradient and crossgradient wells (BDC-05-21 through BDC-05-24). The groundwater monitoring matrix (from the work plan) is presented in Table 3.

Samples collected for baseline and performance monitoring were analyzed for target contaminants and breakdown products (PCE, TCE, *c*DCE, and VC); non-toxic end products (ethene and ethane); parameters indicative of aquifer redox conditions [dissolved oxygen (DO), oxidation-reduction potential (ORP), nitrate, ferrous iron, sulfate, and methane]; and total organic carbon (TOC) and pH indicative of electron donor. In accordance with the Work Plan, laboratory analysis of methane/ethane/ethene/acetylene was only performed at select wells. In addition, metals analysis for total and dissolved copper and arsenic was performed during baseline and semiannual monitoring. Laboratory analysis was performed by Analytical Resources Inc. (ARI) in 2011, and by Eurofins Lancaster Laboratories (LLI) starting in 2012. Other parameters (DO, ORP, ferrous iron, and pH) were measured in the field. Groundwater monitoring data are presented in Table 1. Laboratory reports for baseline and performance monitoring in the reporting period are presented in Appendix C.

Nitrate analysis was discontinued based on monitoring results indicating it was not a useful parameter for evaluation of aquifer redox conditions. Nitrate was not detected at most wells during baseline sampling and not detected at any wells during the November 2011 and February 2012 post-injection sampling events. Ecology was notified that nitrate analysis would be discontinued beginning with the May 2012 sampling event.

Groundwater elevations were measured at new injection and MWs during the November 2011 and May and November 2012 semiannual sampling events. Consistent with previous data, results show generally west southwesterly groundwater flow, with a northerly component near wells BDC-05-10 and BDC-05-11. These groundwater flow directions are consistent with contaminant distribution in the plume. Groundwater elevation contours for November 2011, May 2012, and November 2012 are presented on Figures 4 through 6. Cumulative groundwater elevation data for SWMU-17 wells is presented in Appendix D.

3.0 DISCUSSION OF RESULTS

This section presents discussion and interpretation of data obtained during baseline monitoring and post-injection performance monitoring. Monitoring results are summarized in a cumulative data table (Table 1), presented on various figures and appendices, and discussed further in the following sections. Figures 7 through 14 show VOCs concentrations over time at selected wells: BDC-05-02 and BDC-05-07 (source zone IWs); BDC-05-10 and BDC-05-16 (plume IWs); BDC-05-19 (MW between IWs in the core of the plume); and BDC-05-20 and BDC-05-21 (MWs at downgradient edge of the plume). A table of VOC concentrations converted to molar equivalents and molar fractions is presented in Appendix E. Time plots for molar concentrations of VOCs and breakdown products for selected wells are presented in Appendix F. Time plots of redox parameters (methane, sulfate, and DO) and TOC for selected wells are presented in Appendix G.

Evaluation of results must include consideration of whether data is from IWs or MWs. These well types are identified in Table 1 and are identified by different symbols on Figures 2 and 3. Characteristics of these two groups of wells are as follows:

- IWs: IWs are generally located within the high concentration core of the PCE/TCE plume. Due to higher initial concentrations of PCE and TCE, biodegradation to breakdown products and end products is most apparent. Because these wells were used for injection, TOC concentrations (indicative of electron donor) are likely to be higher and persist for longer than at nearby MWs. Similarly, enhanced aquifer redox conditions are likely to develop sooner and persist for a longer than in the rest of the aquifer.
- MWs: Groundwater data from MWs provide insight to the downgradient and cross-gradient extent of treatment effects, including distribution of TOC, enhanced redox conditions, and dechlorination breakdown products and end products. An understanding of the MW locations relative to the plume and to IWs is also important for evaluation of the data, as follows:
    - Some MWs are within the core of the contaminant plume (BDC-05-03 and BDC-05-19). Similar to the IWs, higher initial concentrations of PCE and TCE at these MWs makes biodegradation to breakdown products and end products most apparent. For example, end product ethene is present at BDC-05-19, indicating full dechlorination is occurring due to donor injection at the upgradient IW.
    - Other MWs are at the fringes of the plume, both downgradient (BDC-05-20) and crossgradient (BDC-05-04, BDC-05-08, BDC-05-18, BDC-05-21, BDC-05-22, and BDC-05-24), and an additional well is far downgradient (BDC-05-23). Changes in concentrations of PCE, TCE, and breakdown products at these wells are generally not observed due to low initial concentrations of PCE and TCE. Some of these wells have slightly elevated TOC concentrations, indicating the extent of downgradient and crossgradient donor transport.
    - An additional MW is located upgradient of the plume (BDC-05-05). This well is sampled for continued evaluation of background conditions and is unaffected by bioremediation.

3.1 BASELINE CONDITIONS

Baseline monitoring took place on July 31, 2011 at all wells except for five pre-existing wells (BDC-05-03 through BDC-05-05, BDC-05-07, and BDC-05-08) for which May 2011 data was used as baseline. Baseline data from the new wells are consistent with the extent of contaminant as described in the Work Plan, which was based on direct-push data and pre-existing MWs (Landau Associates 2011). The highest baseline concentrations of PCE and TCE were 39 µg/L (BDC-05-10) and 28 µg/L (BDC-05-15), respectively. PCE and TCE concentrations at downgradient and cross-gradient wells located outside the core of the plume were relatively low for one or both constituents (BDC-05-04, BDC-05-18, BDC-05-20, and BDC-05-22) or not detected (BDC-05-08, BDC-05-21, BDC-05-23, and BDC-05-24).

Baseline aquifer redox conditions were variable, with more highly reducing conditions occurring at source zone wells BDC-05-02 and BDC-05-07 due to prior pilot testing. At BDC-05-02 and BDC-05-07, redox conditions were sulfate-reducing to methanogenic, as evidenced by relatively low sulfate and elevated methane concentrations. Downgradient of these two wells, mild to moderately reducing conditions (nitrate to iron-reducing) predominated as evidenced by low nitrate concentrations, presence of ferrous iron (Fe II), and moderate to high sulfate concentrations. Baseline TOC concentrations were below 10 milligrams per liter (mg/L) at most wells, the threshold generally considered to represent sufficient electron donor to support reductive dechlorination (Major et al. 2003).

3.2 POST-INJECTION CONDITIONS

Groundwater monitoring results show that *in situ* anaerobic bioremediation has been enhanced following the August 2011 electron donor injection. Results indicate enhanced aquifer redox conditions, enhanced desorption of contaminant mass, and enhanced reductive dechlorination. Complete reductive dechlorination is occurring, as indicated by detection of end product ethene at a number of wells.

3.2.1 TREATMENT CONDITION CATEGORIES

Based on monitoring results, SWMU-17 wells can be separated into three categories relating to evidence of enhanced conditions for bioremediation treatment:

1. **Direct Evidence**: 14 wells show direct evidence of enhanced bioremediation consisting of increased TOC above baseline, reduced aquifer redox conditions, and changed concentrations of PCE, TCE, or breakdown products. These wells consist of:
   - All eleven IWs: BDC-05-02, BDC-05-07, BDC-05-09 through BDC-05-17
   - Three MWs:
     - BDC-05-03 (17 ft downgradient of IW BDC-05-11)
     - BDC-05-18 (12 ft crossgradient of IW BDC-05-10)
     - BDC-05-19 (10 ft downgradient of IW BDC-05-12).

2. **Some Evidence**: Four MWs show some evidence of enhanced bioremediation consisting of elevated TOC or a change in concentrations of PCE, TCE, or breakdown products, but not both:

   - BDC-05-08 (24 ft crossgradient of IWs BDC-05-12 and BDC-05-13),
   - BDC-05-20 (31 ft downgradient of IW BDC-05-17)
   - BDC-05-21 (30 ft crossgradient of IW BDC-05-17)
   - BDC-05-24 (18 ft crossgradient of IW BDC-05-14).

3. **No Evidence**: Four MWs show no evidence of enhanced bioremediation (these wells will not be discussed further in this report):

   - BDC-05-04 (22 ft crossgradient of IW BDC-05-07)
   - BDC-05-05 (upgradient of IW BDC-05-02)
   - BDC-05-22 (48 ft crossgradient of IW BDC-05-17),
   - BDC-05-23 (170 ft downgradient of IW BDC-05-17).

Based on this categorization of well results, bioremediation has been substantially enhanced at IWs and at MWs located up to 17 ft downgradient and 12 ft cross-gradient of IWs. Some evidence of bioremediation occurs at MWs located up to 31 ft downgradient and 30 ft cross-gradient of IWs. Wells without evidence of enhanced bioremediation are at the edges of the plume or far downgradient.

3.2.2 TOC AND REDOX CONDITIONS

Following the August 2011 injection, monitoring results indicate aquifer TOC and redox conditions have been enhanced throughout the core of the contaminant plume. These results indicate conditions conducive to enhanced bioremediation of PCE/TCE and breakdown products.

In November 2011, TOC increased from low baseline levels at all IWs to a range of 550 to 5360 mg/L as a result of donor injection. As of November 2012, TOC remains elevated (between 26 and 266 mg/L) at all IWs.

Increases in TOC at MWs indicate an outward expansion in the extent of treatment effects downgradient and cross-gradient from the IWs. As of November 2011, TOC had increased from baseline at cross-gradient MW BDC-05-18 (22 mg/L), and at downgradient wells BDC-05-03(70 mg/L) and BDC-05-19 (170 mg/L); this increased TOC was not observed in subsequent monitoring of BDC-05-18 and BDC-05-03, but continued at downgradient well BDC-05-19, ranging from 68 to 296 mg/L. In May 2012, increased TOC was also observed at cross-gradient wells BDC-05-08 (12.4 mg/L) and BDC-05-21 (12.3 mg/L), before returning to near-baseline concentrations. Short-lived increases in TOC at the four cross-gradient wells in November 2011 and May 2012 indicate some distribution of injected donor at distances of 12 to 30 ft cross-gradient of IWs. However, the short-lived increase in TOC at these wells is not adequate for sustained treatment and is not considered direct evidence of enhanced bioremediation.

Highly reducing conditions required for reductive dechlorination have been achieved throughout the core of the plume, as indicated by decreasing concentrations of sulfate and increasing concentrations of methane in all IWs through November 2012. Highly reducing conditions have also been achieved at downgradient wells BDC-05-19 and BDC-05-20, located 10 and 21 ft downgradient of IWs, respectively. At other downgradient and cross-gradient MWs, redox changes have been minor (e.g., decreasing DO) or short-lived (e.g. a brief decrease in sulfate followed by a rebound to baseline levels).

3.2.3 REDUCTIVE DECHLORINATION

Monitoring results indicate enhanced reductive dechlorination is occurring at most SWMU-17 wells. This includes all IWs with baseline detections of PCE/TCE and most downgradient MWs.

Reductive dechlorination has resulted in PCE and TCE concentrations reduction and conversion to breakdown products at all but one of the eleven IWs. The exception is BDC-05-02, where PCE and TCE were below reporting limits at the July 2011 baseline sampling due to prior treatment resulting from the 2008 pilot test. As of November 2012, PCE and TCE concentrations were below reporting limits at all IWs, with the exception of a low detection of TCE at BDC-05-07 (0.4 µg/L). At well BDC-05-10 in November 2012, which had the highest baseline concentration of PCE and the second highest concentration of TCE of all SWMU-17 wells, the decrease of PCE and TCE to below reporting limits represents reduction of greater than 96 percent. Increases in one or more breakdown products (*c*DCE, VC, ethene, and ethane) were observed at all IWs with the exception of BDC-05-07.

At three of four downgradient MWs, concentrations of PCE and/or TCE have decreased from baseline due to reductive dechlorination, with corresponding conversion to breakdown products. Results at these wells are as follows:

- BDC-05-19 (approximately 10 ft downgradient of IW BDC-05-12 and in the core of the PCE/TCE plume): November 2012 results for PCE (<1.0 µg/L) and TCE (1.1 µg/L) represent greater than 93 percent reductions from baseline. Increased concentrations of breakdown products *c*DCE, VC, and end product ethene were observed starting in February 2012.
- BDC-05-20 (located at the leading edge of the plume and approximately 31 ft downgradient of IW BDC-05-17): PCE remained below reporting limits and concentrations of TCE steadily decreased from 7.0 µg/L to 0.6 µg/L in November 2012. Breakdown product VC increased concurrently to 3.5 µg/L in November 2012.
- BDC-05-03 (17 ft downgradient of IW BDC-05-11): PCE and TCE were not detected in November 2012, a decrease from relatively low but persistent concentrations before and after injection.
- Evidence of reductive dechlorination is not observed at far downgradient MW BDC-05-23. PCE and TCE concentrations have remained low or not detected while *c*DCE concentrations have steadily increased from 3.2 to 6.9 µg/L in November 2012. Increasing cDCE appears to result from upgradient dechlorination and transport of *c*DCE to this well.

Substantial reductive dechlorination is not observed at the six crossgradient MWs, where baseline concentrations of PCE and TCE were mostly low or not detected. At MW BDC-05-18 (approximately

12 ft cross-gradient from IW BDC-05-10), somewhat higher baseline concentrations of PCE (3.6 µg/L) decreased to 1 µg/L in November 2012, with a corresponding increase in cDCE from 6.6 to 16 µg/L; there is direct evidence of enhanced TOC and redox conditions at this well as described in Section 3.2.2.

Complete reductive dechlorination is evidenced by detection of innocuous end product ethene in November 2012 at nine wells consisting of BDC-05-09 (69 µg/L), BDC-05-10 (8.5 µg/L), BDC-05-11 (7.6 µg/L), BDC-05-13 (3.7 µg/L), BDC-05-14 (1.4 µg/L), BDC-05-15 (1.8 µg/L), BDC-05-16 (4.0 µg/L), BDC-05-17 (2.0 µg/L), and BDC-05-19 (5.5 µg/L). Additionally, end product ethane was detected in November 2011 at well BDC-05-10 (1.7 µg/L). Although 2008 pilot test results were inconclusive as to whether cDCE could be further dechlorinated to VC and non-toxic end products ethene and ethane at SWMU-17, these results demonstrate complete reductive dechlorination to these end products.

3.2.4 DESORPTION

Enhanced desorption of contaminant mass is evidenced at some wells where substantial concentrations of breakdown product *c*DCE have been observed relative to baseline concentrations of PCE and TCE. This is most notable at source zone IW BDC-05-02, where baseline concentrations of PCE (<1.0 µg/L), TCE (<1.0 µg/L), and cDCE (10 µg/L) had increased substantially at the first monitoring event following injection (November 2011) to PCE (8.4 µg/L), TCE (4.8 µg/L), and cDCE (150 µg/L). PCE and TCE subsequently decreased to below reporting limits at this well, while cDCE increased to a maximum of 220 µg/L before declining to 32 µg/L in November 2012. Similar results were observed at BDC-05-09, where the maximum concentration of cDCE (250 µg/L in May 2012) was substantially higher than concurrent or prior detections of parent products PCE and TCE. This was also observed at wells BDC-05-07, BDC-05-10, BDC-05-16, and BDC-05-19. This enhanced desorption is apparent in the concentration plots for these six well presented on Figures 7 through 12. By comparision, desorption effects are not readily apparent for BDC-05-20 and BDC-05-21 in concentration plots presented on Figures 13 and 14.

This occurrence of breakdown product concentrations, substantially higher than parent products, results from enhanced desorption of PCE and/or TCE from the aquifer matrix, and subsequent rapid dechlorination in the aqueous phase. This evidence of enhanced desorption is commonly observed with *in situ* bioremediation and is a beneficial treatment mechanism to treat the total mass present in the aquifer and prevent contaminant concentration rebound following the period of active treatment (Parsons, 2004; Suthersan et. al., 2002).

Enhanced desorption becomes most apparent when concentrations of PCE, TCE, and breakdown products are converted to molar concentrations for direct comparision of the moles of each compound present. Through reductive dechlorination, 1 mole of PCE dechlorinates sequentially to 1 mole of TCE, to 1 mole of cDCE, to one mole of VC, and to 1 mole of ethene+ethane. Enhanced desorption can also be observed in the change with time of total chloroethenes (i.e., the molar sum of PCE, TCE, cDCE, and VC). Enhanced desorption is evidenced by higher molar concentrations of breakdown products (e.g., cDCE) than parent products PCE/TCE and by a concentration of total chloroethenes that increases with time following bioremediation injection. Concentration data converted to molar equivalents is presented in Appendix E and molar VOC concentrations plots are presented in Appendix F. Enhanced desorption is apparent for wells BDC-05-02, BDC-05-07, BDC-05-09, BDC-05-10, BDC-05-16, and BDC-05-19 (Figures F-1 through F-6). By comparision, desorption effects are not readily apparent for BDC-05-20 and BDC-05-21 on Figures F-7 and F-8. Conversion of sorbed PCE and TCE mass to aqueous phase *c*DCE represents a significant reduction in toxicity, and the total mass of chlorinated ethenes will decrease with time as remaining PCE and TCE is desorbed and reductive dechlorination continues.

3.2.5 PROGRESS OF REDUCTIVE DECHLORINATION

IWs and MWs are at various stages of treatment, depending on their locations relative to the core of the plume and the aquifer area where bioremediation has been enhanced. Reductive dechlorination progresses sequentially from parent products PCE and TCE, to breakdown products *c*DCE and VC, to non-toxic end products ethene and ethane. Bacteria prefer to degrade PCE over TCE, TCE over *c*DCE, and *c*DCE over VC because more energy is obtained from the more chlorinated (i.e., oxidized) compounds. As a result of this sequential degradation, the concentrations of parent, breakdown, and end products peak sequentially as treatment progresses.

The treatment stage of each well can be assessed at any given time by examining which parent, breakdown, or end products are predominant. Concentration data for PCE, TCE, cDCE, VC, and ethene+ethane are presented as molar equivalents [i.e., µmoles per liter (µmoles/L)] and molar fractions in Appendix E. For a given well and sampling event, molar fractions are calculated by dividing the molar concentration of each compound by the total ethenes (i.e., total chloroethenes+ethene+ethane) molar concentration. Changes over time in the predominant compound (i.e., has the largest molar fraction) demonstrates progress of sequential reductive dechlorination through breakdown products to end products. In the molar fraction data presented in Appendix E, the predominant ethene is highlighted for each sample result. From the shading, it is apparent that a baseline predominance of PCE, TCE, or cDCE has progressed to a predominance of cDCE, VC, or ethene/ethane, demonstrating substantial treatment progression in the 15 months since donor injection. As of November 2012, VC is predominant at seven wells and end product ethene predominates at five wells. As of November 2012, treatment had progressed to such an extent at IWs BDC-05-13 and BDC-05-16, that only VC and ethene were detected.

Figure 15 presents a generalized sequence of parent, breakdown, and end products that result from reductive dechlorination over time. The range of baseline conditions, consisting of PCE to cDCE predominance, is shown. Conditions as of November 2012 (excluding upgradient well BDC-05-05) are represented by a range of cDCE to ethene predominance.

3.2.6 PROGRESS OF CONTAMINANT CONCENTRATION REDUCTION

Treatment progress is also evaluated by comparing PCE, TCE, cDCE, and VC concentrations to preliminary screening levels (Landau Associates 2002) and proposed cleanup levels (Landau Associates 2013). Analytical results are presented with screening levels and proposed cleanup levels in Table 1. Results of this comparison are described below:

- Eight wells had baseline PCE detections that exceeded the 9 µg/L preliminary screening level; TCE, cDCE, and VC baseline concentrations were below screening levels. As of November 2012, all results were below screening levels.
- Baseline detections exceeded the proposed cleanup levels for PCE (8 wells), TCE (13 wells), and VC (1 well), while baseline *c*DCE concentrations were below the proposed cleanup level. As of November 2012, detections exceeded the proposed cleanup levels for TCE (2 wells) and VC (11 wells); PCE and *c*DCE results at all wells had decreased to below proposed cleanup levels. At 8 of 11 wells where the proposed cleanup level for VC was exceeded in November 2012, ethene and/or ethane were also detected, indicating that complete reductive dechlorination is occurring. We expect VC dechlorination to ethene and will continue and that VC concentrations will decrease below the proposed cleanup level with additional time, as aquifer conditions remain conducive to ongoing treatment (Section 3.2.2).
- At all wells where direct evidence of enhanced bioremediation was observed (all eleven IWs and three MWs as discussed in Section 3.2.1), baseline results exceeded proposed cleanup levels for PCE and/or TCE. With a single exception, this baseline condition transitioned to no exceedances (4 wells) or exceedance of VC only (9 wells) in November 2012. MW BDC-05-18 (12 ft crossgradient of IW BDC-05-10) was the exception, where TCE exceeded the proposed TCE cleanup level in July 2011 and in November 2012. At BDC-05-18, TCE concentrations have fluctuated while PCE has steadily decreased concurrent with increases of *c*DCE; this data is consistent with PCE degradation to TCE and then cDCE.

3.2.7 METALS

Concentrations of arsenic and copper increased at many SWMU-17 wells following the August 2011 injection. These results are consistent with what was observed during bioremediation pilot testing.

As of November 2012, 19 of 22 sampled wells had total and dissolved arsenic concentrations above the proposed cleanup level (Landau Associates 2013) of 0.008 mg/L. November concentrations at 16 of these wells were higher than baseline; these wells consist of all IWs and 5 MWs (BDC-05-04, BDC-05-19, BDC-05-21, BDC-05-22, and BDC-05-23). The highest concentration was a total arsenic result of 0.088 mg/L at well BDC-05-19. At half the 16 wells with November 2012 concentrations higher than baseline, November results were lower than earlier peak concentrations, indicating declining concentrations at these wells. Solubilization of reduced arsenic (along with manganese and iron) is a localized and temporary phenomenon that occurs within the portion of the aquifer that has been artificially reduced through donor amendment; once the injected donor has been consumed and natural conditions are re-established, these metals should return to the less soluble forms that existed prior to donor amendment (Suthersan et al. 2002, ESTCP 2006).

As of November 2012, total and dissolved copper concentrations were below the proposed cleanup level (Landau Associates 2013) of 0.008 mg/L at all 22 wells. Total and/or dissolved copper concentrations increased at all IWs and at MWs BDC-05-19 and BDC-05-21 compared to baseline, then decreased. The highest concentration detected was total copper of 0.032 mg/L at the core of the plume (MW BDC-05-19 in May 2012). Copper concentrations also increased during the 2008 pilot test, but were short-lived, followed by a returning to baseline conditions (Landau Associates 2010b).

4.0 PLANNED ACTIONS AND SCHEDULE

Planned actions for 2013 include quarterly (February and September) and semiannual (May and November) monitoring events. TOC concentrations remain elevated at SWMU-17 IWs, indicating that additional injections are not necessary at this time. Further injection may be planned based on evaluation of future quarterly or semiannual monitoring results.

4.1 CHANGES TO MONITORING PROGRAM

Minor changes to the monitoring program are made based on monitoring results. These changes are as follows:

- Methane, ethene, ethane, and acetylene analysis at BDC-05-21 and BDC-05-24 will be added for both quarterly and semiannual sampling events, and at BDC-05-03 for semiannual events. These are wells with direct evidence or some evidence of enhanced bioremediation (Section 3.2.1). Analysis of these additional parameters will improve evaluation of aquifer redox conditions and treatment.
- As described in Section 2.3, nitrate analysis was discontinued beginning in May 2012.
- During the reporting period, there was a change in the TOC laboratory method accredited by Ecology, changing the accredited method from Method 415.1 to Method SM5310C.

All of these changes are reflected in a revised groundwater monitoring matrix presented in Table 4.

5.0 USE OF REPORT

This annual evaluation report has been prepared for the exclusive use of The Boeing Company for specific application to the Boeing Developmental Center. 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.

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

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Clinton L. Jacob, P.E., L.G.
Principal Engineer

MCV/CLJ/tam

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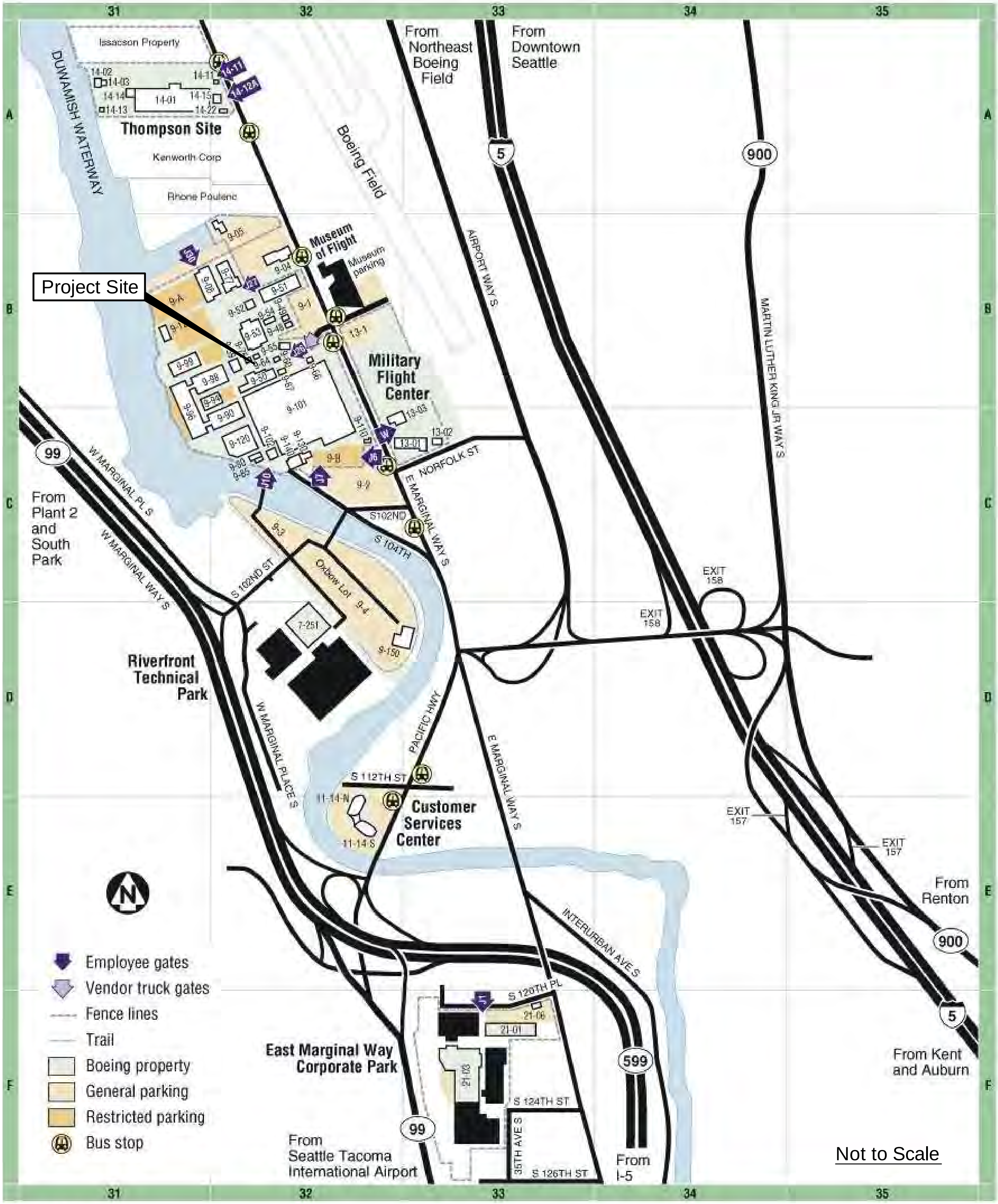

Map Provided by Boeing, March 2000

Boeing/Developmental Center/Evaluation Report | V:\025\093\111.030\SWMU-17 Full Scale WP\Figure 1.dwg (A) "Figure 1" 6/2/2011

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Boeing Developmental Center Tukwila, Washington	**Vicinity Map**	Figure 1

Note

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Boeing Developmental Center
Tukwila, Washington

SWMU-17 Site Plan

Figure
2

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LANDAU ASSOCIATES, INC. | V:\025\093\112.021\SWMU-17\Figure 2-4.dwg (A) "Figure 3" 5/1/2013

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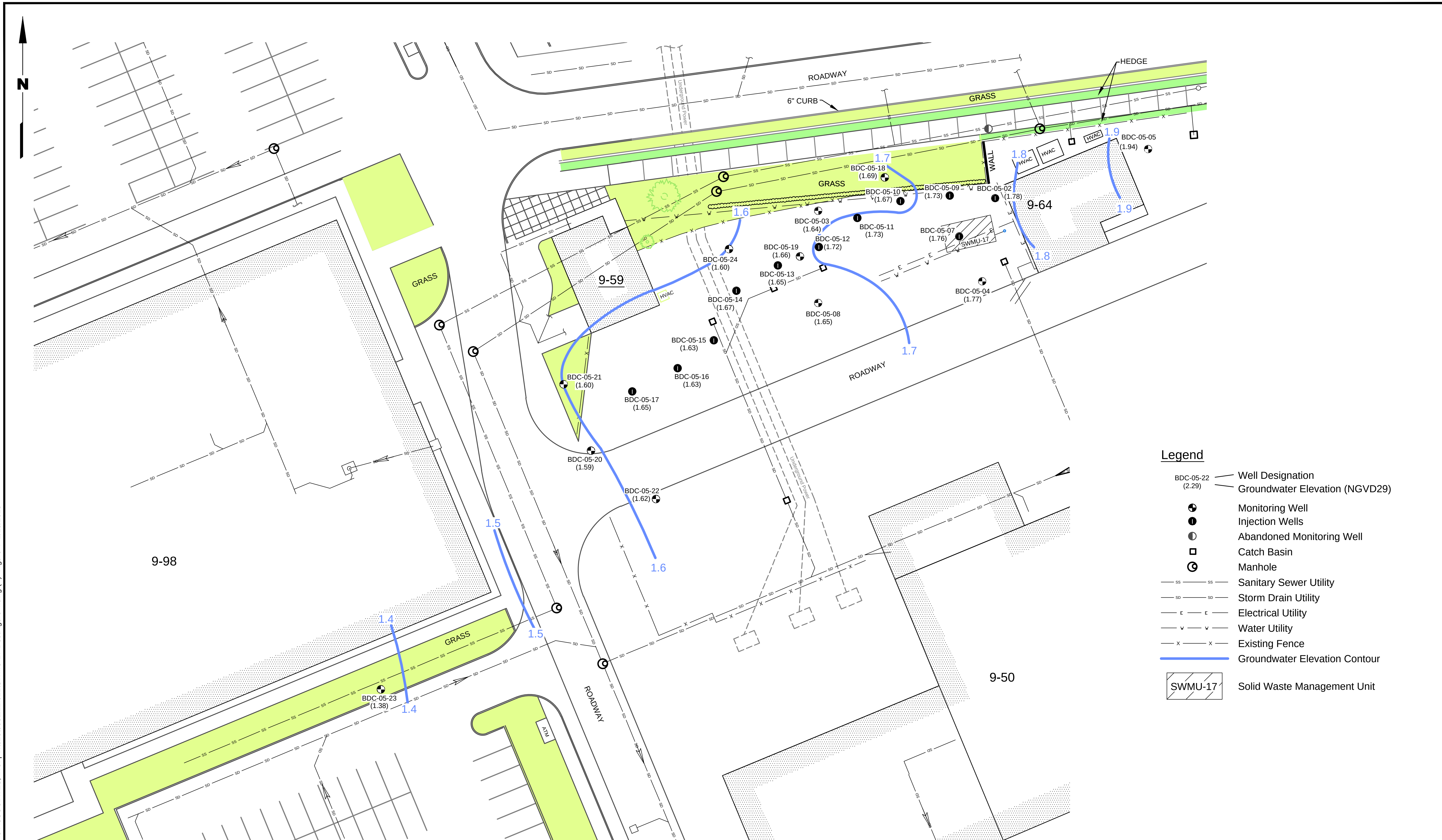
0 40 80
Scale in Feet

Boeing Developmental Center
Tukwila, Washington

PCE/TCE Groundwater Plume Prior to Full-Scale Treatment

Figure 3



LANDAU ASSOCIATES, INC. | V:\025\093\112.021\SWMU-17-Dec\Figure 4.dwg (A) "Figure 4" 1/15/2013

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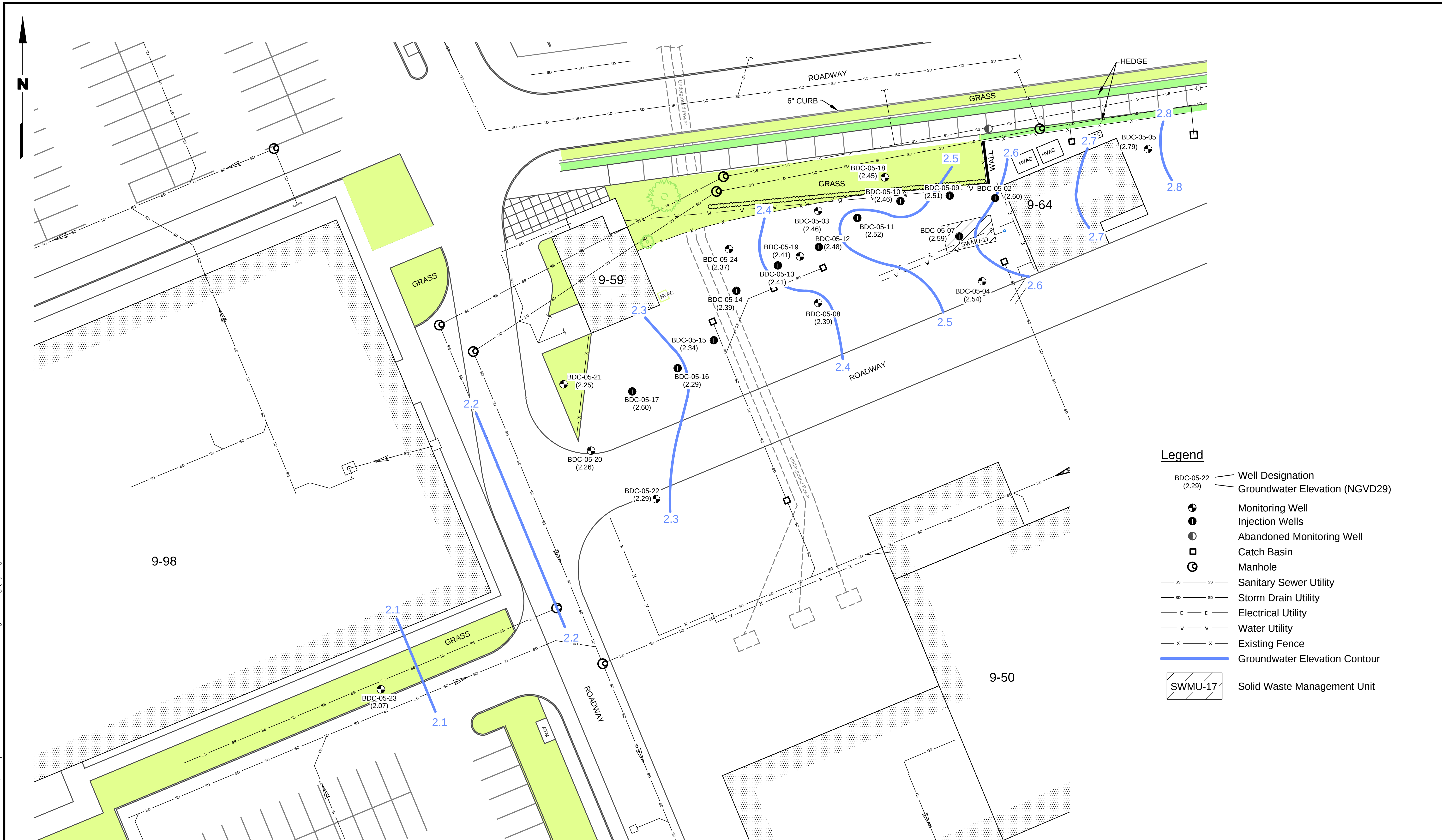
Scale in Feet

Boeing Developmental Center
Tukwila, Washington

Groundwater Elevations
November 2011

Figure 4



LANDAU ASSOCIATES, INC. | V:\025\093\112.021\SWMU-17-Dec\Figure 5.dwg (A) "Figure 5" 1/14/2013

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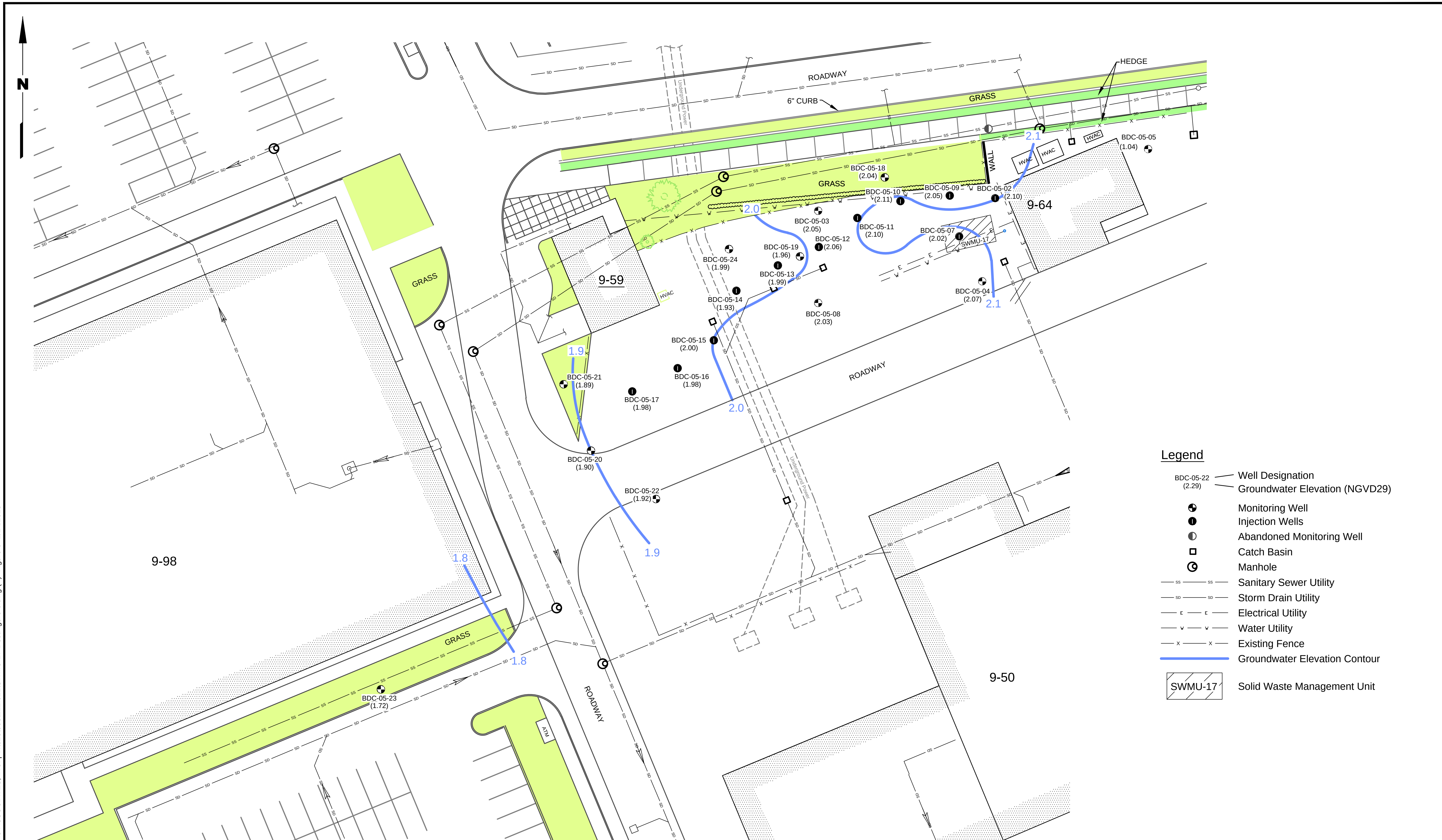
Boeing Developmental Center
Tukwila, Washington

Groundwater Elevations
May 2012

Figure
5



LANDAU ASSOCIATES, INC. | V:\025\093\112.021\SWMU-17-Dec\Figure 6.dwg (A) "Figure 6" 1/14/2013

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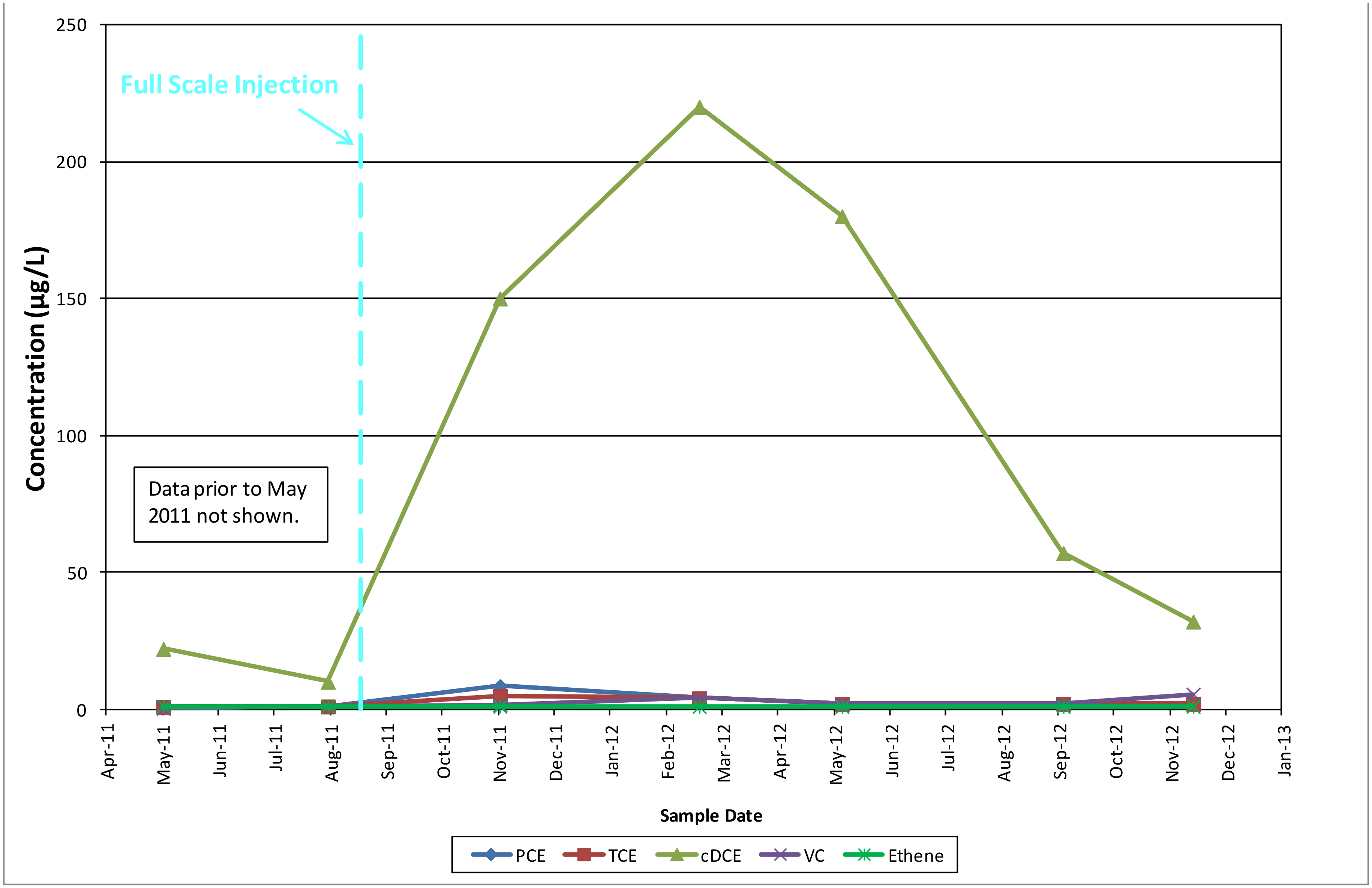
0 40 80
Scale in Feet

Boeing Developmental Center
Tukwila, Washington

Groundwater Elevations
November 2012

Figure
6



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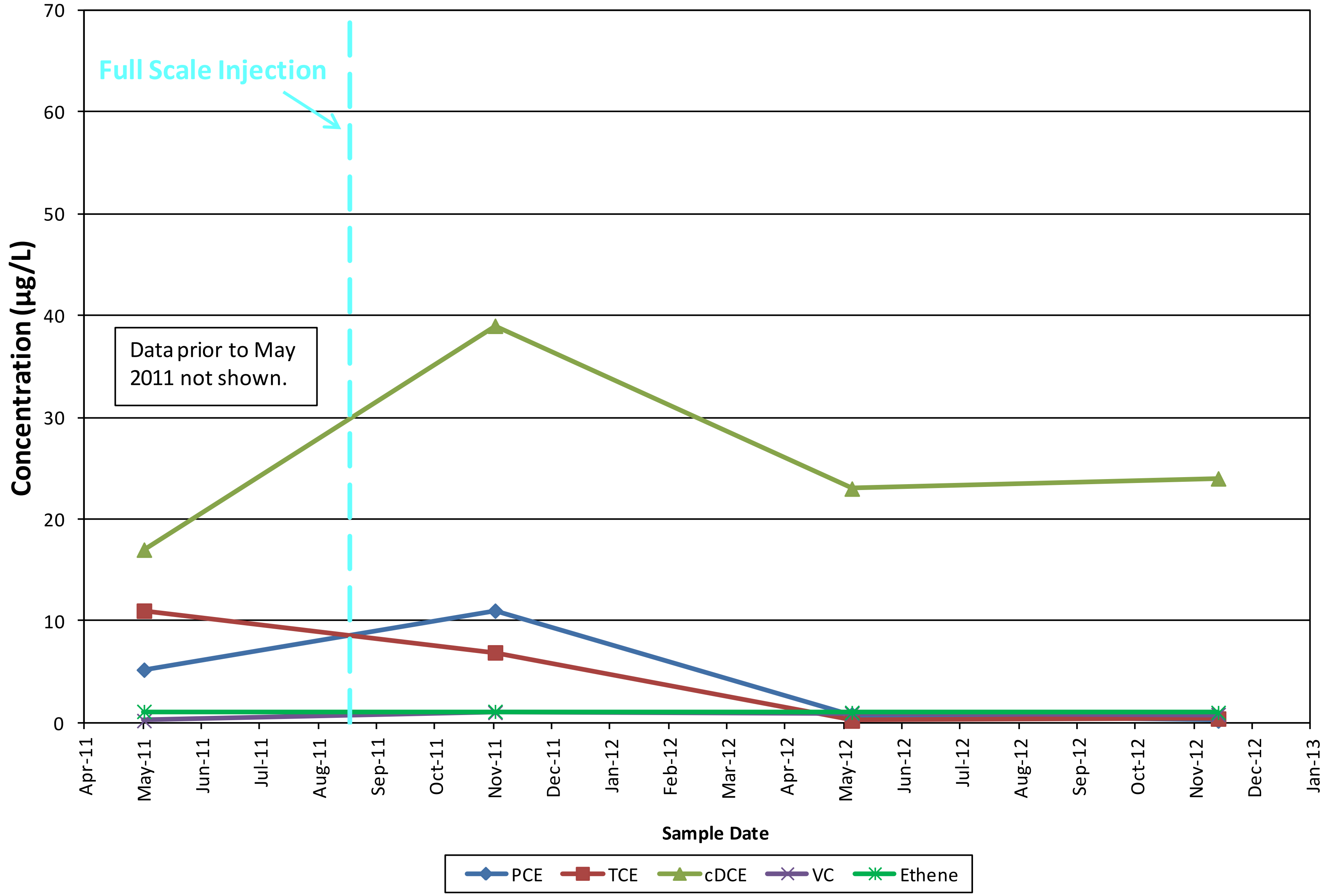
Boeing Developmental Center Tukwila, Washington	**Source Zone Injection Well BDC-05-02 VOCs**	Figure 7



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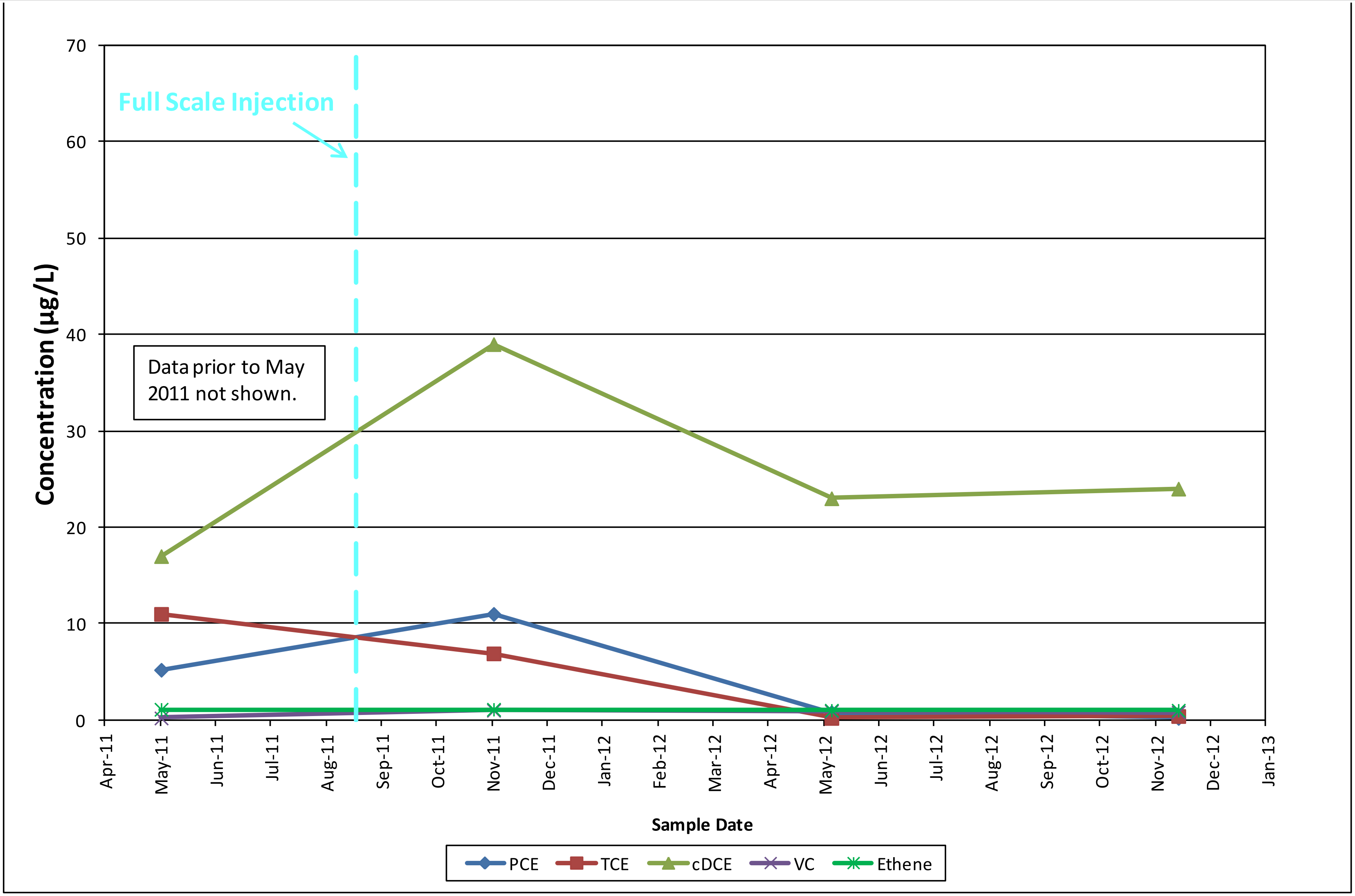
Boeing Developmental Center
Tukwila, Washington

Source Zone Injection
Well BDC-05-07 VOCs

Figure
8

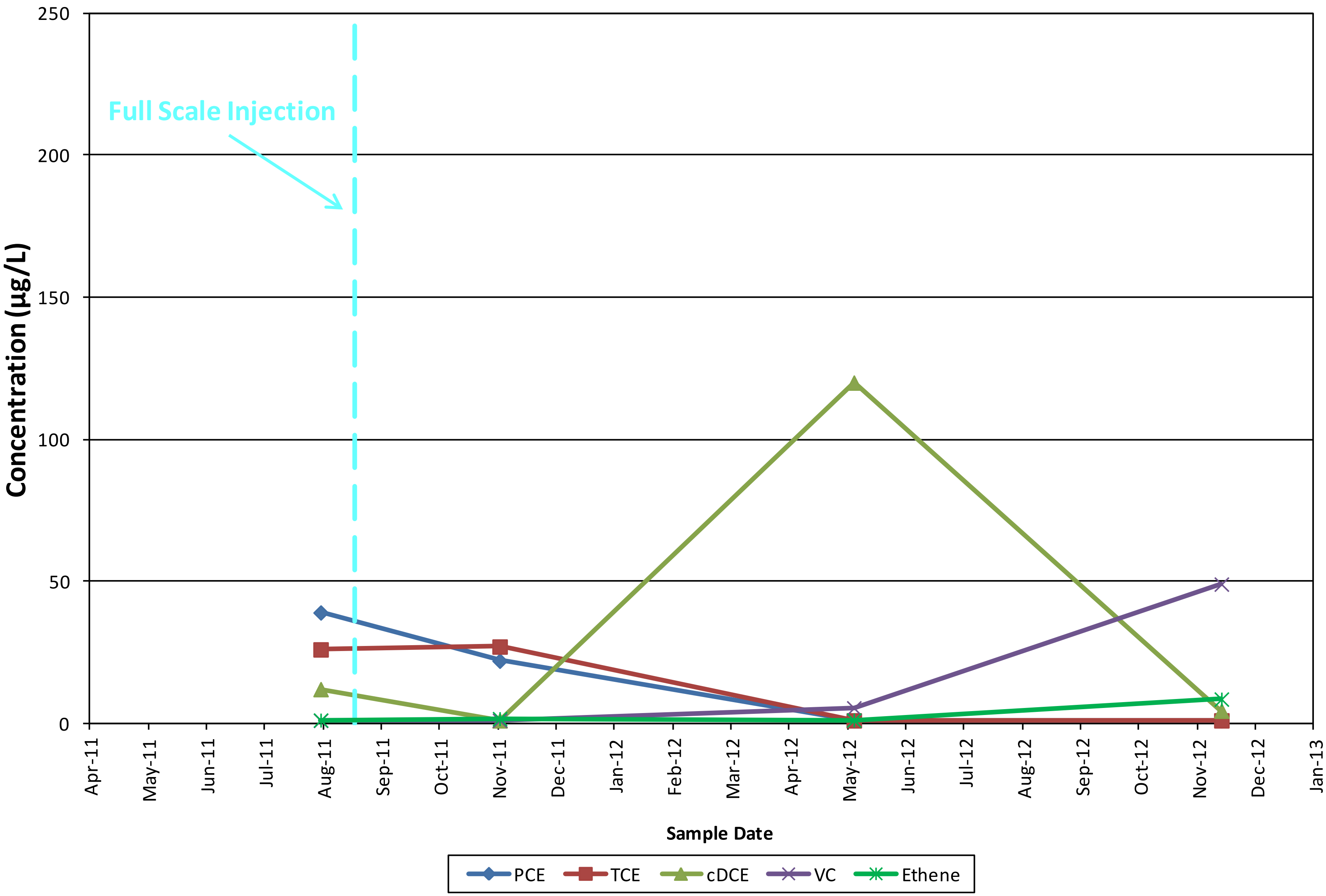


Landau Associates

Boeing Developmental Center
Tukwila, Washington

Non-Source Zone Injection
Well BDC-05-07 VOCs

Figure
9



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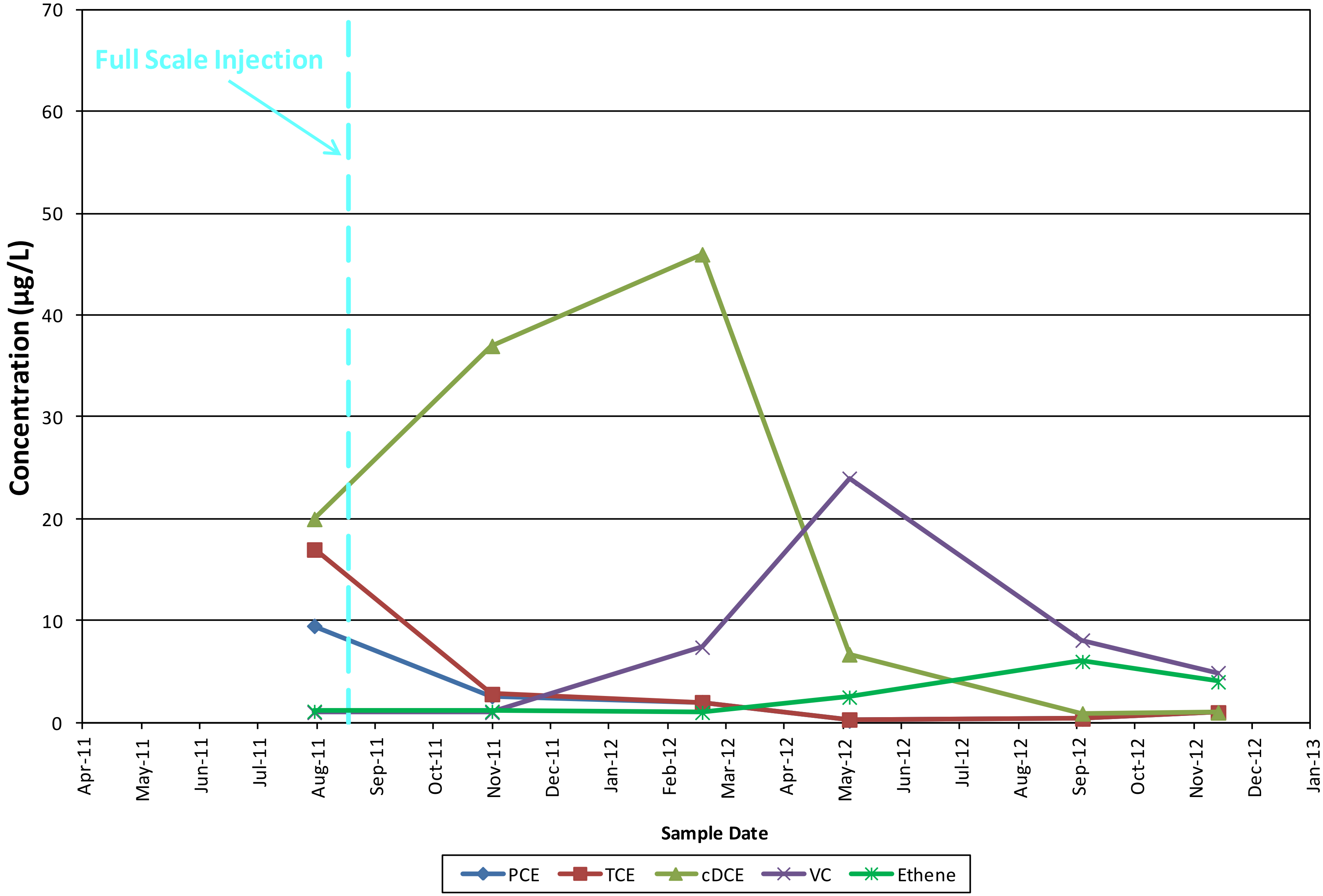
Boeing Developmental Center
Tukwila, Washington

Non-Source Zone Injection
Well BDC-05-10 VOCs

Figure
10



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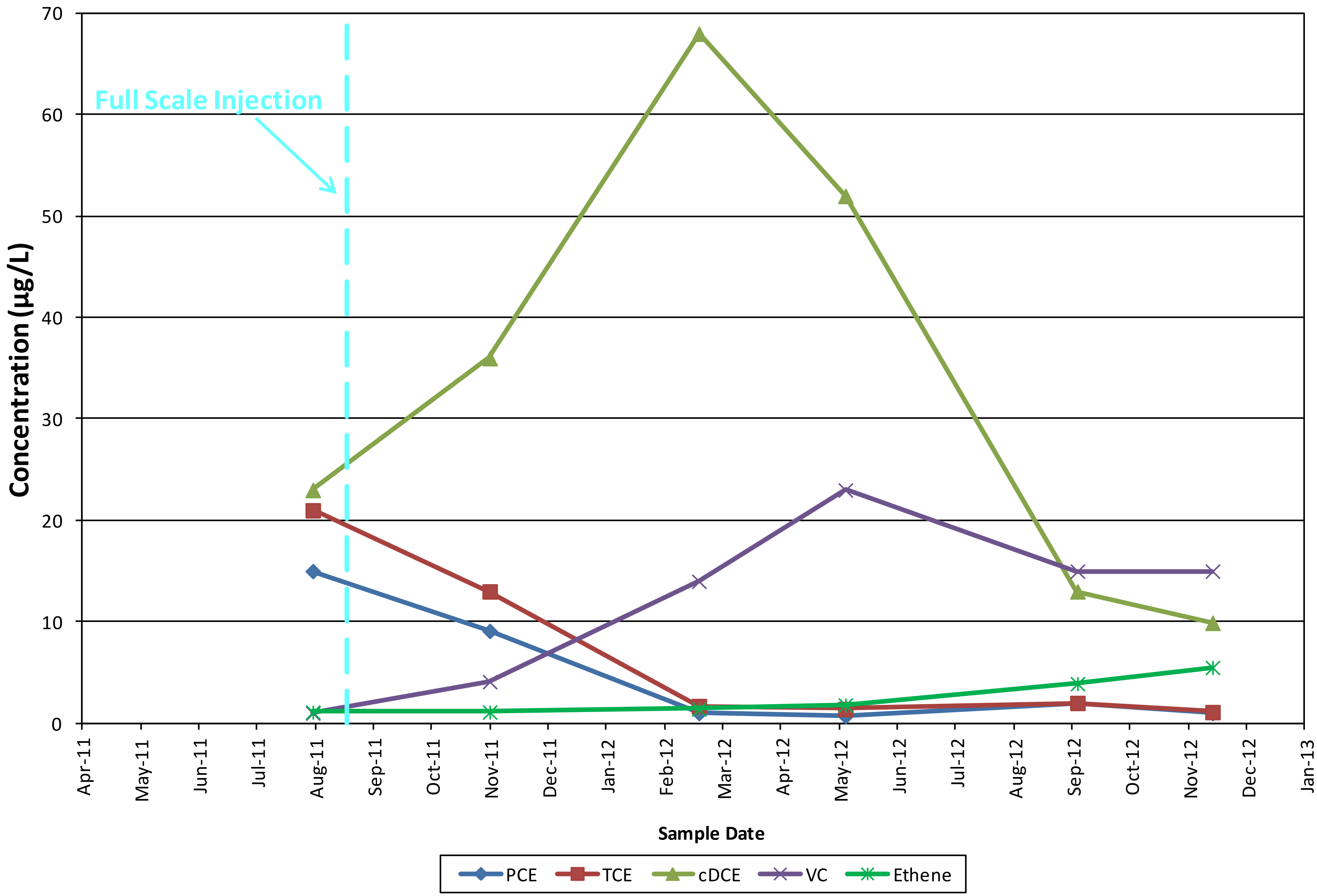
Non-Source Zone Injection
Well BDC-05-16 VOCs

Figure
11



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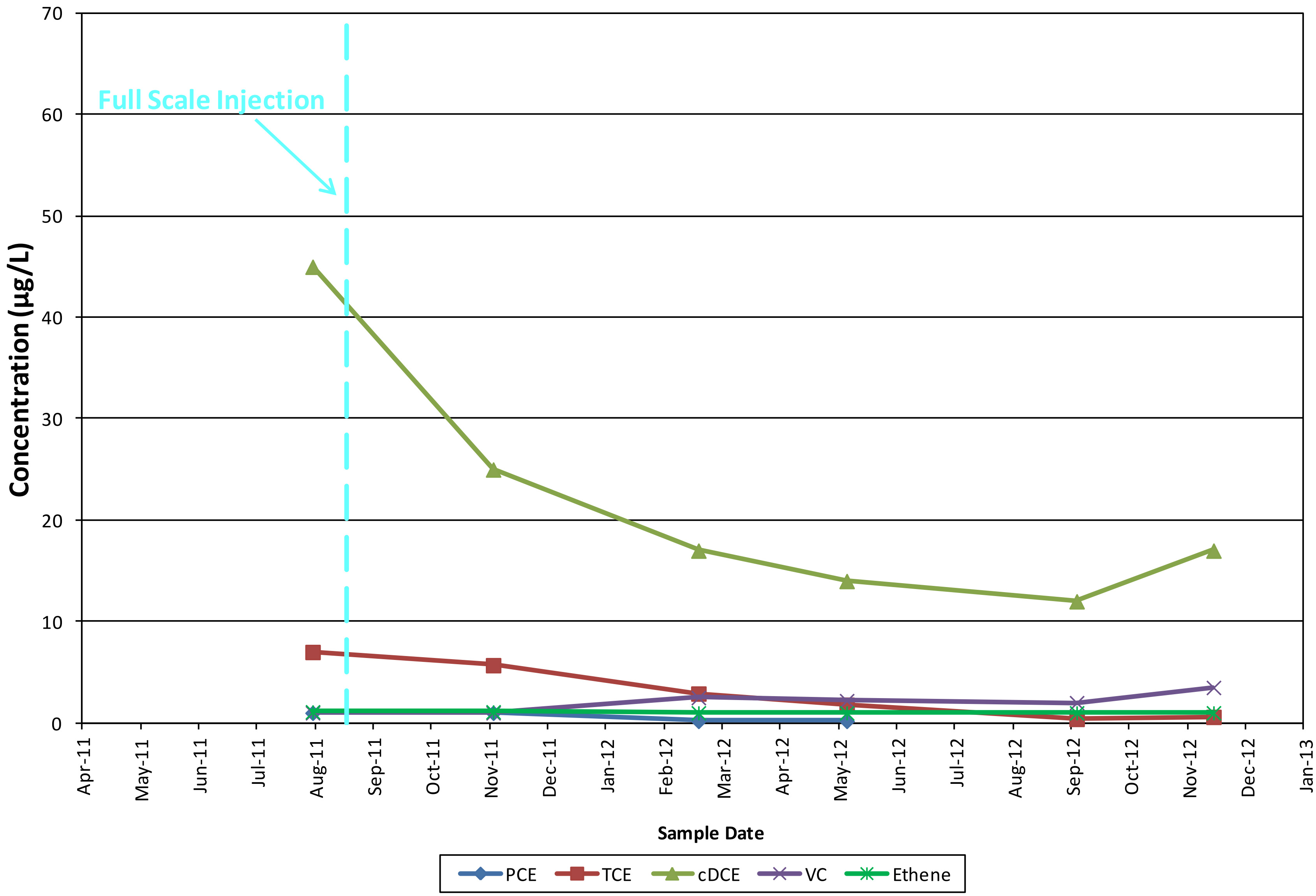
Monitoring Well BDC-05-19 VOCs

Figure
12



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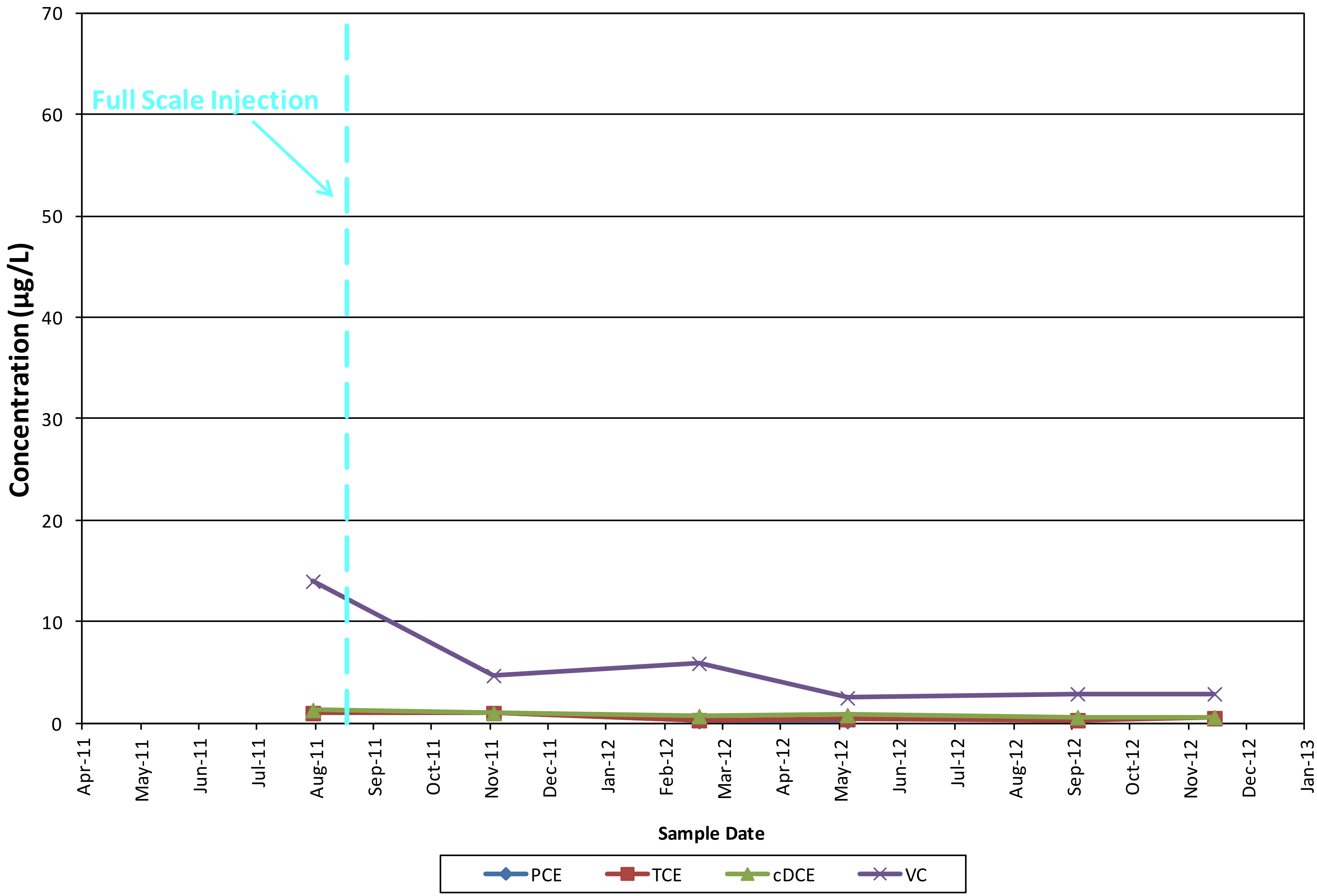
Monitoring Well BDC-05-20 VOCs

Figure
13


70
60
50
40
30
20
10
0
Full Scale Injection
Concentration (µg/L)
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
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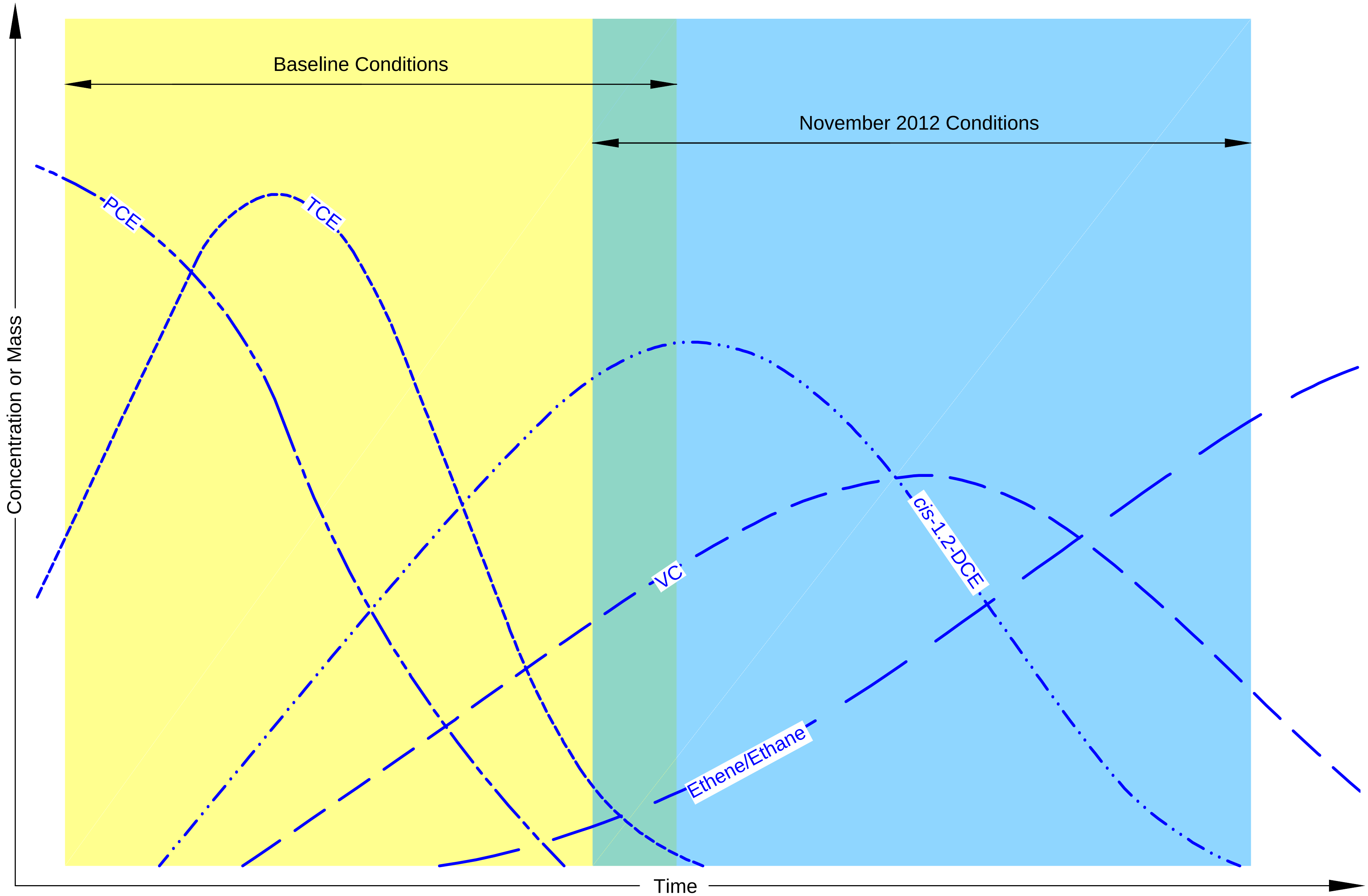
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Sample Date
PCE
TCE
cDCE
VC



Adapted from: ITRC,1999

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Stages of Treatment Progression

Figure 15

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection Elapsed Time From Injection (days)	Full Injection #1 Elapsed Time From Injection (days)	Volatile Organic Compounds: PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	Metals: As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	Aquifer Redox Conditions: DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	Donor Indicators: TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments
BDC-05-02	5/21/2007	-526		20	24	1.2	<1.0				0.003	0.002	0.004	<0.002									
(IW)	11/26/2007	-337		12	14	1.3	<1.0				0.001	<0.001	<0.002	<0.002									
	5/22/2008	-159		14	20	1.2	<0.2				0.002	<0.001	0.004	<0.002									
BDC-05-02	10/23/2008	-5		31	62	2.9	<1.0	<1.1	<1.2	<1.1	0.003	0.003	0.006	<0.002	5.15	0.4	0.2	13.0	0.19	87.1	5.5	6.47	
BDC-05-02	11/20/2008	23		5.1	4.2	0.7	<0.2	<1.1	<1.2	<1.1	0.017	0.011	0.008	<0.002	0.29	<0.1	1.8	64.8	3.3	-111	430	6.47	
BDC-05-02	12/16/2008	49		6.6	7.3	1.3	<1.0	<1.1	<1.2	<1.1	0.024	0.017	0.030	0.003	1.28	<0.1	3.4	88.8	2.9	-225	610	6.41	
BDC-05-02	1/16/2009	80		7.5	22	3.7	<1.0	<1.1	<1.2	<1.1	0.022	0.014	0.029	<0.002	0.09	<1.0	3.5	6.9	6.2	-304	732	6.10	
BDC-05-02	2/11/2009	106		9.5	17	12	<1.0	<1.1	<1.2	<1.1	0.046	0.040	0.004	<0.002	2.36	<0.1	4.0	<0.1	13.2	-99	433	6.32	
BDC-05-02	3/9/2009	132		9.1	8.1	25	<1.0	<1.1	<1.2	<1.1	0.041	0.036	0.004	<0.002	0.09	<1.0	3.5	<1.0	22.9	-102	317	6.43	
BDC-05-02	4/16/2009	170		7.3	6.0	41	<1.0	<1.1	<1.2	<1.1	0.029	0.025	0.003	<0.002	1.78	<0.1	3.0	<0.5	26.3	-97	274	6.59	
BDC-05-02	5/13/2009	197		4.4	4.6	35	1.4	<1.1	<1.2		0.024	0.019	0.004	0.002	0.27	<0.1	5.2	<0.1	23.0	-63	215	6.61	
BDC-05-02	8/16/2009	292		1.8	1.1	49	<1.0	<1.1	<1.2	<1.1	0.023	0.017	0.009	<0.002	1.58	<0.5	3.6	<0.5	22.6	-23	125	6.77	Black tint, black flakes, suspended solids
BDC-05-02	11/13/2009	381		1.0	<1.0	70	<1.0	<1.1	<1.2	<1.1	0.020	0.016	0.003	<0.002	1.07	<0.1	2.8	0.3	21.1	-26	44.1	6.05	Black tint
BDC-05-02	2/16/2010	476		<1.0	<1.0	54	<1.0	<1.1	<1.2	<1.1	0.022	0.020	0.005	0.002	1.52	<0.5	2.0	0.5	22.5	763	86.7	6.87	
BDC-05-02	5/18/2010	567		<1.0	1.0	32	<1.0	<1.1	<1.2	<1.1	0.013	0.012	<0.002	<0.002	1.83	<0.5	2.3	<0.5	18.4	515	20.6	6.69	
BDC-05-02	8/17/2010	658		<1.0	<1.0	23	<1.0	<1.1	<1.2	<1.1	0.010	0.008	<0.002	<0.002	2.82	0.2	2.7	1.4	20.2	55	13.3	6.74	
BDC-05-02	11/9/2010	742		<1.0	<1.0	14	<1.0	<1.1	<1.2	<1.1	0.006	0.005	<0.002	<0.002	2.77	<0.1	2.2	0.3	16.9	72	10.8	6.83	
BDC-05-02	2/15/2011	840		<1.0	<1.0	13	<1.0	<1.1	<1.2	<1.1	0.007	0.006	0.003	<0.002	2.43	<0.1	3.0	0.7	17.8	114	13.2	6.80	
BDC-05-02	5/2/2011	916		0.6	0.9	22	0.3	<1.1	<1.2	<1.1	0.008	0.007	<0.002	<0.002	2.09	<0.1	1.4	0.2	13.3	13	9.8	6.86	
BDC-05-02	7/31/2011	1006	-18	<1.0	<1.0	10	<1.0	<1.1	<1.2	<1.1	0.006	0.005	<0.002	<0.002	1.97	<0.1	3.2	0.2	15.0	-35	8.7	6.82	
BDC-05-02	11/2/2011	1100	76	8.4	4.8	150	1.6	<1.1	<1.2	<1.1	0.025	0.022	0.010	0.010	2.40	<0.1	3.5	1.4	9.0	-28	5360	5.43	
BDC-05-02	2/19/2012	1209	185	<4.0	<4.0	220	<4.0	<1.0	<1.0	<1.0					1.37	<0.5	1.3	<1.5	8.5	-32	673	6.70	
BDC-05-02	5/7/2012	1287	263	<2.0	<2.0	180	<2.0	<1.0	<1.0	<1.0	0.051	0.049	0.004	<0.002	0.60		2.2	0.8	19.0	35	412	6.71	
BDC-05-02	9/5/2012	1408	384	<2.0	<2.0	57	<2.0	<1.0	<1.0	<1.0					0.11		1.8	<0.3	10.0	71	116	6.45	
BDC-05-02	11/15/2012	1479	455	<2.0	<2.0	32	5.5	<1.0	<1.0	<1.0	0.014	0.013	<0.003	<0.002	0.03		1.2	<0.3	20.0	17	106	6.49	
BDC-05-03	5/21/2007	-526		3.5	8.1	11	<1.0				0.003	<0.001	0.004	<0.002									
(MW 17 ft DG)	11/26/2007	-337		2.3	4.4	7.2	<1.0				0.002	<0.001	0.003	<0.002									
	5/22/2008	-159		3.8	8.5	13	<0.2				0.002	<0.001	0.003	<0.002									
BDC-05-03	10/23/2008	-5		4.2	8.2	17	<0.2	<1.1	<1.2	<1.1	0.004	0.002	0.004	0.002	0.37	<0.1	0.1	4.9	2.1	48.9	4.9	6.23	
BDC-05-03	11/20/2008	23		1.8	2.1	2.7	<0.2	<1.1	<1.2	<1.1	0.003	0.001	0.004	<0.002	2.07	0.9	1.6	8.5	3.6	-8	7.0	6.23	
BDC-05-03	12/16/2008	49		2.2	4.1	5.8	<1.0	<1.1	<1.2	<1.1	0.001	<0.001	0.002	<0.002	1.20	0.4	2.4	20.1	4.7	-67	5.4	6.44	
BDC-05-03	1/16/2009	80		1.5	1.2	<1.0	<1.0	<1.1	<1.2	<1.1	0.001	<0.001	0.002	<0.002	0.71	1.7	0.4	10.3	1.5 J	-144	3.2	6.17	
BDC-05-03	2/11/2009	106		1.8	3.2	4.4	<1.0	<1.1	<1.2	<1.1	0.002	<0.001	0.002	<0.002	2.43	0.9	2.4	6.2	5.4	-60	5.4	6.59	
BDC-05-03	3/9/2009	132		1.3	1.7	1.4	<1.0	<1.1	<1.2	<1.1	<0.001	<0.001	<0.002	<0.002	0.86	1.0	1.0	6.6	4.3	39	4.8	6.48	
BDC-05-03	4/16/2009	170		1.5	2.2	2.8	<1.0	<1.1	<1.2	<1.1	0.001	0.002	<0.002	<0.002	1.42	1.0	1.4	4.8	3.3	14	5.4	6.69	
BDC-05-03	5/13/2009	197		1.2	2.1	3.4	<1.0	<1.1	<1.2		0.001	0.0004	0.004	0.002	1.06	1.0	3.0	4.8	6.9	31	5.5	6.75	
BDC-05-03	8/16/2009	292		2.2	4.3	8.1	<1.0	<1.1	<1.2	<1.1	0.001	0.001	<0.002	<0.002	0.85	0.1	3.0	3.0	8.3	-42	6.5	7.11	
BDC-05-03	11/13/2009	381		1.2	1.2	<1.0	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.003	<0.002	1.66	0.2	3.0	5.6	5.0	57	4.3	6.37	
BDC-05-03	2/16/2010	476		1.4	1.0	<1.0	<1.0	<1.1	<1.2	<1.1	0.002	<0.001	0.005	0.005	1.25	2.5	0.0	8.6	<0.0007	663	3.5	6.30	
BDC-05-03	5/18/2010	567		1.2	1.8	2.7	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.004	0.003	0.88	1.5	2.0	4.9	2.4	346	4.7	6.42	
BDC-05-03	8/17/2010	658		2.3	5.2	14	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.003	<0.002	2.10	0.2	2.7	2.8	7.1	73	7.6	6.79	
BDC-05-03	11/9/2010	742		1.4	1.7	3.7	<1.0	<1.1	<1.2	<1.1	0.001	0.001	0.003	<0.002	3.20	0.5	2.2	5.3	3.0	133	4.7	7.61	
BDC-05-03	2/15/2011	840		1.3	<1.0	2.3	<1.0	<1.1	<1.2	<1.1	0.001	0.0003	0.005	0.003	2.86	0.7	0.0	6.2	4.6	166	5.4	7.01	
BDC-05-03	5/2/2011	916	-108	1.7	1.0	0.2	<0.2	<1.1	<1.2	<1.1	0.002	0.0004	0.005	0.003	3.31	0.8	0.0	5.5	0.3	203	4.1	6.91	
BDC-05-03	11/2/2011	1100	76	1.4	1.6	20	2.0				0.018	0.017	0.004	0.002	1.20	<0.1	1.6	<1.0		-60	70.0	6.72	
BDC-05-03	5/6/2012	1286	262	0.6	1.3	<0.2	0.3				0.002	0.004	0.003	0.010	0.02		1.2	10.3		82	4.9	6.26	
BDC-05-03	11/15/2012	1479	455	<0.5	<0.5	<0.5	0.7				0.008	0.007	0.003	<0.002	0.01		0.3	1.2		13	8.3	6.79	

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection	Full Injection #1	Volatile Organic Compounds							Metals				Aquifer Redox Conditions						Donor Indicators		
		Elapsed Time From Injection (days)	Elapsed Time From Injection (days)	PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments
BDC-05-04	5/21/2007	-526		<1.0	<1.0	1.4	<1.0				0.018	<0.001	<0.002	<0.002									
(MW 22 ft XG)	11/26/2007	-337		<1.0	<1.0	1.6	<1.0				0.009	<0.001	<0.002	<0.002									
	5/22/2008	-159		1.5	0.9	1.2	<0.2				0.018	<0.001	<0.002	<0.002									
BDC-05-04	10/23/2008	-5		1.1	0.8	2.1	<0.2	<1.1	<1.2	<1.1	0.009	<0.001	<0.002	<0.002	2.45	7.6	0.1	31.0	0.3	73.5	3.8	6.33	
BDC-05-04	11/20/2008	23		1.1	0.7	3.6	<0.2	<1.1	<1.2	<1.1	0.019	<0.001	<0.002	<0.002	0.59	4.5	0.8	25,2	0.05	-16	5.1	6.25	
BDC-05-04	12/16/2008	49		<1.0	<1.0	2.4	<1.0	<1.1	<1.2	<1.1	0.019	0.002	0.003	<0.002	0.55	5.5	1.0	30.4	1.6	-98	6.9	6.24	
BDC-05-04	1/16/2009	80		<1.0	<1.0	2.0	<1.0	<1.1	<1.2	<1.1	0.017	<0.001	<0.002	<0.002	0.06	4.3	1.0	21.8	1.5	-192	5.1	6.23	
BDC-05-04	2/11/2009	106		1.0	<1.0	1.5	<1.0	<1.1	<1.2	<1.1	0.020	<0.001	<0.002	<0.002	2.45	5.9	1.0	31.8	1.1	-54	6.8	6.17	
BDC-05-04	3/9/2009	132		1.0	<1.0	1.3	<1.0	<1.1	<1.2	<1.1	0.014	0.001	0.002	<0.002	0.27	4.8	1.5	30.1	0.2	35	5.2	6.22	
BDC-05-04	4/16/2009	170		1.2	<1.0	<1.0	<1.0	<1.1	<1.2	<1.1	0.011	0.001	<0.002	<0.002	1.48	5.9	1.4	33.6	<0.0007	68	5.7	6.29	
BDC-05-04	5/13/2009	197		<1.0	<1.0	1.0	<1.0	<1.1	<1.2		0.007	0.001	0.002	0.002	0.33	4.5	1.6	26.6	0.4	49	5.2	6.37	
BDC-05-04	8/16/2009	292		1.3	<1.0	<1.0	<1.0	<1.1	<1.2	<1.1	0.012	0.001	0.002	<0.002	0.86	5.4	2.2	30.6	<0.0007	93	5.0	6.97	
BDC-05-04	11/13/2009	381		<1.0	<1.0	1.2	<1.0	<1.1	<1.2	<1.1	0.005	0.001	<0.002	<0.002	0.56	2.2	3.0	18.4	2.4	109	4.4	5.86	
BDC-05-04	2/16/2010	476		<1.0	<1.0	1.1	<1.0	<1.1	<1.2	<1.1	0.004	0.002	0.012	0.002	0.88	<0.1	3.3	24.6	1.5	899	8.9	6.24	
BDC-05-04	5/18/2010	567		1.1	<1.0	1.2	<1.0	<1.1	<1.2	<1.1	0.014	0.001	0.005	<0.002	0.75	<0.1	3.0	25.4	1.3	473	7.1	6.19	
BDC-05-04	8/17/2010	658		<1.0	<1.0	3.0	<1.0	<1.1	<1.2	<1.1	0.012	0.002	0.006	<0.002	1.00	<0.1	2.8	17.7	3.5	108	8.7	6.48	
BDC-05-04	11/9/2010	742		<1.0	<1.0	4.3	<1.0	<1.1	<1.2	<1.1	0.008	0.004	<0.002	<0.002	2.21	<0.1	2.2	21.3	3.0	101	7.2	6.84	
BDC-05-04	2/15/2011	840		<1.0	<1.0	2.9	<1.0	<1.1	<1.2	<1.1	0.007	0.004	<0.002	<0.002	2.50	<0.1	2.4	19.4	4.5	93	6.9	6.85	
BDC-05-04	5/2/2011	916	-108	0.4	0.5	3.1	<0.2	<1.1	<1.2	<1.1	0.008	0.004	<0.002	<0.002	1.69	<0.1	2.2	18.0	1.8	49	6.8	6.76	
BDC-05-04	11/2/2011	1100	76	<1.0	<1.0	4.2	<1.0				0.007	0.006	<0.002	<0.002	1.52	<1.0	1.2	<1.0		-3	6.6	7.17	
BDC-05-04	5/7/2012	1287	263	0.4	0.6	3.6	<0.2				0.017	0.016	<0.002	<0.002	0.16		2.0	21.5		98	8.6	6.39	
BDC-05-04	11/16/2012	1480	456	<0.5	<0.5	3.3	<0.5				0.012	0.010	0.002	<0.002	0.02		1.2	14.3		27	6.5	6.65	
BDC-05-05	5/21/2007	-526		<1.0	<1.0	<1.0	<1.0				0.002	<0.001	0.003	<0.002									
(MW UG)	11/26/2007	-337		<1.0	<1.0	<1.0	<1.0				<0.001	<0.001	<0.002	<0.002									
	5/22/2008	-159		0.3	0.8	<0.2	<0.2				0.002	<0.001	0.003	<0.002									
BDC-05-05	10/23/2008	-5																					
BDC-05-05	11/20/2008	23		0.3	0.7	<0.2	<0.2				0.005	0.001	0.005	0.003	4.61					52		6.25	
BDC-05-05	12/16/2008	49																					
BDC-05-05	1/16/2009	80																					
BDC-05-05	2/11/2009	106																					
BDC-05-05	3/9/2009	132																					
BDC-05-05	4/16/2009	170																					
BDC-05-05	5/13/2009	197		<1.0	<1.0	<1.0	<1.0				0.003	<0.001	0.006	0.002	3.24					68		6.72	
BDC-05-05	8/16/2009	292																					
BDC-05-05	11/13/2009	381		<1.0	<1.0	<1.0	<1.0				0.001	<0.001	<0.002	<0.002	2.85	1.2	0.0	8.7		166		5.84	
BDC-05-05	2/16/2010	476																					
BDC-05-05	5/18/2010	567		<1.0	<1.0	<1.0	<1.0				0.002	0.0004	0.002	<0.002	3.47		0.0			494		6.74	
BDC-05-05	8/17/2010	658																					
BDC-05-05	11/9/2010	742		<1.0	1.1	<1.0	<1.0				0.001	0.0004	0.003	<0.002	3.20					135		6.90	
BDC-05-05	2/15/2011	840																					
BDC-05-05	5/2/2011	916	-108	0.3	0.8	<0.2	<0.2				0.001	0.0003	0.003	<0.002	3.40					158		6.98	
BDC-05-05	11/2/2011	1100	76	<1.0	1.2	<1.0	<1.0				0.001	0.0003	0.002	0.003	2.84	<0.1	0.0	7.5		85	1.7	7.66	
BDC-05-05	5/6/2012	1286	262	0.4	0.9	<0.2	<0.2				<0.001	<0.001	0.003	<0.002	3.23		0.0	22.1		219	1.1	6.42	
BDC-05-05	11/16/2012	1480	456	<0.5	1.1	<0.5	<0.5	<1.0	<1.0	<1.0	0.001	0.0005	0.003	<0.002	1.76		0.2	20.6	<0.003	27	<1.0	6.82	

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection	Full Injection #1	Volatile Organic Compounds							Metals				Aquifer Redox Conditions						Donor Indicators		
		Elapsed Time From Injection (days)	Elapsed Time From Injection (days)	PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments
BDC-05-07	5/21/2007	-526		30	22	10	<1.0				0.003	<0.001	0.014	0.009									
(IW)	11/26/2007	-337		28	25	11	<1.0				<0.001	<0.001	0.011	0.002									
	5/22/2008	-159		33	32	9.2	<0.2				0.002	<0.001	0.012	0.006									
BDC-05-07	10/23/2008	-5		22	24	14	<0.2	<1.1	<1.2	<1.1	0.004	0.002	0.022	0.013	9.71	9.6	0.0	33.4	0.6	86.0	7.8	6.47	
BDC-05-07	11/20/2008	23		17	17	4.9	<0.2	<1.1	<1.2	<1.1	0.003	<0.001	0.016	0.010	0.60	2.2	0.4	15.8	0.2	-27	4.6	6.46	
BDC-05-07	12/16/2008	49		16	25	7.2	<1.0	<1.1	<1.2	<1.1	0.003	0.001	0.016	0.012	1.20	4.8	0.0	29.4	0.6	-107	6.1	6.49	
BDC-05-07	1/16/2009	80		20	23	6.4	<1.0	<1.1	<1.2	<1.1	0.002	<0.001	0.013	0.008	0.00	8.4	0.0	32.6	0.03	-182	6.3	6.38	
BDC-05-07	2/11/2009	106		23	28	9.9	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.017	0.012	2.05	11.2	0.0	37.5	1.5	-68	9.3	6.37	
BDC-05-07	3/9/2009	132		20	21	8.4	<1.0	<1.1	<1.2	<1.1	<0.002	<0.001	0.013	0.009	0.00	8.8	0.3	35.3	5.5	-23	6.8	6.37	
BDC-05-07	4/16/2009	170		20	21	11	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.015	0.008	0.27	8.2	0.0	31.2	5.1	35	8.1	6.43	
BDC-05-07	5/13/2009	197		11	13	7.5	<1.0	<1.1	<1.2		0.002	0.001	0.016	0.008	0.29	6.8	0.4	27.2	7.9	34	7.3	6.47	
BDC-05-07	8/16/2009	292		11	12	13	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.010	<0.002	0.74	2.3	2.0	23.2	6.8	67	8.2	6.73	
BDC-05-07	11/13/2009	381		6.5	5.3	5.6	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.004	<0.002	0.50	<0.1	2.8	5.7	4.7	16	9.1	6.48	
BDC-05-07	2/16/2010	476		6.4	6.9	28	<1.0	<1.1	<1.2	<1.1	0.004	0.003	0.017	0.006	1.04	<0.1	2.5	20.4	5.2	839	14.7	6.88	
BDC-05-07	5/18/2010	567		5.8	9.2	41	1.2	<1.1	<1.2	<1.1	0.009	0.003	0.009	<0.002	1.06	<0.5	2.0	16.4	6.0	525	14.8	6.77	
BDC-05-07	8/17/2010	658		2.8	7.8	19	<1.0	<1.1	<1.2	<1.1	0.006	0.003	0.008	<0.002	2.30	<0.1	2.5	8.6	7.1	-15	18.8	7.34	
BDC-05-07	11/9/2010	742		<1.0	9.4	20	<1.0	<1.1	<1.2	<1.1	0.008	0.005	0.009	<0.002	2.42	<0.1	2.2	15.2	5.1	13	15.2	7.35	
BDC-05-07	2/15/2011	840		<1.0	8.7	20	<1.0	<1.1	<1.2	<1.1	0.013	0.010	0.012	0.002	3.02	<0.1	2.8	11.8	5.1	21	14.0	7.16	
BDC-05-07	5/2/2011	916	-108	5.2	11	17	<0.2	<1.1	<1.2	<1.1	0.017	0.004	0.014	0.003	2.14	0.1	2.6	15.6	3.2	33	16.8	6.90	
BDC-05-07	11/2/2011	1100	76	11	6.9	39	<1.0	<1.1	<1.2	<1.1	0.042	0.035	0.010	0.006	2.06	<0.1	2.4	<1.0	16.1	-51	1780	6.31	
BDC-05-07	5/7/2012	1287	263	0.8	<0.2	23	0.9	<1.0	<1.0	<1.0	0.026	0.024	0.003	<0.002	0.17		1.6	0.4	27.0	100	48.5	6.34	
BDC-05-07	11/15/2012	1479	455	<0.2	0.4	24	0.8	<1.0	<1.0	<1.0	0.016	0.017	<0.002	<0.002	0.01		1.6	<0.3	23.0	3.0	26	6.60	
BDC-05-08	10/23/2008	-5		1.1	3.7	3.5	<0.2	<1.1	<1.2	<1.1	0.007	<0.001	0.004	<0.002	1.90	0.3	0.0	8.9	4.7	-12.0	5.1	6.65	
(MW 24 ft XG)	11/20/2008	23		1.1	3.4	4.2	<0.2	<1.1	<1.2	<1.1	0.035	0.004	0.036	<0.002	0.80	0.7	2.2	7.2	5.5	-43	5.9	6.63	
	12/16/2008	49		1.2	4.3	4.3	<1.0	<1.1	<1.2	<1.1	0.008	0.001	0.006	<0.002	0.50	0.9	4.6	21.8	3.6	-99	5.4	6.61	
BDC-05-08	1/16/2009	80		1.3	4.2	3.6	<1.0	<1.1	<1.2	<1.1	0.008	0.002	0.007	<0.002	0.25	1.7	3.0	7.0	6.9	-185	5.8	6.59	
BDC-05-08	2/11/2009	106		<1.0	3.2	3.9	<1.0	<1.1	<1.2	<1.1	0.019	0.001	0.010	<0.002	2.38	0.3	4.4	4.7	4.4	-78	7.0	6.69	
BDC-05-08	3/9/2009	132		<1.0	2.7	3.5	<1.0	<1.1	<1.2	<1.1	0.009	0.003	0.007	<0.002	0.07	<0.1	3.6	3.8	4.9	-4	6.7	6.65	
BDC-05-08	4/16/2009	170		<1.0	2.3	4.4	<1.0	<1.1	<1.2	<1.1	0.007	0.003	0.006	<0.002	0.42	<0.1	2.0	1.7	6.7	-8	6.8	6.80	
BDC-05-08	5/13/2009	197		<1.0	1.6	3.0	<1.0	<1.1	<1.2		0.009	0.003	0.007	0.002	1.77	<0.1	4.0	0.8	11.4	-13	6.0	6.87	
BDC-05-08	8/16/2009	292		<1.0	2.1	3.5	<1.0	<1.1	<1.2	<1.1	0.012	0.008	<0.002	<0.002	0.87	<0.1	2.8	5.3	13.2	-20	6.1	7.15	
BDC-05-08	11/13/2009	381		<1.0	1.2	3.1	<1.0	<1.1	<1.2	<1.1	0.011	0.008	0.007	<0.002	0.73	<0.1	2.8	3.3	17.4	0.8	8.4	6.44	
BDC-05-08	2/16/2010	476		<1.0	<1.0	2.3	<1.0	<1.1	<1.2	<1.1	0.024	0.009	0.024	<0.002	0.63	<0.1	3.0	0.8	13.1	841	8.3	6.76	
BDC-05-08	5/18/2010	567		<1.0	<1.0	2.4	<1.0	<1.1	<1.2	<1.1	0.031	0.011	0.027	<0.002	0.96	<0.1	3.0	0.8	14.9	451	7.3	6.92	
BDC-05-08	8/17/2010	658		<1.0	<1.0	2.3	<1.0	<1.1	<1.2	<1.1	0.014	0.009	0.013	<0.002	2.57	<0.1	3.2	0.5	10.1	-30	7.2	7.30	
BDC-05-08	11/9/2010	742		<1.0	<1.0	3.5	<1.0	<1.1	<1.2	<1.1	0.031	0.012	0.031	<0.002	2.74	<0.1	2.4	0.3	14.2	59	7.6	7.17	
BDC-05-08	2/15/2011	840		<1.0	<1.0	2.1	<1.0	<1.1	<1.2	<1.1	0.021	0.010	0.016	<0.002	2.36	<0.1	5.0	0.3	14.1	66	8.7	7.08	
BDC-05-08	5/2/2011	916	-108	<0.2	<0.2	2.2	<0.2	<1.1	<1.2	<1.1	0.029	0.010	0.024	<0.002	2.15	<0.1	2.4	0.7	7.8	-28	8.0	7.17	
BDC-05-08	11/2/2011	1100	76	<1.0	<1.0	2.4	<1.0				0.014	0.010	0.012	0.003	1.15	<0.1	1.2	0.8		-53	7.3	6.88	
BDC-05-08	5/6/2012	1286	262	<0.2	<0.2	2.7	<0.2				0.021	0.020	0.007	0.002	0.01		2.5	0.4		42	12.4	6.77	
BDC-05-08	11/16/2012	1480	456	<0.5	<0.5	1.3	<0.5				0.014	0.010	0.005	<0.002	0.01		1.0	<0.3		5	8.1	6.91	

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection	Full Injection #1	Volatile Organic Compounds							Metals				Aquifer Redox Conditions						Donor Indicators		
		Elapsed Time From Injection (days)	Elapsed Time From Injection (days)	PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments
BDC-05-09	7/31/2011		-18	30	20	22	<1.0	<1.1	<1.2	<1.1	0.007	0.007	<0.002	<0.002	1.37	<0.1	2.5	12.1	1.4	15	5.5	6.89	
(IW)	11/2/2011		76	37	56	44	1.3	<1.1	<1.2	<1.1	0.042	0.040	0.009	0.006	2.80	<0.1	3.0	7.6	4.3	80	4360	5.24	
	5/7/2012		263	3.0	1.1	250	3.9	<1.0	<1.0	<1.0	0.059	0.052	0.011	<0.002	0.69		2.2	0.5	18.0	85	531	6.33	
BDC-05-09	11/15/2012		455	<2.0	<2.0	24	20	69	<1.0	<1.0	0.074	0.070	0.006	<0.002	0.01		1.2	<0.3	27.0	-10	266	6.71	
BDC-05-10	7/31/2011		-18	39	26	12	<1.0	<1.1	<1.2	<1.1	0.002	0.002	<0.002	<0.002	1.41	<0.1	2.0	19.7	0.3	76	4.5	6.84	
(IW)	11/2/2011		76	22	27	1.0	<1.0	1.6	1.7	<1.1	0.038	0.037	0.008	0.004	2.43	<0.1	2.2	10.9	0.1	-38	2030	5.72	
	5/6/2012		262	<1.0	<1.0	120	5.4	1.1	<1.0	<1.0	0.052	0.048	0.012	<0.002	0.02		1.7	0.4	19.0	58	270	6.48	
BDC-05-10	11/15/2012		455	<1.0	<1.0	4.4	49	8.5	<1.0	<1.0	0.069	0.060	0.003	<0.002	0.02		1.0	<0.3	24.0	-11	122	6.63	
BDC-05-11	7/31/2011		-18	16	19	5.8	<1.0	<1.1	<1.2	<1.1	0.005	0.005	<0.002	<0.002	1.41	<0.1	2.0	4.0	1.4	65	3.9	6.93	
(IW)	11/2/2011		76	9.6	20	12	<1.0	<1.1	<1.2	<1.1	0.039	0.037	0.013	0.004	2.16	<0.1	1.8	<1.0	1.0	-38	1330	5.72	
	5/6/2012		262	0.2	0.5	44	7.2	1.6	<1.0	<1.0	0.038	0.034	0.009	0.002	0.01		1.4	0.5	18.0	70	284	6.42	
BDC-05-11	11/15/2012		455	<1.0	<1.0	6.1	5.7	7.6	<1.0	<1.0	0.043	0.038	0.003	<0.002	0.02		1.3	<0.3	26.0	-15	73.8	6.76	
BDC-05-12	7/31/2011		-18	15	18	16	<1.0	<1.1	<1.2	<1.1	0.002	0.002	0.002	<0.002	1.60	0.1	2.4	8.4	4.0	26	7.0	7.02	
(IW)	11/2/2011		76	11	17	11	<1.0	<1.1	<1.2	<1.1	0.041	0.031	0.012	0.009	2.60	<0.1	3.5	5.6	1.0	-77	2960	5.83	
	2/19/2012		185	<0.4	<0.4	53	1.8	<1.0	<1.0	<1.0					1.7	<0.5	2.0	<1.5	17.0	-2	279	6.59	
BDC-05-12	5/6/2012		262	<0.2	<0.2	39	3.4	<1.0	<1.0	<1.0	0.082	0.071	0.005	<0.002	0.03		2.5	0.8	21.0	65	83.2	6.45	
BDC-05-12	9/5/2012		384	<0.2	<0.2	6.5	3.3	1.0	<1.0	<1.0					0.13		1.8	<0.3	22.0	80	50.4	6.48	
BDC-05-12	11/15/2012		455	<1.0	<1.0	7.9	5.4	1.1	<1.0	<1.0	0.037	0.036	0.002	<0.002	0.03		1.3	<0.3	27.0	7	52.9	6.56	
BDC-05-13	7/31/2011		-18	5.2	6.6	2.6	<1.0	<1.1	<1.2	<1.1	0.003	0.002	0.002	<0.002	1.73	<0.1	2.0	2.3	5.0	-1	6.0	7.06	
(IW)	11/1/2011		75	<1.0	1.2	39	<1.0	<1.1	<1.2	<1.1	0.068	0.064	0.017	0.003	1.82	<1.0	1.5	<1.0	2.2	-70	550	6.65	
	5/6/2012		262	<0.2	<0.2	13	3.9	1.7	<1.0	<1.0	0.051	0.046	0.003	<0.002	0.03		3.0	0.4	19.0	78	34.2	6.40	
BDC-05-13	11/15/2012		455	<1.0	<1.0	<1.0	2.3	3.7	<1.0	<1.0	0.060	0.055	<0.002	<0.002	0.04		2.2	<0.3	22.0	-9	30.2	6.75	
BDC-05-14	7/31/2011		-18	2.8	6.8	2.8	<1.0	<1.1	<1.2	<1.1	0.004	0.004	0.004	<0.002	1.76	<0.1	2.0	10.1	6.5	-15	8.6	7.00	
(IW)	11/1/2011		75	2.5	6.7	13	<1.0	<1.1	<1.2	<1.1	0.083	0.074	0.022	0.002	1.87	<1.0	2.3	<1.0	4.0	-124	725	6.13	
	5/6/2012		262	<0.2	0.4	3.0	1.1	<1.0	<1.0	<1.0	0.012	0.009	<0.002	<0.002	0.08		1.7	0.6	23.0	99	41.5	6.33	
BDC-05-14	11/15/2012		455	<0.2	<0.2	1.1	2.0	1.4	<1.0	<1.0	0.022	0.019	<0.002	<0.002	0.11		2.2	<0.3	24.0	-1.4	39.9	6.66	
BDC-05-15	7/31/2011		-18	9.6	28	58	<1.0	<1.1	<1.2	<1.1	0.019	0.019	<0.002	<0.002	1.91	<0.1	1.3	18.6	0.8	-0.9	10.3	7.00	
(IW)	11/1/2011		75	4.8	9.8	15	<1.0	<1.1	<1.2	<1.1	0.061	0.058	0.010	0.009	2.38	<0.1	3.0	11.3	3.5	-0.1	4420	5.67	
	5/6/2012		262	<2.0	<2.0	49	6.3	<1.0	<1.0	<1.0	0.057	0.047	0.009	0.004	0.07		1.8	<0.3	21.0	93	423	6.36	
BDC-05-15	11/15/2012		455	<1.0	<1.0	1.5	7.5	1.8	<1.0	<1.0	0.054	0.049	<0.002	<0.002	0.02		0.8	<0.3	27.0	8	71.2	6.61	
BDC-05-16	7/31/2011		-18	9.5	17	20	<1.0	<1.1	<1.2	<1.1	0.006	0.006	0.002	<0.002	1.91	<0.1	1.5	8.9	3.1	-8	7.8	7.06	
(IW)	11/1/2011		75	2.6	2.8	37	<1.0	<1.1	<1.2	<1.1	0.079	0.074	0.005	0.002	2.30	<1.0	2.5	2.8	3.1	7	2250	5.51	
	2/19/2012		185	<2.0	<2.0	46	7.4	<1.0	<1.0	<1.0					1.59	<0.5	2.2	<1.5	18.0	128	1270	5.12	
BDC-05-16	5/6/2012		262	<0.2	0.3	6.7	24	2.5	<1.0	<1.0	0.042	0.039	0.003	<0.002	0.06		2.5	<0.3	25.0	121	207	6.28	
BDC-05-16	9/5/2012		384	<0.4	<0.4	0.9	8.1	6.0	<1.0	<1.0					0.12		2.0	<0.3	22.0	64	40.6	6.67	
BDC-05-16	11/15/2012		455	<1.0	<1.0	<1.0	4.9	4.0	<1.0	<1.0	0.041	0.037	<0.002	<0.002	0.02		1.0	<0.3	28.0	7	32.3	6.68	
BDC-05-17	7/31/2011		-18	11	22	34	<1.0	<1.1	<1.2	<1.1	0.004	0.004	0.003	0.002	2.03	0.6	1.5	16.0	0.30	59	10.2	6.95	
(IW)	11/1/2011		75	3.2	4.8	5.1	<1.0	<1.1	<1.2	<1.1	0.053	0.047	0.005	<0.002	2.61	<1.0	2.4	23.9	2.8	-50	3500	5.74	
	5/6/2012		262	<2.0	<2.0	9.3	5.6	<1.0	<1.0	<1.0	0.058	0.026	0.003	<0.002	0.24		2.0	0.7	15.0	182	839	6.08	
BDC-05-17	11/15/2012		455	<5.0	<5.0	<5.0	5.4	2.0	<1.0	<1.0	0.081	0.062	<0.002	<0.002	0.02		1.0	<0.3	23.0	13	73.5	6.62	

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection	Full Injection #1	Volatile Organic Compounds							Metals				Aquifer Redox Conditions						Donor Indicators		
		Elapsed Time From Injection (days)	Elapsed Time From Injection (days)	PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments
BDC-05-18	7/31/2011		-18	3.6	5.0	6.6	<1.0	<1.1	<1.2	<1.1	0.019	0.020	<0.002	<0.002	1.57	<0.1	2.4	4.5	3.9	-19	3.2	7.13	
(MW 12 ft XG)	11/1/2011		75	2.8	4.0	7.6	<1.0	<1.1	<1.2	<1.1	0.019	0.020	0.003	0.003	1.37	<0.1	1.2	1.2	4.3	-106	21.7	6.88	
	2/19/2012		185	1.8	3.7	12	<0.2	<1.0	<1.0	<1.0					0.19	<0.5	2.2	<1.5	11.0	9	2.7	6.66	
BDC-05-18	5/6/2012		262	2.0	4.0	9.6	<0.2	<1.0	<1.0	<1.0	0.013	0.013	<0.002	<0.002	0.21		2.5	2.1	7.5	132	2.5	6.39	
BDC-05-18	9/5/2012		384	1.5	3.1	11	0.2	<1.0	<1.0	<1.0					0.13		1.5	2.0	7.9	58	1.8	6.91	
BDC-05-18	11/15/2012		455	1.0	4.3	16	<0.5	<1.0	<1.0	<1.0	0.015	0.014	<0.002	<0.002	0.48		1.4	2.4	8.3	25	1.7	6.62	
BDC-05-19	7/31/2011		-18	15	21	23	<1.0	<1.1	<1.2	<1.1	0.002	0.001	0.002	<0.002	1.81	0.2	2.6	5.2	4.7	34	7.3	6.97	
(MW 10 ft DG)	11/1/2011		75	9.1	13	36	4.1	<1.1	<1.2	<1.1	0.020	0.020	0.007	<0.002	1.53	<1.0	1.8	2.5	4.5	-142	170	6.82	
	2/19/2012		185	<1.0	1.7	68	14	1.4	<1.0	<1.0					0.85	<0.5	2.0	<1.5	22.0	36	296	6.40	
BDC-05-19	5/6/2012		262	0.7	1.4	52	23	1.8	<1.0	<1.0	0.058	0.052	0.032	0.008	0.02		2.0	1.4	25.0	69	244	6.39	
BDC-05-19	9/5/2012		384	<2.0	<2.0	13	15	3.9	<1.0	<1.0					0.19		1.8	1.4	19.0	73	68.0	6.43	
BDC-05-19	11/15/2012		455	<1.0	1.1	9.9	15	5.5	<1.0	<1.0	0.088	0.074	0.006	<0.002	0.21		1.6	1.8	24.0	3	68.1	6.58	
BDC-05-20	7/31/2011		-18	<1.0	7.0	45	<1.0	<1.1	<1.2	<1.1	0.011	0.011	<0.002	<0.002	2.33	<0.1	1.5	7.4	0.2	-42	10.8	7.12	
(MW 31 ft DG)	11/3/2011		77	<1.0	5.7	25	1.0	<1.1	<1.2	<1.1	0.010	0.011	<0.002	<0.002	1.54	<0.1	1.0	6.0	4.6	11	8.3	7.14	
	2/19/2012		185	<0.2	2.9	17	2.5	<1.0	<1.0	<1.0					0.35	<0.5	1.5	<1.5	16.0	31	8.2	6.69	
BDC-05-20	5/7/2012		263	<0.2	1.8	14	2.2	<1.0	<1.0	<1.0	0.011	0.011	<0.002	<0.002	0.69		1.8	2.3	20.0	20	11.1	6.66	
BDC-05-20	9/5/2012		384	<0.4	<0.4	12	2.0	<1.0	<1.0	<1.0					0.08		1.4	<0.3	14.0	67	12.1	6.75	
BDC-05-20	11/16/2012		456	<0.5	0.6	17	3.5	<1.0	<1.0	<1.0	0.012	0.013	<0.002	<0.002	0.07		2.0	<0.3	18.0	0.9	13.1	6.88	
BDC-05-21	7/31/2011		-18	<1.0	<1.0	1.3	14	2.6	<1.2	<1.1	0.006	0.006	<0.002	<0.002	2.98	<0.1	3.2	0.2	5.6	-31	6.4	7.33	
(MW 30 ft XG)	11/3/2011		77	<1.0	<1.0	1.0	4.7				0.005	0.005	<0.002	<0.002	1.95	<0.1	1.4	6.3		-12	5.2	7.29	
	2/19/2012		185	<0.2	0.3	0.7	5.9								0.40	<0.5	1.4	<1.5		47	7.2	6.65	
BDC-05-21	5/7/2012		263	<0.2	0.4	0.8	2.5				0.010	0.011	0.005	<0.002	0.86		1.5	1.9		-35	12.3	6.76	
BDC-05-21	9/5/2012		384	<0.2	0.3	0.6	2.9								0.08		2.5	1.4		62	9.5	6.78	
BDC-05-21	11/16/2012		456	<0.5	<0.5	0.6	2.9				0.020	0.020	<0.002	<0.002	0.02		1.5	0.6		-4	8.9	6.92	
BDC-05-22	7/31/2011		-18	<1.0	1.1	9.6	1.0	<1.1	<1.2	<1.1	0.025	0.024	<0.002	<0.002	2.02	<0.1	2.2	14.0	5.1	-59	7.9	7.21	
(MW 48 ft XG)	11/3/2011		77	<1.0	2.1	10	<1.0				0.020	0.020	<0.002	<0.002	1.46	<0.1	0.8	18.1		19	6.1	7.08	
	2/19/2012		185	<0.2	2.0	13	0.4								0.43	<0.5	1.2	17.0		110	6.2	6.73	
BDC-05-22	5/7/2012		263	<0.2	2.0	11	0.5				0.025	0.023	0.002	<0.002	0.81		1.6	19.4		32	8.4	6.68	
BDC-05-22	9/5/2012		384	<0.2	1.8	9.5	0.8								0.06		2.2	14.7		75	7.6	6.71	
BDC-05-22	11/16/2012		456	<0.5	1.6	10	0.7				0.033	0.031	<0.002	<0.002	0.02		0.8	17.8		5	7.7	6.93	
BDC-05-23	7/31/2011		-18	<1.0	<1.0	3.2	<1.0	<1.1	<1.2	<1.1	0.005	0.005	0.002	<0.002	2.72	<0.1	2.2	8.6	6.0	-101	9.1	7.47	
(MW 170ft DG)	11/3/2011		77	<1.0	<1.0	4.8	<1.0				0.005	0.006	<0.002	<0.002	1.45	<0.1	1.0	25.2		1	8.8	7.08	
	2/19/2012		185	<0.2	0.6	4.7	0.7								0.96	<0.5	1.2	8.9		162	8.1	6.33	
BDC-05-23	5/7/2012		263	<0.2	0.7	5.4	0.8				0.008	0.008	<0.002	<0.002	0.07		2.0	15.8		45	9.3	6.70	
BDC-05-23	9/5/2012		384	<0.2	0.7	6.2	0.9								0.08		1.9	8.8		78	11.3	6.84	
BDC-05-23	11/16/2012		456	<0.5	0.8	6.9	0.5				0.012	0.010	<0.002	<0.002	0.09		1.0	4.9		-6	11.6	7.06	
BDC-05-24	7/31/2011		-18	<1.0	<1.0	1.6	1.6	<1.1	<1.2	<1.1	0.003	0.003	<0.002	<0.002	1.67	<0.1	2.0	1.1	7.6	-7	10.0	7.06	
(MW 18 ft XG)	11/1/2011		75	<1.0	2.0	4.0	2.2				0.002	0.002	<0.002	<0.002	1.50	<0.1	1.6	0.3		-2.6	8.1	7.06	
	2/19/2012		185	<0.2	0.2	0.7	0.8								0.31	<0.5	1.8	<1.5		63	9.8	6.55	
BDC-05-24	5/6/2012		262	<0.2	1.3	2.8	1.0				0.006	0.004	<0.002	<0.002	0.03			0.9		73	9.1	6.60	
BDC-05-24	9/5/2012		384	<0.2	1.2	4.0	0.9								0.08		2.0	<0.3		67	7.4	6.67	
BDC-05-24	11/15/2012		455	<0.5	<0.5	1.2	<0.5				0.002	0.003	<0.002	<0.002	0.13		1.0	<0.3		-1.7	10.7	6.94	

TABLE 1
GROUNDWATER DATA SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

		Pilot Injection	Full Injection #1	Volatile Organic Compounds							Metals				Aquifer Redox Conditions						Donor Indicators		
		Elapsed Time From Injection (days)	Elapsed Time From Injection (days)	PCE (µg/L)	TCE (µg/L)	*c* DCE (µg/L)	VC (µg/L)	Ethene (µg/L)	Ethane (µg/L)	Acetylene (µg/L)	As, Tot (mg/L)	As, Dis (mg/L)	Cu, Tot (mg/L)	Cu, Dis (mg/L)	DO (mg/L)	Nitrate (mg-N/L)	Iron II (mg/L)	Sulfate (mg/L)	Methane (mg/L)	ORP (mV)	TOC (mg/L)	pH	
Preliminary Screening Level (Fresh Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0034	0.0034									
Preliminary Screening Level (Marine Surface Water)				9	81	NA	525	NA	NA	NA	0.005	0.005	0.0089 (a)	0.0089 (a)									
Proposed Groundwater Cleanup Levels (b)				5.3	1.4	134	2.4	NA	NA	NA	0.008	0.008	0.008	0.008									
Well	Date																						Comments

PCE = Tetrachloroethene
TCE = Trichloroethene
c DCE = cis-1,2-Dichloroethene
VC = Vinyl Chloride
As = Arsenic
Cu = Copper
Tot = Total

Dis = Dissolved
DO = Dissolved Oxygen
ORP = Oxidation Reduction Potential
TOC = Total Organic Carbon
NA = Not Applicable, not available
µg/L = micrograms per liter
mg/L = milligrams per liter

IW = Injection Well
MW = Monitoring Well
DG = Downgradient; distance from nearest injection well
UG = Upgradient
XG = Crossgradient; distance from nearest injection well
(shaded) not analyzed
Box = Exceedance of proposed groundwater cleanup level.

(a) Hardness dependent; hardness assumed to be 75.4 mg/L.
(b) Landau Associates 2013.

Injection Dates:

10/28/2008	Pilot Injection: BDC-05-02 only
8/18/2011	Full Injection #1: BDC-05-02, BDC-05-07, and BDC-09 through BDC-05-17; performed 8/15/11-8/18/11

TABLE 2
AUGUST 2011 INJECTION SUMMARY
BOEING DEVELOPMENTAL CENTER SWMU-17

Well ID	Injection Date and Time		Pre-Flush Duration (min)	Injection Duration (min)	Post-Flush Duration (min)	Injection Volume (gal)						LactOil™ Concentration in Injection Solution (%)	Vegetable Oil Concentration in Injection Solution (%)	Ethyl Lactate Concentration in Injection Solution (%)	Average Injection Rate (gpm)			Pressure Range (psi) (a)
						Pre-Flush	LactOil™	Water	Injection Solution	Post-Flush	Total				Pre-Flush	Injection Solution	Post-Flush	
BDC-05-14	08/15/11	14:40	5	98	5	192	320	5,315	5,635	244	6,071	5.7	2.8	1.9	38	58	49	0
BDC-05-17	08/16/11	10:15	6	76	10	192	320	5,317	5,637	244	6,073	5.7	2.8	1.9	32	74	24	0 - 2
BDC-05-15	08/16/11	14:21	4	90	5	192	320	5,431	5,751	244	6,187	5.6	2.7	1.9	48	64	49	0 - <1
BDC-05-16	08/17/11	9:28	3	87	5	192	320	5,315	5,635	174	6,001	5.7	2.8	1.9	64	65	35	0
BDC-05-09	08/17/11	12:16	10	94	10	244	320	5,250	5,570	200	6,014	5.7	2.8	2.0	24	59	20	0 - <1
BDC-05-13	08/17/11	13:50	9	90	10	250	320	5,084	5,404	200	5,854	5.9	2.9	2.0	28	60	20	0
BDC-05-11	08/18/11	8:22	6	84	10	242	320	5,442	5,762	200	6,204	5.6	2.7	1.9	40	69	20	0 - 2
BDC-05-12	08/18/11	10:06	7	107	10	288	320	5,314	5,634	200	6,122	5.7	2.8	1.9	41	53	20	0
BDC-05-07	08/18/11	11:57	6	73	10	244	320	5,444	5,764	200	6,208	5.6	2.7	1.9	41	79	20	0
BDC-05-10	08/18/11	14:00	10	90	10	244	320	5,258	5,578	200	6,022	5.7	2.8	2.0	24	62	20	0 - <1
BDC-05-02	08/18/11	15:15	12	65	10	244	320	5,292	5,612	200	6,056	5.7	2.8	1.9	20	86	20	0
					Whole Site:	**2,524**	**3,520**	**58,462**	**61,982**	**2,306**	**66,812**	**5.7**	**2.8**	**1.9**				

(a) Target pressure was < 15 to 20 psi. However, little to no backpressure was observed at all injection wells.

TABLE 3
BIOREMEDIATION GROUNDWATER MONITORING MATRIX
BOEING DEVELOPMENTAL CENTER SWMU-17

		Quarterly	Semiannual	Explanation
Injection Wells				
02	(a) (b) (c)	(a) (c)	(a) (b) (c)	existing well
07	(a) (b) (c)		(a) (b) (c)	existing well
09	(a) (b) (c)		(a) (b) (c)	new well
10	(a) (b) (c)		(a) (b) (c)	new well
11	(a) (b) (c)		(a) (b) (c)	new well
12	(a) (b) (c)	(a) (c)	(a) (b) (c)	new well
13	(a) (b) (c)		(a) (b) (c)	new well
14	(a) (b) (c)		(a) (b) (c)	new well
15	(a) (b) (c)		(a) (b) (c)	new well
16	(a) (b) (c)	(a) (c)	(a) (b) (c)	new well
17	(a) (b) (c)		(a) (b) (c)	new well
Monitoring Wells				
03	existing data		(a) (b)	existing monitoring well
04	existing data		(a) (b)	existing monitoring well
05	existing data		(a) (b)	existing monitoring well
08	existing data		(a) (b)	existing monitoring well
18	(a) (b) (c)	(a) (c)	(a) (b) (c)	new core of plume well
19	(a) (b) (c)	(a) (c)	(a) (b) (c)	new core of plume well
20	(a) (b) (c)	(a) (c)	(a) (b) (c)	new downgradient well
21	(a) (b) (c)	(a)	(a) (b)	new downgradient well
22	(a) (b) (c)	(a)	(a) (b)	new downgradient well
23	(a) (b) (c)	(a)	(a) (b)	new downgradient well
24	(a) (b) (c)	(a)	(a) (b)	new crossgradient well

(a) Laboratory Parameters (method): Volatile Organic Compounds (VOCs) Short List (8260) - tetrachoroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), vinyl chloride (VC); total organic carbon (TOC; 415.1); Sulfate/Nitrate (E300).
Field Parameters: ferris iron (Fe2), pH, dissolved oxygen (DO), oxygen reduction potential (ORP), temperature.

(b) Laboratory Parameters (method): total (nonfiltered) and dissolved (field filtered) copper (3010A) and arsenic (200.8 ICP-MS).

(c) Laboratory Parameters (method): Methane/Ethane/Ethene/Acetylene (RSK-175).

TABLE 4
BIOREMEDIATION GROUNDWATER MONITORING MATRIX (REVISED)
BOEING DEVELOPMENTAL CENTER SMWU-17

	Quarterly	Semiannual	Explanation
Injection Wells			
02	(a) (c)	(a) (b) (c)	head of plume
07		(a) (b) (c)	location of former UST
09		(a) (b) (c)	core of plume
10		(a) (b) (c)	core of plume
11		(a) (b) (c)	core of plume
12	(a) (c)	(a) (b) (c)	core of plume
13		(a) (b) (c)	core of plume
14		(a) (b) (c)	core of plume
15		(a) (b) (c)	core of plume
16	(a) (c)	(a) (b) (c)	core of plume
17		(a) (b) (c)	core of plume
Monitoring Wells			
03		(a) (b) (c)	downgradient
04		(a) (b)	crossgradient
05		(a) (b)	upgradient
08		(a) (b)	crossgradient
18	(a) (c)	(a) (b) (c)	crossgradient
19	(a) (c)	(a) (b) (c)	downgradient
20	(a) (c)	(a) (b) (c)	downgradient
21	(a) (c)	(a) (b) (c)	crossgradient
22	(a)	(a) (b)	crossgradient
23	(a)	(a) (b)	downgradient
24	(a) (c)	(a) (b) (c)	crossgradient

UST = underground storage tank

(a) Laboratory Parameters (method): Volatile Organic Compounds (VOCs) Short List (8260) - tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), vinyl chloride (VC), total organic carbon (TOC; SM5310C), sulfate (E300).
Field Parameters: Fe2; pH, dissolved oxygen (DO), oxygen reduction potential (ORP), temperature.

(b) Laboratory Parameters (method): total (nonfiltered) and dissolved (field filtered) copper (3010A) and arsenic (200.8 ICP-MS).

(c) Laboratory Parameters (method): Methane/Ethane/Ethene/Acetylene (RSK-175).

NOTE: Changes to original monitoring matrix are shown in red.

APPENDIX A

Boring Logs and Well Construction Diagrams

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.

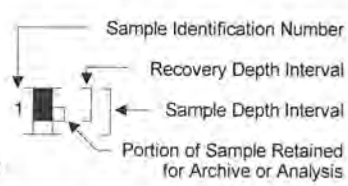
4. Soil density or consistency descriptions are based on judgement using a combination of sampler penetration blow counts, drilling or excavating conditions, field tests, and laboratory tests, as appropriate.

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 | Boeing Developmental Center Tukwila, Washington | Soil Classification System and Key | Figure A-1

BDC-05-09

SAMPLE DATA

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data
~3.5		■	a1	2	PID = 2.5
~8.5		■	a1	16	PID = 1.4
~13.5		■	a1	4	PID = 2.0
~18.5		■	a1	6	PID = 1.3
~23.5		■	a1	11	PID = 1.5

SOIL PROFILE

Drilling Method: Hollow-Stem Auger

Ground Elevation (ft): NM

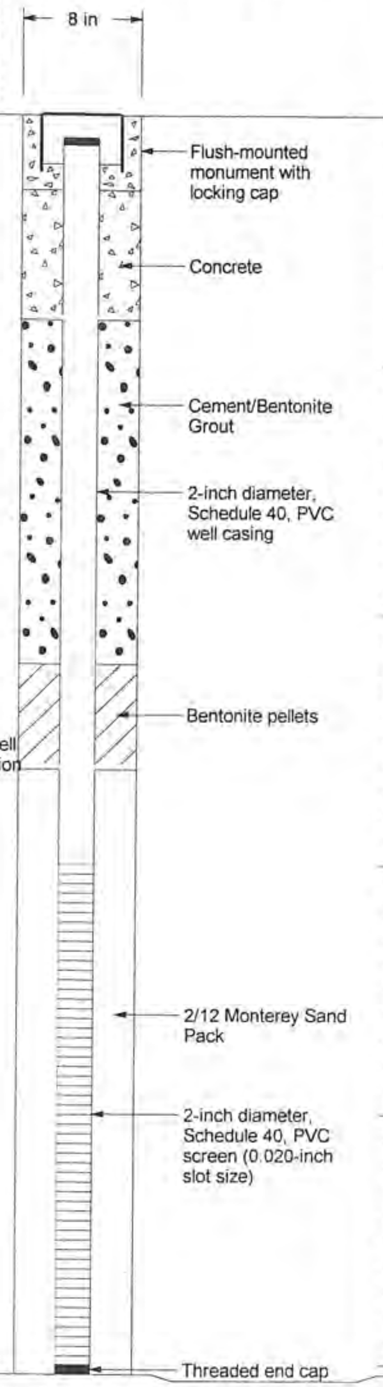
Drilled By: Cascade Drilling Inc.

USCS Symbol	Description
CONC	Concrete slab
SP	Brown, fine SAND, with trace silt (no odor, no sheen) (very loose, damp)
SP-SM	Brown, fine SAND, with silt (no odor, no sheen) (very loose, damp)
	with trace medium sand (medium dense, damp)
SP	Brown, fine SAND, with trace medium sand and trace silt (no odor, no sheen) (medium dense, damp)
	with trace coarse sand (very loose, wet)
SP-SM	Brown, fine SAND, with silt (no odor, no sheen) (very loose, wet)
SP	Black, fine SAND, with trace medium sand, trace silt, and red andesite specks (no odor, no sheen) (loose, wet)
	@ 18.5 ft: dark brown to black, no red andesite specks
	black, with red andesite specks

GROUNDWATER

Water Level: After well installation (approx. 12.5 ft)

Injection Well Detail



Boring Completed 07/08/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/08/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Injection Well BDC-05-09

Figure A-2

BDC-05-10

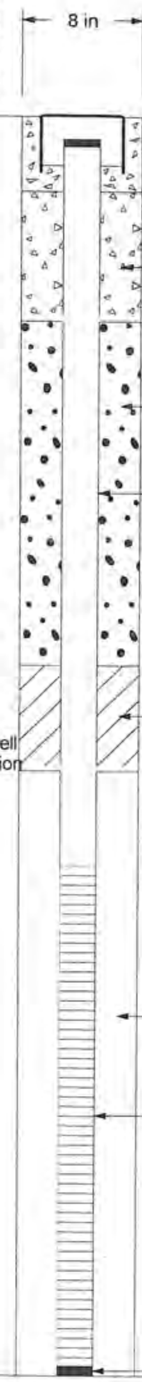
SAMPLE DATA | **SOIL PROFILE** | **GROUNDWATER**

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): NM
Drilled By: Cascade Drilling Inc.

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
0						CONC	Concrete slab
						SP-SM	Dark brown, fine SAND, with silt and trace organic material and silt globules (no odor, no sheen) (very loose, moist)
		▮	a1	6	PID = 2.0	SM	Dark brown, silty, fine SAND, with trace gravel (no odor, no sheen) (very loose, moist)
5						SP	Dark brown, fine SAND, with medium sand (no odor, no sheen) (very loose, moist)
						SM	Dark brown, silty, fine SAND (no odor, no sheen) (loose, moist)
		▮	a1	11	PID = 2.1	SP	Dark brown, fine SAND, with medium sand, trace coarse sand, and trace silt (no odor, no sheen) (loose, moist)
10						SP-SM	Dark brown, fine SAND, with silt, trace medium and coarse sand (no odor, no sheen) (very loose, moist)
		▮	a1	2	PID = 1.9	SM	Blackish-brown, silty, fine SAND, with trace organic material (no odor, no sheen) (very loose, wet)
15						SP	Blackish-brown, fine SAND, with trace silt and silt lenses (slight chemical odor, no sheen) (very loose, wet)
		▮	a1	6	PID = 3.5		
20							
		▮	a1	15	PID = 2.5		brownish-black, with trace coarse sand (no odor, no sheen) (loose, wet) @ 23.5 ft: lens (2 inches thick) dark brown, with silt
25							

Water Level: ▽ After well installation (approx. 12.5 ft)

Injection Well Detail



Boring Completed 07/07/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/07/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

LANDAU ASSOCIATES

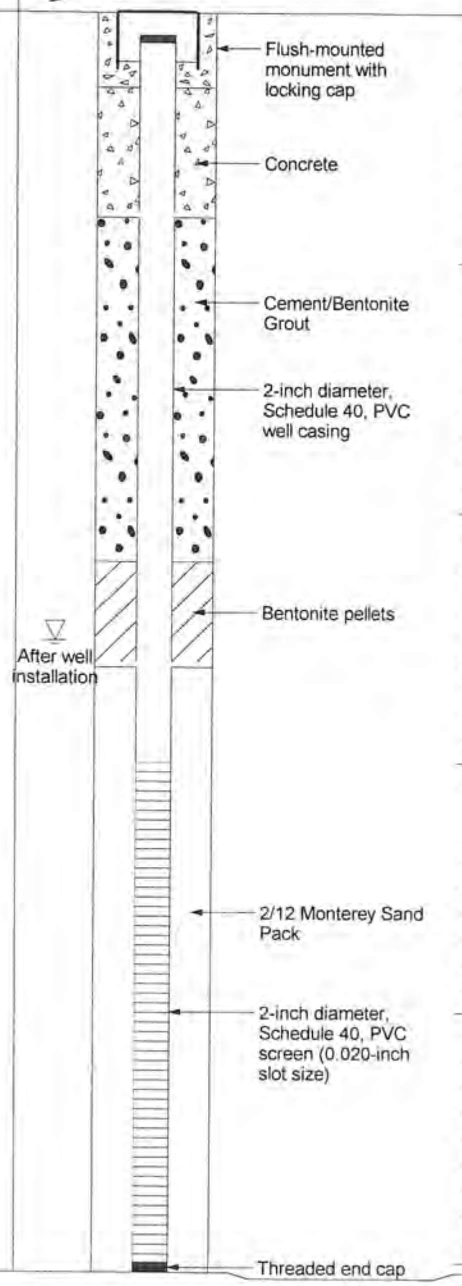
Boeing Developmental Center
Tukwila, Washington

Log of Injection Well BDC-05-10

Figure A-3

BDC-05-11

SAMPLE DATA						SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level / Injection Well Detail
0–25								Soil samples not collected.	



Boring Completed 07/07/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/07/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

BDC-05-12

SAMPLE DATA / SOIL PROFILE / GROUNDWATER

Drilling Method: Hollow-Stem Auger

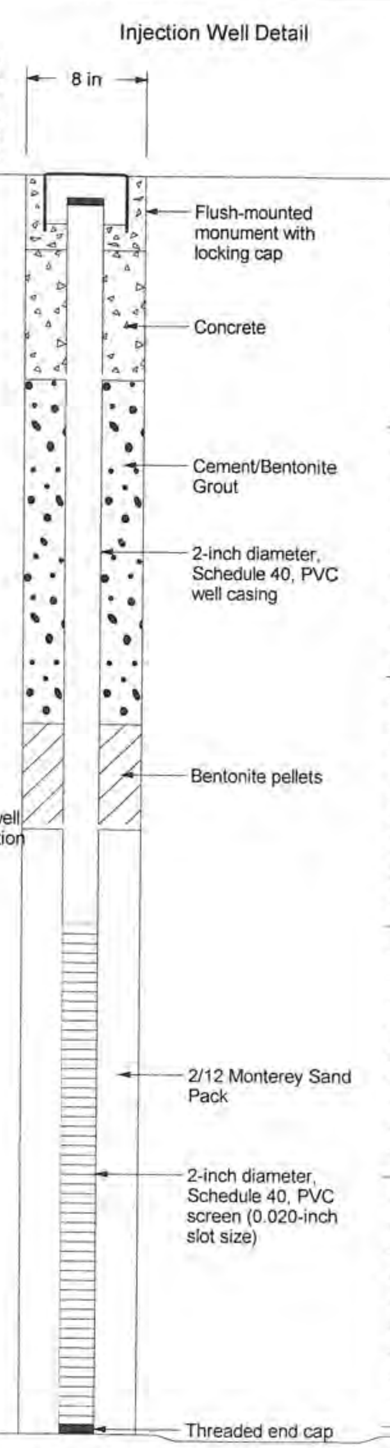
Ground Elevation (ft): NM

Drilled By: Cascade Drilling Inc.

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
0						CONC	Concrete slab
						SP	Dark brown, fine SAND, with trace silt (no odor, no sheen) (loose, moist)
		■	a1	10	PID = 4.9	ML	Black, sandy SILT (slight chemical odor, no sheen) (stiff, moist) @3.75 ft: dark brown (no odor, no sheen)
5						SP	Dark brown, fine SAND, with trace silt, mottled with black sandy silt (slight chemical odor, no sheen) (very loose, moist)
		■	a1	3	PID = 3.4	ML	Dark brown, rust-mottled, sandy SILT (slight chemical odor, no sheen) (soft, moist)
10						SP-SM	Dark brown, fine SAND, with silt (slight chemical odor, no sheen) (very loose, moist) mottled with black, sandy silt (very slight chemical odor, no sheen)
		■	a1	4	PID = 3.2	SM	Blackish-brown, silty, fine SAND (very slight chemical odor, no sheen) (very loose, wet)
15						SP	Blackish-brown, fine SAND, with trace silt, and dark brown and black silt globules (slight chemical odor, no sheen) (loose, wet)
		■	a1	7	PID = 3.6		
20							
		■	a1	10	PID = 3.8		with brown silt globules @ 23.5 ft: lens (1 inch thick) of coarser fine sand
25							

Water Level: ▽ After well installation

Injection Well Detail



Boring Completed 07/07/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/07/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Injection Well BDC-05-12

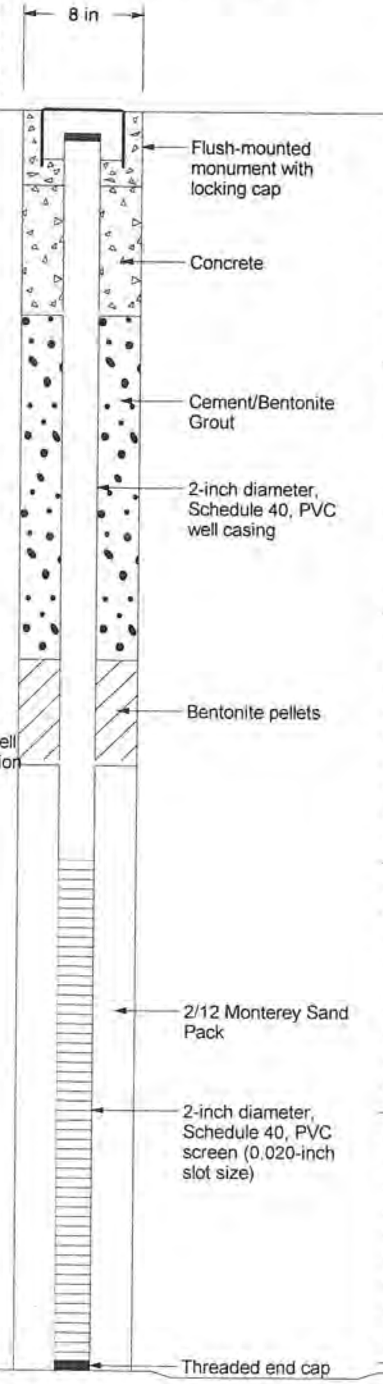
Figure A-5

BDC-05-13

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): NM
Drilled By: Cascade Drilling Inc.

SAMPLE DATA: Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	SOIL PROFILE: USCS Symbol	Description	GROUNDWATER: Water Level
0						CONC	Concrete slab	
						SP-SM	Dark brown, fine SAND, with silt (no odor, no sheen) (very loose, moist)	
			a1	4	PID = 10.0	SM	Dark brown, very silty, fine SAND (no odor, no sheen) (very loose, moist)	
5								
						SP-SM	Dark brown, fine SAND, with silt and silt lenses (no odor, no sheen) (very loose, moist)	
			a1	3	PID = 6.7			
10								
			a1	5	PID = 6.9		dark brown to black (very loose, wet)	After well installation
15								
						SP	Dark brown to black, fine SAND, with trace silt (no odor, no sheen) (medium dense, wet)	
			a1	16	PID = 6.5			
20								
			a1	10	PID = 10.0		(loose, wet)	
25								

Injection Well Detail



Boring Completed 07/06/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/06/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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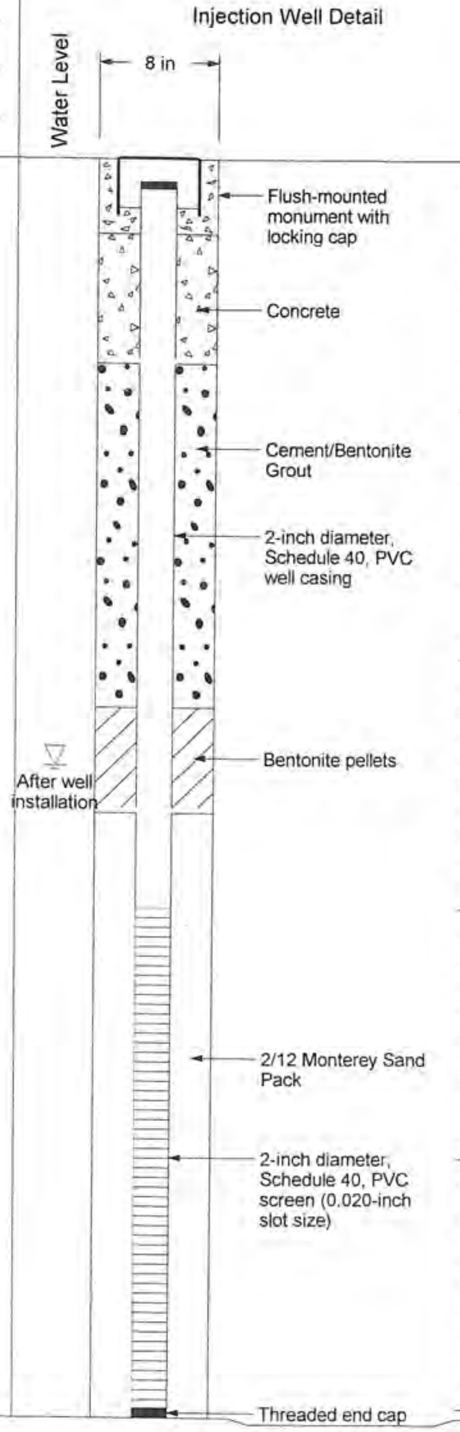
Tukwila, Washington

Log of Injection Well BDC-05-13

Figure A-6

BDC-05-14

SAMPLE DATA						SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level
0								Soil samples not collected.	
5									
10									
15									
20									
25									



Boring Completed 07/06/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/06/11
Total Depth of Injection Well = 25.2 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.

25093. 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Injection Well BDC-05-14

Figure A-7

BDC-05-15

Drilling Method: Hollow-Stem Auger

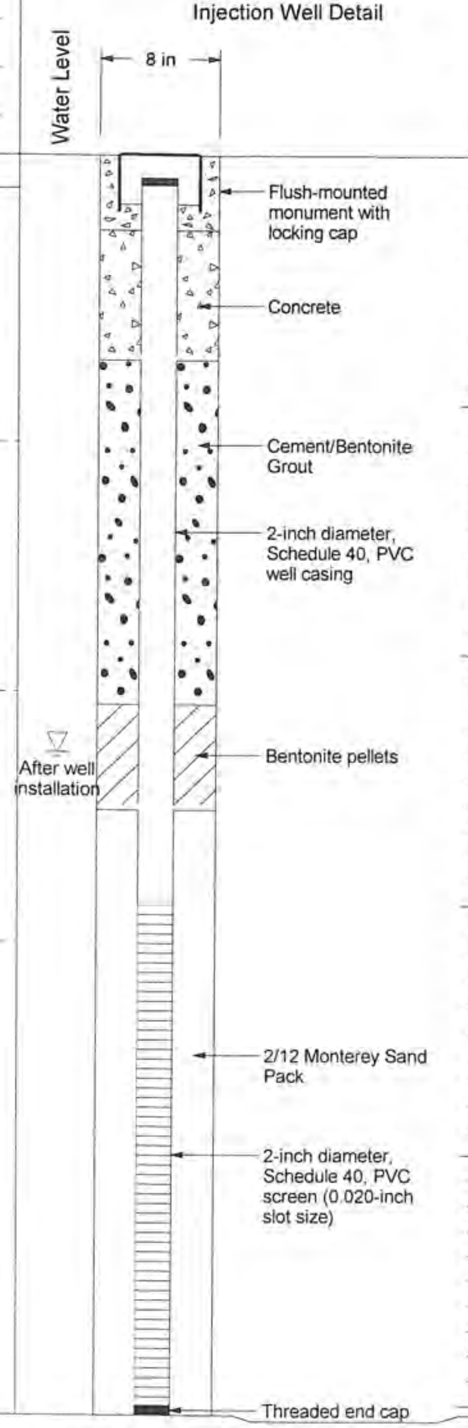
Ground Elevation (ft): NM

Drilled By: Cascade Drilling Inc.

SAMPLE DATA / SOIL PROFILE

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
0						CONC	Concrete slab
						ML	Dark brown, sandy SILT (no odor, no sheen) (stiff, moist)
~4			a1	15	PID = 4.8		
~6						SP	Dark brown, fine SAND with trace silt (no odor, no sheen) (very loose, moist)
~8			a1	4	PID = 4.6		
~11						SP-SM	Dark brown, fine SAND with silt (no odor, no sheen) (very loose, moist)
~13			a1	4	PID = 2.8		@ 13 ft: lens (2.5 inches thick) rust-mottled @ 13.2 ft: dark gray @ 13.4 ft: silt seams
~16						SP	Dark gray, fine SAND with silt lenses (no odor, no sheen) (medium dense, wet)
~18			a1	17	PID = 6.3		
~23			a1	25	PID = 5.9		coarsening with depth, with trace silt and trace gravel

GROUNDWATER



Boring Completed 07/05/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/06/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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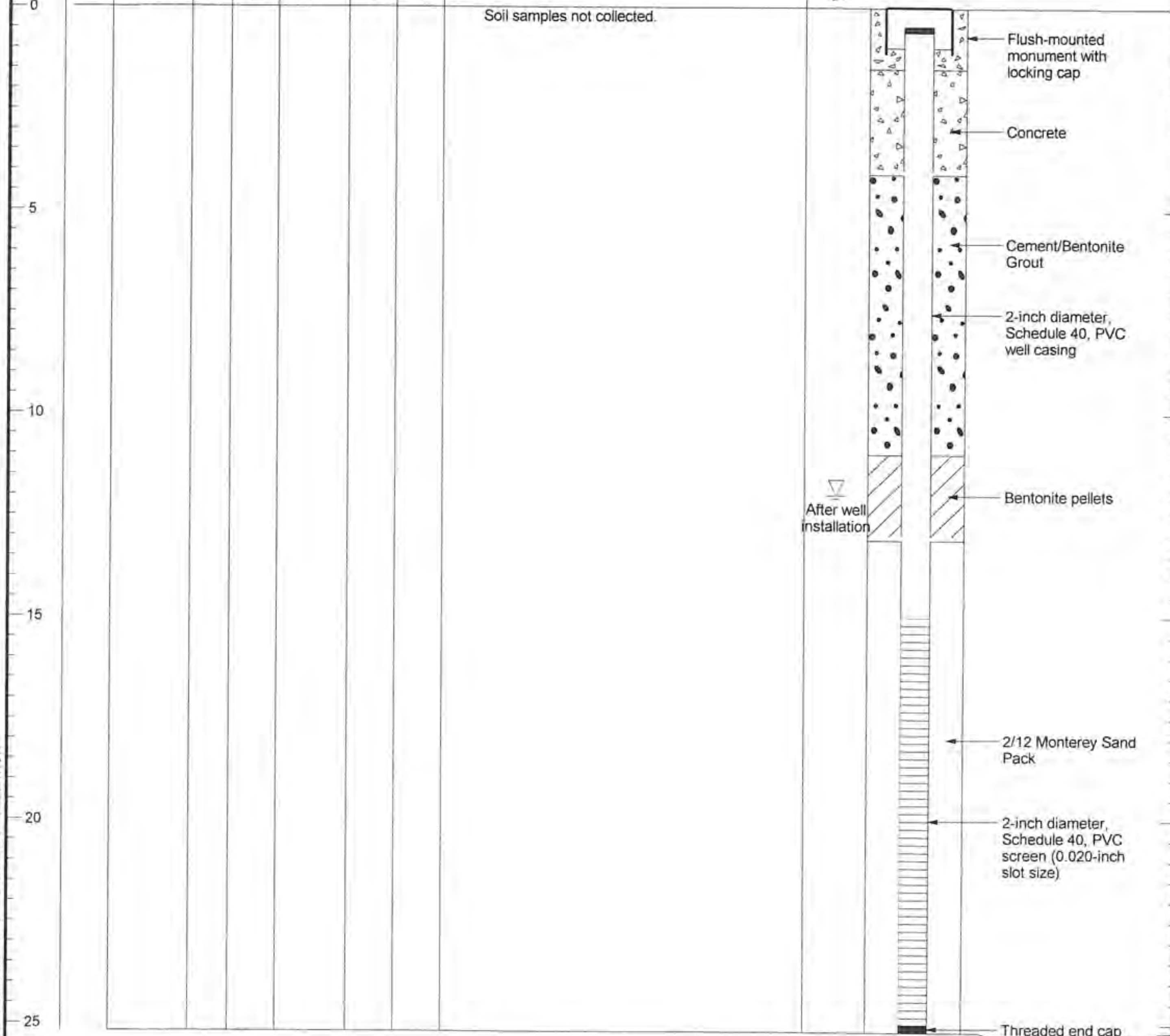
Tukwila, Washington

Log of Injection Well BDC-05-15

Figure A-8

BDC-05-16

SAMPLE DATA						SOIL PROFILE			GROUNDWATER	
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level	Injection Well Detail
0								Soil samples not collected.		



Boring Completed 07/06/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/06/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Injection Well BDC-05-16

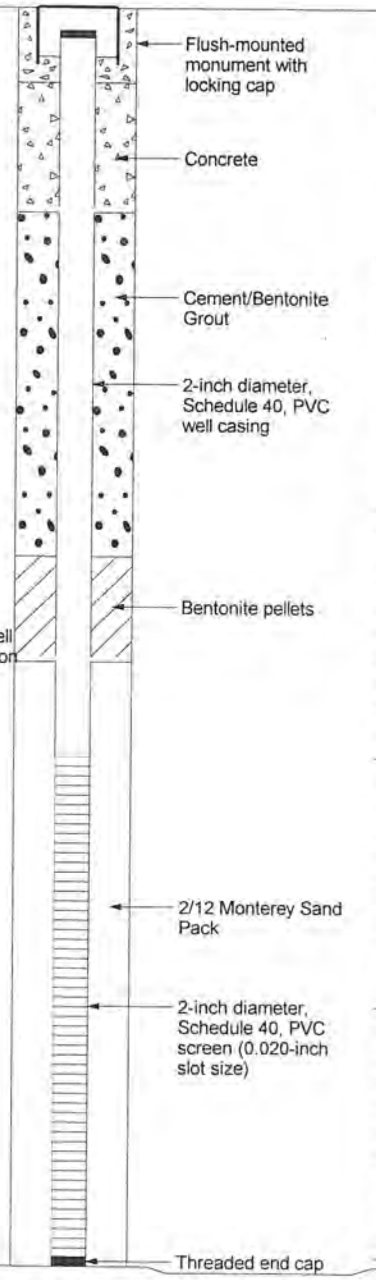
Figure A-9

BDC-05-17

SAMPLE DATA					SOIL PROFILE		GROUNDWATER
Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level
					CONC	Concrete slab	
					SP/ ML	Dark brown, interbedded fine SAND and sandy SILT (no odor, no sheen) (very loose and soft, moist)	
	▮	a1	3	PID = 1.0			
					SP	Brownish gray, fine SAND (no odor, no sheen) (very loose, moist)	
	▮	a1	5	PID = 1.6			
	▮	a1	10	PID = 0.4		dark gray, with trace silt (loose, moist)	▽ After well installation
	▮	a1	25	PID = 1.5		no silt (medium dense, wet) @ 18.5 ft: lens (1 inch thick) sandy SILT (very stiff, wet)	
	▮	a1	28	PID = 2.2		with medium sand, fine gravel, wood debris, and organic matter	

Depth (ft): 0, 5, 10, 15, 20, 25

Injection Well Detail



Boring Completed 07/05/11
Total Depth of Boring = 25.2 ft.

Injection Well Completed 07/05/11
Total Depth of Injection Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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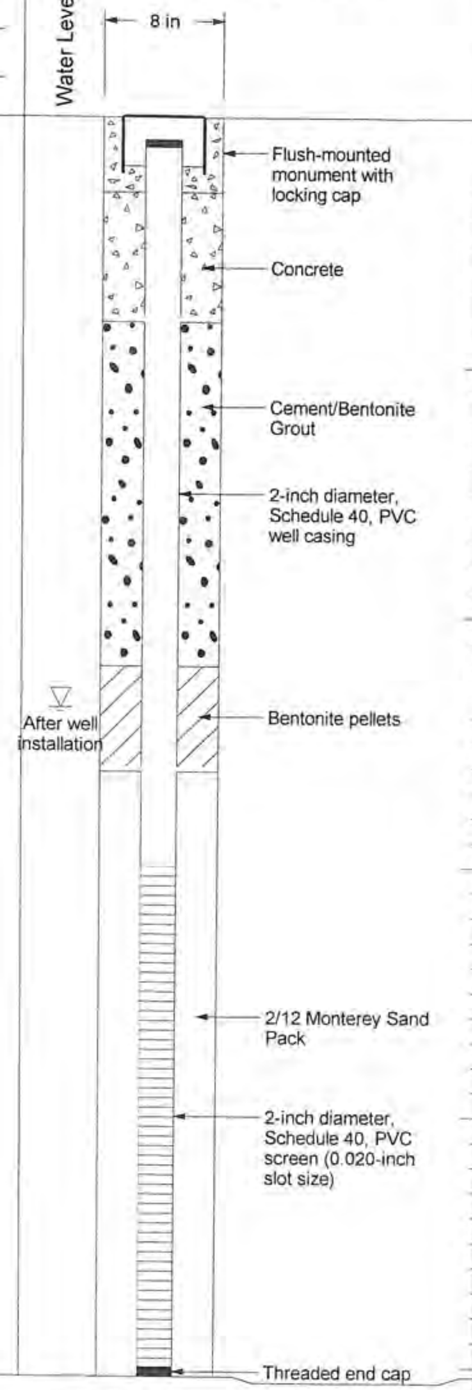
Tukwila, Washington

Log of Injection Well BDC-05-17

Figure A-10

BDC-05-18

SAMPLE DATA						SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level
0								Soil samples not collected.	



Boring Completed 07/08/11
Total Depth of Boring = 25.2 ft.

Monitoring Well Completed 07/08/11
Total Depth of Monitoring Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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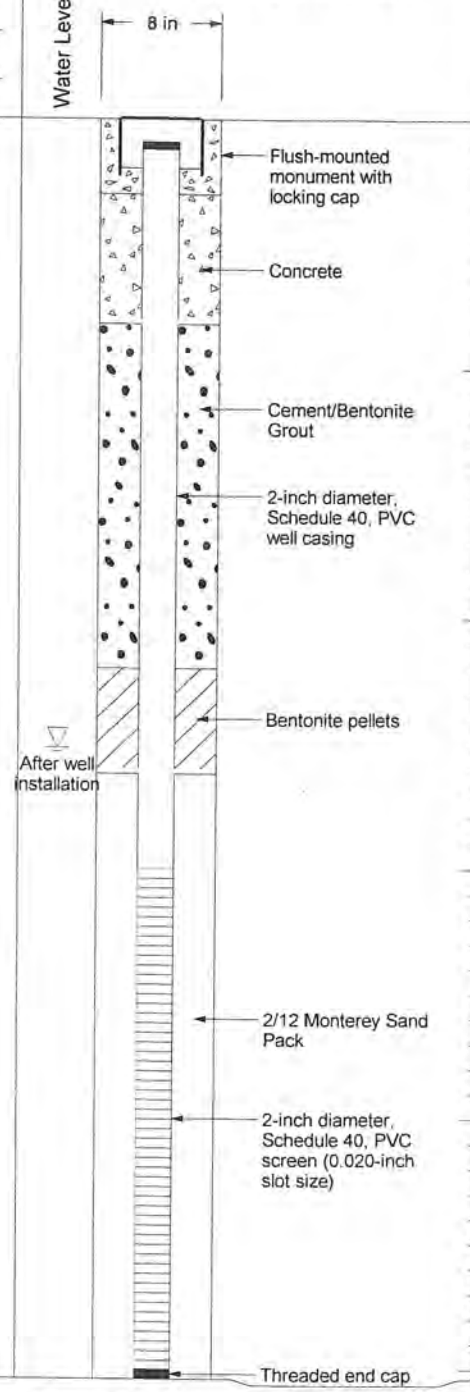
Boeing Developmental Center
Tukwila, Washington

Log of Monitoring Well BDC-05-18

Figure A-11

BDC-05-19

SAMPLE DATA						SOIL PROFILE			GROUNDWATER	
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level	Monitoring Well Detail
0								Soil samples not collected.		
5										
10										
15										
20										
25										



Boring Completed 07/07/11
Total Depth of Boring = 25.2 ft.

Monitoring Well Completed 07/07/11
Total Depth of Monitoring Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Monitoring Well BDC-05-19

Figure A-12

BDC-05-20

Drilling Method: Hollow-Stem Auger

Ground Elevation (ft): NM

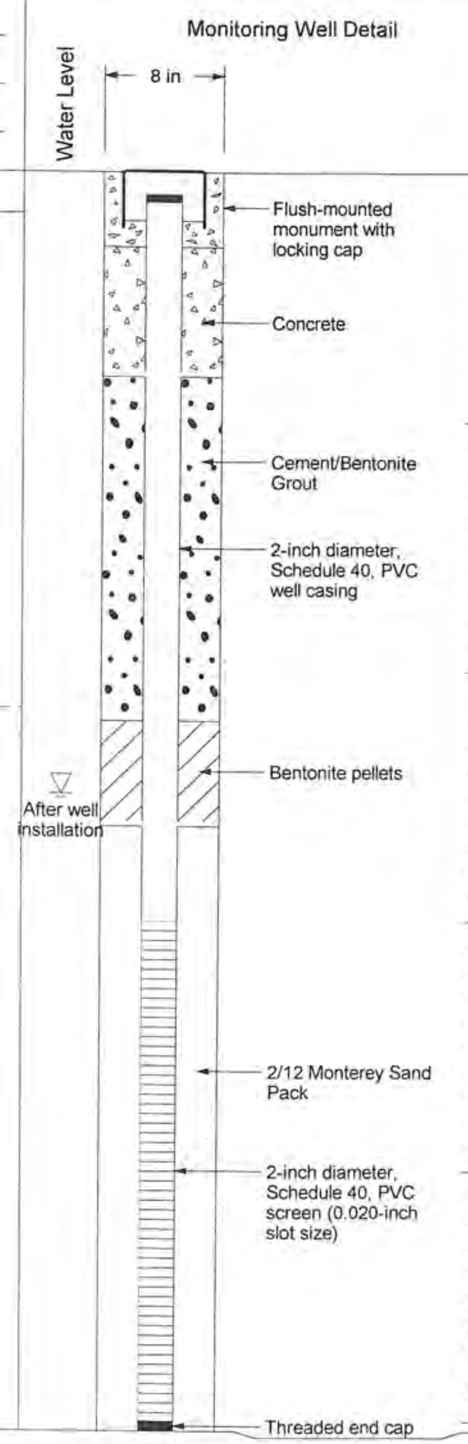
Drilled By: Cascade Drilling Inc.

SAMPLE DATA / SOIL PROFILE

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
0						CONC	Concrete slab
						SP-SM	Dark brown, fine SAND, with trace silt and silt lenses (no odor, no sheen) (loose to medium dense, moist)
		■	i		PID = 0.8		
		■	a1	6	PID = 0.7		rust mottled, with silt and silt lenses (very loose, moist)
						SP	Dark gray, fine SAND, with wood debris and trace silt (slight solvent odor, no sheen) (loose, wet)
		■	a1	11	PID = 0.6		
		■	a1	33	PID = 1.1		black (no odor, no sheen) (medium dense, wet)
		■	a1	35	PID = 1.3		(slight chemical odor, no sheen)
25							

GROUNDWATER

Water Level



Boring Completed 07/05/11
Total Depth of Boring = 25.2 ft.

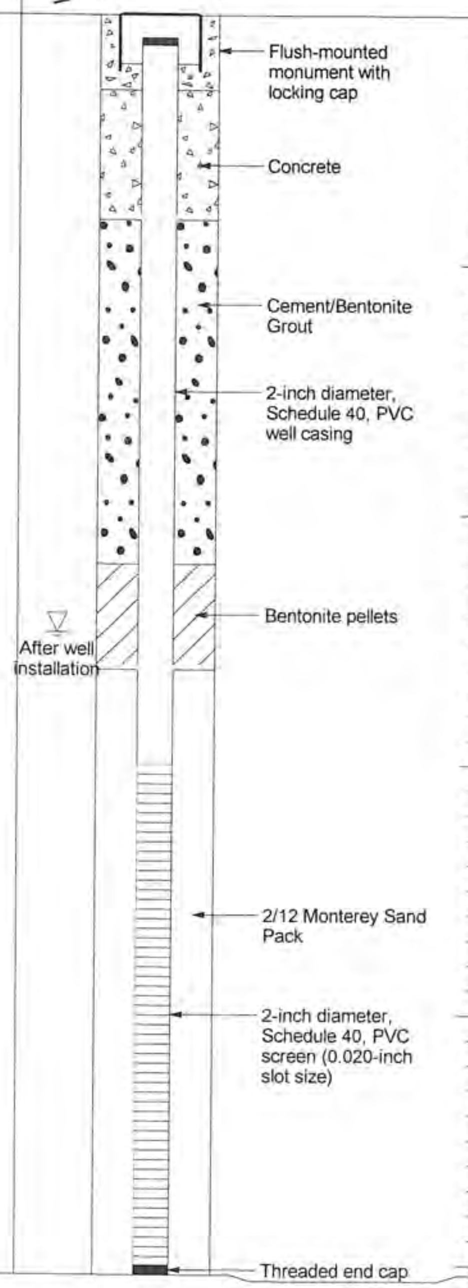
Monitoring Well Completed 07/05/11
Total Depth of Monitoring Well = 25.2 ft.

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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

BDC-05-21

SAMPLE DATA						SOIL PROFILE			GROUNDWATER	
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level	Monitoring Well Detail
0–25								Soil samples not collected.	After well installation	



Depth scale (ft): 0, 5, 10, 15, 20, 25

Boring Completed 07/08/11
Total Depth of Boring = 25.2 ft

Monitoring Well Completed 07/08/11
Total Depth of Monitoring Well = 25.2 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	Boeing Developmental Center Tukwila, Washington	Log of Monitoring Well BDC-05-21	Figure A-14

BDC-05-22

SAMPLE DATA / SOIL PROFILE / GROUNDWATER

Drilling Method: Hollow-Stem Auger

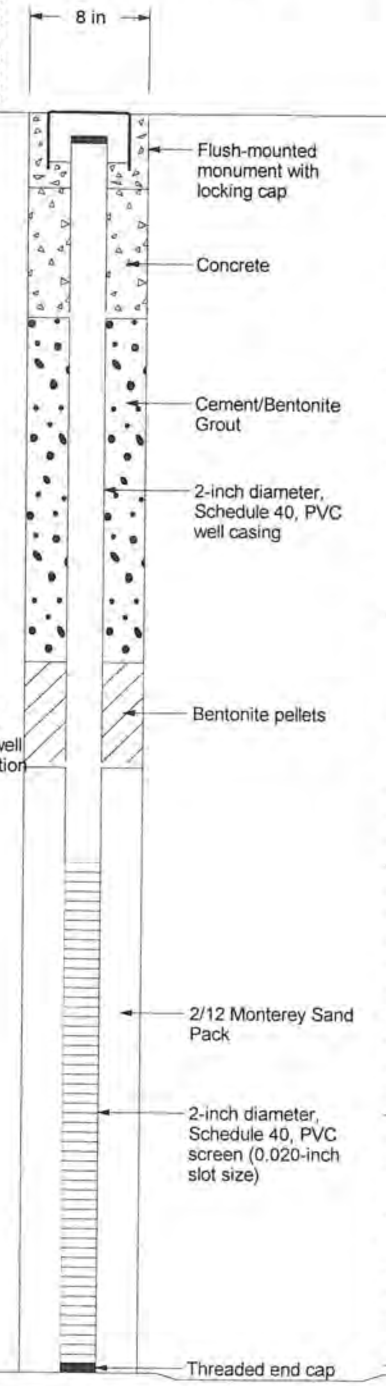
Ground Elevation (ft): NM

Drilled By: Cascade Drilling Inc.

Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
0						CONC	Concrete slab
						SP	Brown, fine SAND, with trace silt (no odor, no sheen) (loose, damp)
3			a1	14	PID = 2.0	ML	@ 3 ft: Dark brown, sandy SILT (no odor, no sheen) (stiff, moist), transitioning to brown, very sandy at 3.25 ft
						SP-SM	@3.5 ft: Brown, fine to medium SAND, with silt (no odor, no sheen) (loose, damp)
						SP	Brown, fine SAND, with trace silt (no odor, no sheen) (very loose, damp)
8			a1	4	PID = 2.0		@ 8 ft: lens (6 inches thick) silty
							@ 8.5 ft: fine to medium
13			a1	8	PID = 2.2		dark brown, fine, with trace medium sand and red andesite specks (loose, wet)
18			a1	18	PID = 2.0		black (medium dense, wet)
23			a1	8	PID = 1.7		(loose, wet)
25							

Water Level: After well installation

Monitoring Well Detail



Boring Completed 07/08/11
Total Depth of Boring = 25.2 ft.

Monitoring Well Completed 07/08/11
Total Depth of Monitoring Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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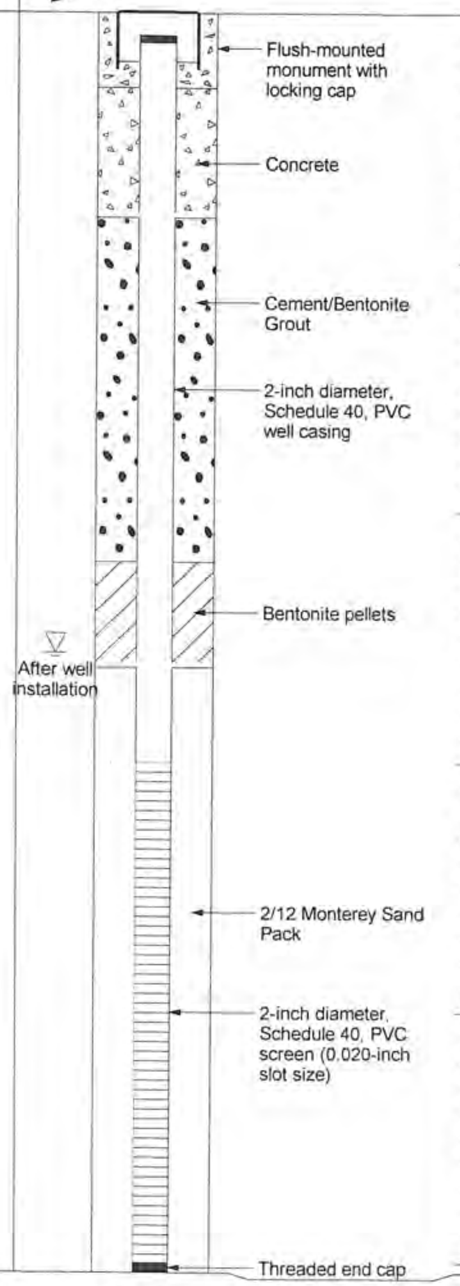
Boeing Developmental Center
Tukwila, Washington

Log of Monitoring Well BDC-05-22

Figure A-15

BDC-05-23

SAMPLE DATA						SOIL PROFILE			GROUNDWATER	
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.	Water Level	Monitoring Well Detail
0								Soil samples not collected.		
5										
10										
15									After well installation	
20										
25										



Boring Completed 07/11/11
Total Depth of Boring = 25.2 ft.

Monitoring Well Completed 07/11/11
Total Depth of Monitoring Well = 25.2 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.

25093 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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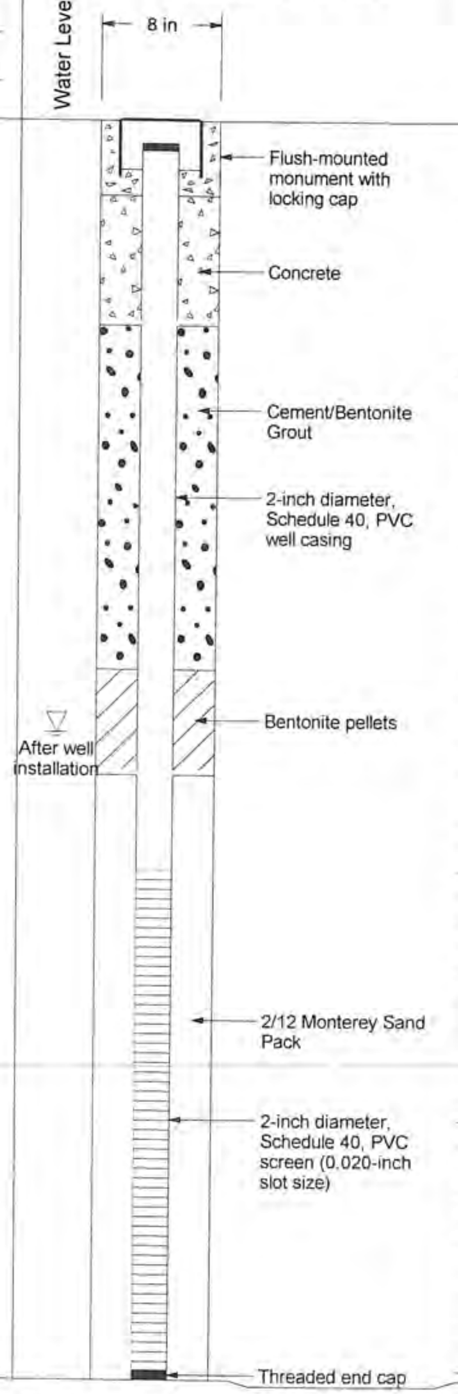
Tukwila, Washington

Log of Monitoring Well BDC-05-23

Figure A-16

BDC-05-24

SAMPLE DATA							SOIL PROFILE			GROUNDWATER	
Depth (ft)	Elevation	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): NM Drilled By: Cascade Drilling Inc.		Water Level	Monitoring Well Detail
0								Soil samples not collected.			
5											
10											
15											
20											
25											



Boring Completed 07/06/11
Total Depth of Boring = 25.2 ft.

Monitoring Well Completed 07/07/11
Total Depth of Monitoring Well = 25.2 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.

25093. 4/30/13 N:\PROJECTS\025093.GPJ WELL LOG W/ ELEVATION

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Tukwila, Washington

Log of Monitoring Well BDC-05-24

Figure A-17

APPENDIX B

Confirmation of UIC Registration

From: Shaleen-Hansen, Mary (ECY) [maha461@ECY.WA.GOV]
Sent: Monday, August 08, 2011 11:17 AM
To: Martin Valeri
Subject: RE: UIC registration - additional wells at Boeing UIC site #20128

Martin,

With the information provided in your email the UIC wells for UIC site 20128, Boeing are rule authorized. As you know, down gradient monitoring is required to help determine if the injected products and reactions products are hydraulically maintained on site.

Mary Shaleen Hansen
Dept of Ecology
Water Quality Program
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From: Martin Valeri [mailto:mvaleri@landauinc.com]
Sent: Friday, August 05, 2011 3:57 PM
To: Shaleen-Hansen, Mary (ECY)
Cc: Clint Jacob
Subject: RE: UIC registration - additional wells at Boeing UIC site #20128

Mary,

I just wanted to check and see if the UIC registration was completed for the Boeing Developmental Center wells. We are still planning to inject starting Monday, August 15. Can you please cc Clint Jacob (Landau project manager for the injection) on any reply, as I will be out of the office in the coming weeks. Thank you.

Martin Valeri, EIT ¨ Senior Staff Engineer
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From: Shaleen-Hansen, Mary (ECY) [mailto:maha461@ECY.WA.GOV]
Sent: Monday, July 25, 2011 11:51 AM
To: Martin Valeri
Subject: RE: UIC registration - additional wells at Boeing UIC site #20128

Martin, I don't have any follow up questions.

Mary Shaleen Hansen
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From: Martin Valeri [mailto:mvaleri@landauinc.com]
Sent: Friday, July 15, 2011 10:42 AM

To: Shaleen-Hansen, Mary (ECY)
Cc: Clint Jacob
Subject: UIC registration - additional wells at Boeing UIC site #20128

Mary,

As a follow-up to our phone conversation yesterday, here is the information on the new wells at the Boeing Developmental Center in Tukwila, to be added to existing UIC site #20128. Nine new wells are to be added (BDC-05-09 through BDC-05-17). See the attached table for well info, lat/long, etc. Also attached is the work plan for injection and monitoring (figure 7 shows all wells and the PCE/TCE plume contours). In summary, the nine new wells and two existing (already registered) wells (all screened from 15-25 feet) will be injected for treatment of groundwater. Each well will be injected with 5,300 gal of water from a nearby hydrant amended with 320 gal LactOil (49% vegetable oil, 34% ethyl lactate, 17% water) and 2 lbs yeast extract. You can read more about injection in Section 4.2 of the work plan. The injections will be hydraulically contained on site. The wells are located near the center of the DC property, well away from property boundaries. Groundwater monitoring will be performed at 10 wells, 4 downgradient, 4 crossgradient, and 2 within the main plume. These wells are BDC-05-03, BDC-05-04, BDC-05-08, and BDC-05-18 through BDC-05-24 (see figure 7 again). You can read more about monitoring in Section 5.0 of the work plan. The site is registered as a Voluntary clean-up site, but Byung Maeng (Ecology NW Regional office) continues to provide oversight under the VCP.

The first injection is scheduled for the week of August 15. I trust that is far enough away to get the registration completed well before then, yes? Please let me know if you need anything else from me at this point. Thank you!

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APPENDIX C

Laboratory Reports

APPENDIX D

Cumulative Groundwater Elevations

TABLE D-1
CUMULATIVE GROUNDWATER ELEVATIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

Well	Well Depth (ft)	Top of Well Casing Elevation (NGVD29)	Nov 2012		May 2012		Nov 2011		July 2011		May 2011		Nov 2010		May 2010		Nov 2009		May 2009		Nov 2008	
			Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)
BDC-05-02	25.35	14.41	12.31	2.10	11.81	2.60	12.63	1.78	12.35	2.06	11.81	2.60	12.10	2.31	12.14	2.27	12.05	2.36	12.19	2.22	12.20	2.21
BDC-05-03	25.47	14.41	12.36	2.05	11.95	2.46	12.77	1.64			11.94	2.47	12.21	2.20	12.24	2.17	12.11	2.30	12.29	2.12	12.28	2.13
BDC-05-04	25.36	14.59	12.52	2.07	12.05	2.54	12.82	1.77			12.03	2.56	12.30	2.29	12.33	2.26	12.22	2.37	12.40	2.19	12.35	2.24
BDC-05-05	24.18	14.44	13.40	1.04	11.65	2.79	12.50	1.94			11.61	2.83	11.95	2.49	11.97	2.47	11.89	2.55	12.02	2.42	12.00	2.44
BDC-05-07	25.30	13.99	11.97	2.02	11.40	2.59	12.23	1.76			11.42	2.57	11.95	2.04	11.75	2.24	11.95	2.04	11.82	2.17	11.80	2.19
BDC-05-08	27.00	14.67	12.64	2.03	12.28	2.39	13.02	1.65			12.20	2.47	12.49	2.18	12.51	2.16	12.39	2.28	12.79	1.88	12.57	2.10
BDC-05-09	24.55	14.40	12.36	2.05	11.90	2.51	12.68	1.73	12.27	2.13												
BDC-05-10	24.57	14.41	12.30	2.11	11.95	2.46	12.74	1.67	12.27	2.14												
BDC-05-11	24.85	14.65	12.55	2.10	12.13	2.52	12.92	1.73	12.60	2.05												
BDC-05-12	24.87	14.72	12.66	2.06	12.24	2.48	13.00	1.72	12.57	2.15												
BDC-05-13	24.78	14.43	12.44	1.99	12.02	2.41	12.78	1.65	12.35	2.08												
BDC-05-14	24.85	14.22	12.29	1.93	11.83	2.39	12.55	1.67	12.23	1.99												
BDC-05-15	24.48	13.97	11.97	2.00	11.63	2.34	12.34	1.63	11.95	2.02												
BDC-05-16	24.89	14.07	12.09	1.98	11.78	2.29	12.44	1.63	12.05	2.02												
BDC-05-17	24.82	14.25	12.27	1.98	11.65	2.60	12.60	1.65	12.27	1.98												
BDC-05-18	24.69	13.79	11.75	2.04	11.34	2.45	12.10	1.69	11.84	1.95												
BDC-05-19	24.85	14.56	12.60	1.96	12.15	2.41	12.90	1.66	12.59	1.97												
BDC-05-20	24.80	14.34	12.44	1.90	12.08	2.26	12.75	1.59	12.47	1.87												
BDC-05-21	24.86	14.19	12.30	1.89	11.94	2.25	12.59	1.60	12.34	1.85												
BDC-05-22	25.01	14.16	12.24	1.92	11.87	2.29	12.54	1.62	12.27	1.89												
BDC-05-23	25.10	14.46	12.74	1.72	12.39	2.07	13.08	1.38	12.79	1.67												
BDC-05-24	24.73	14.19	12.20	1.99	11.82	2.37	12.59	1.60	12.28	1.91												

Well	Well Depth (ft)	Top of Well Casing Elevation (NGVD29)	May 2008		Nov 2007		May 2007		Nov 2006		May 2006		November 2005		May 2005		October 2004		May 2004	
			Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)
BDC-05-02	25.27	14.41	12.28	2.09	12.31	2.06	12.23	2.14	11.53	2.84	12.21	2.16	12.21	2.16	11.86	2.51	12.40	1.97	12.24	2.13
BDC-05-03	25.47	14.41	12.47	1.94	12.51	1.90	12.45	1.96	11.75	2.66	12.40	2.01	12.43	1.98	12.07	2.34	12.60	1.81	12.46	1.95
BDC-05-04	25.36	14.59	12.58	2.01	12.57	2.02	12.54	2.05	11.85	2.74	12.54	2.05	12.52	2.07	12.17	2.42	12.72	1.87	12.55	2.04
BDC-05-05	24.18	14.44	12.18	2.26	12.30	2.14	12.07	2.37	11.51	2.93	12.16	2.28	12.16	2.28	11.87	2.57	12.41	2.03	12.12	2.32
BDC-05-07	25.30	13.99	12.02	1.97	12.03	1.96	11.96	2.03	11.27	2.72	11.94	2.05	11.96	2.03	11.59	2.40	12.14	1.85	11.97	2.02

Well	Well Depth (ft)	Top of Well Casing Elevation (NGVD29)	November 2003		June 2003		December 2002		June 2002		December 2001		June 2001		December 2000		June 2000		November 1999	
			Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)	Depth to Water (ft)	Water Elevation (NGVD29)
BDC-05-02	25.27	14.41	12.08	2.29	12.47	1.90	12.40	1.97	12.25	2.12	11.45	2.92	12.38	1.99	12.56	1.81	12.37	2.00	12.03	2.34
BDC-05-03	25.47	14.41	12.28	2.13	12.66	1.75	12.60	1.81	12.47	1.94	11.70	2.71	12.56	1.85	12.82	1.59	12.56	1.85	12.33	2.08
BDC-05-04	25.36	14.59	12.40	2.19	12.80	1.79	12.71	1.88	12.57	2.02	11.78	2.81	12.69	1.90	12.86	1.73	12.65	1.94	12.33	2.26
BDC-05-05	24.18	14.44	12.13	2.31	12.51	1.93	12.42	2.02	12.22	2.22	11.38	3.06	12.37	2.07	12.53	1.91	12.36	2.08	11.96	2.48
BDC-05-07	25.30	13.99	11.81	2.18	12.18	1.81	12.11	1.88	12.02	1.97	11.18	2.81	12.10	1.89	12.28	1.71	12.08	1.91	11.72	2.27

Notes:
Depth to Water measurements taken from top of well casing
BDC-05-02 was modifed in October 2008 for utilization as an injection well. Elevation changed from 14.37 to 14.41 and total depth changed from 25.35 to 25.27.

APPENDIX E

VOCs in Molar Equivalents and Molar Fractions

TABLE E-1
VOCS IN MOLAR EQUIVALENTS AND MOLAR FRACTIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

		Elapsed Time From Injection (days)		Volatile Organic Compounds - µg/L						Volatile Organic Compounds - micromoles/Liter (a)								Volatile Organic Compounds - Molar Fraction (b)					
Well	Date	Pilot Injection	Full Injection #1	PCE	TCE	*c* DCE	VC	Ethene	Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane	Total Chloroethenes (c)	Ethene + Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane
BDC-05-02	5/21/2007	-526		20	24	1.2	<1.0			0.12	0.18	0.01	0.00	0.00	0.00	0.32	0.00	0.38	0.58	0.04	0.00	0.00	0.00
(IW)	11/26/2007	-337		12	14	1.3	<1.0			0.07	0.11	0.01	0.00	0.00	0.00	0.19	0.00	0.38	0.55	0.07	0.00	0.00	0.00
	5/22/2008	-159		14	20	1.2	<0.2			0.08	0.15	0.01	0.00	0.00	0.00	0.25	0.00	0.34	0.61	0.05	0.00	0.00	0.00
BDC-05-02	10/23/2008	-5		31	62	2.9	<1.0	<1.1	<1.2	0.19	0.47	0.03	0.00	0.00	0.00	0.69	0.00	0.27	0.69	0.04	0.00	0.00	0.00
BDC-05-02	11/20/2008	23		5.1	4.2	0.7	<0.2	<1.1	<1.2	0.03	0.03	0.01	0.00	0.00	0.00	0.07	0.00	0.44	0.46	0.10	0.00	0.00	0.00
BDC-05-02	12/16/2008	49		6.6	7.3	1.3	<1.0	<1.1	<1.2	0.04	0.06	0.01	0.00	0.00	0.00	0.11	0.00	0.37	0.51	0.12	0.00	0.00	0.00
BDC-05-02	1/16/2009	80		7.5	22	3.7	<1.0	<1.1	<1.2	0.05	0.17	0.04	0.00	0.00	0.00	0.25	0.00	0.18	0.67	0.15	0.00	0.00	0.00
BDC-05-02	2/11/2009	106		9.5	17	12	<1.0	<1.1	<1.2	0.06	0.13	0.12	0.00	0.00	0.00	0.31	0.00	0.18	0.42	0.40	0.00	0.00	0.00
BDC-05-02	3/9/2009	132		9.1	8.1	25	<1.0	<1.1	<1.2	0.05	0.06	0.26	0.00	0.00	0.00	0.37	0.00	0.15	0.16	0.69	0.00	0.00	0.00
BDC-05-02	4/16/2009	170		7.3	6.0	41	<1.0	<1.1	<1.2	0.04	0.05	0.42	0.00	0.00	0.00	0.51	0.00	0.09	0.09	0.83	0.00	0.00	0.00
BDC-05-02	5/13/2009	197		4.4	4.6	35	1.4	<1.1	<1.2	0.03	0.04	0.36	0.02	0.00	0.00	0.44	0.00	0.06	0.08	0.81	0.05	0.00	0.00
BDC-05-02	8/16/2009	292		1.8	1.1	49	<1.0	<1.1	<1.2	0.01	0.01	0.51	0.00	0.00	0.00	0.52	0.00	0.02	0.02	0.96	0.00	0.00	0.00
BDC-05-02	11/13/2009	381		1.0	<1.0	70	<1.0	<1.1	<1.2	0.01	0.00	0.72	0.00	0.00	0.00	0.73	0.00	0.01	0.00	0.99	0.00	0.00	0.00
BDC-05-02	2/16/2010	476		<1.0	<1.0	54	<1.0	<1.1	<1.2	0.00	0.00	0.56	0.00	0.00	0.00	0.56	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	5/18/2010	567		<1.0	1.0	32	<1.0	<1.1	<1.2	0.00	0.01	0.33	0.00	0.00	0.00	0.34	0.00	0.00	0.02	0.98	0.00	0.00	0.00
BDC-05-02	8/17/2010	658		<1.0	<1.0	23	<1.0	<1.1	<1.2	0.00	0.00	0.24	0.00	0.00	0.00	0.24	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	11/9/2010	742		<1.0	<1.0	14	<1.0	<1.1	<1.2	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	2/15/2011	840		<1.0	<1.0	13	<1.0	<1.1	<1.2	0.00	0.00	0.13	0.00	0.00	0.00	0.13	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	5/2/2011	916		0.6	0.9	22	0.3	<1.1	<1.2	0.00	0.01	0.23	0.00	0.00	0.00	0.24	0.00	0.01	0.03	0.94	0.02	0.00	0.00
BDC-05-02	7/31/2011	1006	-18	<1.0	<1.0	10	<1.0	<1.1	<1.2	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	11/2/2011	1100	76	8.4	4.8	150	1.6	<1.1	<1.2	0.05	0.04	1.55	0.03	0.00	0.00	1.66	0.00	0.03	0.02	0.93	0.02	0.00	0.00
BDC-05-02	2/19/2012	1209	185	<4.0	<4.0	220	<4.0	<1.0	<1.0	0.00	0.00	2.27	0.00	0.00	0.00	2.27	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	5/7/2012	1287	263	<2.0	<2.0	180	<2.0	<1.0	<1.0	0.00	0.00	1.86	0.00	0.00	0.00	1.86	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	9/5/2012	1408	384	<2.0	<2.0	57	<2.0	<1.0	<1.0	0.00	0.00	0.59	0.00	0.00	0.00	0.59	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-02	11/15/2012	1479	455	<2.0	<2.0	32	5.5	<1.0	<1.0	0.00	0.00	0.33	0.09	0.00	0.00	0.42	0.00	0.00	0.00	0.79	0.21	0.00	0.00
BDC-05-03	5/21/2007	-526		3.5	8.1	11	<1.0			0.02	0.06	0.11	0.00	0.00	0.00	0.20	0.00	0.11	0.31	0.58	0.00	0.00	0.00
(MW 17 ft DG)	11/26/2007	-337		2.3	4.4	7.2	<1.0			0.01	0.03	0.07	0.00	0.00	0.00	0.12	0.00	0.11	0.28	0.61	0.00	0.00	0.00
	5/22/2008	-159		3.8	8.5	13	<0.2			0.02	0.06	0.13	0.00	0.00	0.00	0.22	0.00	0.10	0.29	0.60	0.00	0.00	0.00
BDC-05-03	10/23/2008	-5		4.2	8.2	17	<0.2	<1.1	<1.2	0.03	0.06	0.18	0.00	0.00	0.00	0.26	0.00	0.10	0.24	0.67	0.00	0.00	0.00
BDC-05-03	11/20/2008	23		1.8	2.1	2.7	<0.2	<1.1	<1.2	0.01	0.02	0.03	0.00	0.00	0.00	0.05	0.00	0.20	0.29	0.51	0.00	0.00	0.00
BDC-05-03	12/16/2008	49		2.2	4.1	5.8	<1.0	<1.1	<1.2	0.01	0.03	0.06	0.00	0.00	0.00	0.10	0.00	0.13	0.30	0.57	0.00	0.00	0.00
BDC-05-03	1/16/2009	80		1.5	1.2	<1.0	<1.0	<1.1	<1.2	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.50	0.50	0.00	0.00	0.00	0.00
BDC-05-03	2/11/2009	106		1.8	3.2	4.4	<1.0	<1.1	<1.2	0.01	0.02	0.05	0.00	0.00	0.00	0.08	0.00	0.13	0.30	0.56	0.00	0.00	0.00
BDC-05-03	3/9/2009	132		1.3	1.7	1.4	<1.0	<1.1	<1.2	0.01	0.01	0.01	0.00	0.00	0.00	0.04	0.00	0.22	0.37	0.41	0.00	0.00	0.00
BDC-05-03	4/16/2009	170		1.5	2.2	2.8	<1.0	<1.1	<1.2	0.01	0.02	0.03	0.00	0.00	0.00	0.05	0.00	0.17	0.31	0.53	0.00	0.00	0.00
BDC-05-03	5/13/2009	197		1.2	2.1	3.4	<1.0	<1.1	<1.2	0.01	0.02	0.04	0.00	0.00	0.00	0.06	0.00	0.12	0.27	0.60	0.00	0.00	0.00
BDC-05-03	8/16/2009	292		2.2	4.3	8.1	<1.0	<1.1	<1.2	0.01	0.03	0.08	0.00	0.00	0.00	0.13	0.00	0.10	0.25	0.64	0.00	0.00	0.00
BDC-05-03	11/13/2009	381		1.2	1.2	<1.0	<1.0	<1.1	<1.2	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.44	0.56	0.00	0.00	0.00	0.00
BDC-05-03	2/16/2010	476		1.4	1.0	<1.0	<1.0	<1.1	<1.2	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.53	0.47	0.00	0.00	0.00	0.00
BDC-05-03	5/18/2010	567		1.2	1.8	2.7	<1.0	<1.1	<1.2	0.01	0.01	0.03	0.00	0.00	0.00	0.05	0.00	0.15	0.28	0.57	0.00	0.00	0.00
BDC-05-03	8/17/2010	658		2.3	5.2	14	<1.0	<1.1	<1.2	0.01	0.04	0.14	0.00	0.00	0.00	0.20	0.00	0.07	0.20	0.73	0.00	0.00	0.00
BDC-05-03	11/9/2010	742		1.4	1.7	3.7	<1.0	<1.1	<1.2	0.01	0.01	0.04	0.00	0.00	0.00	0.06	0.00	0.14	0.22	0.64	0.00	0.00	0.00
BDC-05-03	2/15/2011	840		1.3	<1.0	2.3	<1.0	<1.1	<1.2	0.01	0.00	0.02	0.00	0.00	0.00	0.03	0.00	0.25	0.00	0.75	0.00	0.00	0.00
BDC-05-03	5/2/2011	916	-108	1.7	1.0	0.2	<0.2	<1.1	<1.2	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.51	0.38	0.10	0.00	0.00	0.00
BDC-05-03	11/2/2011	1100	76	1.4	1.6	20	2.0			0.01	0.01	0.21	0.03	0.00	0.00	0.26	0.00	0.03	0.05	0.80	0.12	0.00	0.00
BDC-05-03	5/6/2012	1286	262	0.6	1.3	<0.2	0.3			0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.20	0.54	0.00	0.26	0.00	0.00
BDC-05-03	11/15/2012	1479	455	<0.5	<0.5	<0.5	0.7			0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	1.00	0.00	0.00

TABLE E-1
VOCS IN MOLAR EQUIVALENTS AND MOLAR FRACTIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

		Elapsed Time From Injection (days)		Volatile Organic Compounds - µg/L						Volatile Organic Compounds - micromoles/Liter (a)								Volatile Organic Compounds - Molar Fraction (b)					
Well	Date	Pilot Injection	Full Injection #1	PCE	TCE	*c* DCE	VC	Ethene	Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane	Total Chloroethenes (c)	Ethene + Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane
BDC-05-04	5/21/2007	-526		<1.0	<1.0	1.4	<1.0			0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00
(MW 40 ft XG)	11/26/2007	-337		<1.0	<1.0	1.6	<1.0			0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
	5/22/2008	-159		1.5	0.9	1.2	<0.2			0.01	0.01	0.01	0.00	0.00	0.00	0.03	0.00	0.32	0.24	0.44	0.00	0.00	0.00
BDC-05-04	10/23/2008	-5		1.1	0.8	2.1	<0.2	<1.1	<1.2	0.01	0.01	0.02	0.00	0.00	0.00	0.03	0.00	0.19	0.18	0.63	0.00	0.00	0.00
BDC-05-04	11/20/2008	23		1.1	0.7	3.6	<0.2	<1.1	<1.2	0.01	0.01	0.04	0.00	0.00	0.00	0.05	0.00	0.14	0.11	0.76	0.00	0.00	0.00
BDC-05-04	12/16/2008	49		<1.0	<1.0	2.4	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	1/16/2009	80		<1.0	<1.0	2.0	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	2/11/2009	106		1.0	<1.0	1.5	<1.0	<1.1	<1.2	0.01	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.28	0.00	0.72	0.00	0.00	0.00
BDC-05-04	3/9/2009	132		1.0	<1.0	1.3	<1.0	<1.1	<1.2	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.31	0.00	0.69	0.00	0.00	0.00
BDC-05-04	4/16/2009	170		1.2	<1.0	<1.0	<1.0	<1.1	<1.2	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BDC-05-04	5/13/2009	197		<1.0	<1.0	1.0	<1.0	<1.1	<1.2	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	8/16/2009	292		1.3	<1.0	<1.0	<1.0	<1.1	<1.2	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BDC-05-04	11/13/2009	381		<1.0	<1.0	1.2	<1.0	<1.1	<1.2	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	2/16/2010	476		<1.0	<1.0	1.1	<1.0	<1.1	<1.2	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	5/18/2010	567		1.1	<1.0	1.2	<1.0	<1.1	<1.2	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.35	0.00	0.65	0.00	0.00	0.00
BDC-05-04	8/17/2010	658		<1.0	<1.0	3.0	<1.0	<1.1	<1.2	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	11/9/2010	742		<1.0	<1.0	4.3	<1.0	<1.1	<1.2	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	2/15/2011	840		<1.0	<1.0	2.9	<1.0	<1.1	<1.2	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	5/2/2011	916	-108	0.4	0.5	3.1	<0.2	<1.1	<1.2	0.00	0.00	0.03	0.00	0.00	0.00	0.04	0.00	0.06	0.10	0.84	0.00	0.00	0.00
BDC-05-04	11/2/2011	1100	76	<1.0	<1.0	4.2	<1.0			0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-04	5/7/2012	1287	263	0.4	0.6	3.6	<0.2			0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.05	0.10	0.84	0.00	0.00	0.00
BDC-05-04	11/16/2012	1480	456	<0.5	<0.5	3.3	<0.5			0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-05	5/21/2007	-526		<1.0	<1.0	<1.0	<1.0			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(MW UG)	11/26/2007	-337		<1.0	<1.0	<1.0	<1.0			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5/22/2008	-159		0.3	0.8	<0.2	<0.2			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.23	0.77	0.00	0.00	0.00	0.00
BDC-05-05	10/23/2008	-5								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	11/20/2008	23		0.3	0.7	<0.2	<0.2			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.25	0.75	0.00	0.00	0.00	0.00
BDC-05-05	12/16/2008	49								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	1/16/2009	80								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	2/11/2009	106								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	3/9/2009	132								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	4/16/2009	170								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	5/13/2009	197		<1.0	<1.0	<1.0	<1.0			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	8/16/2009	292								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	11/13/2009	381		<1.0	<1.0	<1.0	<1.0			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	2/16/2010	476								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	5/18/2010	567		<1.0	<1.0	<1.0	<1.0			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	8/17/2010	658								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	11/9/2010	742		<1.0	1.1	<1.0	<1.0			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	1.00	0.00	0.00	0.00	0.00
BDC-05-05	2/15/2011	840								0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BDC-05-05	5/2/2011	916	-108	0.3	0.8	<0.2	<0.2			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.23	0.77	0.00	0.00	0.00	0.00
BDC-05-05	11/2/2011	1100	76	<1.0	1.2	<1.0	<1.0			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	1.00	0.00	0.00	0.00	0.00
BDC-05-05	5/6/2012	1286	262	0.4	0.9	<0.2	<0.2			0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.26	0.74	0.00	0.00	0.00	0.00
BDC-05-05	11/16/2012	1480	456	<0.5	1.1	<0.5	<0.5	<1.0	<1.0	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	1.00	0.00	0.00	0.00	0.00

TABLE E-1
VOCS IN MOLAR EQUIVALENTS AND MOLAR FRACTIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

		Elapsed Time From Injection (days)		Volatile Organic Compounds - µg/L						Volatile Organic Compounds - micromoles/Liter (a)								Volatile Organic Compounds - Molar Fraction (b)					
Well	Date	Pilot Injection	Full Injection #1	PCE	TCE	*c*DCE	VC	Ethene	Ethane	PCE	TCE	*c*DCE	VC	Ethene	Ethane	Total Chloroethenes (c)	Ethene + Ethane	PCE	TCE	*c*DCE	VC	Ethene	Ethane
BDC-05-07	5/21/2007	-526		30	22	10	<1.0			0.18	0.17	0.10	0.00	0.00	0.00	0.45	0.00	0.40	0.37	0.23	0.00	0.00	0.00
(IW)	11/26/2007	-337		28	25	11	<1.0			0.17	0.19	0.11	0.00	0.00	0.00	0.47	0.00	0.36	0.40	0.24	0.00	0.00	0.00
BDC-05-07	5/22/2008	-159		33	32	9.2	<0.2			0.20	0.24	0.09	0.00	0.00	0.00	0.54	0.00	0.37	0.45	0.18	0.00	0.00	0.00
BDC-05-07	10/23/2008	-5		22	24	14	<0.2	<1.1	<1.2	0.13	0.18	0.14	0.00	0.00	0.00	0.46	0.00	0.29	0.40	0.31	0.00	0.00	0.00
BDC-05-07	11/20/2008	23		17	17	4.9	<0.2	<1.1	<1.2	0.10	0.13	0.05	0.00	0.00	0.00	0.28	0.00	0.36	0.46	0.18	0.00	0.00	0.00
BDC-05-07	12/16/2008	49		16	25	7.2	<1.0	<1.1	<1.2	0.10	0.19	0.07	0.00	0.00	0.00	0.36	0.00	0.27	0.53	0.21	0.00	0.00	0.00
BDC-05-07	1/16/2009	80		20	23	6.4	<1.0	<1.1	<1.2	0.12	0.18	0.07	0.00	0.00	0.00	0.36	0.00	0.33	0.48	0.18	0.00	0.00	0.00
BDC-05-07	2/11/2009	106		23	28	9.9	<1.0	<1.1	<1.2	0.14	0.21	0.10	0.00	0.00	0.00	0.45	0.00	0.31	0.47	0.22	0.00	0.00	0.00
BDC-05-07	3/9/2009	132		20	21	8.4	<1.0	<1.1	<1.2	0.12	0.16	0.09	0.00	0.00	0.00	0.37	0.00	0.33	0.44	0.24	0.00	0.00	0.00
BDC-05-07	4/16/2009	170		20	21	11	<1.0	<1.1	<1.2	0.12	0.16	0.11	0.00	0.00	0.00	0.39	0.00	0.31	0.41	0.29	0.00	0.00	0.00
BDC-05-07	5/13/2009	197		11	13	7.5	<1.0	<1.1	<1.2	0.07	0.10	0.08	0.00	0.00	0.00	0.24	0.00	0.27	0.41	0.32	0.00	0.00	0.00
BDC-05-07	8/16/2009	292		11	12	13	<1.0	<1.1	<1.2	0.07	0.09	0.13	0.00	0.00	0.00	0.29	0.00	0.23	0.31	0.46	0.00	0.00	0.00
BDC-05-07	11/13/2009	381		6.5	5.3	5.6	<1.0	<1.1	<1.2	0.04	0.04	0.06	0.00	0.00	0.00	0.14	0.00	0.29	0.29	0.42	0.00	0.00	0.00
BDC-05-07	2/16/2010	476		6.4	6.9	28	<1.0	<1.1	<1.2	0.04	0.05	0.29	0.00	0.00	0.00	0.38	0.00	0.10	0.14	0.76	0.00	0.00	0.00
BDC-05-07	5/18/2010	567		5.8	9.2	41	1.2	<1.1	<1.2	0.03	0.07	0.42	0.02	0.00	0.00	0.55	0.00	0.06	0.13	0.77	0.04	0.00	0.00
BDC-05-07	8/17/2010	658		2.8	7.8	19	<1.0	<1.1	<1.2	0.02	0.06	0.20	0.00	0.00	0.00	0.27	0.00	0.06	0.22	0.72	0.00	0.00	0.00
BDC-05-07	11/9/2010	742		<1.0	9.4	20	<1.0	<1.1	<1.2	0.00	0.07	0.21	0.00	0.00	0.00	0.28	0.00	0.00	0.26	0.74	0.00	0.00	0.00
BDC-05-07	2/15/2011	840		<1.0	8.7	20	<1.0	<1.1	<1.2	0.00	0.07	0.21	0.00	0.00	0.00	0.27	0.00	0.00	0.24	0.76	0.00	0.00	0.00
BDC-05-07	5/2/2011	916	-108	5.2	11	17	<0.2	<1.1	<1.2	0.03	0.08	0.18	0.00	0.00	0.00	0.29	0.00	0.11	0.29	0.60	0.00	0.00	0.00
BDC-05-07	11/2/2011	1100	76	11	6.9	39	<1.0	<1.1	<1.2	0.07	0.05	0.40	0.00	0.00	0.00	0.52	0.00	0.13	0.10	0.77	0.00	0.00	0.00
BDC-05-07	5/7/2012	1287	263	0.8	<0.2	23	0.9	<1.0	<1.0	0.00	0.00	0.24	0.01	0.00	0.00	0.26	0.00	0.02	0.00	0.93	0.06	0.00	0.00
BDC-05-07	11/15/2012	1479	455	<0.2	0.4	24	0.8	<1.0	<1.0	0.00	0.00	0.25	0.01	0.00	0.00	0.26	0.00	0.00	0.01	0.94	0.05	0.00	0.00
BDC-05-08	10/23/2008	-5		1.1	3.7	3.5	<0.2	<1.1	<1.2	0.01	0.03	0.04	0.00	0.00	0.00	0.07	0.00	0.09	0.40	0.51	0.00	0.00	0.00
(MW 20 ft XG)	11/20/2008	23		1.1	3.4	4.2	<0.2	<1.1	<1.2	0.01	0.03	0.04	0.00	0.00	0.00	0.08	0.00	0.09	0.34	0.57	0.00	0.00	0.00
	12/16/2008	49		1.2	4.3	4.3	<1.0	<1.1	<1.2	0.01	0.03	0.04	0.00	0.00	0.00	0.08	0.00	0.09	0.39	0.53	0.00	0.00	0.00
BDC-05-08	1/16/2009	80		1.3	4.2	3.6	<1.0	<1.1	<1.2	0.01	0.03	0.04	0.00	0.00	0.00	0.08	0.00	0.10	0.42	0.48	0.00	0.00	0.00
BDC-05-08	2/11/2009	106		<1.0	3.2	3.9	<1.0	<1.1	<1.2	0.00	0.02	0.04	0.00	0.00	0.00	0.06	0.00	0.00	0.38	0.62	0.00	0.00	0.00
BDC-05-08	3/9/2009	132		<1.0	2.7	3.5	<1.0	<1.1	<1.2	0.00	0.02	0.04	0.00	0.00	0.00	0.06	0.00	0.00	0.36	0.64	0.00	0.00	0.00
BDC-05-08	4/16/2009	170		<1.0	2.3	4.4	<1.0	<1.1	<1.2	0.00	0.02	0.05	0.00	0.00	0.00	0.06	0.00	0.00	0.28	0.72	0.00	0.00	0.00
BDC-05-08	5/13/2009	197		<1.0	1.6	3.0	<1.0	<1.1	<1.2	0.00	0.01	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.28	0.72	0.00	0.00	0.00
BDC-05-08	8/16/2009	292		<1.0	2.1	3.5	<1.0	<1.1	<1.2	0.00	0.02	0.04	0.00	0.00	0.00	0.05	0.00	0.00	0.31	0.69	0.00	0.00	0.00
BDC-05-08	11/13/2009	381		<1.0	1.2	3.1	<1.0	<1.1	<1.2	0.00	0.01	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.22	0.78	0.00	0.00	0.00
BDC-05-08	2/16/2010	476		<1.0	<1.0	2.3	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	5/18/2010	567		<1.0	<1.0	2.4	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	8/17/2010	658		<1.0	<1.0	2.3	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	11/9/2010	742		<1.0	<1.0	3.5	<1.0	<1.1	<1.2	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	2/15/2011	840		<1.0	<1.0	2.1	<1.0	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	5/2/2011	916	-108	<0.2	<0.2	2.2	<0.2	<1.1	<1.2	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	11/2/2011	1100	76	<1.0	<1.0	2.4	<1.0			0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	5/6/2012	1286	262	<0.2	<0.2	2.7	<0.2			0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-08	11/16/2012	1480	456	<0.5	<0.5	1.3	<0.5			0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BDC-05-09	7/31/2011		-18	30	20	22	<1.0	<1.1	<1.2	0.18	0.15	0.23	0.00	0.00	0.00	0.56	0.00	0.32	0.27	0.41	0.00	0.00	0.00
(IW)	11/2/2011		76	37	56	44	1.3	<1.1	<1.2	0.22	0.43	0.45	0.02	0.00	0.00	1.12	0.00	0.20	0.38	0.40	0.02	0.00	0.00
	5/7/2012		263	3.0	1.1	250	3.9	<1.0	<1.0	0.02	0.01	2.58	0.06	0.00	0.00	2.67	0.00	0.01	0.00	0.97	0.02	0.00	0.00
BDC-05-09	11/15/2012		455	<2.0	<2.0	24	20	69	<1.0	0.00	0.00	0.25	0.32	2.46	0.00	0.57	2.46	0.00	0.00	0.08	0.11	0.81	0.00
BDC-05-10	7/31/2011		-18	39	26	12	<1.0	<1.1	<1.2	0.24	0.20	0.12	0.00	0.00	0.00	0.56	0.00	0.42	0.36	0.22	0.00	0.00	0.00
(IW)	11/2/2011		76	22	27	1.0	<1.0	1.6	1.7	0.13	0.21	0.01	0.00	0.06	0.06	0.35	0.11	0.29	0.44	0.02	0.00	0.12	0.12
	5/6/2012		262	<1.0	<1.0	120	5.4	1.1	<1.0	0.00	0.00	1.24	0.09	0.04	0.00	1.32	0.04	0.00	0.00	0.91	0.06	0.03	0.00
BDC-05-10	11/15/2012		455	<1.0	<1.0	4.4	49	8.5	<1.0	0.00	0.00	0.05	0.78	0.30	0.00	0.83	0.30	0.00	0.00	0.04	0.69	0.27	0.00

TABLE E-1
VOCS IN MOLAR EQUIVALENTS AND MOLAR FRACTIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

Well	Date	Elapsed Time From Injection (days)		Volatile Organic Compounds - µg/L						Volatile Organic Compounds - micromoles/Liter (a)								Volatile Organic Compounds - Molar Fraction (b)					
		Pilot Injection	Full Injection #1	PCE	TCE	*c* DCE	VC	Ethene	Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane	Total Chloroethenes (c)	Ethene + Ethane	PCE	TCE	*c* DCE	VC	Ethene	Ethane
BDC-05-11	7/31/2011		-18	16	19	5.8	<1.0	<1.1	<1.2	0.10	0.14	0.06	0.00	0.00	0.00	0.30	0.00	0.32	0.48	0.20	0.00	0.00	0.00
(IW)	11/2/2011		76	9.6	20	12	<1.0	<1.1	<1.2	0.06	0.15	0.12	0.00	0.00	0.00	0.33	0.00	0.17	0.46	0.37	0.00	0.00	0.00
	5/6/2012		262	0.2	0.5	44	7.2	1.6	<1.0	0.00	0.00	0.45	0.12	0.06	0.00	0.57	0.06	0.00	0.01	0.72	0.18	0.09	0.00
BDC-05-11	11/15/2012		455	<1.0	<1.0	6.1	5.7	7.6	<1.0	0.00	0.00	0.06	0.09	0.27	0.00	0.15	0.27	0.00	0.00	0.15	0.21	0.64	0.00
BDC-05-12	7/31/2011		-18	15	18	16	<1.0	<1.1	<1.2	0.09	0.14	0.17	0.00	0.00	0.00	0.39	0.00	0.23	0.35	0.42	0.00	0.00	0.00
(IW)	11/2/2011		76	11	17	11	<1.0	<1.1	<1.2	0.07	0.13	0.11	0.00	0.00	0.00	0.31	0.00	0.21	0.42	0.37	0.00	0.00	0.00
	2/19/2012		185	<0.4	<0.4	53	1.8	<1.0	<1.0	0.00	0.00	0.55	0.03	0.00	0.00	0.58	0.00	0.00	0.00	0.95	0.05	0.00	0.00
BDC-05-12	5/6/2012		262	<0.2	<0.2	39	3.4	<1.0	<1.0	0.00	0.00	0.40	0.05	0.00	0.00	0.46	0.00	0.00	0.00	0.88	0.12	0.00	0.00
BDC-05-12	9/5/2012		384	<0.2	<0.2	6.5	3.3	1.0	<1.0	0.00	0.00	0.07	0.05	0.04	0.00	0.12	0.04	0.00	0.00	0.43	0.34	0.23	0.00
BDC-05-12	11/15/2012		455	<1.0	<1.0	7.9	5.4	1.1	<1.0	0.00	0.00	0.08	0.09	0.04	0.00	0.17	0.04	0.00	0.00	0.39	0.42	0.19	0.00
BDC-05-13	7/31/2011		-18	5.2	6.6	2.6	<1.0	<1.1	<1.2	0.03	0.05	0.03	0.00	0.00	0.00	0.11	0.00	0.29	0.46	0.25	0.00	0.00	0.00
(IW)	11/1/2011		75	<1.0	1.2	39	<1.0	<1.1	<1.2	0.00	0.01	0.40	0.00	0.00	0.00	0.41	0.00	0.00	0.02	0.98	0.00	0.00	0.00
	5/6/2012		262	<0.2	<0.2	13	3.9	1.7	<1.0	0.00	0.00	0.13	0.06	0.06	0.00	0.20	0.06	0.00	0.00	0.52	0.24	0.24	0.00
BDC-05-13	11/15/2012		455	<1.0	<1.0	<1.0	2.3	3.7	<1.0	0.00	0.00	0.00	0.04	0.13	0.00	0.04	0.13	0.00	0.00	0.00	0.22	0.78	0.00
BDC-05-14	7/31/2011		-18	2.8	6.8	2.8	<1.0	<1.1	<1.2	0.02	0.05	0.03	0.00	0.00	0.00	0.10	0.00	0.17	0.53	0.30	0.00	0.00	0.00
(IW)	11/1/2011		75	2.5	6.7	13	<1.0	<1.1	<1.2	0.02	0.05	0.13	0.00	0.00	0.00	0.20	0.00	0.08	0.25	0.67	0.00	0.00	0.00
	5/6/2012		262	<0.2	0.4	3.0	1.1	<1.0	<1.0	0.00	0.00	0.03	0.02	0.00	0.00	0.05	0.00	0.00	0.06	0.60	0.34	0.00	0.00
BDC-05-14	11/15/2012		455	<0.2	<0.2	1.1	2.0	1.4	<1.0	0.00	0.00	0.01	0.03	0.05	0.00	0.04	0.05	0.00	0.00	0.12	0.34	0.54	0.00
BDC-05-15	7/31/2011		-18	9.6	28	58	<1.0	<1.1	<1.2	0.06	0.21	0.60	0.00	0.00	0.00	0.87	0.00	0.07	0.25	0.69	0.00	0.00	0.00
(IW)	11/1/2011		75	4.8	9.8	15	<1.0	<1.1	<1.2	0.03	0.07	0.15	0.00	0.00	0.00	0.26	0.00	0.11	0.29	0.60	0.00	0.00	0.00
	5/6/2012		262	<2.0	<2.0	49	6.3	<1.0	<1.0	0.00	0.00	0.51	0.10	0.00	0.00	0.61	0.00	0.00	0.00	0.83	0.17	0.00	0.00
BDC-05-15	11/15/2012		455	<1.0	<1.0	1.5	7.5	1.8	<1.0	0.00	0.00	0.02	0.12	0.06	0.00	0.14	0.06	0.00	0.00	0.08	0.60	0.32	0.00
BDC-05-16	7/31/2011		-18	9.5	17	20	<1.0	<1.1	<1.2	0.06	0.13	0.21	0.00	0.00	0.00	0.39	0.00	0.15	0.33	0.52	0.00	0.00	0.00
(IW)	11/1/2011		75	2.6	2.8	37	<1.0	<1.1	<1.2	0.02	0.02	0.38	0.00	0.00	0.00	0.42	0.00	0.04	0.05	0.91	0.00	0.00	0.00
	2/19/2012		185	<2.0	<2.0	46	7.4	<1.0	<1.0	0.00	0.00	0.47	0.12	0.00	0.00	0.59	0.00	0.00	0.00	0.80	0.20	0.00	0.00
BDC-05-16	5/6/2012		262	<0.2	0.3	6.7	24	2.5	<1.0	0.00	0.00	0.07	0.38	0.09	0.00	0.46	0.09	0.00	0.00	0.13	0.71	0.16	0.00
BDC-05-16	9/5/2012		384	<0.4	<0.4	0.9	8.1	6.0	<1.0	0.00	0.00	0.01	0.13	0.21	0.00	0.14	0.21	0.00	0.00	0.03	0.37	0.61	0.00
BDC-05-16	11/15/2012		455	<1.0	<1.0	<1.0	4.9	4.0	<1.0	0.00	0.00	0.00	0.08	0.14	0.00	0.08	0.14	0.00	0.00	0.00	0.35	0.65	0.00
BDC-05-17	7/31/2011		-18	11	22	34	<1.0	<1.1	<1.2	0.07	0.17	0.35	0.00	0.00	0.00	0.58	0.00	0.11	0.29	0.60	0.00	0.00	0.00
(IW)	11/1/2011		75	3.2	4.8	5.1	<1.0	<1.1	<1.2	0.02	0.04	0.05	0.00	0.00	0.00	0.11	0.00	0.18	0.34	0.49	0.00	0.00	0.00
	5/6/2012		262	<2.0	<2.0	9.3	5.6	<1.0	<1.0	0.00	0.00	0.10	0.09	0.00	0.00	0.19	0.00	0.00	0.00	0.52	0.48	0.00	0.00
BDC-05-17	11/15/2012		455	<5.0	<5.0	<5.0	5.4	2.0	<1.0	0.00	0.00	0.00	0.09	0.07	0.00	0.09	0.07	0.00	0.00	0.00	0.55	0.45	0.00
BDC-05-18	7/31/2011		-18	3.6	5.0	6.6	<1.0	<1.1	<1.2	0.02	0.04	0.07	0.00	0.00	0.00	0.13	0.00	0.17	0.30	0.53	0.00	0.00	0.00
(MW 10 ft XG)	11/1/2011		75	2.8	4.0	7.6	<1.0	<1.1	<1.2	0.02	0.03	0.08	0.00	0.00	0.00	0.13	0.00	0.13	0.24	0.62	0.00	0.00	0.00
	2/19/2012		185	1.8	3.7	12	<0.2	<1.0	<1.0	0.01	0.03	0.12	0.00	0.00	0.00	0.16	0.00	0.07	0.17	0.76	0.00	0.00	0.00
BDC-05-18	5/6/2012		262	2.0	4.0	9.6	<0.2	<1.0	<1.0	0.01	0.03	0.10	0.00	0.00	0.00	0.14	0.00	0.09	0.22	0.70	0.00	0.00	0.00
BDC-05-18	9/5/2012		384	1.5	3.1	11	0.2	<1.0	<1.0	0.01	0.02	0.11	0.00	0.00	0.00	0.15	0.00	0.06	0.16	0.76	0.02	0.00	0.00
BDC-05-18	11/15/2012		455	1.0	4.3	16	<0.5	<1.0	<1.0	0.01	0.03	0.17	0.00	0.00	0.00	0.20	0.00	0.03	0.16	0.81	0.00	0.00	0.00
BDC-05-19	7/31/2011		-18	15	21	23	<1.0	<1.1	<1.2	0.09	0.16	0.24	0.00	0.00	0.00	0.49	0.00	0.19	0.33	0.49	0.00	0.00	0.00
(MW 10 ft DG)	11/1/2011		75	9.1	13	36	4.1	<1.1	<1.2	0.05	0.10	0.37	0.07	0.00	0.00	0.59	0.00	0.09	0.17	0.63	0.11	0.00	0.00
	2/19/2012		185	<1.0	1.7	68	14	1.4	<1.0	0.00	0.01	0.70	0.22	0.05	0.00	0.94	0.05	0.00	0.01	0.71	0.23	0.05	0.00
BDC-05-19	5/6/2012		262	0.7	1.4	52	23	1.8	<1.0	0.00	0.01	0.54	0.37	0.06	0.00	0.92	0.06	0.00	0.01	0.55	0.37	0.07	0.00
BDC-05-19	9/5/2012		384	<2.0	<2.0	13	15	3.9	<1.0	0.00	0.00	0.13	0.24	0.14	0.00	0.37	0.14	0.00	0.00	0.26	0.47	0.27	0.00
BDC-05-19	11/15/2012		455	<1.0	1.1	9.9	15	5.5	<1.0	0.00	0.01	0.10	0.24	0.20	0.00	0.35	0.20	0.00	0.02	0.19	0.44	0.36	0.00

TABLE E-1
VOCS IN MOLAR EQUIVALENTS AND MOLAR FRACTIONS
BOEING DEVELOPMENTAL CENTER SWMU-17

		Elapsed Time From Injection (days)		Volatile Organic Compounds - µg/L						Volatile Organic Compounds - micromoles/Liter (a)								Volatile Organic Compounds - Molar Fraction (b)					
Well	Date	Pilot Injection	Full Injection #1	PCE	TCE	*c*DCE	VC	Ethene	Ethane	PCE	TCE	*c*DCE	VC	Ethene	Ethane	Total Chloroethenes (c)	Ethene + Ethane	PCE	TCE	*c*DCE	VC	Ethene	Ethane
BDC-05-20	7/31/2011		-18	<1.0	7.0	45	<1.0	<1.1	<1.2	0.00	0.05	0.46	0.00	0.00	0.00	0.52	0.00	0.00	0.10	0.90	0.00	0.00	0.00
(MW 23 ft DG)	11/3/2011		77	<1.0	5.7	25	1.0	<1.1	<1.2	0.00	0.04	0.26	0.02	0.00	0.00	0.32	0.00	0.00	0.14	0.81	0.05	0.00	0.00
	2/19/2012		185	<0.2	2.9	17	2.5	<1.0	<1.0	0.00	0.02	0.18	0.04	0.00	0.00	0.24	0.00	0.00	0.09	0.74	0.17	0.00	0.00
BDC-05-20	5/7/2012		263	<0.2	1.8	14	2.2	<1.0	<1.0	0.00	0.01	0.14	0.04	0.00	0.00	0.19	0.00	0.00	0.07	0.75	0.18	0.00	0.00
BDC-05-20	9/5/2012		384	<0.4	<0.4	12	2.0	<1.0	<1.0	0.00	0.00	0.12	0.03	0.00	0.00	0.16	0.00	0.00	0.00	0.79	0.21	0.00	0.00
BDC-05-20	11/16/2012		456	<0.5	0.6	17	3.5	<1.0	<1.0	0.00	0.00	0.18	0.06	0.00	0.00	0.24	0.00	0.00	0.02	0.74	0.24	0.00	0.00
BDC-05-21	7/31/2011		-18	<1.0	<1.0	1.3	14	2.6	<1.2	0.00	0.00	0.01	0.22	0.09	0.00	0.24	0.09	0.00	0.00	0.04	0.68	0.28	0.00
(MW 25 ft XG)	11/3/2011		77	<1.0	<1.0	1.0	4.7			0.00	0.00	0.01	0.08	0.00	0.00	0.09	0.00	0.00	0.00	0.12	0.88	0.00	0.00
	2/19/2012		185	<0.2	0.3	0.7	5.9			0.00	0.00	0.01	0.09	0.00	0.00	0.10	0.00	0.00	0.02	0.07	0.91	0.00	0.00
BDC-05-21	5/7/2012		263	<0.2	0.4	0.8	2.5			0.00	0.00	0.01	0.04	0.00	0.00	0.05	0.00	0.00	0.06	0.16	0.78	0.00	0.00
BDC-05-21	9/5/2012		384	<0.2	0.3	0.6	2.9			0.00	0.00	0.01	0.05	0.00	0.00	0.05	0.00	0.00	0.04	0.11	0.85	0.00	0.00
BDC-05-21	11/16/2012		456	<0.5	<0.5	0.6	2.9			0.00	0.00	0.01	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.12	0.88	0.00	0.00
BDC-05-22	7/31/2011		-18	<1.0	1.1	9.6	1.0	<1.1	<1.2	0.00	0.01	0.10	0.02	0.00	0.00	0.12	0.00	0.00	0.07	0.80	0.13	0.00	0.00
(MW 30 ft XG)	11/3/2011		77	<1.0	2.1	10	<1.0			0.00	0.02	0.10	0.00	0.00	0.00	0.12	0.00	0.00	0.13	0.87	0.00	0.00	0.00
	2/19/2012		185	<0.2	2.0	13	0.4			0.00	0.02	0.13	0.01	0.00	0.00	0.16	0.00	0.00	0.10	0.86	0.04	0.00	0.00
BDC-05-22	5/7/2012		263	<0.2	2.0	11	0.5			0.00	0.02	0.11	0.01	0.00	0.00	0.14	0.00	0.00	0.11	0.83	0.06	0.00	0.00
BDC-05-22	9/5/2012		384	<0.2	1.8	9.5	0.8			0.00	0.01	0.10	0.01	0.00	0.00	0.12	0.00	0.00	0.11	0.79	0.10	0.00	0.00
BDC-05-22	11/16/2012		456	<0.5	1.6	10	0.7			0.00	0.01	0.10	0.01	0.00	0.00	0.13	0.00	0.00	0.10	0.82	0.09	0.00	0.00
BDC-05-23	7/31/2011		-18	<1.0	<1.0	3.2	<1.0	<1.1	<1.2	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
(MW 170ft DG	11/3/2011		77	<1.0	<1.0	4.8	<1.0			0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	1.00	0.00	0.00	0.00
	2/19/2012		185	<0.2	0.6	4.7	0.7			0.00	0.00	0.05	0.01	0.00	0.00	0.06	0.00	0.00	0.07	0.75	0.17	0.00	0.00
BDC-05-23	5/7/2012		263	<0.2	0.7	5.4	0.8			0.00	0.01	0.06	0.01	0.00	0.00	0.07	0.00	0.00	0.07	0.75	0.17	0.00	0.00
BDC-05-23	9/5/2012		384	<0.2	0.7	6.2	0.9			0.00	0.01	0.06	0.01	0.00	0.00	0.08	0.00	0.00	0.06	0.76	0.17	0.00	0.00
BDC-05-23	11/16/2012		456	<0.5	0.8	6.9	0.5			0.00	0.01	0.07	0.01	0.00	0.00	0.09	0.00	0.00	0.07	0.83	0.09	0.00	0.00
BDC-05-24	7/31/2011		-18	<1.0	<1.0	1.6	1.6	<1.1	<1.2	0.00	0.00	0.02	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.39	0.61	0.00	0.00
(MW 20 ft XG)	11/1/2011		75	<1.0	2.0	4.0	2.2			0.00	0.02	0.04	0.04	0.00	0.00	0.09	0.00	0.00	0.17	0.45	0.38	0.00	0.00
	2/19/2012		185	<0.2	0.2	0.7	0.8			0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.07	0.34	0.59	0.00	0.00
BDC-05-24	5/6/2012		262	<0.2	1.3	2.8	1.0			0.00	0.01	0.03	0.02	0.00	0.00	0.05	0.00	0.00	0.18	0.53	0.29	0.00	0.00
BDC-05-24	9/5/2012		384	<0.2	1.2	4.0	0.9			0.00	0.01	0.04	0.01	0.00	0.00	0.06	0.00	0.00	0.14	0.64	0.22	0.00	0.00
BDC-05-24	11/15/2012		455	<0.5	<0.5	1.2	<0.5			0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.00	0.00

PCE = Tetrachloroethene
TCE = Trichloroethene
*c*DCE = cis-1,2-Dichloroethene
VC = Vinyl Chloride
As = Arsenic
Cu = Copper
Tot = Total

Dis = Dissolved
DO = Dissolved Oxygen
ORP = Oxidation Reduction Potential
TOC = Total Organic Carbon
NA = Not Applicable
µg/L = micrograms pr liter
mg/L = milligrams per liter

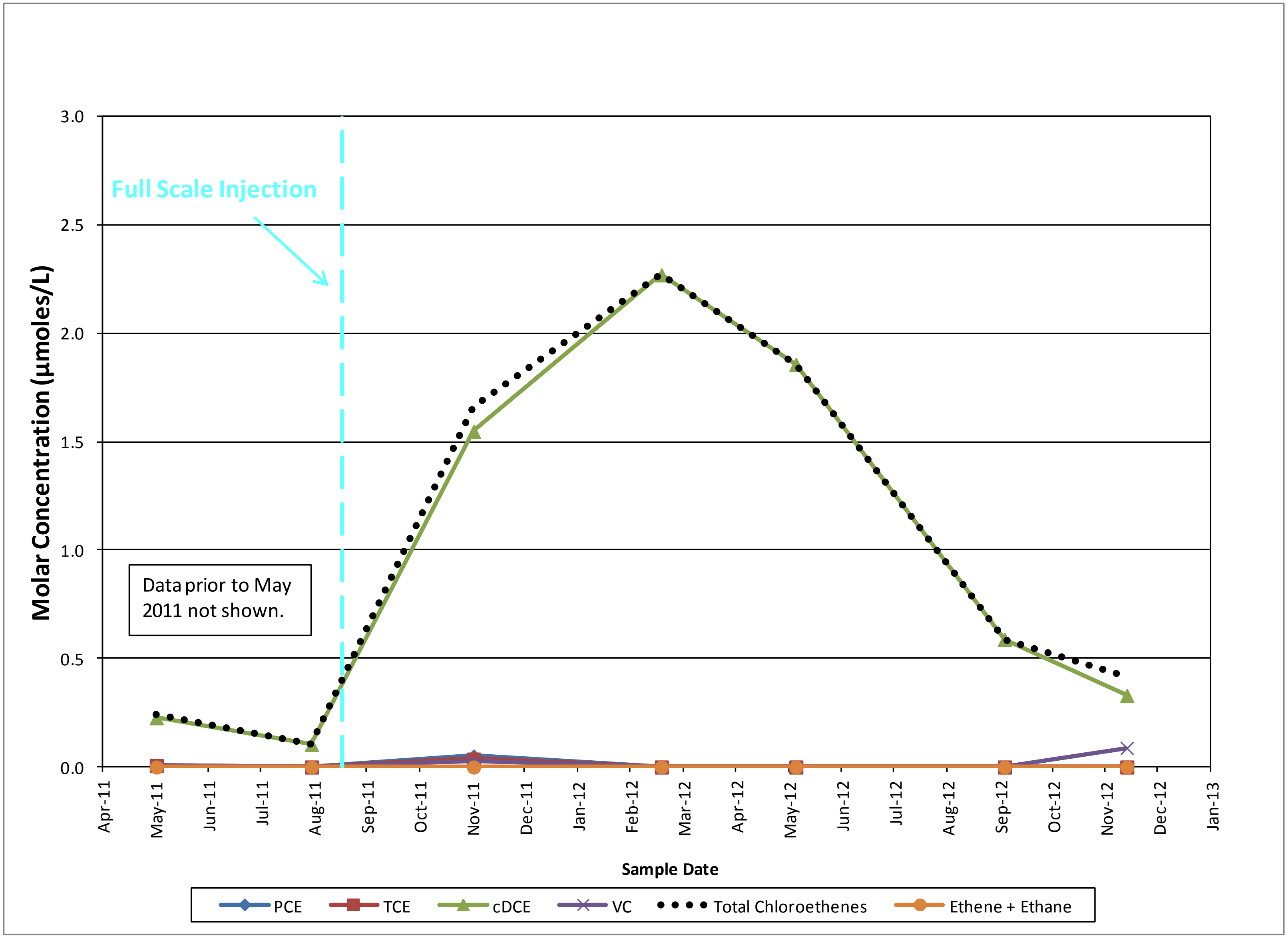
IW = Injection Well
MW = Monitoring Well
DG = Downgradient of injection wells
UG = Upgradient of injection wells
XG = Crossgradient of injection wells
[green shading] = No sample collected or sample not analyzed for specified constituent.
[blue shading] highlights the predominant ethene

(a) Reporting limits for non-detect results replaced with zero
(b) Indicates the fraction of total ethenes due to each compound
(c) Sum of PCE, TCE, *c*DCE, and VC.

Injection Dates:
10/28/2008 Pilot Injection: BDC-05-02 only
8/18/2011 Full Injection #1: BDC-05-02, BDC-05-07, and BDC-05-09 through BDC-05-17; performed 8/15/11-8/18/11

APPENDIX F

Time Plots – Molar Concentrations of VOCs and Breakdown Products



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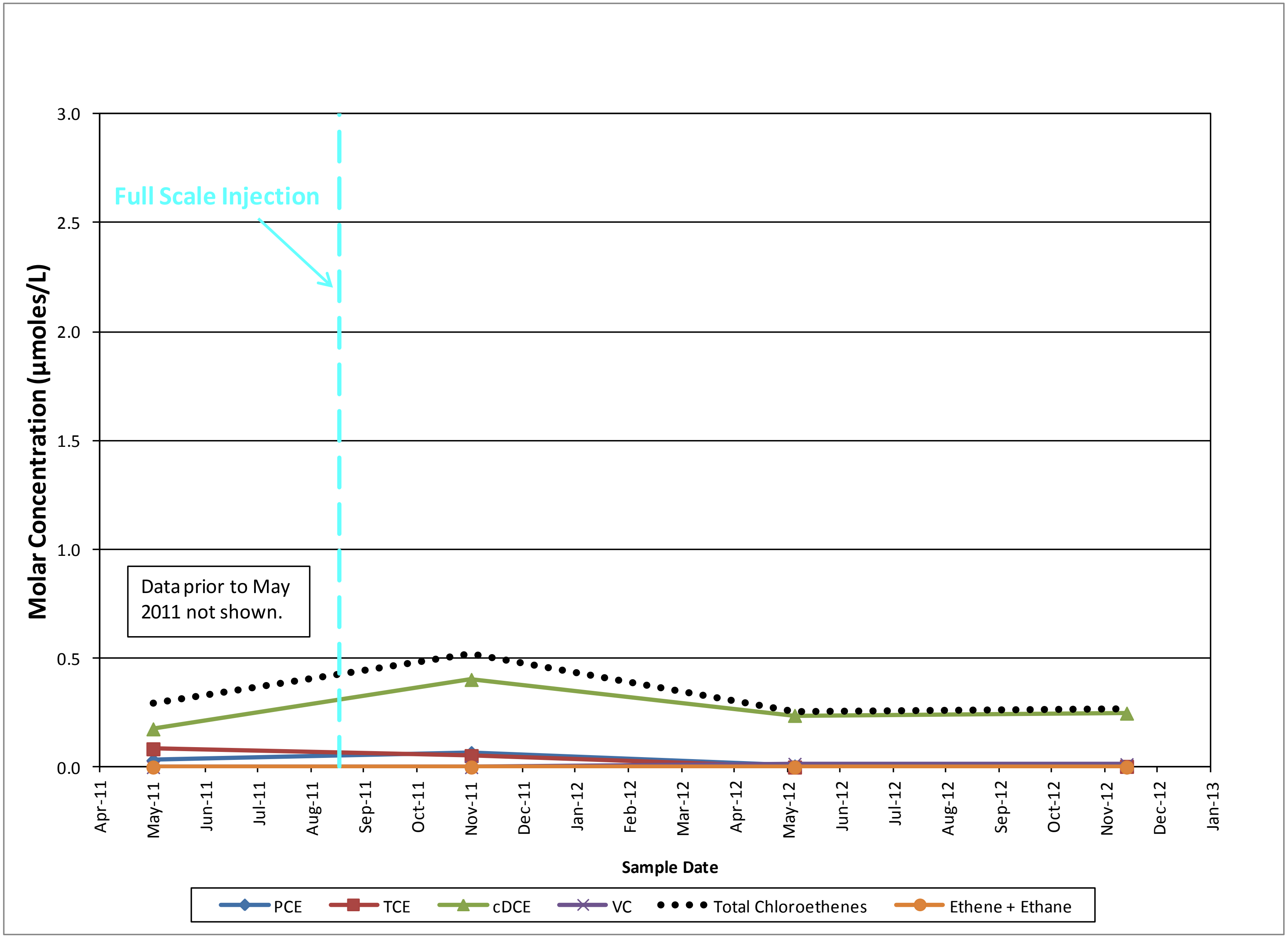
Source Zone
Injection Well BDC-05-02 VOCs
(Molar Equivalents)

Figure
F-1



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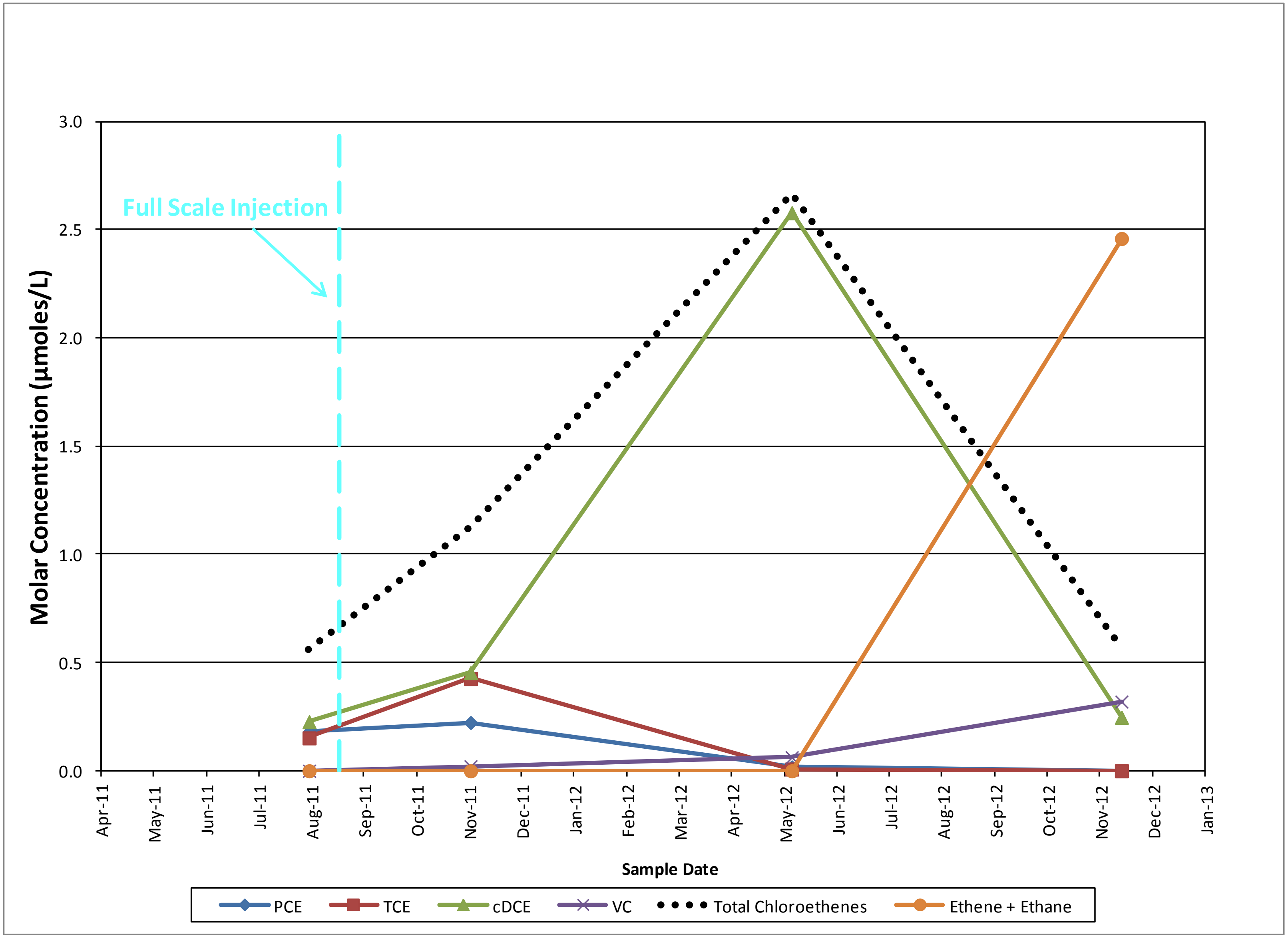
Tukwila, Washington

Source Zone
Injection Well BDC-05-07 VOCs
(Molar Equivalents)

Figure
F-2



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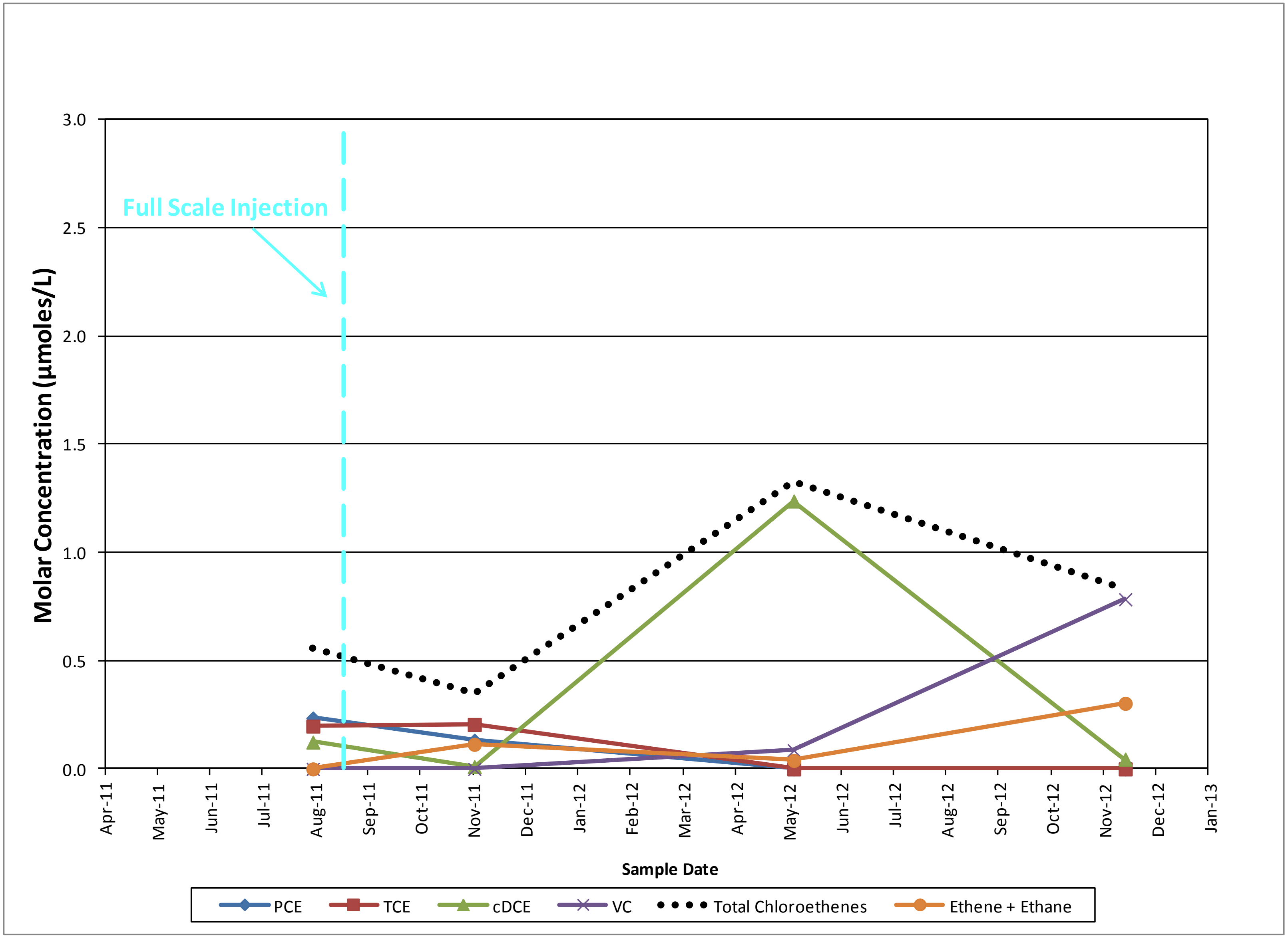
Tukwila, Washington

Non-Source Zone
Injection Well BDC-05-09 VOCs
(Molar Equivalents)

Figure
F-3



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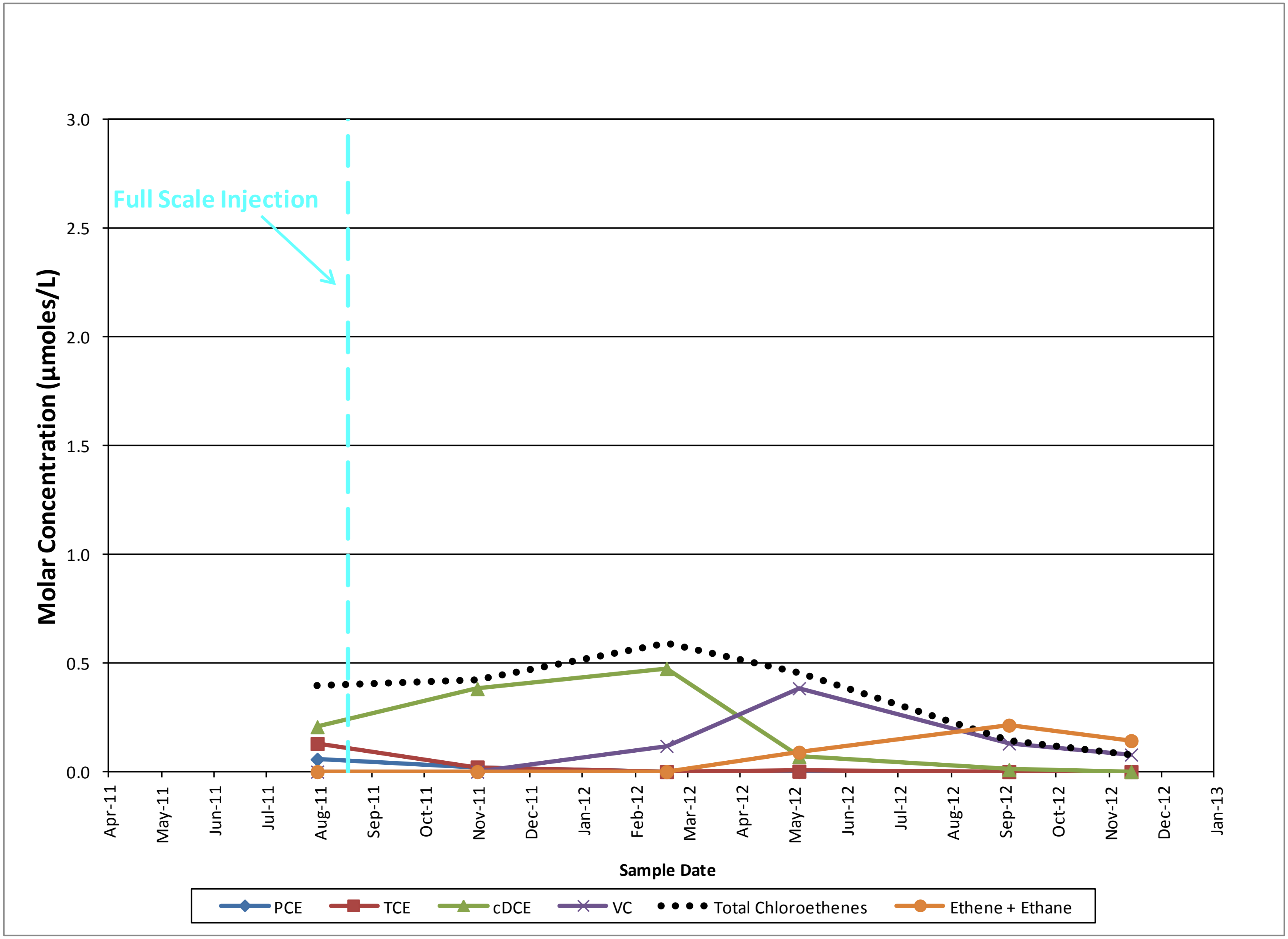
Non-Source Zone
Injection Well BDC-05-10 VOCs
(Molar Equivalents)

Figure
F-4



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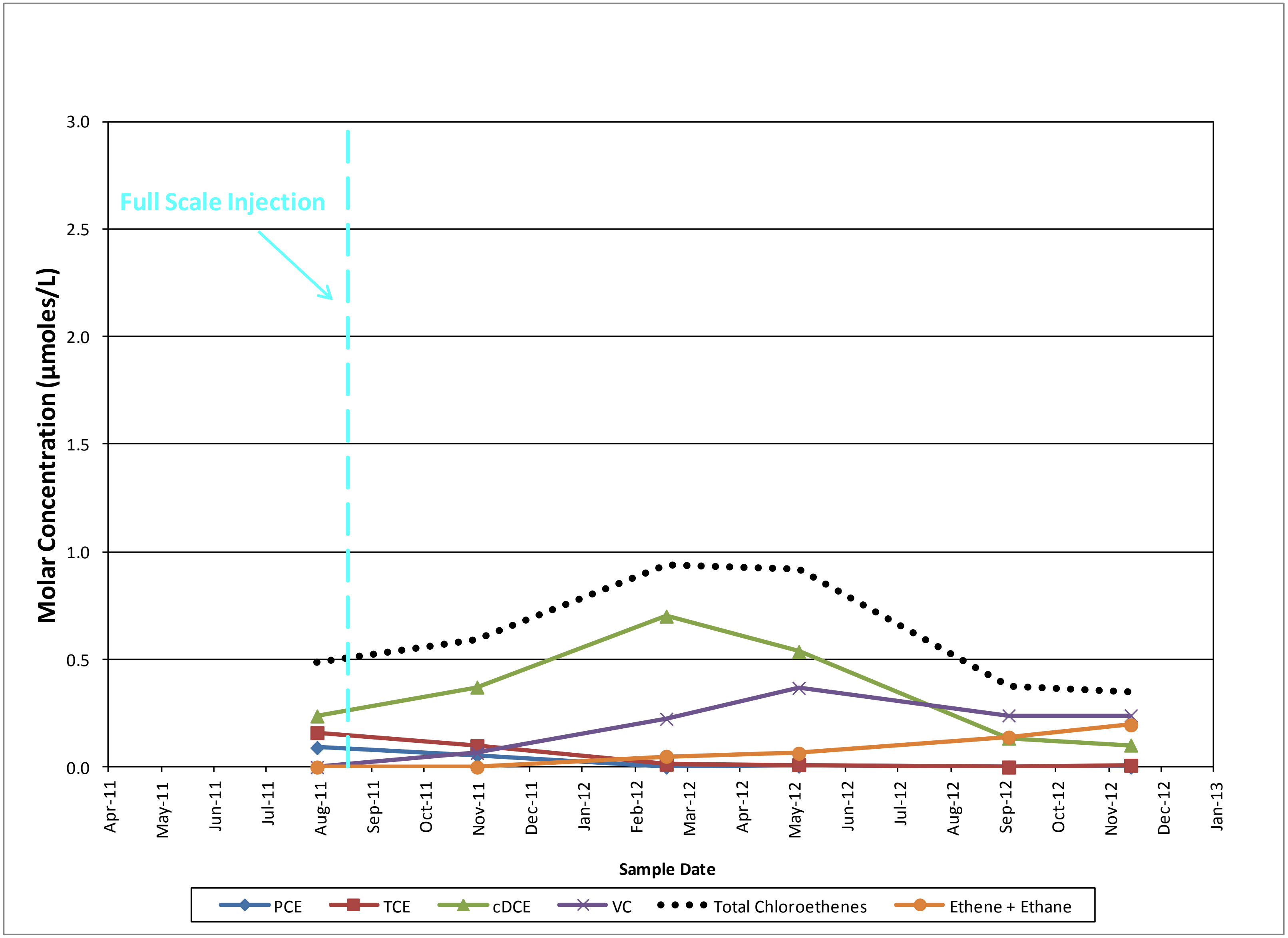
Non-Source Zone
Injection Well BDC-05-16 VOCs
(Molar Equivalents)

Figure
F-5



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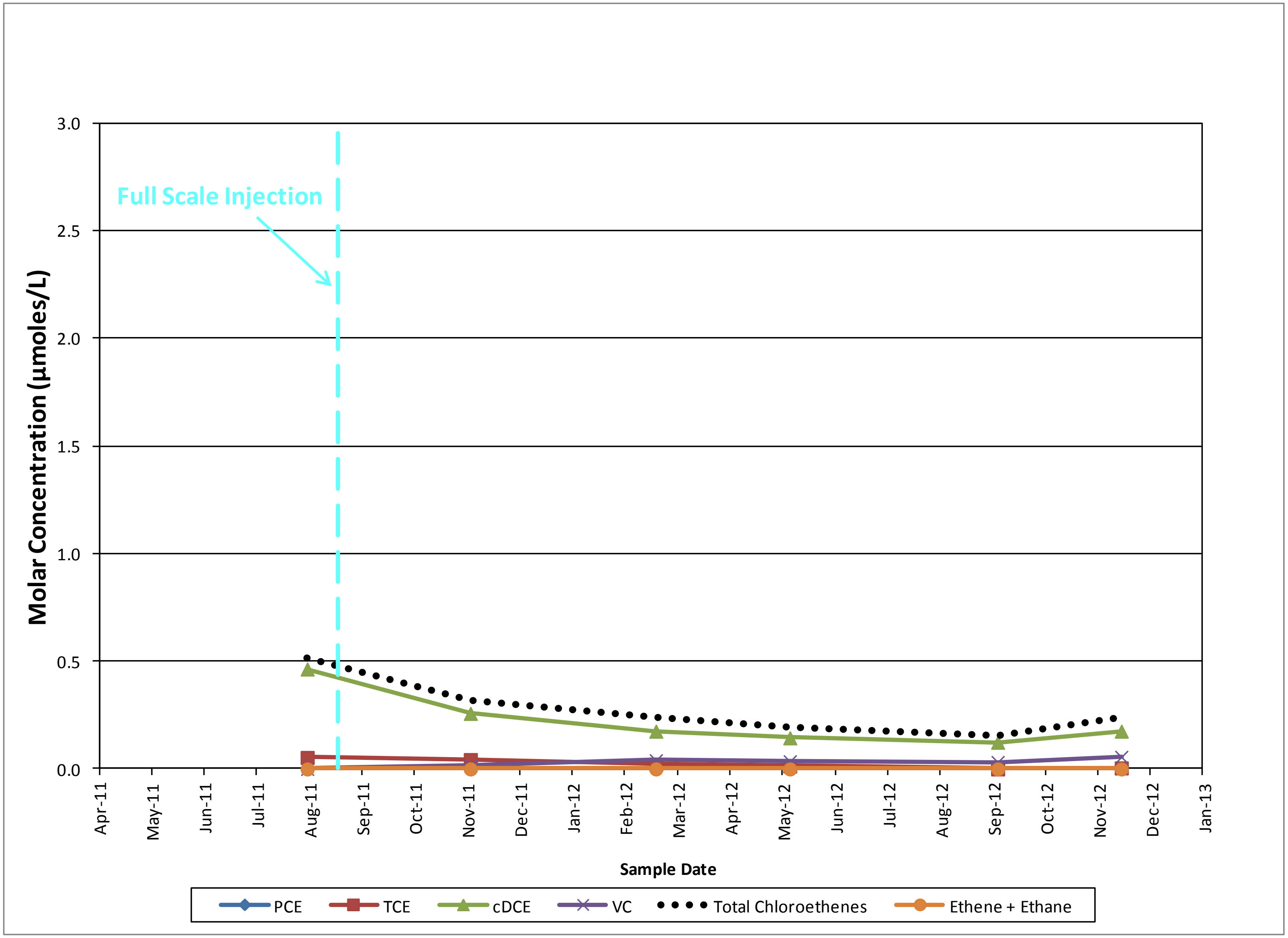
Monitoring Well BDC-05-19 VOCs (Molar Equivalents)

Figure F-6

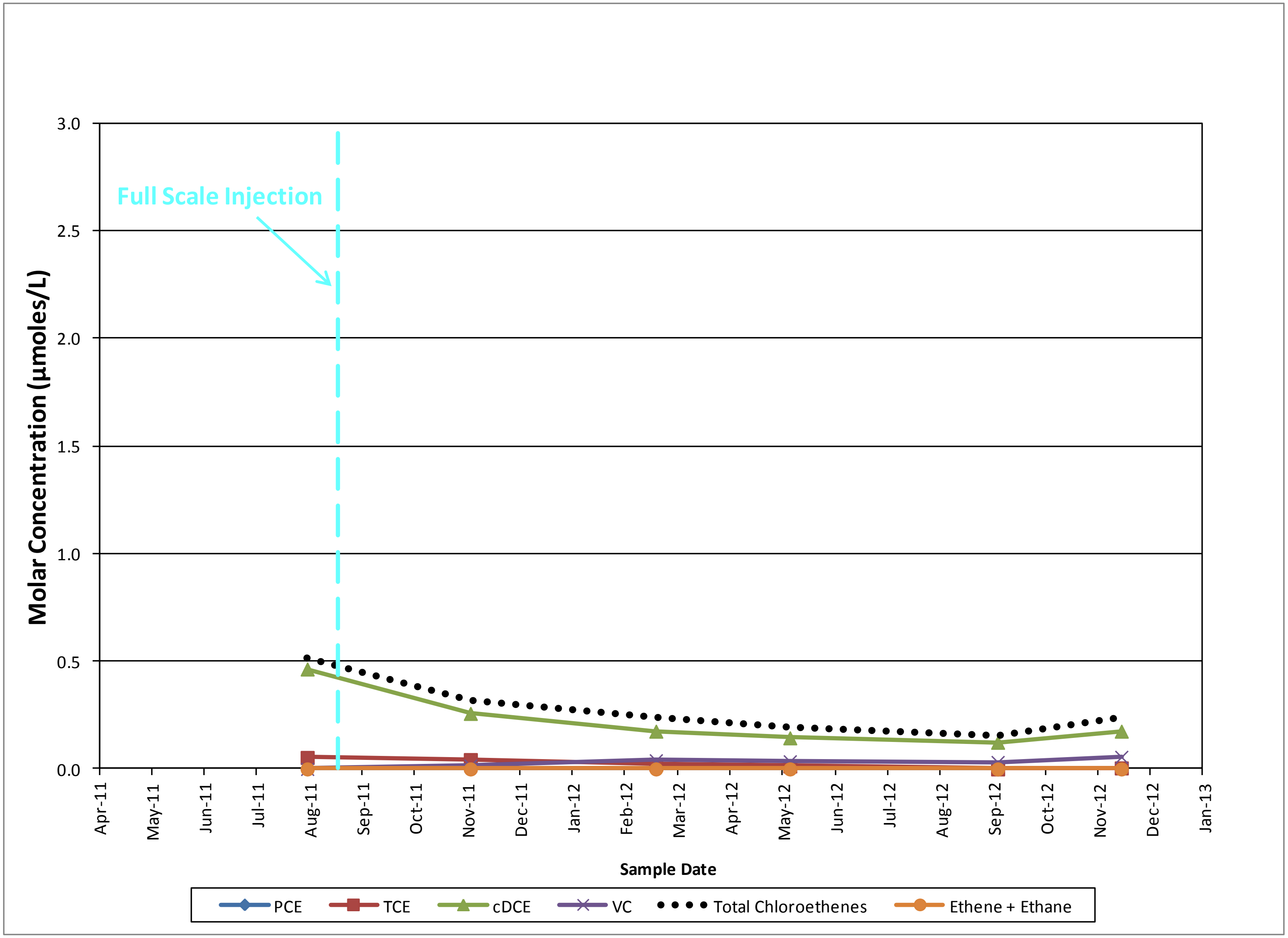


Landau Associates

Boeing Developmental Center
Tukwila, Washington

Monitoring Well BDC-05-20 VOCs (Molar Equivalents)

Figure
F-7



Landau Associates

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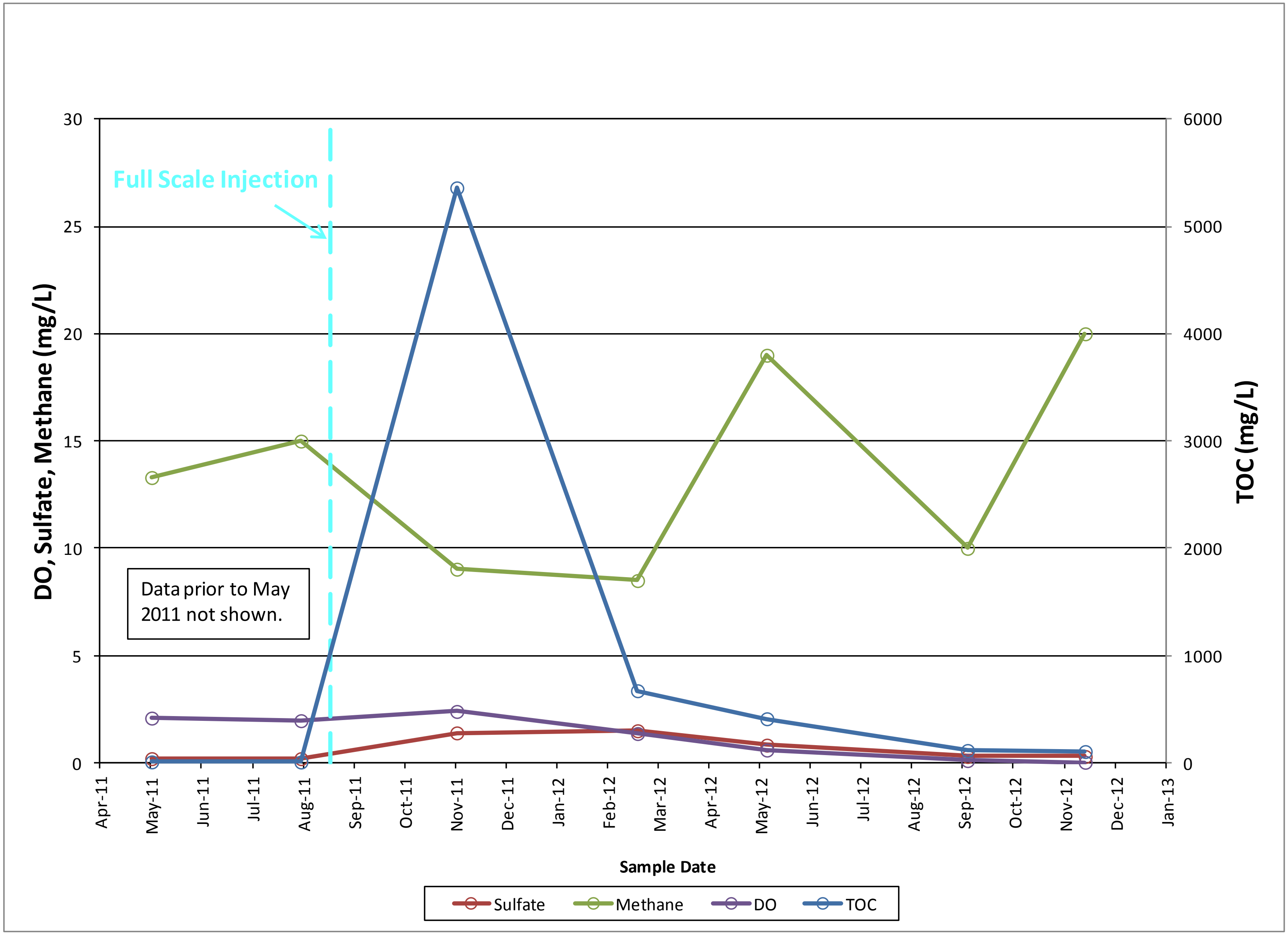
Tukwila, Washington

Monitoring Well BDC-05-21 VOCs (Molar Equivalents)

Figure
F-8

APPENDIX G

Time Plots – Aquifer Redox Parameters and TOC



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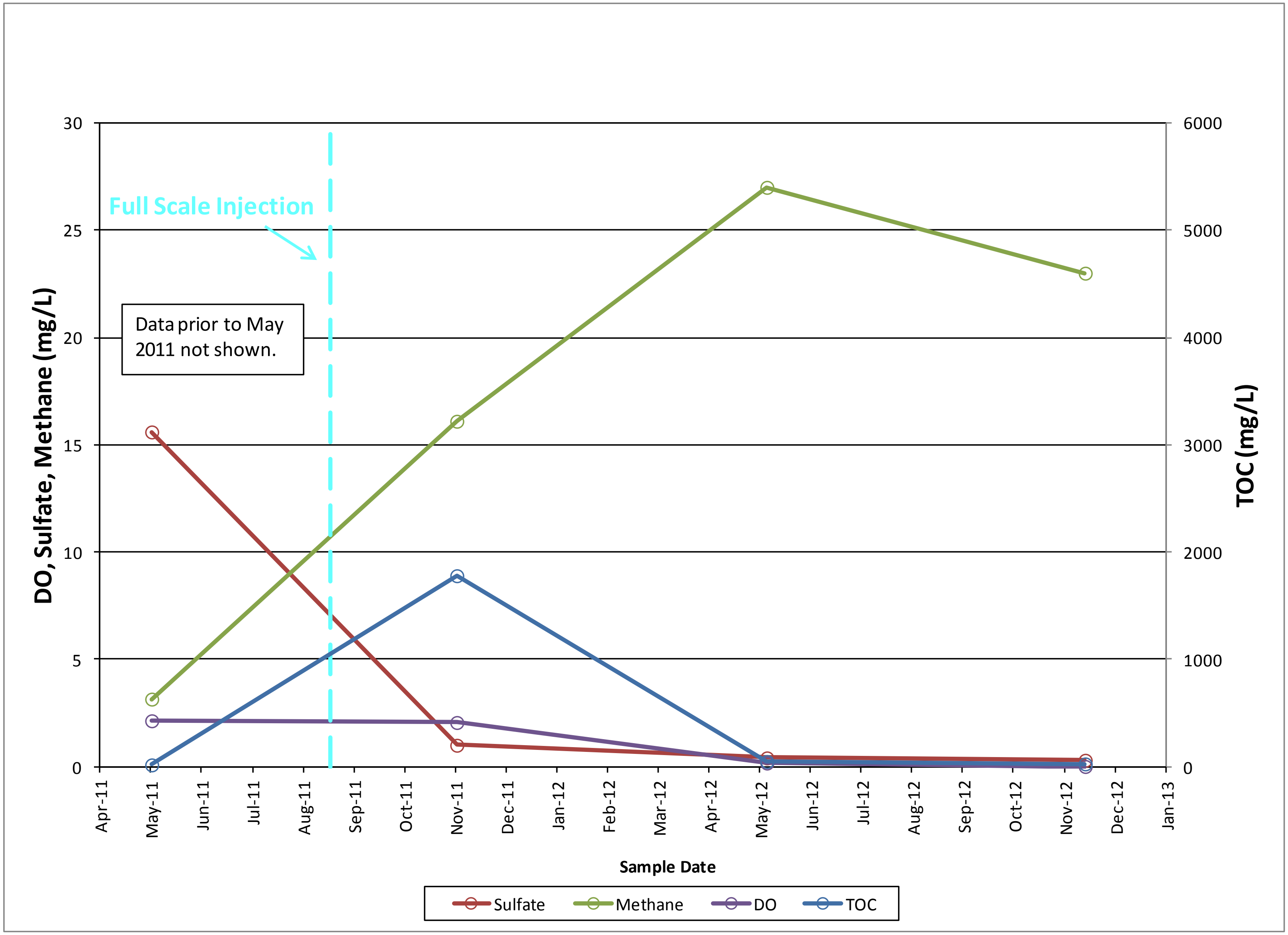
Source Zone
Injection Well BDC-05-02
Redox and TOC

Figure
G-1



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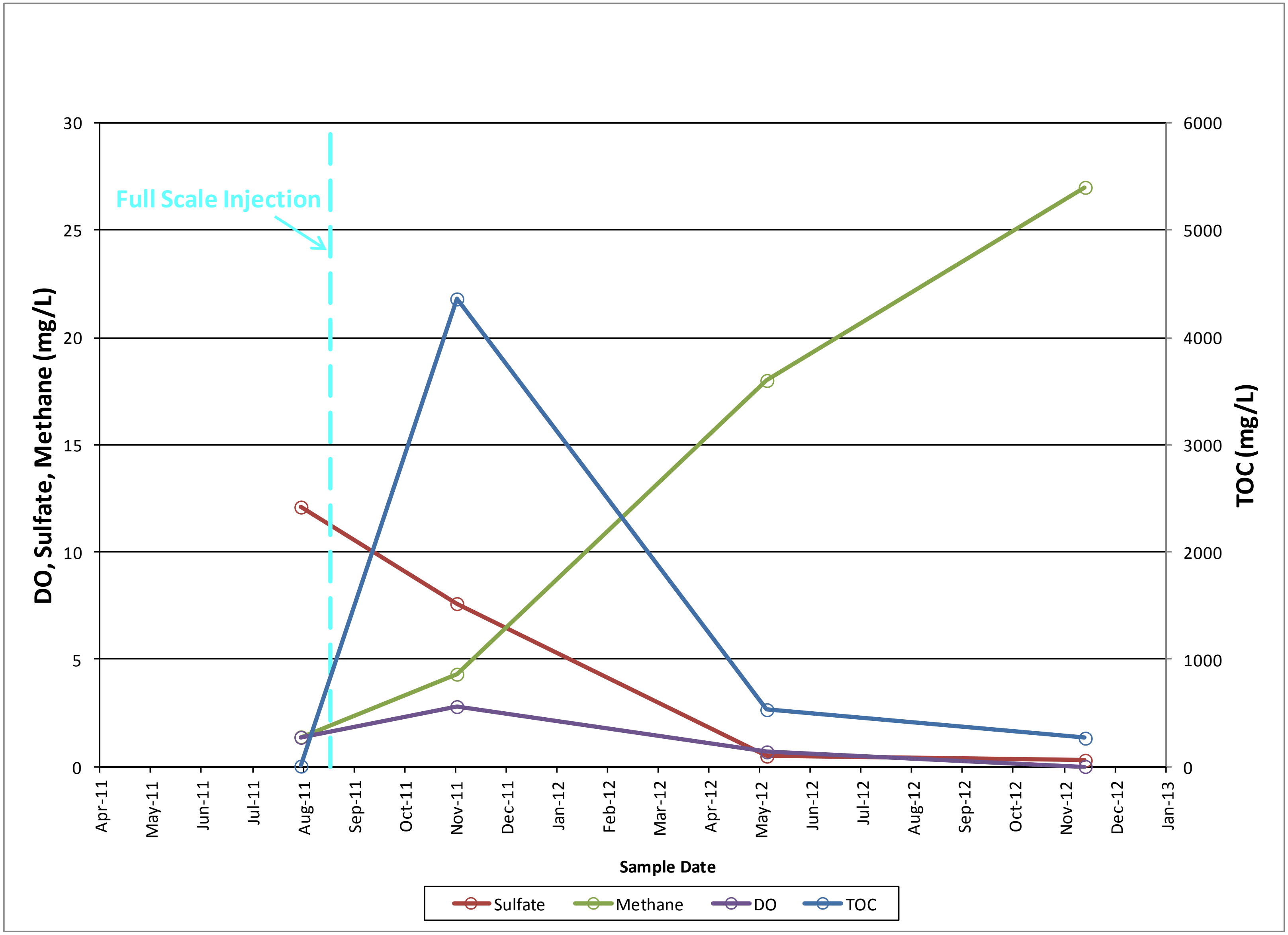
Source Zone
Injection Well BDC-05-07
Redox and TOC

Figure
G-2



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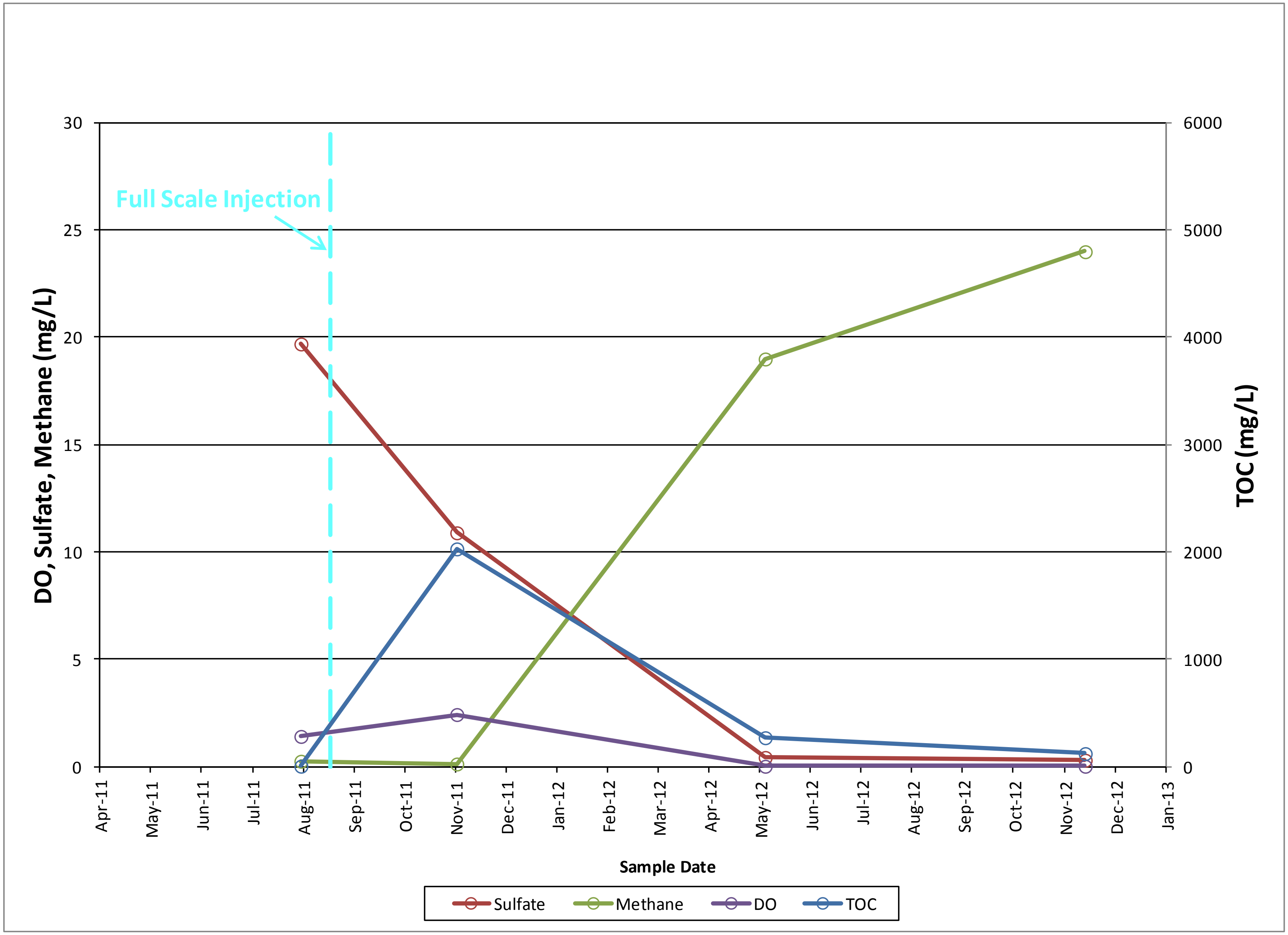
Non-Source Zone
Injection Well BDC-05-09
Redox and TOC

Figure
G-3



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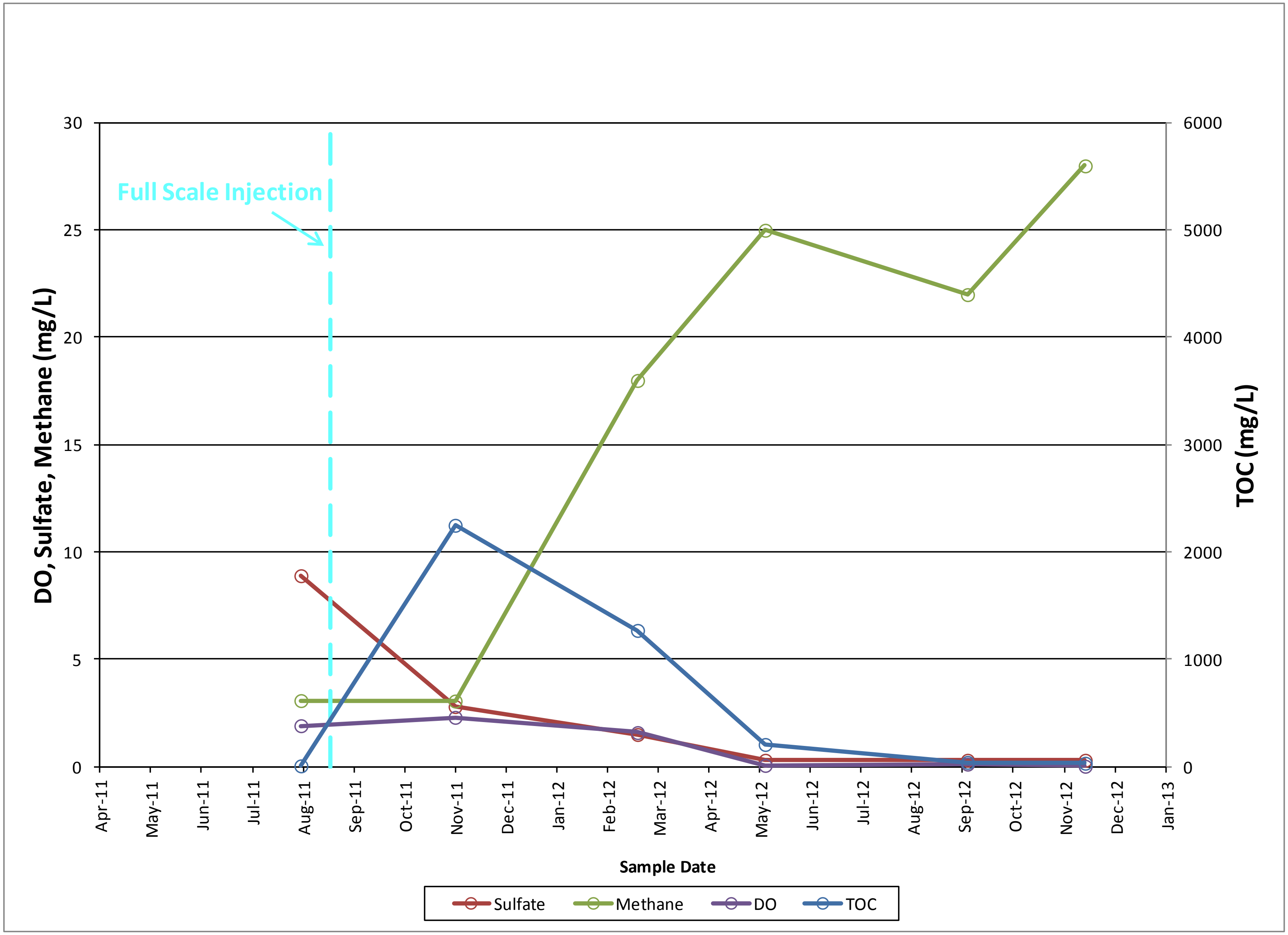
Boeing Developmental Center Tukwila, Washington	**Non-Source Zone Injection Well BDC-05-10 Redox and TOC**	Figure G-4



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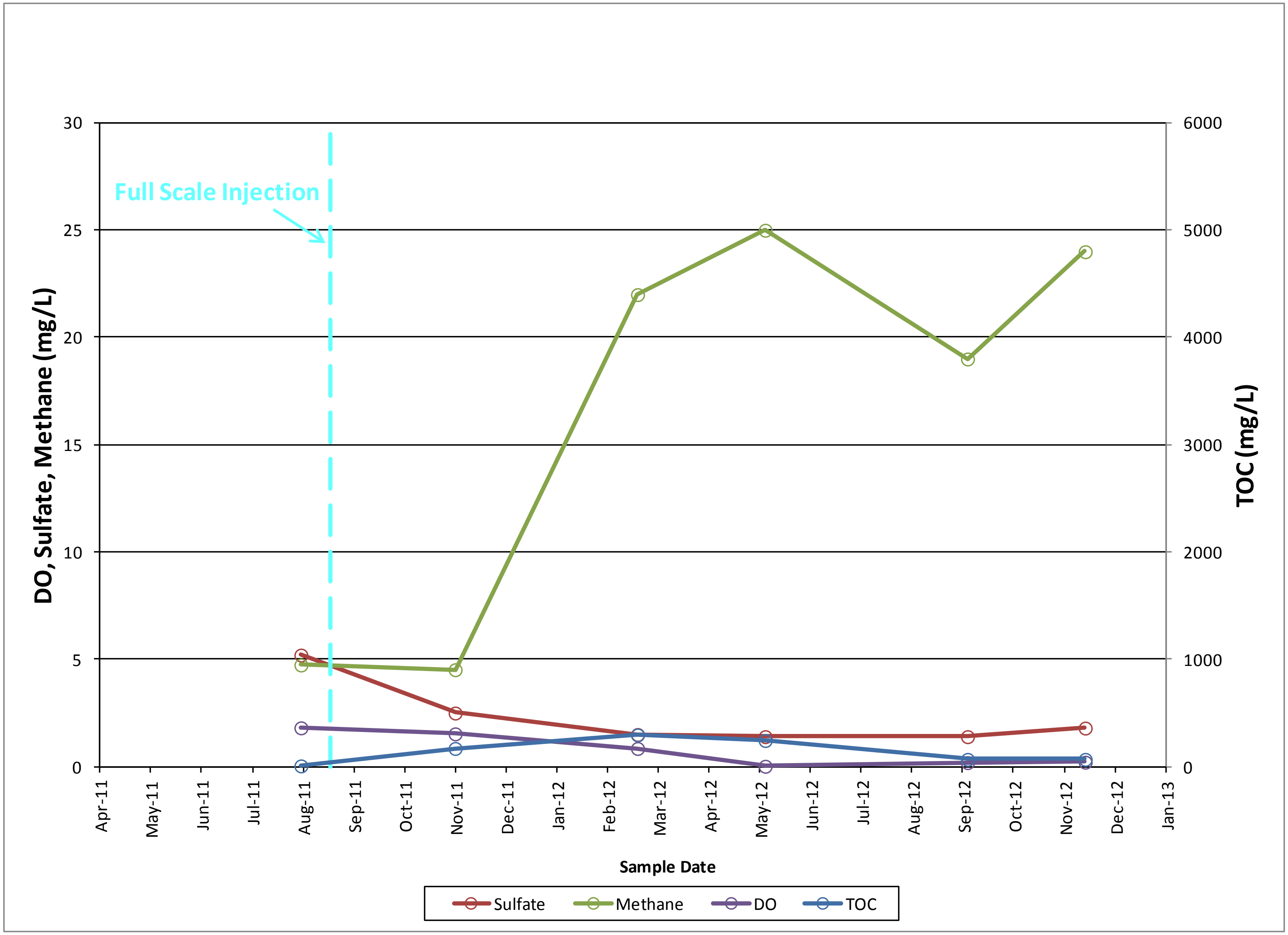
Non-Source Zone
Injection Well BDC-05-16
Redox and TOC

Figure
G-5



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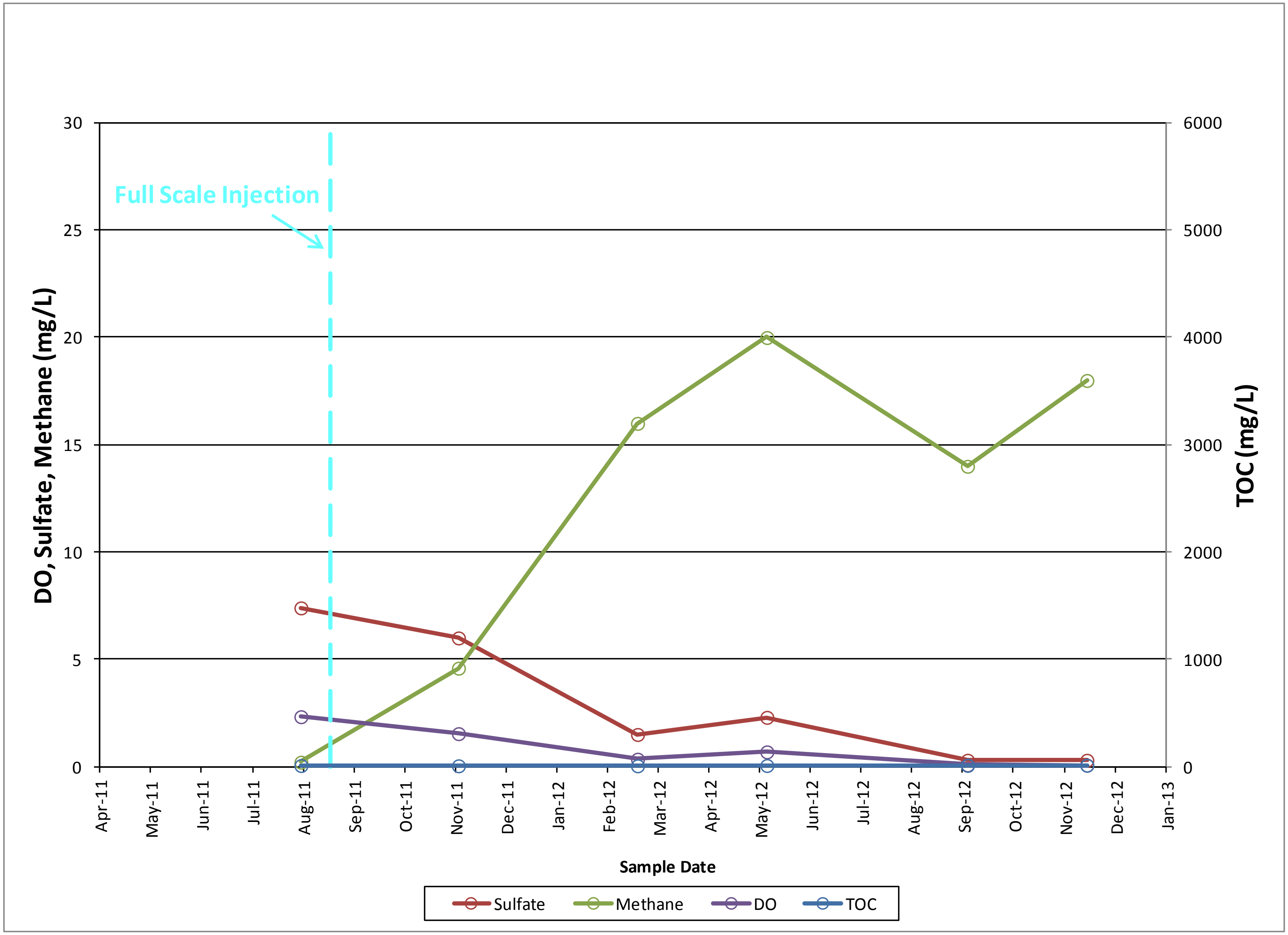
Monitoring Well BDC-05-19
Redox and TOC

Figure
G-6



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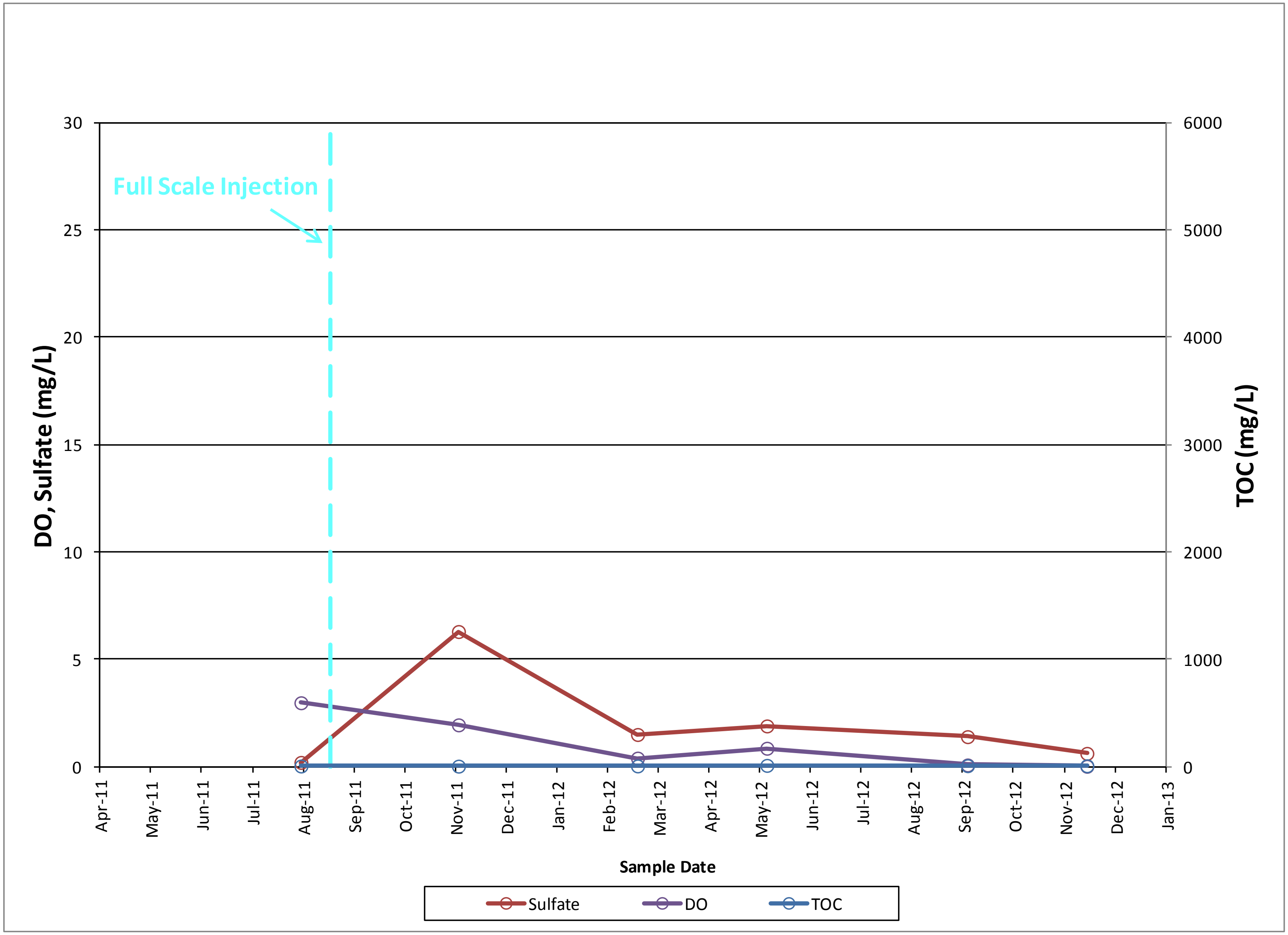
Boeing Developmental Center
Tukwila, Washington

Monitoring Well BDC-05-20
Redox and TOC

Figure
G-7



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Monitoring Well BDC-05-21
Redox and TOX

Figure
G-8