2015 Annual Report
AOC-05 Remedial Action
Enhanced Anaerobic Biodegradation of Gasoline-Range Petroleum Hydrocarbons
Boeing Developmental Center
Tukwila, Washington

June 1, 2016

Prepared for

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Date: June 1, 2016
Project No.: 0025093.116.012
File path: P:\025\093\FileRm\R\AOC-05\Annuals\AOC-05 2015 Ann\Boeing_DC_Landau_060116_AOC 2015 Annual Rpt.docx
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1.0 INTRODUCTION

This document presents the 2015 annual report for the anaerobic bioremediation remedial action performed at Area of Concern (AOC)-05 of The Boeing Company's (Boeing) Developmental Center (DC) in Tukwila, Washington (Figure 1). Remedial action is performed to stimulate anaerobic biodegradation of gasoline contamination resulting from a 1985 release from a former leaking underground storage tank (UST) near injection well BDC-103. AOC-05 wells and site features are shown on Figure 2. Anaerobic bioremediation remedial action was performed in general accordance with the Remedial Action Work Plan (Work Plan; Landau Associates [LAI] 2007a).

This annual report summarizes the activities and results for March 2015 through March 2016. Nitrate solution was injected to well BDC-103 in March 2016.

Following this introductory section, the report is organized into five main sections. Sections 2 and 3 provide an overview of the remedial approach and a summary of prior work, as context to activities and results in the current reporting period. Section 4 documents activities during the reporting period, and Section 5 presents discussion of reporting period results. Section 6 provides a summary and describes planned activities.

2.0 OVERVIEW OF REMEDIAL APPROACH

Anaerobic bioremediation at AOC-05 is accomplished through stimulation of micro-organisms present in the aquifer to degrade petroleum hydrocarbons. The addition of nitrate (electron acceptor) allows the native bacteria to utilize petroleum as food (electron donor).

Biodegradation of total petroleum hydrocarbons (TPH) occurs through microbially mediated reactions whereby micro-organisms obtain energy by oxidation-reduction (redox) reactions. Total petroleum hydrocarbons (TPH) is used as the electron donor 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 more easily and more substantially reduced. When oxygen is depleted, bacteria sequentially use the less oxidized electron acceptors in the following order: nitrate, manganese (IV), ferric iron, sulfate, and carbon dioxide.

Biodegradation of petroleum hydrocarbons can occur under both aerobic and anaerobic conditions. Stimulation of anaerobic degradation can be the preferred approach in naturally anaerobic aquifers (such as the one at the DC) where stimulation of aerobic conditions is unlikely to be effective due to high natural demand for oxygen (Wiedemeier et al. 1999). An attempt in 2002 to stimulate aerobic bioremediation of TPH in AOC-05 through injection of oxygen release compound (ORC™) was ineffective due to the naturally anaerobic condition (LAI 2006a). During anaerobic biodegradation of TPH, nitrate (or sulfate) functions as the electron acceptor for microbial degradation of the TPH electron donor. In addition to the work being performed at the Boeing DC, nitrate amendment to enhance anaerobic biodegradation has been successfully implemented on other full-scale remediation projects for gasoline-range and fuel oil-range TPH, both nationally (Lozier and Hicks 2005; Wasserman et. al. 2005) and in Washington State (LAI 2012a).

3.0 SUMMARY OF PREVIOUS WORK

Full-scale anaerobic bioremediation began in 2008 following anaerobic bioremediation pilot testing performed in 2007. The 2007 pilot testing, using a single injection well (BDC-103; LAI 2007b), was expanded to full-scale treatment in 2008 utilizing existing injection well BDC-103 and new injection well BDC-104. Following baseline groundwater monitoring for full-scale treatment, and prior to the current reporting period, nitrate was injected nine times, as follows:

- three times in 2008 (both wells)
- twice in 2009 (both wells)
- once in 2010 (BDC-103 only)
- twice in 2012 (BDC-103 only)
- once in 2013 (BDC-103 only).

3.1 Pilot Testing

The 2007 bioremediation pilot testing demonstrated degradation of petroleum hydrocarbons resulting from a one-time addition of ammonium nitrate (LAI 2007b). Post-injection monitoring showed that concentrations of TPH in the gasoline range (TPH-G) decreased by about 50 percent compared to baseline over 4 months of post-injection monitoring, while benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds decreased as much as 98 percent (LAI 2007b). As expected, contaminant concentrations rebounded upon depletion of injected nitrate due to groundwater returning to equilibrium with sorbed mass and non-aqueous phase liquid (NAPL) mass remaining in the aquifer.

3.2 Well Installation and Baseline Monitoring

Full-scale implementation of anaerobic bioremediation began with the installation of one additional injection well (BDC-104) and baseline monitoring of all four AOC-05 wells (BDC-101, BDC-102, BDC-103, and BDC-104) in February 2008. The new well was installed somewhat upgradient (east) and cross-gradient (north) of existing injection well BDC-103, to enhance treatment coverage during nitrate injections. BDC-103 is located within the tank pit of the former UST. BDC-104 is located near the known upgradient edge of contamination associated with the former UST (LAI 2004). Injection of both wells allowed for groundwater transport of injected nitrate solution to the area of highest contamination. The well locations and their estimated radii of injection (ROIs) are shown relative to the area of groundwater contamination on Figure 2.

Baseline monitoring was performed prior to full-scale treatment to determine starting contaminant concentrations and aquifer redox conditions at the four AOC-05 wells (BDC-101, BDC-102, BDC-103, and BDC-104). Baseline results indicated nitrate- to sulfate-reducing conditions at source zone wells BDC-103 and BDC-104, nitrate- to iron-reducing conditions at downgradient well BDC-102, and aerobic to nitrate-reducing conditions at downgradient well BDC-101; the same conditions as

indicated by pre-pilot test baseline monitoring (LAI 2006b). Prior to full-scale treatment, baseline (February 2008) concentrations of TPH-G were in excess of the preliminary screening level at both source zone wells BDC-103 and BDC 104, and the baseline benzene concentrations exceeded the preliminary screening level at BDC 103; preliminary screening levels in use at that time were developed in a prior DC site summary report (LAI 2002). TPH-G and BTEX were not detected at downgradient wells BDC-101 and BDC-102 during baseline sampling, but had been during prior sampling extending back to 2001. Full results of baseline monitoring are included in the data summary presented in Table 1. Proposed cleanup levels (PCULs) developed in 2013 (LAI 2013a) are presented in Table 1 and contaminant concentrations above PCULs are boxed. Data discussed in this section may be compared to screening levels to maintain a consistent historic narrative; however, data from 2014 forward is evaluated against the PCULs.

3.3 Prior Full-Scale Nitrate Injections and Performance Results

As indicated above, nitrate solution was injected nine times at AOC-05 following baseline groundwater monitoring and prior to the current reporting period. Nitrate solutions were injected to wells BDC-103 and BDC-104 three times during 2008 (February, June, and November) and twice during 2009 (June and November). After 2009, injections were required at BDC-103 only, with injections occurring in 2010 (September), 2012 (February and November), and 2013 (November). In accordance with the work plan (LAI 2007a), the standard injection dose of nitrate was 6,500 gallons of 1,000 milligrams per liter (mg/L) nitrate solution (225 mg/L as nitrogen [mg-N/L]).

Prior performance results from 2008 through February 2015 indicated effective treatment of TPH-G and BTEX at source zone wells BDC-103 and BDC-104, while maintaining low to non-detect contaminant levels at downgradient wells BDC-101 and BDC-102. Detailed analysis of groundwater sampling results for 2008 through February 2015 can be found in previous annual reports (LAI 2009, 2010, 2011, 2012b, 2013b, 2014, 2015). Cumulative performance monitoring results are presented in Table 1. Treatment progress and key milestones are described for each year below and summarized in Table 2.

2008

- Nitrate was consumed rapidly following the first two injection events.
- After the third injection event (November 2008), monitoring indicated slower consumption of injected nitrate and a partial rebound in concentrations of petroleum hydrocarbons at source zone well BDC-103, despite the presence of adequate nitrate for continued treatment. This rebound of contaminant concentration, despite adequate nitrate, suggested that biodegradation in AOC-05 had become nutrient-limited.

2009

- During the fourth injection event (June 2009), ammonium phosphate was added to the nitrate injection fluid to overcome the observed treatment slowdown thought to be caused by a deficiency of the macro-nutrient phosphorus. The amount of phosphate added to the

injection solution was based on a nitrogen-to-phosphorus ratio of 10:1, a commonly cited optimal nutrient ratio (Metcalf and Eddy 2002). The amount of yeast extract (which provides micro-nutrients) was also increased from 2 pounds (lbs) to 4 lbs per well. During this single injection event, the nitrate concentration injected was decreased by two thirds to 330 mg/L nitrate (75 mg-N/L) to limit the addition of nitrate while evaluating the effects of the ammonium phosphate.

- Data from the July 2009 sampling event suggested that consumption of nitrate and bioremediation of contaminants had resumed following the addition of ammonium phosphate to the injection solution. Based on these results, ammonium phosphate was added to subsequent injection solutions.
- During the fifth injection (November 2009), nitrate was increased back to the standard concentration at well BDC-103. Although TPH-G and BTEX were not detected during prior sampling events in July or September 2009 at well BDC-104, a half-concentration injection (500 mg/L nitrate [112 mg-N/L]) was performed at that well to treat contamination previously characterized to the north and east of well BDC-103 that may not have been within the ROI of BDC-103.

2010

- Contaminant concentrations decreased substantially following the fifth injection, with results from the February 2010 sampling event showing TPH-G and benzene concentrations below preliminary screening levels at BDC-103 for the first time since monitoring began in 2001.
- Contaminant concentrations at BDC-103 rebounded again in May and August 2010 as nitrate was consumed, prompting a sixth injection (September 2010).

2011

- Contaminant concentrations decreased to historical lows at source zone well BDC-103 in February 2011. All contaminant concentrations were below reporting limits and/or screening levels at all four AOC-05 monitoring wells during this event.
- In May 2011, TPH-G concentrations fell below the laboratory reporting limit of 0.25 mg/L at well BDC-103 for the first time since monitoring began in 2001.
- A substantial rebound in contaminant concentrations was observed in November 2011 upon nitrate depletion. This rebound was coincident with a rise in groundwater levels resulting in a higher water table than had been observed during prior years of treatment. It is likely that the higher water table caused groundwater to contact higher portions of the contaminant smear zone not treated by prior injection events.

2012

- The November 2011 rebound prompted a seventh injection at BDC-103 (February 2012). Sampling following the February 2012 injection showed substantial decreases in contaminant concentrations at BDC-103 and abundant nitrate for resumed treatment.
- Contaminant concentrations at BDC-103 rebounded somewhat in September 2012 as nitrate was consumed, prompting an eighth injection.

2013

- In February 2013, contaminant concentrations at BDC-103 were all below reporting limits with the exception of low-level detections of total xylenes. These were the lowest concentrations observed at well BDC-103 since monitoring began in 2001.
- August 2013 groundwater monitoring results at BDC-103 showed a substantial decrease in nitrate (from 161 mg-N/L to 17.8 mg-N/L) coincident with an increase in contaminant concentrations. These results prompted the ninth injection event in November 2013.

2014

- In February 2014 (included in the 2013 reporting period), TPH-G and BTEX concentrations were below laboratory reporting limits at well BDC-103, with the exception of low level xylenes. February 2014 was the second time that these contaminants were below reporting limits since monitoring began in 2001 (first occurred in February 2013.)
- In May 2014, all contaminant concentrations were below laboratory reporting limits for all four AOC-5 monitoring wells; this is the first time this had occurred since monitoring began in 2001.
- In August 2014, the benzene concentration at BDC-103 was detected slightly above the PCUL, but the following quarter (November 2014) the concentration had declined back below the reporting limit.

As indicated in the Work Plan (LAI 2007a), the Washington State Department of Ecology (Ecology) required an action level for nitrate of 10 mg-N/L for the AOC-05 remedial action. Detection of nitrate above the action level at either of the two nearest downgradient wells (BDC-101 or BDC-102) for two consecutive sampling events triggers implementation of additional groundwater monitoring at four wells located farther downgradient (BDC-05-04, MW-17A, MW-18A, and MW-21A). Semiannual monitoring for nitrate is required to continue at these four downgradient wells for 1 year after nitrate at wells BDC-101 and BDC-102 decreases below 10 mg-N/L. Based on continued periodic exceedances of the action level at wells BDC-101 and BDC-102, semiannual nitrate monitoring has been performed at the four downgradient wells since November 2009. Nitrate has not been detected at the four downgradient wells (BDC-05-04, MW-17A, MW-18A, and MW-21A) above the 10 mg-N/L action level since the semiannual monitoring was first triggered. Cumulative downgradient nitrate monitoring results are included in Table 3.

4.0 REMEDIATION ACTIVITIES DURING THIS REPORTING PERIOD

This section describes remediation activities and monitoring results for the current reporting period of March 2015 through March 2016. In this reporting period, nitrate solution was injected once (in March 2016) to well BDC-103. Well BDC-104 was not injected because TPH and BTEX have remained below reporting limits at well BDC-104 since May 2009, with the exception of low level detections in February 2013. The reporting period includes four quarterly monitoring events, and two semi-annual downgradient nitrate monitoring events.

The March 2016 injection event at BDC-103 was conducted in accordance with the Work Plan (LAI 2007a) and associated 2009 modifications, which included added ammonium phosphate and a double dose of yeast extract (LAI 2010) with the following modifications:

- The injection volume was increased by 50 percent to extend the ROI. This same injection volume was used for the 8th and 9th injection events in 2012 and 2013.
- The mass of ammonium nitrate and associated ammonium phosphate was half of the standard dose used for the 8th and 9th injections. This lower mass of electron acceptor is intended to provide treatment of residual contamination without causing extended nitrate longevity beyond the period required to complete aquifer treatment. The resulting mix consisted of approximately 66 lbs of CAN-27 ammonium nitrate fertilizer, 11 lbs of ammonium phosphate, and 5 lbs of yeast extract mixed with approximately 9,750 gallons of potable water. This injection mix resulted in a nitrate injection solution concentration of approximately 500 mg/L.

During the March 2016 injection event, as was done during the previous three injection events, a higher injection flow rate was targeted in an effort to create more mounding of injection fluid above the water table. Near the end of the injection period, with approximately 1,200 gallons remaining, injection fluid began to seep from seams in the concrete pavement within 5 feet (ft) of the injection well. This limited seepage was contained and collected for disposal using a wet-dry shop vacuum. The injection rate was then reduced to minimize seepage. The observed seepage through the pavement confirms the desired mounding above the water table, which is typically present at 11 to 12 ft below ground surface (bgs). Mounding of injection fluid above the water table is intended to contact and treat contamination that may remain in a higher portion of the smear zone, which can contribute to groundwater contaminant rebound during periods of higher groundwater.

The progress of petroleum hydrocarbon biodegradation was evaluated through quarterly performance groundwater monitoring at the four AOC-05 wells (BDC-101 through BDC-104). Monitoring was performed in April, July, and October 2015, and in January 2016. In accordance with the Work Plan (LAI 2007a), samples were analyzed for contaminant concentrations (TPH-G and BTEX) and parameters indicative of aquifer redox conditions (dissolved oxygen [DO], oxidation-reduction potential [ORP], nitrate, ferrous iron, sulfate, and pH). Samples were also analyzed for nitrite. A summary of monitoring results for the four AOC-05 wells (BDC 101 through BDC-104) is presented with cumulative data in Table 1.

Semiannual monitoring for nitrate continued in April and October 2015 at the four monitoring wells located farther downgradient of AOC-05 (MW-17A, MW-18A, MW-21A, and BDC-05-04). These results are presented with cumulative data in Table 3. Semiannual monitoring for nitrate is required to continue at these four downgradient wells for 1 year after nitrate at wells BDC-101 and BDC-102 decreases below 10 mg-N/L.

TPH-G, BTEX, nitrate, nitrite, and sulfate were analyzed in the laboratory, while other parameters (DO, ORP, ferrous iron, and pH) were measured in the field. Laboratory analysis was performed by Eurofins Lancaster Laboratories Environmental (LLI).

5.0 DISCUSSION OF RESULTS DURING THIS REPORTING PERIOD

Performance monitoring results for the current reporting period from March 2015 through March 2016 indicate continued effective treatment of TPH-G and BTEX at AOC-05. Highlights are presented below and summarized in Table 2.

- Contaminant concentrations at BDC-101, BDC-102, and BDC-104 remained below laboratory reporting limits.
- TPH-G concentrations at BDC-103 were below the laboratory reporting limit for three of the four quarters. The TPH-G concentration (19 micrograms per liter [µg/L]) was above the reporting limit and the PCUL in October 2015.
- BTEX were below the laboratory reporting limits at BDC-103 in April 2015, but were detected in July 2015, October 2015, and January 2016. Benzene and ethylbenzene were above the PCUL during each of these three quarters, and total xylenes were above the PCUL in October. Toluene remained below the PCUL during this reporting period.
- Nitrate at BDC-103 showed a substantial decrease from April 2015 (75 mg-N/L) to July 2015 (8 mg-N/L), coincident with the increases in TPH-G and BTEX.
- The nitrate concentration at BDC-103 recovered in January 2016 to a concentration of 33 mg-N/L. This increase in nitrate coincided with a decline in contaminant concentrations and the highest groundwater elevations observed onsite since monitoring began.
- Some contaminant concentrations remained above the PCULs during the October 2015 and January 2016 sampling events, prompting the tenth injection event in March 2016.

These contaminant and nitrate data at BDC-103 suggest that some contaminant mass remained upon depletion of nitrate between April and July, causing a rebound in contaminant concentrations. Once nitrate concentrations recovered in the aquifer in January 2016, treatment resumed and contaminant concentrations declined. The January 2016 nitrate recovery is likely due to the concurrent historically high groundwater elevations (Figure 3), causing the water table to come into contact with nitrate present in the vadose zone from mounding of injection fluid during prior injection events.

Monitoring results are presented on Figures 4 through 11, summarized in Table 1, and discussed further in the following sections. TPH-G and BTEX concentrations at BDC-103 and BDC-104 are plotted against time (from the period of nitrate pilot testing through full-scale treatment) on Figures 4 and 5, respectively. Concentrations of TPH-G and benzene (the compounds that have most commonly exceeded PCULs) are plotted since monitoring began in June 2001 on Figures 6 through 9 for wells BDC-101 through BDC-104. Concentrations of nitrate, TPH-G, and benzene are plotted against time for injected wells BDC-103 and BDC-104 on Figures 10 and 11, respectively. Cumulative monitoring results in Table 1 are compared to PCULs (LAI 2013a) and contaminant concentrations above PCULs are boxed.

5.1 TPH-G and BTEX

TPH-G and/or BTEX were detected in July 2015, October 2015, and January 2016 at BDC-103; these detections represent the first contaminant detections in almost 2 years (since November 2013), with the exception of a low benzene detection in August 2014 (Figure 4). At the other three AOC-05 wells (BDC-101, BDC-102, and BDC-104) contaminant concentrations were below their respective reporting limits during the entire reporting period. Changes in contaminant concentrations at BDC-103 for the reporting period are further described as follows:

- TPH-G was detected above the PCUL (0.8 mg/L) at 19 µg/L in October 2015, the first detection of TPH-G since November 2013. The remaining three quarters, TPH-G remained below the reporting limit (0.25 mg/L). The reporting limit represents a decrease of 99.6 percent from the 2008 baseline concentration of 66 mg/L.
- Benzene was detected above the PCUL (2.0 µg/L) in July 2015, October 2015, and January 2016; it had previously been below the reporting limit (1.0 µg/L) since November 2014. Benzene concentrations during the reporting period peaked in October 2015 (480 µg/L) and then declined in January 2016 (4 µg/L), which represents a 99.6 percent decrease from the 2008 baseline concentration of 1,100 µg/L.
- Toluene has remained below the PCUL (1,294 µg/L) since February 2012. The highest toluene concentration observed during the reporting period was 740 µg/L (October 2015), well below the PCUL. The toluene concentration of 1.2 µg/L from the most recent sampling event (January 2016) represents more than a 99.9 percent contaminant reduction compared to the 2008 baseline concentration of 2,600 µg/L.
- Ethylbenzene was detected above the PCUL (1.7 µg/L) in July 2015, October 2015, and January 2016; it had previously been below the reporting limit (1.0 µg/L) since February 2014. Concentrations during the reporting period peaked in October 2015 (600 µg/L) and then declined in January 2016 (3 µg/L), which represents a 99.6 percent decrease from the 2008 baseline concentration of 700 µg/L.
- Total xylenes were detected above the PCUL (1,546 µg/L) at 2,650 µg/L in October 2015, the first detection above the PCUL since November 2011. Concentrations declined to 19 µg/L in January 2016, which represents a 99.8 percent decrease from the 2008 baseline of 9,400 µg/L.

5.2 Nitrate and Nitrite

Nitrate was monitored at the four AOC-05 wells and at the four downgradient wells. Nitrite was also monitored at the four AOC-05 wells.

As discussed in Section 5.0, aquifer nitrate concentrations decreased at well BDC-103 from April (75 mg-N/L) to July (8 mg-N/L) and October (<0.1 mg-N/L) 2015, due to nitrate consumption for biodegradation of TPH. Nitrate concentrations at BDC-103 increased in January 2016 to 33 mg-N/L, which was likely due to historically high groundwater causing the water table to come into contact with nitrate present in the vadose zone from mounding of injection fluid during prior injection events. A nitrate injection was conducted in March 2016 to provide continued treatment to the aquifer.

Per the Work Plan (LAI 2007a), detection of nitrate above the action level of 10 mg-N/L at either BDC-101 or BDC-102 for two consecutive sampling events triggers additional groundwater monitoring at farther downgradient wells MW-17A, MW-18A, MW-21A, and BDC-05-04. Nitrate concentrations at BDC-101 exceeded the action level during April 2015, July 2015, and January 2016 sample events, and was below the action level during the October 2015 sampling event. Nitrate concentrations at well BDC-102 exceeded the action level during the April, July, and October 2015 sampling events, but was below the action level in the January 2016 sampling event. Semiannual nitrate monitoring at four downgradient wells continued during this reporting period. All downgradient detections remained below the 10 mg-N/L action level, with the highest detection occurring at BDC-05-04 (5 mg-N/L) in April 2015. Per the Work Plan, semiannual monitoring for nitrate will continue at the four down-gradient wells for 1 year after nitrate at wells BDC-101 and BDC-102 drops below 10 mg-N/L. Cumulative monitoring results for downgradient wells are summarized in Table 3 and presented on Figure 12.

It is not uncommon to detect low levels of nitrite as a result of nitrate reduction. Nitrite is a highly reactive, short-lived compound that is further reduced through nitrous oxide and nitric oxide to nitrogen gas (Environment Agency 2005). Nitrite has been commonly detected at injection wells since the start of full-scale injection activities. However, during this reporting period, all nitrite concentrations were below the reporting limit (0.10 mg-N/L), which is likely due to the generally low nitrate concentrations observed and confirms that any nitrite is being quickly reduced.

6.0 SUMMARY AND PLANNED ACTIVITIES

Data suggest that bioremediation treatment of TPH is nearing completion in AOC-05, as indicated by the slow consumption of nitrate between the November 2013 and March 2016 injection events and the extended time period, with low to not detected contaminant concentrations from November 2013 until July 2015. However, some contaminant mass remains in the aquifer, as indicated by the rebound of TPH-G and BTEX concentrations at BDC-103, when nitrate was depleted in July 2015. Despite the fact that benzene and ethylbenzene concentrations remained above PCULs at BDC-103 during the last monitoring event of this reporting period (January 2016), the data indicate substantial contaminant concentration reductions of more than 99 percent compared to 2008 baseline conditions.

To address the remaining contaminants near well BDC-103, an injection event was conducted at BDC-103 in March 2016. TPH-G and BTEX have been below proposed CULs at wells BDC-101, BDC-102, and BDC-104 since 2009.

Additional nitrate injections at AOC-05 will continue, as needed, to treat remaining aqueous-phase, sorbed-phase, and/or NAPL contamination until contaminant concentrations remain consistently below PCULs and it has been demonstrated that substantial rebound of contaminant concentrations will not occur. It is understood that rebound will continue to occur as long as contaminant mass remains in the sorbed-phase or as NAPL within the aquifer or in upper portions of the smear zone that are periodically contacted by the water table. Upon depletion of nitrate in the aquifer, groundwater concentrations will return to equilibrium with remaining TPH mass present in non-aqueous phase. Treatment will be complete when rebound no longer occurs upon depletion of injected nitrate.

As an injection event was completed in March 2016, another injection is not needed at this time; however, additional injections may be scheduled if monitoring results indicate rebound of contaminant concentrations following depletion of nitrate. Modification of the injection approach will be evaluated on an ongoing basis, using the most current monitoring data. Ammonium phosphate (to prevent a nutrient stall), higher injection rates (to achieve mounding for contact with higher portions of the smear zone), and the larger injection volume (to extend the ROI and increase the longevity of treatment) will likely continue to be utilized for future injections, if any.

Groundwater monitoring will continue at the four AOC-05 wells and at the four downgradient wells. AOC-05 groundwater sampling is planned to continue on a quarterly basis to evaluate contaminant treatment and nitrate consumption. The four AOC-05 wells will continue to be sampled for the parameters indicated in the Work Plan and for nitrite. Semiannual monitoring for nitrate only at downgradient wells MW-17A, MW-18A, MW-21A, and BDC-05-04, triggered by nitrate concentrations at wells BDC-101 and BDC-102, will continue per the Work Plan (LAI 2007a).

7.0 USE OF THIS 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.

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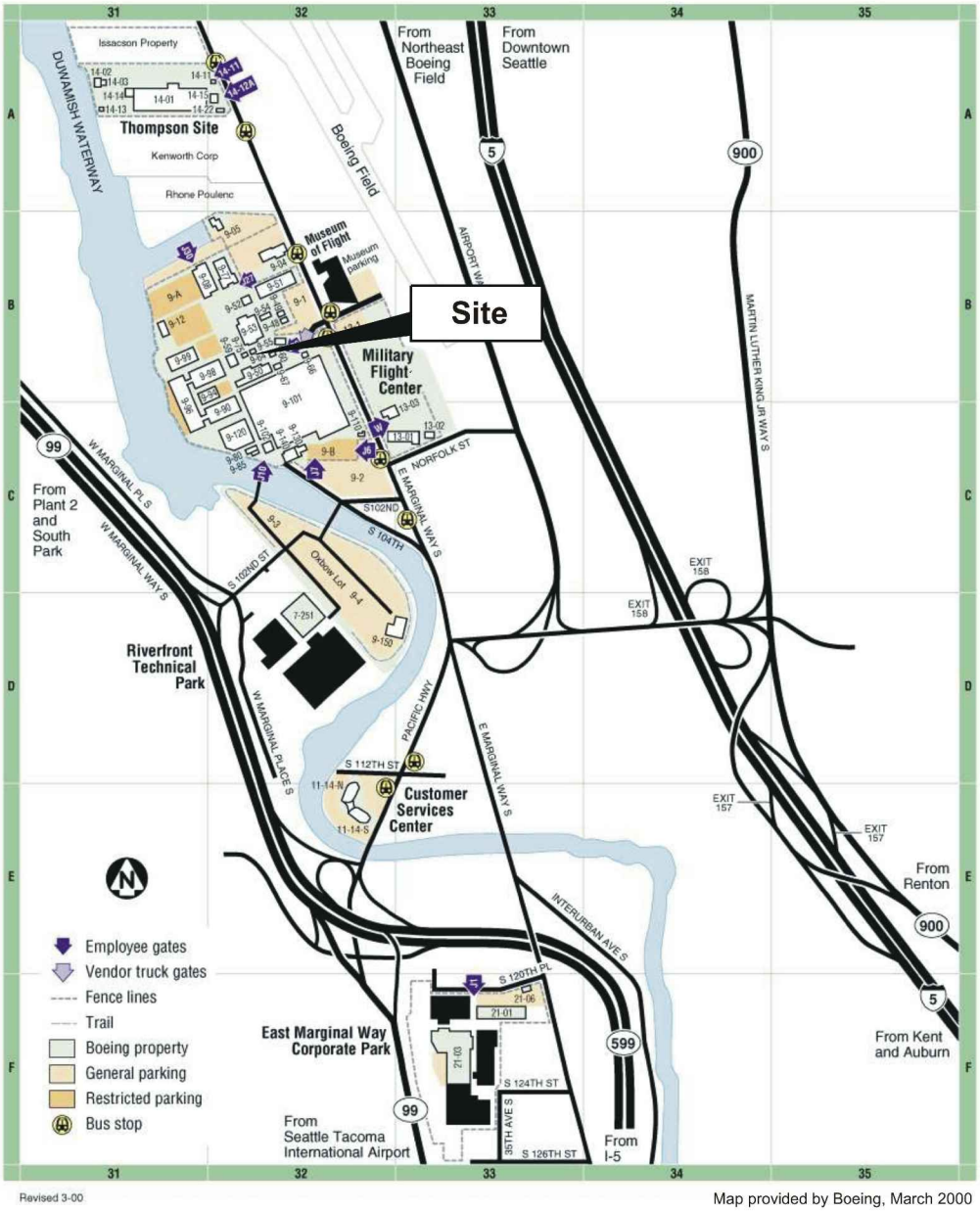
Washington – Developmental Center

9725 East Marginal Way South, Seattle, WA 98108



Revised 3-00

Map provided by Boeing, March 2000

Not To Scale

Boeing Development Center Tukwila, Washington	**Site Location Map**	Figure 1

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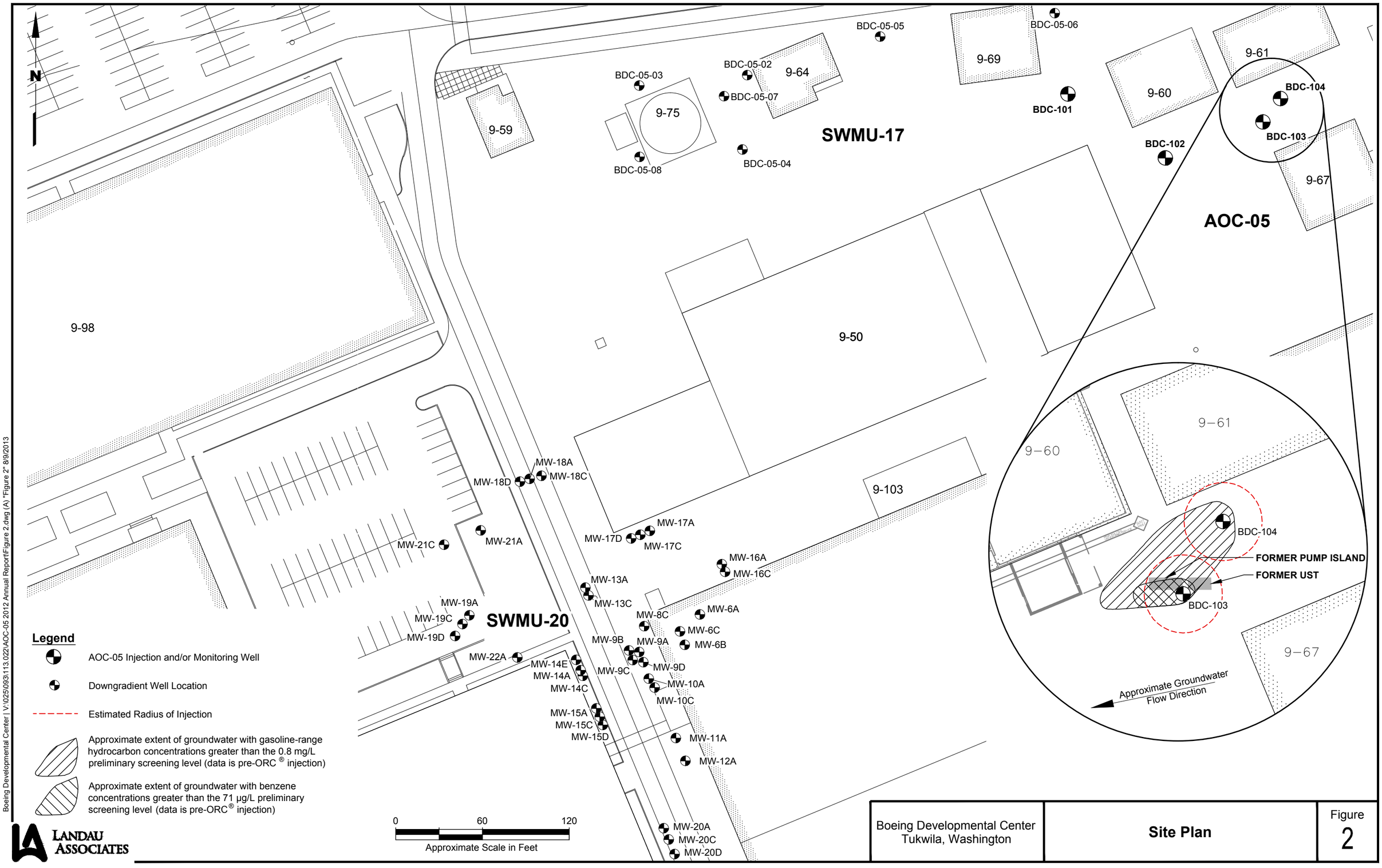
LANDAU ASSOCIATES, INC. | V:\025\093\113.022\AOC-05 2012 Annual Report\Figure 1 Vicmap.dwg (A) "Figure 1" 8/9/2013



Boeing Developmental Center | V:\025\093\113.022\AOC-05 2012 Annual Report\Figure 2.dwg (A) "Figure 2" 8/9/2013

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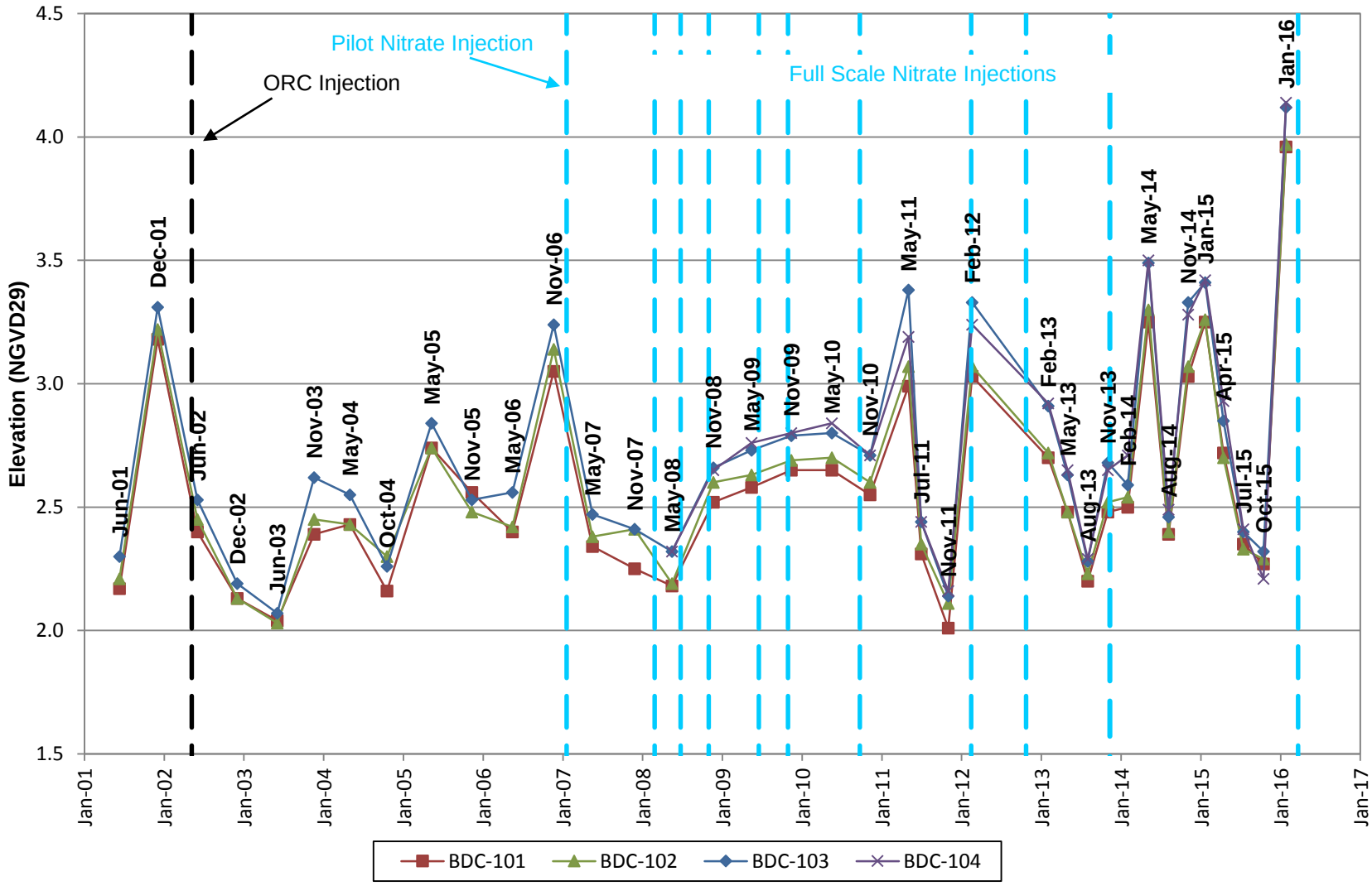
Boeing Developmental Center Tukwila, Washington	**Site Plan**	Figure 2

Source: \\edmdata01\projects\025\093\WIP\T\AOC-5\AOC-05 GW Elev Plot.xlsx



Boeing Developmental Center Tukwila, Washington	**Groundwater Levels**	Figure 3

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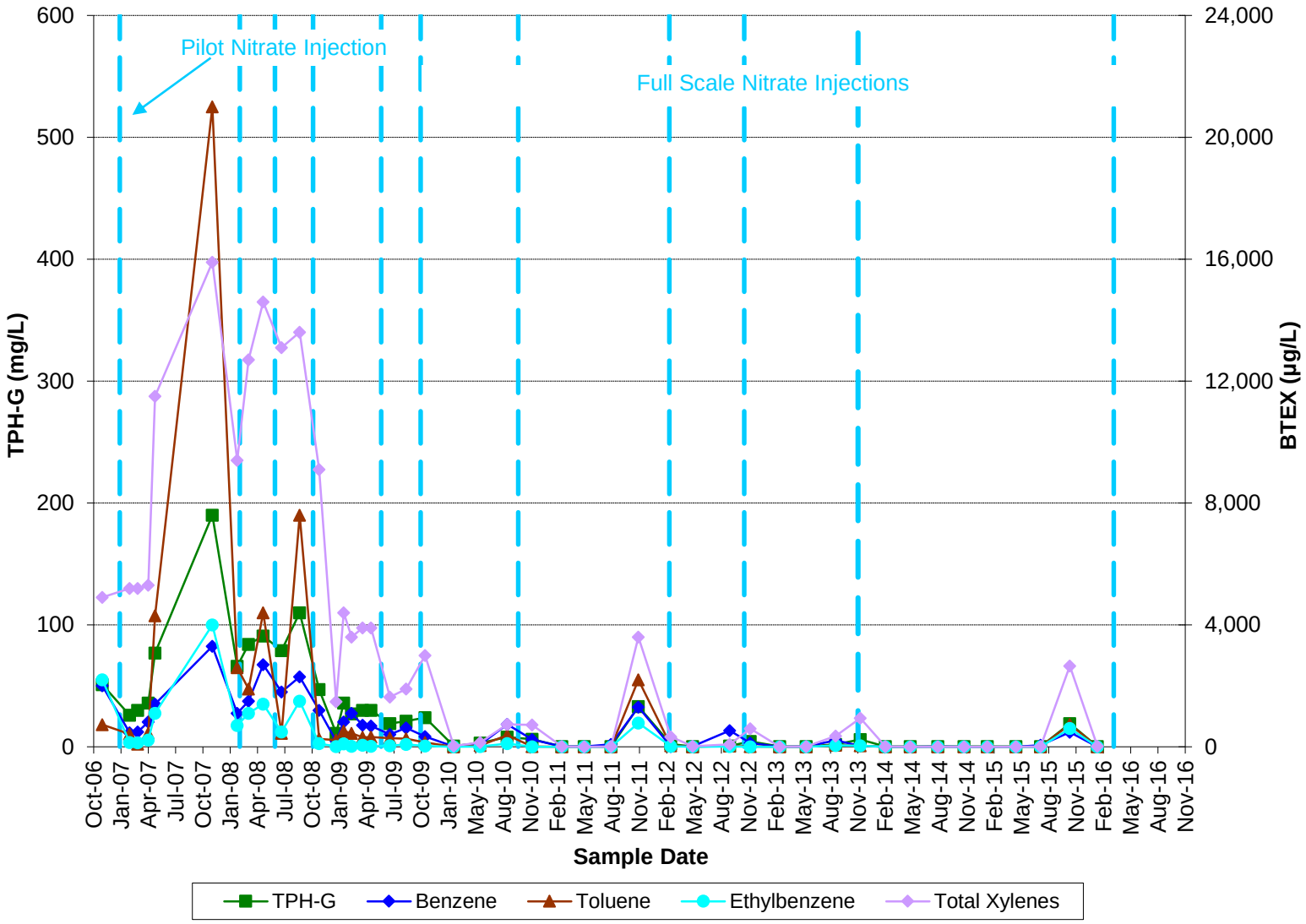
Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



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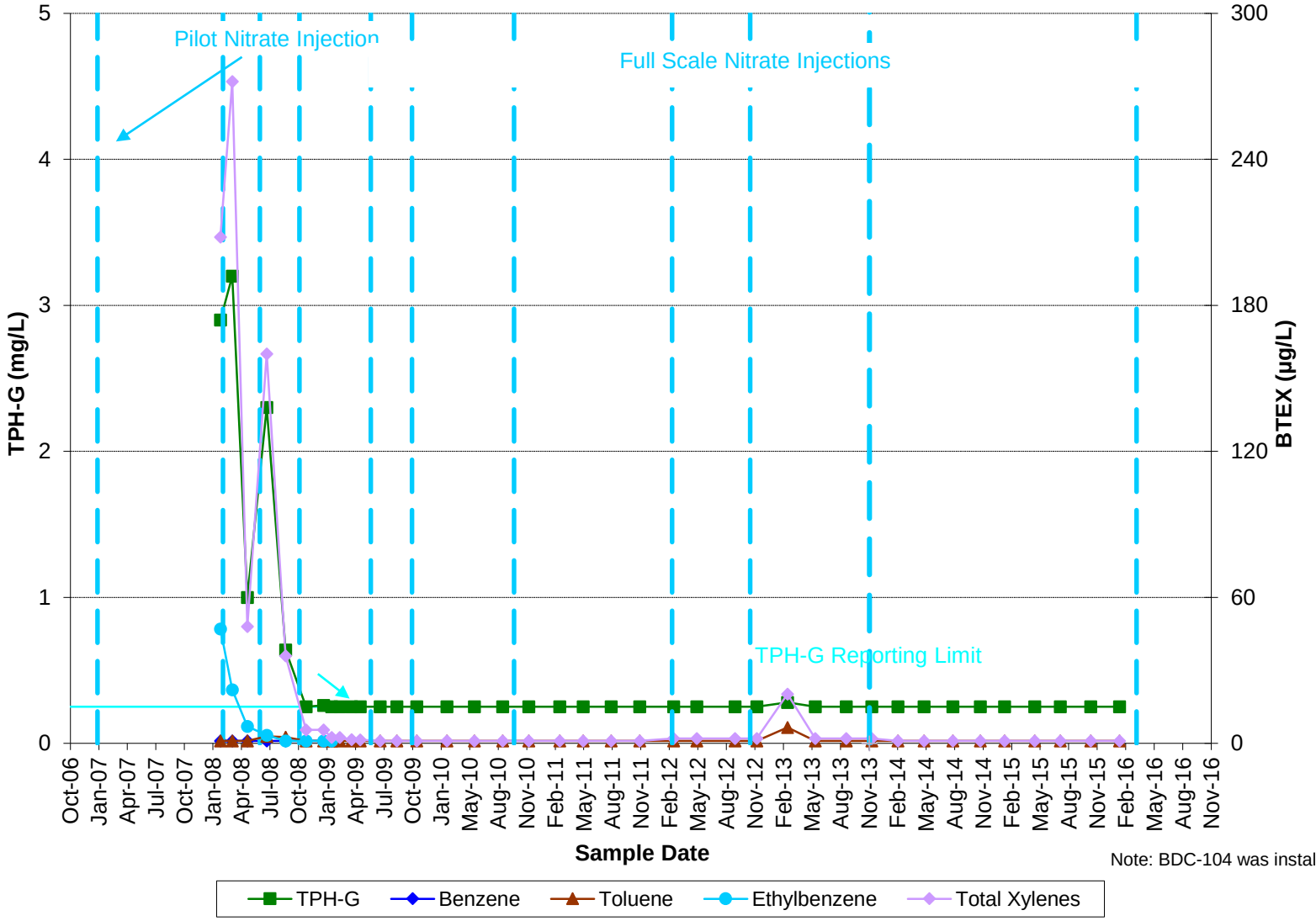
Boeing Developmental Center
Tukwila, Washington

BDC-103 TPH-G and BTEX Concentrations Beginning with 2007 Pilot Testing

Figure
4

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



Note: BDC-104 was installed February 2008

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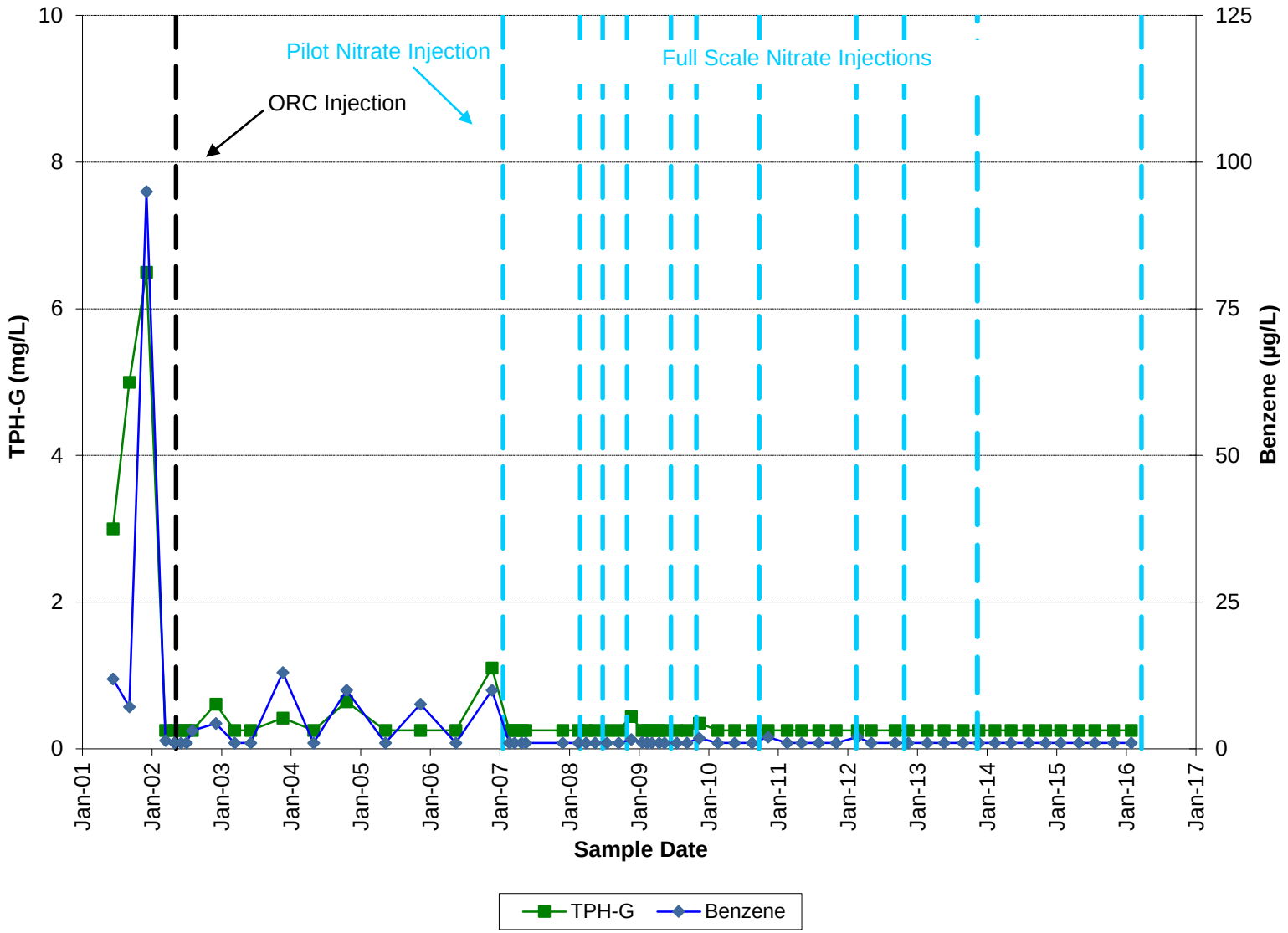
Boeing Developmental Center
Tukwila, Washington

BDC-104 TPH-G and BTEX Concentrations Beginning with 2007 Pilot Testing

Figure
5

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



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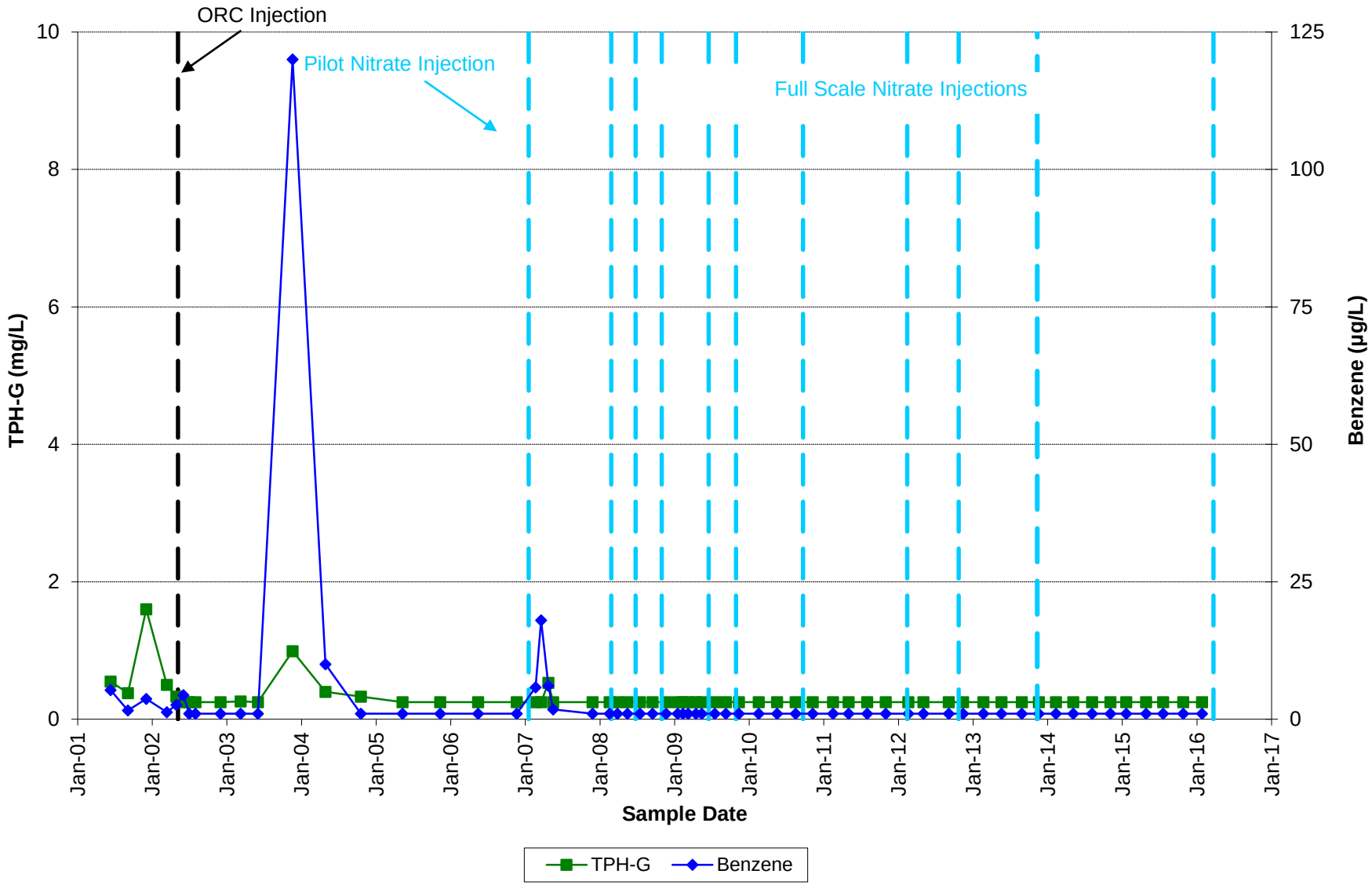
Boeing Developmental Center
Tukwila, Washington

BDC-101 TPH-G and Benzene Concentrations Since 2001

Figure
6

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



Boeing Developmental Center Tukwila, Washington	**BDC-102 TPH-G and Benzene Concentrations Since 2001**	Figure 7

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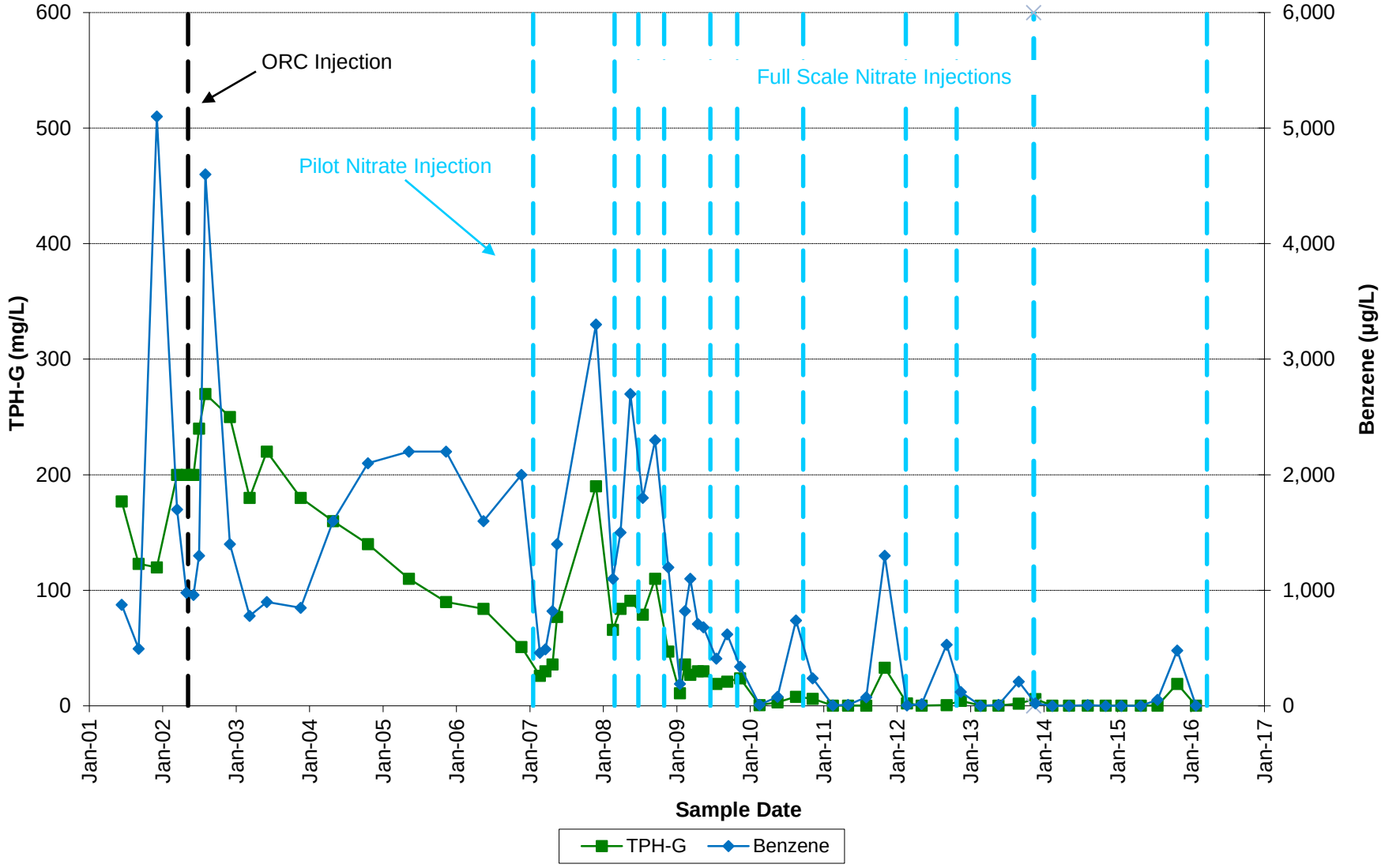
Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



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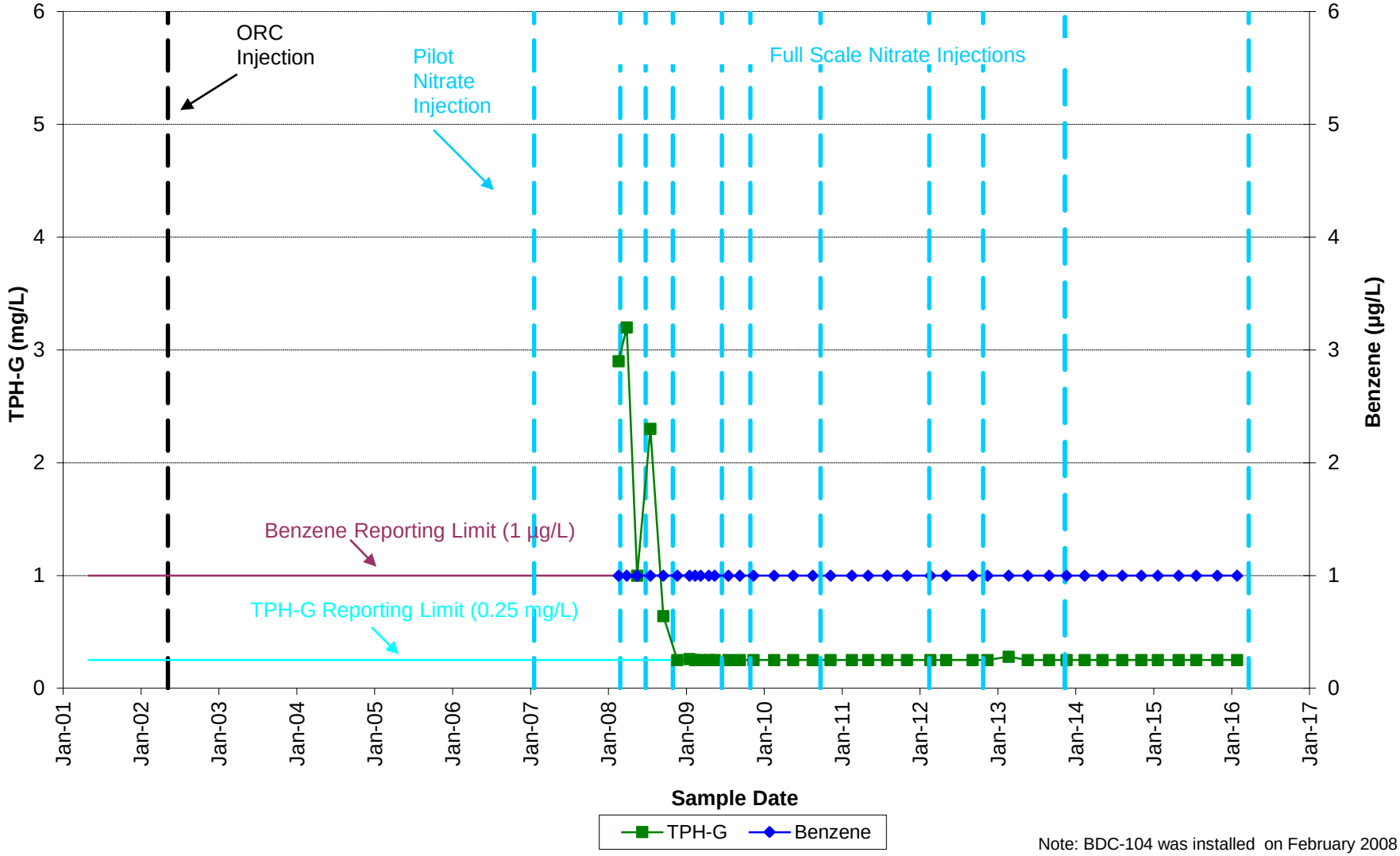
Boeing Developmental Center
Tukwila, Washington

BDC-103 TPH-G and Benzene Concentrations Since 2001

Figure
8

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



Note: BDC-104 was installed on February 2008

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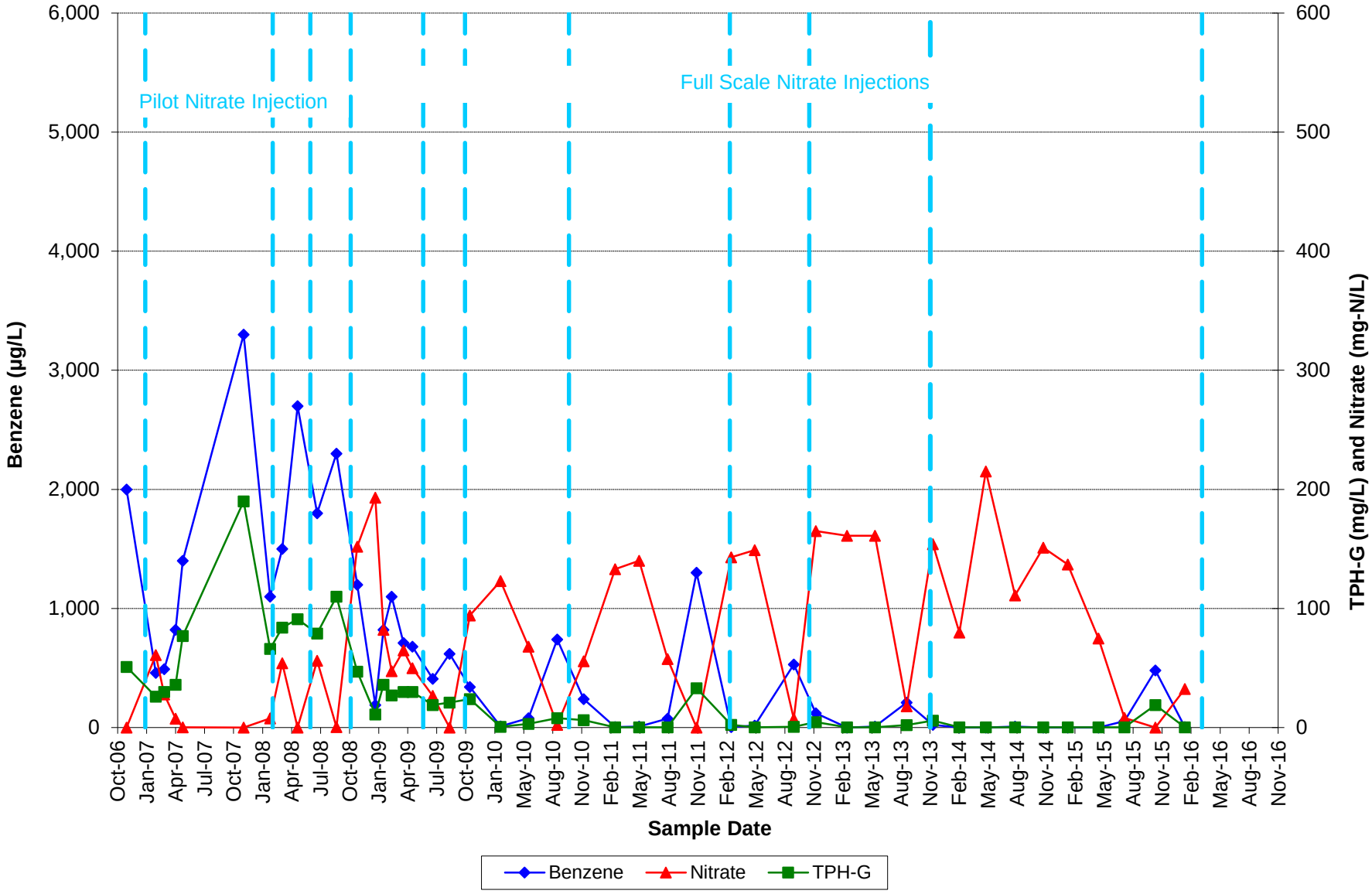
Boeing Developmental Center
Tukwila, Washington

BDC-104 TPH-G and Benzene Concentrations Since 2001

Figure
9

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



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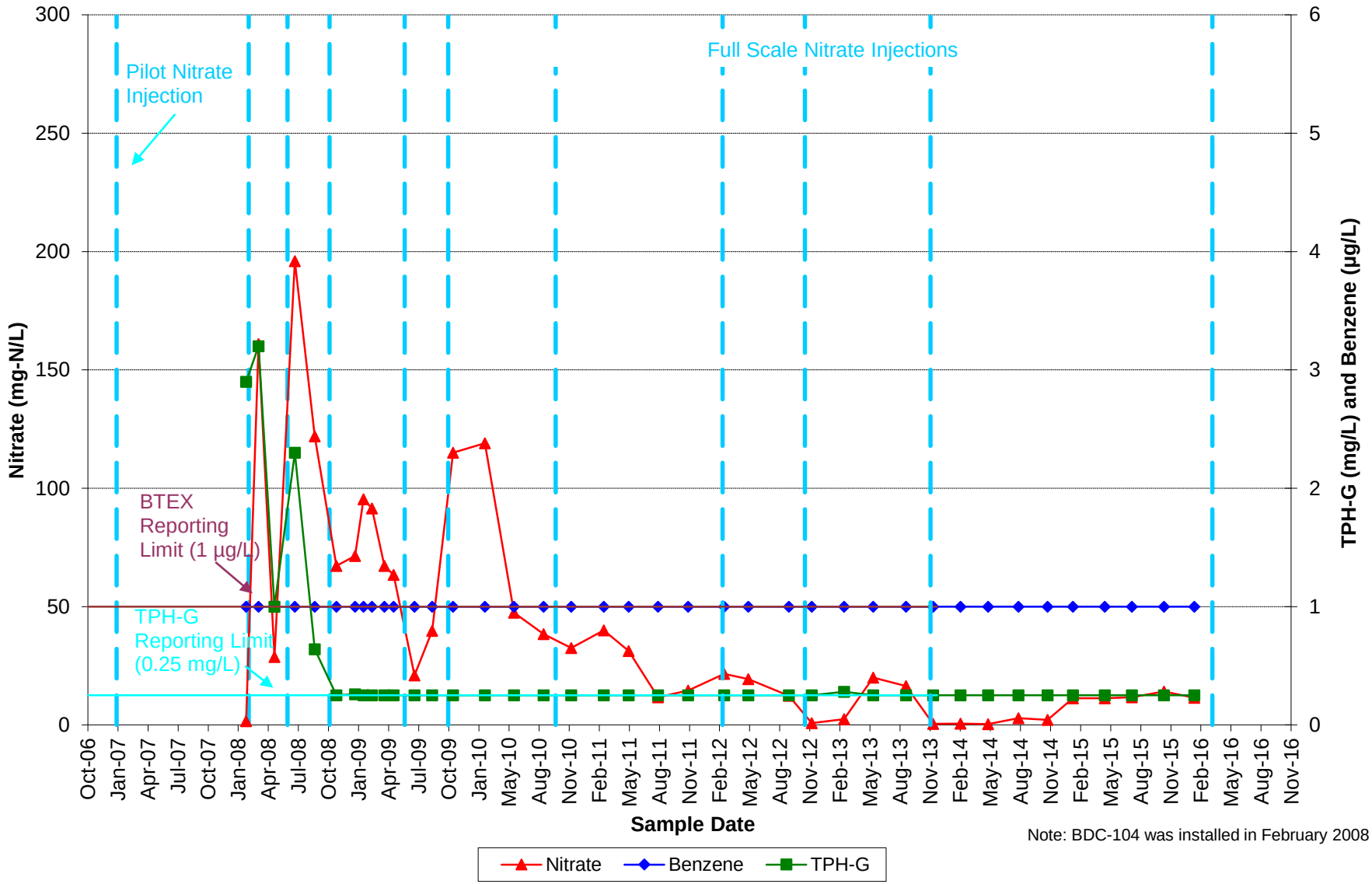
Boeing Developmental Center
Tukwila, Washington

BDC-103 Nitrate, TPH-G, and Benzene Concentrations

Figure
10

Source: P:\025\093\WIP\T\AOC-5\AOC-5 cleanup action tables MASTER.xlsx



Note: BDC-104 was installed in February 2008

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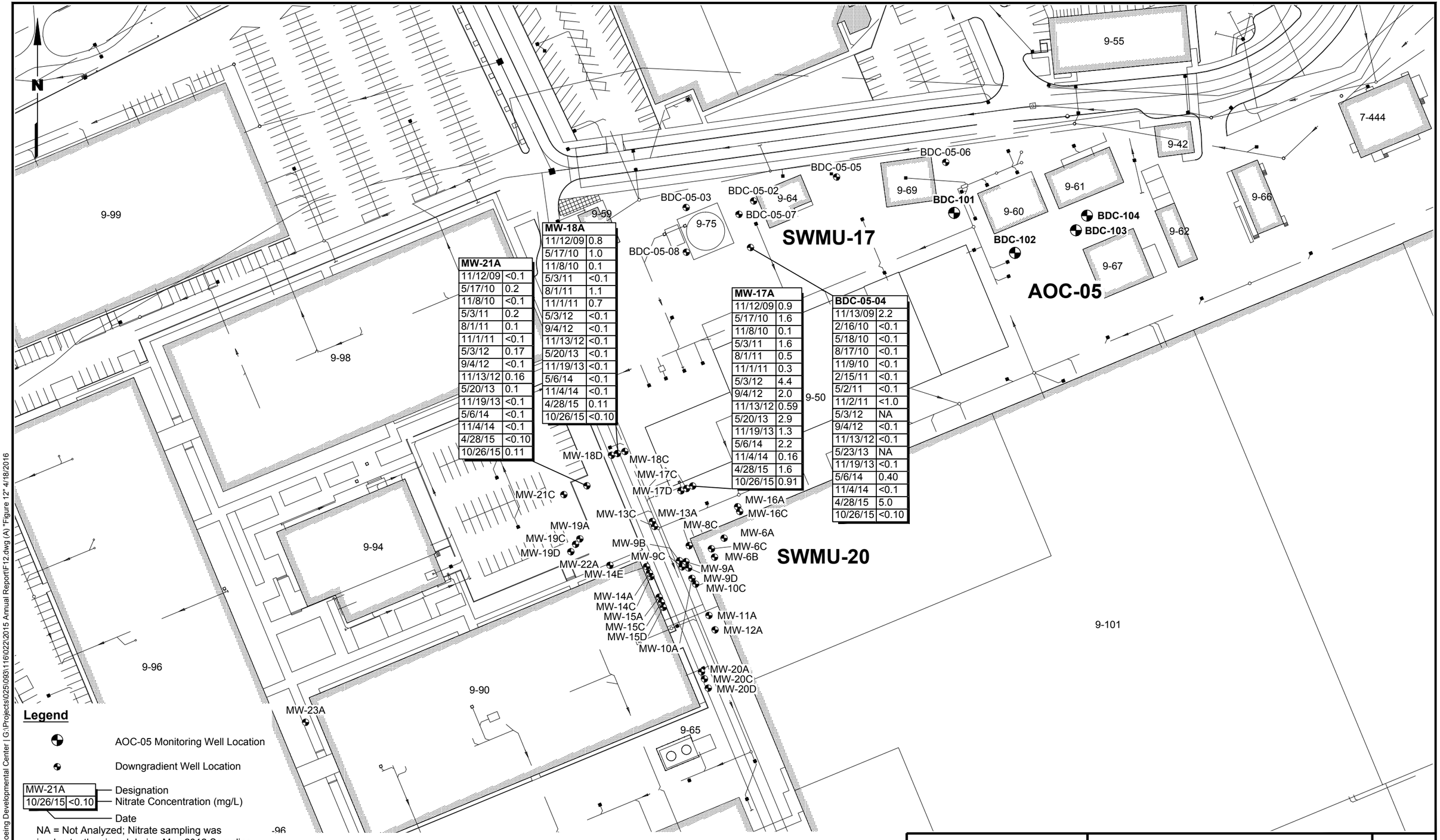
Boeing Developmental Center
Tukwila, Washington

BDC-104 Nitrate, TPH-G, and Benzene Concentrations

Figure
11



Boeing Developmental Center | G:\Projects\025\093\116\022\2015 Annual Report\F12.dwg (A) "Figure 12" 4/18/2016

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Boeing Developmental Center Tukwila, Washington	**Nitrate Concentrations at Downgradient Monitoring Locations**	Figure 12

TABLE 1
AOC-05 CLEANUP ACTION SUMMARY
DEVELOPMENTAL CENTER GROUNDWATER MONITORING

		ORC	Pilot	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale																	
		Injection	Injection	Injection 1	Injection 2	Injection 3	Injection 4	Injection 5	Injection 6	Injection 7	Injection 8	Injection 9	Injection 10																	
		BDC-103	BDC-103	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103	BDC-103	BDC-103	BDC-103	BDC-103	Volatile Organic Compounds (all units in ug/L)							Aquifer Redox Conditions								Donor Indicators	
		Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	TPH-G	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	DO	Nitrate	Nitrite	Iron II	Sulfate	Methane	ORP	TOC	pH	
														(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(mg-N/L)	(mg-N/L)	(mg/L)	(mg/L)	(µg/L)	(mV)	(mg/L)		
Proposed Groundwater Cleanup Levels (a)														**0.8**	**2.0**	**1294**	**1.7**	**NA**	**NA**	**1546**										
Well	Date																													Comments
BDC-101	6/11/2001													3.0	11.9	<1.0	113.1			109.2										
BDC-101	9/4/2001													5.0	7.13	10.7	50.4			53.8										
BDC-101	12/3/2001													6.5	95	1.6	750			650										
BDC-101	3/13/2002													<0.25	1.4	<1.0	4.4			<1.0										
BDC-101	4/29/2002	-8												<0.25	<1.0	<1.0	2.2	<1.0	<1.0	<1.0										
BDC-101	6/3/2002	27												<0.25	1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-101	7/1/2002	55												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-101	8/1/2002	86												<0.25	3.1	<1.0	2.4	<1.0	<1.0	<1.0										
BDC-101	12/2/2002	209												0.61	4.3	<1.0	21	27	6.4	33.4										
BDC-101	3/10/2003	307												<0.25	1.0	<1.0	4.5	3.2	<1.0	3.2										
BDC-101	6/3/2003	392												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-101	11/19/2003	561												0.42	13	<1.0	15	35	<1.0	35	0.36	1.1	0.010	0.2	16	240	120.3			
BDC-101	4/28/2004	722												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-101	10/18/2004	895												0.64	10	<1.0	15	43	<1.0	43										
BDC-101	5/10/2005	1099												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-101	11/10/2005	1283												0.25	7.6	<1.0	2.6	42	<1.0	42	0.96	4.4			34.3		259	2.05		
BDC-101	5/15/2006	1469												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.78	17.8	0.059	0.0	64.1		80			
BDC-101	11/20/2006	1658	-59											1.1	10	<1.0	15	72.0	<1.0	72	0.92	0.122	0.016	2.4	8.7		174			
BDC-101	2/20/2007	1750	33											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.39	15.0	0.047	0.2	50.0		277		6.63	
BDC-101	3/19/2007	1777	60											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.97	8.83	0.037	0.5	38.5		213		6.60	
BDC-101	4/24/2007	1813	96											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.09	9.59	0.041	0.5	34.1		136		6.46	
BDC-101	5/17/2007	1836	119											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.35	9.95	0.046	0.4	35.7		297		6.55	
BDC-101	11/26/2007	2029	312											<0.25	<1.0	<1.0	2.1	6.5	<1.0	6.5	2.30	5.88	0.032	0.0	26.8		287			
BDC-101	2/18/2008	2113	396	-8										<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.55	8.10	0.040	0.0	31.5		341		6.29	
BDC-101	3/27/2008	2151	434	30										<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.19	9.3	<0.10	0.2	40.0		506			
BDC-101	5/15/2008	2200	483	79	-40									<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.57	6.8	<0.10	0.0	24.6		176		6.44	
BDC-101	7/16/2008	2262	545	141	22									<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.34	5.3	<0.10	0.0	21.8		-232		6.52	
BDC-101	9/15/2008	2323	606	202	83	-45								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.22	5.33	0.023	0.0	28.7		153			
BDC-101	11/20/2008	2389	672	268	149	21								0.44	1.6	<1.0	<1.0	<1.0	<1.0	<1.0	1.45	2.9	0.1	0.8	17.1		-22		6.65	
BDC-101	1/16/2009	2446	729	325	206	78								<0.25	1.1	<1.0	<1.0	<1.0	<1.0	<1.0	0	4.40	0.042	0.4	29.5		-245		6.50	
BDC-101	2/11/2009	2472	755	351	232	104								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.62	8.5	<0.1	0.4	39.6		-16		6.43	
BDC-101	3/9/2009	2498	781	377	258	130								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.93	9.4	<0.1	0.0	46.8		54		6.54	
BDC-101	4/16/2009	2536	819	415	296	168								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.69	9.0	<0.1	0.0	36.0		131		6.61	
BDC-101	5/14/2009	2564	847	443	324	196	-34							<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.00	13.0	<0.1	0.0	44.4		68		6.81	
BDC-101	7/17/2009	2628	911	507	388	260	30							<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.80	12.6	<0.1	0.0	49.0		19		7.17	
BDC-101	9/9/2009	2682	965	561	442	314	84	-49						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.25	6.2	<0.1	0.0	31.7		179		6.90	
BDC-101	11/12/2009	2746	1029	625	506	378	148	15						0.35	1.8	<1.0	6.6	16	<1.0	16	1.37	11.3	<0.1	0-0.2	36.7		124		6.53	Very faint iron measurement
BDC-101	2/17/2010	2843	1126	722	603	475	245	112						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.86	13.9	<0.1	0.0	48.7		640		6.55	
BDC-101	5/17/2010	2932	1215	811	692	564	334	201						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.20	20.7	<1.0	0.0	58.7		372		6.86	
BDC-101	8/16/2010	3023	1306	902	783	655	425	292	-37					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.21	15.6	<0.1	0.0	56.9		76		7.21	
BDC-101	11/8/2010	3107	1390	986	867	739	509	376	47					<0.25	2.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.02	2.2	<0.1	0.4	14.7		145		6.97	
BDC-101	2/16/2011	3207	1490	1086	967	839	609	476	147					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	7.46	23.9	<0.1	0.0	68.2		161		7.30	
BDC-101	5/3/2011	3283	1566	1162	1043	915	685	552	223					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.57	23.7	<0.1	0.0	66.2		208		6.99	
BDC-101	8/1/2011	3373	1656	1252	1133	1005	775	642	313					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.50	17.9	<0.1	0.0	48.1		150		7.07	
BDC-101	11/1/2011	3465	1748	1344	1225	1097	867	734	405	-105				<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.69	6.1	<0.1	0.0	24.8		40		7.23	
BDC-101	2/19/2012	3575	1858	1454	1335	1207	977	844	515	5				<0.25	2.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.53	6.6		0.3	27.7		12		6.81	
BDC-101	5/3/2012	3649	1932	1528	1409	1281	1051	918	589	79				<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	3.75	15.9		0.0	51.2		263		6.60	
BDC-101	9/4/2012	3773	2056	1652	1533	1405	1175	1042	713	203	-49			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.88	13.8	<0.10	0.0	36.0		154		6.97	
BDC-101	11/13/2012	3843	2126	1722	1603	1475	1245	1112	783	273	21			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.41	10.3	<0.10	0.0	40.4		150		6.90	
BDC-101	2/20/2013	3942	2225	1821	1702	1574	1344	1211	882	372	120			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	2.55	21.3	<0.10	0.2	68.0		73		6.83	
BDC-101	5/20/2013	4031	2314	1910	1791	1663	1433	1300	971	461	209			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	3.35	17	<0.10	0.0	52.9		-190		6.72	
BDC-101	8/28/2013	4131	2414	2010	1891	1763	1533	1400	1071	561	309	-76		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	1.99	10.5	<0.10	0.0	41.5		-277		6.46	
BDC-101	11/19/2013	4214	2497	2093	1974	1846	1616	1483	1154	644	392	7		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	2.53	7.6	<0.10	0.0	28.3		-173		6.67	
BDC-101	2/11/2014	4298	2581	2177	2058	1930	1700	1567	1238	728	476	91		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.65	7.7	<0.10	0.0	29.1		-223		6.80	
BDC-101	5/6/2014	4382	2665	2261	2142	2014	1784	1651	1322	812	560	175		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.79	19.6	<0.10	0.0	64.2		-149		6.71	
BDC-101	8/7/2014	4475	2758	2354	2235	2107	1877	1744	1415	905	653	268		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.25	17.2	<0.10	0.0	51.4		71		7.22	
BDC-101	11/4/2014	4564	2847	2443	2324	2196	1966	1833	1504	994	742	357		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.22	7.8	<0.10	0.0	29.7		77		6.72	
BDC-101	1/21/2015	4642	2925	2521	2402	2274	2044	1911	1582	1072	820	435		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.07	21.3	<0.10	0.0	44.6		97		6.29	
BDC-101	4/28/2015	4739	3022	2618	2499	2371	2141	2008	1679	1169	917	532		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.55	19.1	<0.10	0.0	48.4		82		6.37	
BDC-101	7/20/2015	4822	3105	2701	2582	2454	2224	2091	1762	1252	1000	615		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.96	19.7	<0.10	0.2	57.2		96		6.30	
BDC-101	10/26/2015	4920	3203	2799	2680	2552	2322	2189	1860	1350	1098	713		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.63	8.8	<0.10	0.0	38.6		92		6.64	
BDC-101	1/27/2016	5013	3296	2892	2773	2645	2415	2282	1953	1443	1191	806	-56	<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	7.37	12.3	<0.10	0.0	40.3		102		6.48	

TABLE 1
AOC-05 CLEANUP ACTION SUMMARY
DEVELOPMENTAL CENTER GROUNDWATER MONITORING

		ORC	Pilot	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale														
		Injection	Injection	Injection 1	Injection 2	Injection 3	Injection 4	Injection 5	Injection 6	Injection 7	Injection 8	Injection 9	Injection 10														
		BDC-103	BDC-103	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103	BDC-103	BDC-103	BDC-103	BDC-103	Volatile Organic Compounds (all units in ug/L)							Aquifer Redox Conditions							Donor Indicators	
		Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	TPH-G	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	DO	Nitrate	Nitrite	Iron II	Sulfate	Methane	ORP	TOC	pH	
														(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(mg-N/L)	(mg-N/L)	(mg/L)	(mg/L)	(µg/L)	(mV)	(mg/L)		
Proposed Groundwater Cleanup Levels (a)														**0.8**	**2.0**	**1294**	**1.7**	**NA**	**NA**	**1546**										
Well	Date																													Comments
BDC-102	6/11/2001													0.55	5.33	<1.0	<1.0			<1.0										
BDC-102	9/4/2001													0.38	1.61	1.89	<1.0			1.87										
BDC-102	12/3/2001													1.6	3.7	<1.0	<1.0			3.49										
BDC-102	3/13/2002													0.50	1.3	<1.0	<1.0			<1.0										
BDC-102	4/29/2002	-8												0.33	2.6	<1.0	<1.0	1.1	<1.0	1.1										
BDC-102	6/3/2002	27												<0.25	4.4	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	7/1/2002	55												0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	8/1/2002	86												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	12/2/2002	209												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	3/10/2003	307												0.26	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	6/3/2003	392												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	11/19/2003	561												0.99	120	<1.0	8.5	<1.0	<1.0	<1.0	0.38	0.19	0.011	5.5	46	1100	122.2			
BDC-102	4/28/2004	722												0.40	10	<1.0	<1.0	3.0	<1.0	3.0										
BDC-102	10/18/2004	895												0.33	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	5/10/2005	1099												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0										
BDC-102	11/10/2005	1283												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.82	4.4			34.0		122	18.4		
BDC-102	5/15/2006	1469												<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.21	4.72	0.175	2.2	35.7		-11			
BDC-102	11/20/2006	1658	-59											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.25	<0.250	<0.250	2.2	9.2		163			
BDC-102	2/20/2007	1750	33											<0.25	5.8	<1.0	<1.0	<1.0	<1.0	<1.0	0.47	0.749	0.027	3.0	25.3		-145		6.54	
BDC-102	3/19/2007	1777	60											<0.25	18	<1.0	<1.0	32	<1.0	32	0.88	0.938	0.072	3.0	31.0		-98		6.67	
BDC-102	4/24/2007	1813	96											0.53	6.1	<1.0	3.1	100	<1.0	100	1.20	1.94	0.051	2.8	40.4		-93		6.51	
BDC-102	5/17/2007	1836	119											<0.25	1.8	<1.0	<1.0	7.4	<1.0	7.4	0.84	2.78	0.108	2.6	33.9		286		6.52	
BDC-102	11/26/2007	2029	312											<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.29	1.03	0.247	3.0	55.7		46			
BDC-102	2/18/2008	2113	396	-8										<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.51	3.91	0.054	2.8	42.8		431		5.97	
BDC-102	3/27/2008	2151	434	30										<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.85	1.3	<0.10	2.5	17.9		233			
BDC-102	5/15/2008	2200	483	79	-40									<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.40	3.0	<0.10	3.5	19.2		-115		6.56	
BDC-102	7/16/2008	2262	545	141	22									<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.46	2.5	<0.10	3.2	13.7		-312		6.67	
BDC-102	9/15/2008	2323	606	202	83	-45								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.22	4.28	0.056	3.0	31.6		191			
BDC-102	11/20/2008	2389	672	268	149	21								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.70	0.40	<0.10	2.0	5.6		-70		6.69	
BDC-102	1/16/2009	2446	729	325	206	78								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.00	<0.100	0.200	2.5	8.3		-235		6.70	
BDC-102	2/11/2009	2472	755	351	232	104								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.65	2.4	<0.1	3.0	20.4		-70		6.61	
BDC-102	3/9/2009	2498	781	377	258	130								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.00	0.9	<0.1	3.0	8.7		-46		6.65	
BDC-102	4/16/2009	2536	819	415	296	168								<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.30	0.6	<0.1	3.0	8.3		-7		6.66	
BDC-102	5/14/2009	2564	847	443	324	196	-34							<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.29	0.9	<0.1	3.4	9.8		-35		6.78	
BDC-102	7/17/2009	2628	911	507	388	260	30							<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.66	4.9	<0.1	2.2	28.6		-11		6.46	
BDC-102	9/9/2009	2682	965	561	442	314	84	-49						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.91	0.4	<0.1	2.7	5.5		2.8		6.66	
BDC-102	11/12/2009	2746	1029	625	506	378	148	15						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.93	0.2	<0.1	3.2	2.4		-42.0		6.49	
BDC-102	2/17/2010	2843	1126	722	603	475	245	112						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.90	3.4	0.2	2.8	17.2		892		6.56	
BDC-102	5/17/2010	2932	1215	811	692	564	334	201						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.35	8.4	<1.0	3.0	30.1		440		6.61	
BDC-102	8/16/2010	3023	1306	902	783	655	425	292	-37					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.61	8.9	<0.1	3.0	27.8		82		6.60	
BDC-102	11/8/2010	3107	1390	986	867	739	509	376	47					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.34	0.4	<0.1	2.0	6.9		45		7.09	
BDC-102	2/16/2011	3207	1490	1086	967	839	609	476	147					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.68	3.5	<0.1	2.2	43.3		399		6.88	
BDC-102	5/3/2011	3283	1566	1162	1043	915	685	552	223					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.60	12.1	<0.1	2.0	32.4		40		6.70	
BDC-102	8/1/2011	3373	1656	1252	1133	1005	775	642	313					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	7.01	13.6	<0.1	2.1	28.7		11		6.88	
BDC-102	11/1/2011	3465	1748	1344	1225	1097	867	734	405	-105				<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.45	9.8	<0.1	1.5	30.9		-48		7.19	
BDC-102	2/19/2012	3575	1858	1454	1335	1207	977	844	515	5				<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.25	2.4		1.0	15.4		21		6.60	
BDC-102	5/3/2012	3649	1932	1528	1409	1281	1051	918	589	79				<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.22	11.3		2.5	40.2		248		6.44	
BDC-102	9/4/2012	3773	2056	1652	1533	1405	1175	1042	713	203	-49			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.20	13.2	<5.0	1.5	39.2		130		6.63	
BDC-102	11/13/2012	3843	2126	1722	1603	1475	1245	1112	783	273	21			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.10	1.7	<0.10	1.6	27.7		48		6.77	
BDC-102	2/20/2013	3942	2225	1821	1702	1574	1344	1211	882	372	120			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.17	18.4	<0.10	1.0	58.5		92		6.60	
BDC-102	5/20/2013	4031	2314	1910	1791	1663	1433	1300	971	461	209			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.49	20	<0.10	1.5	62.2		-280		7.31	
BDC-102	8/28/2013	4131	2414	2010	1891	1763	1533	1400	1071	561	309	-76		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	1.93	12.2	<0.10	1.0	39.1		-341		6.45	
BDC-102	11/19/2013	4214	2497	2093	1974	1846	1616	1483	1154	644	392	7		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	3.89	10.6	<0.10	1.2	43.4		-254		6.54	
BDC-102	2/11/2014	4298	2581	2177	2058	1930	1700	1567	1238	728	476	91		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	4.16	19.6	<0.10	2.2	63.0		-246		6.67	
BDC-102	5/6/2014	4382	2665	2261	2142	2014	1784	1651	1322	812	560	175		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.65	14.8	<0.10	1.6	56.1		-275		6.54	
BDC-102	8/7/2014	4475	2758	2354	2235	2107	1877	1744	1415	905	653	268		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.07	26.7	<0.10	1.4	65.8		-65		7.01	
BDC-102	11/4/2014	4564	2847	2443	2324	2196	1966	1833	1504	994	742	357		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.11	22.4	<0.10	1.2	55.9		-15.3		6.47	
BDC-102	1/21/2015	4642	2925	2521	2402	2274	2044	1911	1582	1072	820	435		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.20	12.9	<0.10	1.0	49.7		-22		6.14	
BDC-102	4/28/2015	4739	3022	2618	2499	2371	2141	2008	1679	1169	917	532		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.22	23.1	<0.10	0.6	77.5		28		6.13	
BDC-102	7/20/2015	4822	3105	2701	2582	2454	2224	2091	1762	1252	1000	615		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.33	15.5	<0.10	1.0	63.3		-54		6.18	
BDC-102	10/26/2015	4920	3203	2799	2680	2552	2322	2189	1860	1350	1098	713		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.23	10.9	<0.10	1.0	47.5		-42		6.41	
BDC-102	1/27/2016	5013	3296	2892	2773	2645	2415	2282	1953	1443	1191	806	-56	<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.35	0.62	<0.10	1.0	11.9		-124		6.61	

TABLE 1
AOC-05 CLEANUP ACTION SUMMARY
DEVELOPMENTAL CENTER GROUNDWATER MONITORING

		ORC Injection	Pilot Injection	Full Scale Injection 1	Full Scale Injection 2	Full Scale Injection 3	Full Scale Injection 4	Full Scale Injection 5	Full Scale Injection 6	Full Scale Injection 7	Full Scale Injection 8	Full Scale Injection 9	Full Scale Injection 10																	
		BDC-103	BDC-103	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103	BDC-103	BDC-103	BDC-103	BDC-103	Volatile Organic Compounds (all units in ug/L)							Aquifer Redox Conditions								Donor Indicators	
		Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	TPH-G	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	DO	Nitrate	Nitrite	Iron II	Sulfate	Methane	ORP	TOC	pH	
														(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(mg-N/L)	(mg-N/L)	(mg/L)	(mg/L)	(µg/L)	(mV)	(mg/L)		
Proposed Groundwater Cleanup Levels (a)														**0.8**	**2.0**	**1294**	**1.7**	**NA**	**NA**	**1546**										
Well	Date																													Comments
BDC-103	6/11/2001													177	875	12,010	1,985			11,430										
BDC-103	9/4/2001													123	494	3,760	419			2,636										
BDC-103 (b)	12/3/2001													120	5,100	2,300,000	10,000			3,400,000										
BDC-103	3/13/2002													200	1,700	17,000	4,900			26,400										
BDC-103	4/29/2002	-8												200	980	16,000	5,400	20,000	7,000	27,000										
BDC-103	6/3/2002	27												200	960	17,000	5,100	20,000	7,100	27,100										
BDC-103	7/1/2002	55												240	1,300	16,000	5,200	20,000	6,800	26,800										
BDC-103	8/1/2002	86												270	4,600	18,000	5,200	19,000	6,600	25,600										
BDC-103	12/2/2002	209												250	1,400	15,000	5,000	22,000	6,900	28,900										
BDC-103	3/10/2003	307												180	780	13,000	5,200	20,000	6,700	26,700										
BDC-103	6/3/2003	392												220	900	10,000	5,000	20,000	6,600	26,600										
BDC-103	11/19/2003	561												180	850	8,300	4,500	18,000	5,500	23,500	0.38	0.012	0.011	5.5	53	630	-75.9			
BDC-103	4/28/2004	722												160	1,600	6,600	3,900	16,000	5,100	21,100										
BDC-103	10/18/2004	895												140	2,100	5,500	3,700	15,000	4,400	19,400										
BDC-103	5/10/2005	1099												110	2,200	5,500	3,800	14,000	3,200	17,200										
BDC-103	11/10/2005	1283												90	2,200	3,500	3,700	12,000	2,500	15,000	0.72	<1.0			11.9		147	15.4		
BDC-103	5/15/2006	1469												84	1,600	3,800	3,100	10,000	2,200	12,000	0.92	<0.010	0.054	3.5	15.2		106			
BDC-103	11/20/2006	1658	-59											51	2,000	730	2,200	3,900	1,000	4,900	1.23	<0.10	<0.10	2.4	28.3		202			
BDC-103	2/20/2007	1750	33											26	460	420	140	3,600	1,600	5,200	0.31	60.8	11.1	0.5	99.2		109		6.54	
BDC-103	3/19/2007	1777	60											30	490	88	130	3,500	1,700	5,200	0.63	27.9	8.28	0.4	141		4		6.79	
BDC-103	4/24/2007	1813	96											36	820	440	220	3500	1800	5300	0.84	7.54	3.56	2.4	59.2		-14		6.70	
BDC-103	5/17/2007	1836	119											77	1,400	4,300	1,100	8,300	3,200	11,500	0.61	0.138	0.079	3.6	169		244		6.82	
BDC-103	11/26/2007	2029	312											190	3,300	21,000	4,000	11,000	4,900	15,900	3.37	0.063	0.049	3.6	49.1		-118			
BDC-103	2/18/2008	2113	396	-8										66	1,100	2,600	700	7,500	1,900	9,400	2.06	7.75	0.134	2.8	163		552		5.97	
BDC-103	3/27/2008	2151	434	30										84	1,500	1,900	1,100	9,700	3,000	12,700	1.60	54.1	18	4.0	115.0		182			
BDC-103	5/15/2008	2200	483	79	-40									91	2,700	4,400	1,400	11,000	3,600	14,600	1.38	<0.10	<0.10	3.2	192		-138		7.11	
BDC-103	7/16/2008	2262	545	141	22									79	1,800	440	490	10,000	3,100	13,100	1.61	56.1	16.6	2.8	149		-226		6.72	
BDC-103	9/15/2008	2323	606	202	83	-45								110	2,300	7,600	1,500	10,000	3,600	13,600	0.48	0.330	0.218	3.2	218		189			
BDC-103	11/20/2008	2389	672	268	149	21								47	1,200	260	110	7,000	2,100	9,100	0.21	152	12.5	2.0	120		-1.2		6.66	
BDC-103	1/16/2009	2446	729	325	206	78								11	190	220	12	1,000	480	1,480	0.24	193	2.32	0.6	62.5		-181		6.19	
BDC-103	2/11/2009	2472	755	351	232	104								36	820	510	<100	2,900	1,500	4,400	1.66	82.0	6.7	0.8	178		-65		6.69	
BDC-103	3/9/2009	2498	781	377	258	130								27	1100	440	18	2,400	1,200	3,600	0	47.3	2.4	0.4	192		17		6.80	
BDC-103	4/16/2009	2536	819	415	296	168								30	710	310	<50	2,700	1,200	3,900	0.95	64.8	5.6	0.2-0.4	194		62		6.77	
BDC-103	5/14/2009	2564	847	443	324	196	-34							30	680	320	20	2,400	1,500	3,900	0.48	49.8	4.8	0.8	222		20		6.85	
BDC-103	7/17/2009	2628	911	507	388	260	30							19	410	280	32	630	1,000	1,630	2.60	26.6	2.0	1.0	104		29		6.98	
BDC-103	9/9/2009	2682	965	561	442	314	84	-49						21	620	270	83	700	1200	1,900	0.88	<0.1	<0.1	2.5	134		2.8		7.01	
BDC-103	11/12/2009	2746	1029	625	506	378	148	15						24	340	140	27	1,800	1,200	3,000	1.42	94.1	7.7	0.4	71.7		117		6.11	
BDC-103	2/17/2010	2843	1126	722	603	475	245	112						0.73	10	<1.0	<1.0	3.1	22	25	1.45	123	1.1	0.0	60.3		939		6.22	
BDC-103	5/17/2010	2932	1215	811	692	564	334	201						3.1	79	44	5.2	60	86	146	1.56	67.9	2.6	0.4	71.6		436		6.63	
BDC-103	8/16/2010	3023	1306	902	783	655	425	292	-37					8.0	740	380	110	420	320	740	2.24	2.4	0.1	2.0	72.5		184		6.96	
BDC-103	11/8/2010	3107	1390	986	867	739	509	376	47					6.3	240	11	1.7	180	540	720	7.46	55.8	1.5	0.0	123		199		7.05	
BDC-103	2/16/2011	3207	1490	1086	967	839	609	476	147					0.28	4.6	<1.0	<1.0	<1.0	5.4	5.4	5.18	133	0.6		74.6		508		6.52	
BDC-103	5/3/2011	3283	1566	1162	1043	915	685	552	223					<0.25	9.1	<1.0	<1.0	<1.0	2.2	2.2	2.15	140	0.2	0.0	74.4		393		6.35	
BDC-103	8/1/2011	3373	1656	1252	1133	1005	775	642	313					0.30	76	<1.0	1.8	7.8	2.5	10.3	5.67	57.6	<0.1	0.2	63.2		168		7.09	
BDC-103	11/1/2011	3465	1748	1344	1225	1097	867	734	405	-105				33	1300	2200	780	2300	1300	3,600	1.72	<0.1	<0.1	1.2	8.1		-226		7.38	
BDC-103	2/19/2012	3575	1858	1454	1335	1207	977	844	515	5				2.2	5.1	31	19	260	69	329	0.21	143		0.3	57.1		36		6.41	
BDC-103	5/3/2012	3649	1932	1528	1409	1281	1051	918	589	79				<0.25	16	1.4	<1.0	3.6	14	17.6	0.11	149	0.83	0.0	56.2		239		6.49	
BDC-103	9/4/2012	3773	2056	1652	1533	1405	1175	1042	713	203	-49			0.72	530	24.0	9.4	40	42	82	0.45	7.2	<0.10	0.4	66.9		146		6.80	
BDC-103	11/13/2012	3843	2126	1722	1603	1475	1245	1112	783	273	21			4.5	120	9.5	3.7	210	380	590	1.02	165	2.8	0.4	93.6		108		6.50	
BDC-103	2/20/2013	3942	2225	1821	1702	1574	1344	1211	882	372	120			<0.25	<1.0	<1.0	<1.0	<2.0	3.4	3.4	0.14	161	0.60	0.2	51.6		109		6.42	
BDC-103	5/20/2013	4031	2314	1910	1791	1663	1433	1300	971	461	209			<0.25	9.3	<1.0	<1.0	4.4	1.8	6.2	0.29	161	<0.10	0.0	47.1		-281		7.47	
BDC-103	8/28/2013	4131	2414	2010	1891	1763	1533	1400	1071	561	309	-76		2	210	56	47	260	91	351	1.60	17.8	0.16	0.6	54.2		-290		6.83	
BDC-103	11/19/2013	4214	2497	2093	1974	1846	1616	1483	1154	644	392	7		5.9	22	37	31	590	350	940	4.42	154	2.6	0.0	51.0		-222		6.48	
BDC-103	2/11/2014	4298	2581	2177	2058	1930	1700	1567	1238	728	476	91		<0.25	<1.0	<1.0	<1.0	4.9	3.6	8.5	2.81	79.9	0.15	0.0	99.2		-254		6.77	
BDC-103	5/6/2014	4382	2665	2261	2142	2014	1784	1651	1322	812	560	175		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.19	215	<0.10	0.0	59.8		-233		6.21	
BDC-103	8/7/2014	4475	2758	2354	2235	2107	1877	1744	1415	905	653	268		<0.25	7.8	<1.0	<1.0	2.4	<1.0	2.4	2.67	111	<0.10	0.0	59.7		-46		7.14	
BDC-103	11/4/2014	4564	2847	2443	2324	2196	1966	1833	1504	994	742	357		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.27	151	0.68	0.0	66.7		121		6.31	
BDC-103	1/21/2015	4642	2925	2521	2402	2274	2044	1911	1582	1072	820	435		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.20	137	0.27	0.0	69.1		118		6.05	
BDC-103	4/28/2015	4739	3022	2618	2499	2371	2141	2008	1679	1169	917	532		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.16	74.8	<0.10	0.0	90.3		44		6.23	
BDC-103	7/20/2015	4822	3105	2701	2582	2454	2224	2091	1762	1252	1000	615		<0.25	54	1.0	3.7	8.3	2.6	10.9	0.18	8.1	<0.10	0.2	70.9		-22		6.48	
BDC-103	10/26/2015	4920	3203	2799	2680	2552	2322	2189	1860	1350	1098	713		19	480	740	600	1800	850	2650	0.11	<0.10	<0.10	1.0	0.55		-85		6.61	
BDC-103	1/27/2016	5013	3296	2892	2773	2645	2415	2282	1953	1443	1191	806	-56	<0.25	3.9	1.2	3.3	12	7.0	19	0.22	32.5	<0.10	0.0	102		-10		6.56	

TABLE 1
AOC-05 CLEANUP ACTION SUMMARY
DEVELOPMENTAL CENTER GROUNDWATER MONITORING

		ORC	Pilot	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale														
		Injection	Injection	Injection 1	Injection 2	Injection 3	Injection 4	Injection 5	Injection 6	Injection 7	Injection 8	Injection 9	Injection 10														
		BDC-103	BDC-103	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103/104	BDC-103	BDC-103	BDC-103	BDC-103	BDC-103	Volatile Organic Compounds (all units in ug/L)							Aquifer Redox Conditions							Donor Indicators	
		Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	Elapsed Time from Injection (days)	TPH-G	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	DO	Nitrate	Nitrite	Iron II	Sulfate	Methane	ORP	TOC	pH
														(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(mg-N/L)	(mg-N/L)	(mg/L)	(mg/L)	(µg/L)	(mV)	(mg/L)	
Proposed Groundwater Cleanup Levels (a)														**0.8**	**2.0**	**1294**	**1.7**	**NA**	**NA**	**1546**									
Well	Date																												Comments
BDC-104	2/18/2008	2113	396	-8										2.9	<1.0	<1.0	47	180	28	208	2.09	1.63	0.072	3.0	18.7		598			
BDC-104	3/27/2008	2151	434	30										3.2	<1.0	<1.0	22	220	52	272	1.34	161	0.1	0.5	52.2		259			
BDC-104	5/15/2008	2200	483	79	-40									1.0	<1.0	<1.0	7.0	26	22	48	1.24	28.7	0.7	0.4	26.6		94		6.69	
BDC-104	7/16/2008	2262	545	141	22									2.3	<1.0	2.9	3.3	110	50	160	1.56	196	0.4	0.0	74.7		-221		7.17	
BDC-104	9/15/2008	2323	606	202	83	-45								0.64	<1.0	2.6	<1.0	20	16	36	0.06	122	0.729	0.0	38.4		191			
BDC-104	11/20/2008	2389	672	268	149	21								<0.25	<1.0	<1.0	<1.0	1.4	4.1	5.5	0.96	67.2	<0.10	0.2	24.3		-27		7.46	
BDC-104	1/16/2009	2446	729	325	206	78								0.26	<1.0	<1.0	<1.0	<1.0	5.5	5.5	0.05	71.4	0.204	0.6	34.6		-164		6.86	
BDC-104	2/11/2009	2472	755	351	232	104								<0.25	<1.0	<1.0	<1.0	1.3	1.1	2.4	1.78	95.4 J	0.1	0.2	20.1		-75		6.68	
BDC-104	3/9/2009	2498	781	377	258	130								<0.25	<1.0	<1.0	<1.0	1.3	1.1	2.4	0	91.5	<0.1	0.0	19.2		20		6.67	
BDC-104	4/16/2009	2536	819	415	296	168								<0.25	<1.0	<1.0	<1.0	<1.0	1.6	1.6	0.34	67.2	<0.1	0.0	21.6		67		6.63	
BDC-104	5/14/2009	2564	847	443	324	196	-34							<0.25	<1.0	<1.0	<1.0	<1.0	1.4	1.4	0.51	63.4	<0.1	0.0	20.1		6		6.70	
BDC-104	7/17/2009	2628	911	507	388	260	30							<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.41	21.0	0.5	1.0	30.8		-3		7.30	
BDC-104	9/9/2009	2682	965	561	442	314	84	-49						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.63	39.8	0.1	0.8	41.6		61		7.20	
BDC-104	11/12/2009	2746	1029	625	506	378	148	15						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.99	115	1.4	0.0	24.1		68		6.49	
BDC-104	2/17/2010	2843	1126	722	603	475	245	112						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.73	119	0.1	0.0	111		868		6.93	
BDC-104	5/17/2010	2932	1215	811	692	564	334	201						<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.98	47.4	<1.0	0.6	30.5		482		6.74	
BDC-104	8/16/2010	3023	1306	902	783	655	425	292	-37					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.59	38.4	0.2	2.5	23.6		76		6.92	
BDC-104	11/8/2010	3107	1390	986	867	739	509	376	47					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.87	32.5	<0.1	0.0	18.6		115		7.23	
BDC-104	2/16/2011	3207	1490	1086	967	839	609	476	147					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.48	40.0	<0.1	0.4	24.1		423		6.71	
BDC-104	5/3/2011	3283	1566	1162	1043	915	685	552	223					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.19	31.3	<0.1	1.2	26.8		231		6.63	
BDC-104	8/1/2011	3373	1656	1252	1133	1005	775	642	313					<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.10	11.7	<0.1	0.0	21.2		121		7.20	
BDC-104	11/1/2011	3465	1748	1344	1225	1097	867	734	405	-105				<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.43	14.6	<0.1	0.0	18.7		-53		7.40	
BDC-104	2/19/2012	3575	1858	1454	1335	1207	977	844	515	5				<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.26	21.6		0.0	29.2		66		6.23	
BDC-104	5/3/2012	3649	1932	1528	1409	1281	1051	918	589	79				<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.06	19.4		1.5	26.5		207		6.78	
BDC-104	9/4/2012	3773	2056	1652	1533	1405	1175	1042	713	203	-49			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.68	12.3	<0.10	0.5	22.1		130		7.11	
BDC-104	11/13/2012	3843	2126	1722	1603	1475	1245	1112	783	273	21			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.24	0.80	<0.10		5.1		64		7.19	
BDC-104	2/20/2013	3942	2225	1821	1702	1574	1344	1211	882	372	120			0.28	<1.0	6.5	<1.0	17	3.3	20.3	0.44	2.5	<0.10	0.2	3.6		82		6.96	
BDC-104	5/20/2013	4031	2314	1910	1791	1663	1433	1300	971	461	209			<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	2.01	20.0	<0.10	0.0	20.8		-230		7.16	
BDC-104	8/28/2013	4131	2414	2010	1891	1763	1533	1400	1071	561	309	-76		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	0.52	16.4	<0.10	1.0	35.3		-322		6.82	
BDC-104	11/19/2013	4214	2497	2093	1974	1846	1616	1483	1154	644	392	7		<0.25	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0	8.09	0.47	<0.10	0.0	3.1		-35		7.16	
BDC-104	2/11/2014	4298	2581	2177	2058	1930	1700	1567	1238	728	476	91		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.11	0.54	<0.10	0.0	3.4		-135		7.04	
BDC-104	5/6/2014	4382	2665	2261	2142	2014	1784	1651	1322	812	560	175		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	8.49	0.35	<0.10	0.0	4.2		-113		6.82	
BDC-104	8/7/2014	4475	2758	2354	2235	2107	1877	1744	1415	905	653	268		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.04	2.9	<0.10	0.0	4.4		64		7.44	
BDC-104	11/4/2014	4564	2847	2443	2324	2196	1966	1833	1504	994	742	357		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.66	2.1	<0.10	0.0	10.1		39		6.50	
BDC-104	1/21/2015	4642	2925	2521	2402	2274	2044	1911	1582	1072	820	435		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	4.02	11.3	<0.10	0.0	36.3		135		5.87	
BDC-104	4/28/2015	4739	3022	2618	2499	2371	2141	2008	1679	1169	917	532		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.37	11.3	<0.10	0.0	74.4		85		6.09	
BDC-104	7/20/2015	4822	3105	2701	2582	2454	2224	2091	1762	1252	1000	615		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.18	11.7	<0.10	0.2	74.4		-22		6.48	
BDC-104	10/26/2015	4920	3203	2799	2680	2552	2322	2189	1860	1350	1098	713		<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.20	14.1	<0.10	1.0	84.2		-2.0		6.72	
BDC-104	1/27/2016	5013	3296	2892	2773	2645	2415	2282	1953	1443	1191	806	-56	<0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.13	11.5	<0.10	0.0	69.1		16.0		6.67	

Injection	Months
Dates	Elapsed
5/7/2002	
1/18/2007	57
2/26/2008	13
6/24/2008	4
10/30/2008	4
6/17/2009	8
10/28/2009	4
9/22/2010	11
2/14/2012	17
10/23/2012	8
11/12/2013	13
3/23/2016	29

ORC
Pilot -scale nitrate
1st full scale injection
2nd full scale injection
3rd full scale injection
4th full scale injection (start ammonium phosphate, 1/3 ammonium nitrate dose to both wells)
5th full scale injection (103 full dose, 104 half dose)
6th full scale injection (103 only full dose)
7th full scale injection (103 only full dose)
8th full scale injection (103 only 1.5x volume dose)
9th full scale injection (103 only 1.5x volume dose)
10th full scale injection (103 only 1.5x volume, half concentration dose)

TPH-G = total petroleum hydrocarbon-gasoline
DO = dissolved oxygen
µg/L = micrograms pr liter
mg/L = milligrams per liter
mV = millivolts
NA = not analyzed
NA = not applicable, not available
ORP = oxidation reduction potential
TOC = total organic carbon
= No sample collected or sample not analyzed for specified constituent.
Box = Exceedance of proposed CUL

(a) Proposed Cleanup Standards and Comparison to Site Data, Boeing Developmental Center, Tukwila,Washington (Landau Associates, 5/7/13).
(b) BTEX data questionable for this event. Concentrations inconsistent with TPH-G data for indicated event and BTEX data from other events.

2/19/12 = LLI 1290767, 1291164

TABLE 2
REMEDIATION PROGRESS SUMMARY AND KEY MILESTONES
AOC-05 BIOREMEDIATION REMEDIAL ACTION
BOEING DEVELOPMENTAL CENTER

	2008				2009				2010				2011				2012				2013				2014				2015				2016
	Quarter				Quarter				Quarter				Quarter				Quarter				Quarter				Quarter				Quarter				Quarter
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
BDC-101																																	
TPH-G													*												*	*		*					
Benzene													*												*	*		*					
Toluene													*												*	*		*					
Ethylbenzene													*												*	*		*					
Total Xylenes													*												*	*		*					
BDC-102																																	
TPH-G													*												*	*		*					
Benzene													*												*	*		*					
Toluene													*												*	*		*					
Ethylbenzene													*												*	*		*					
Total Xylenes													*												*	*		*					
BDC-103	NI	NI		NI		NI		NI		NI							NI			NI			NI										NI
TPH-G				↓	↓				↓*				↓*	↓*		*					*				*	*		*				*		
Benzene					↓				↓*				↓*			*					↓*				*	*	*	*			*			
Toluene	↓		↓	↓	↓			↓	↓				*			*					*				*	*		*			*			
Ethylbenzene			↓	↓	↓				↓				*			*					*				*	*		*			*			
Total Xylenes				↓	↓				↓				↓*	↓		*					*				*	↓*	*	*			*			
BDC-104	NI	NI		NI		NI		NI																									
TPH-G		↓		↓									*												*	*		*					
Benzene													*												*	*		*					
Toluene													*												*	*		*					
Ethylbenzene	↓	↓	↓										*												*	*		*					
Total Xylenes		↓	↓	↓	↓	↓	↓						*												*	*		*					

BTEX = benzene, toluene, ethylbenzene, and xylenes
NI = Nitrate injection at the specified well.
TPH-G = total petroleum hydrocarbons- Gasoline range
↓ = The specified contaminant reaches historic lows.

= Contaminant concentration greater than proposed cleanup level.
= Contaminant concentration less than the proposed clean up level, but greater than the laboratory reporting limit.
= Contaminant concentration less than the laboratory reporting limit.

* - Key milestones, described below

2010, 1st Quarter - Concentrations of TPH-G and benzene fall below screening levels for the first time since monitoring began in 2001.
2011, 1st Quarter - Concentrations of all contaminants reach historic lows in BDC-103. All contaminant concentrations are below screening levels in all four wells.
2011, 2nd Quarter - The TPH-G concentration in BDC-103 falls below the laboratory reporting limits for the first time since monitoring began in 2001.
2011, 4th Quarter - Contaminant concentrations rebound due to a high groundwater table, prompting additional injection.
2013, 1st Quarter - Contaminant concentrations were all below reporting limits at BDC-103, with the exception of low-level detections of total xylenes; lowest concentrations since monitoring began in 2001.
2014, 1st Quarter - Contaminant concentrations were all below reporting limits at BDC-103, with the exception of low-level detections of total xylenes; the second time this has occurred since monitoring began in 2001.
2014, 2nd Quarter - Contaminants are below laboratory reporting limits for in all four wells for the first time since monitoring began in 2001.
2014, 3rd Quarter - Concentrations of benzene and total xylenes in BDC-103 rebound slightly due to a historically shallow groundwater table.
2014, 4th Quarter - All contaminant concentrations in all four wells return to below laboratory reporting limits.
2011, 4th Quarter - Contaminant concentrations rebound due to a high groundwater table, prompting additional injection.
2015, 3rd Quarter - BTEX concentrations rebound due to nitrate depletion.
2015, 4th Quarter - TPH-G concentrations rebound due to nitrate depletion.

TABLE 3
NITRATE CONCENTRATIONS AT DOWNGRADIENT MONITORING LOCATIONS
AOC-05 ANAEROBIC BIOREMEDIATION REMEDIAL ACTION
BOEING DEVELOPMENTAL CENTER

				Aquifer Redox Conditions					
				DO	**Nitrate**	Iron II	Sulfate	Methane	ORP
Area	Well	Date		(mg/L)	**(mg-N/L)**	(mg/L)	(mg/L)	(mg/L)	(mV)
SWMU-17	BDC-05-04	5/15/2006	Natural Redox Baseline		**12.3**	2.6	33.4		
SWMU-17	BDC-05-04	10/23/2008		2.45	**7.6**	0.1	31.0	0.29	73.5
SWMU-17	BDC-05-04	11/2/2008		0.59	**4.5**	0.8	25,2	0.05	-16
SWMU-17	BDC-05-04	12/16/2008		0.55	**5.5**	1.0	30.4	1.61	-98
SWMU-17	BDC-05-04	1/16/2009		0.06	**4.3**	1.0	21.8	1.48	-192
SWMU-17	BDC-05-04	2/11/2009		2.45	**5.9**	1.0	31.8	1.06	-54
SWMU-17	BDC-05-04	3/9/2009		0.27	**4.8**	1.5	30.1	0.20	35
SWMU-17	BDC-05-04	4/16/2009		1.48	**5.9**	1.4	33.6	<0.0007	68
SWMU-17	BDC-05-04	5/13/2009		0.33	**4.5**	1.6	26.6	0.37	49
SWMU-17	BDC-05-04	8/16/2009		0.86	**5.4**	2.2	30.6	<0.0007	93
SWMU-17	BDC-05-04	11/13/2009	Downgradient Monitoring Triggered	0.56	**2.2**	3.0	18.4	2.44	109
SWMU-17	BDC-05-04	2/16/2010		0.88	**<0.1**	3.3	24.6	1.49	899
SWMU-17	BDC-05-04	5/18/2010		0.75	**<0.1**	3.0	25.4	1.32	473
SWMU-17	BDC-05-04	8/17/2010		1.00	**<0.1**	2.8	17.1	3.53	108
SWMU-17	BDC-05-04	11/9/2010		2.21	**<0.1**	2.2	21.3	3.00	101
SWMU-17	BDC-05-04	2/15/2011		2.50	**<0.1**	2.4	19.4	4.46	93
SWMU-17	BDC-05-04	5/2/2011		1.69	**<0.1**	2.2	18.0	1.75	49
SWMU-17	BDC-05-04	11/2/2011		1.52	**<1.0**	1.2	<1.0		-3
SWMU-17	BDC-05-04	5/7/2012		0.16		2.0	21.5		98
SWMU-17	BDC-05-04	9/4/2012		0.21	**<0.10**		16.6		96
SWMU-17	BDC-05-04	11/13/2012		0.03	**<0.10**	1.8	16.9		64
SWMU-17	BDC-05-04	5/23/2013		0.49		1.5	13.7		-310
SWMU-17	BDC-05-04	11/19/2013		2.56	**<0.10**	1.0	13.2		-259
SWMU-17	BDC-05-04	5/6/2014		3.49	**0.40**		14.4		-299
SWMU-17	BDC-05-04	11/4/2014		0.05	**<0.10**	1.6	<1.0		-126
SWMU-17	BDC-05-04	4/28/2015		0.11	**5.0**	0.4	13.5		74
SWMU-17	BDC-05-04	10/26/2015		0.08	**<0.10**	1.5	<1.0		-101
SWMU-20	MW-17A	05/15/2006	Natural Redox Baseline		**1.37**	0.0	27.0		
SWMU-20	MW-17A	11/12/2009	Downgradient Monitoring Triggered		**0.9**				
SWMU-20	MW-17A	5/17/2010			**1.6**	0.2	21.0		
SWMU-20	MW-17A	11/8/2010			**0.1**	2.1	15.7		
SWMU-20	MW-17A	5/3/2011			**1.6**	0.0	19.8		
SWMU-20	MW-17A	8/1/2011			**0.5**	0.0	20.5		
SWMU-20	MW-17A	11/1/2011			**0.3**	0.0	23.2		
SWMU-20	MW-17A	5/3/2012			**4.4**	0.0			
SWMU-20	MW-17A	9/4/2012			**2.0**		26.8		
SWMU-20	MW-17A	11/13/2012			**0.59**	0.0	22.9		
SWMU-20	MW-17A	5/20/2013			**2.9**		26.8		
SWMU-20	MW-17A	11/19/2013			**1.3**	0.4	23.9		
SWMU-20	MW-17A	5/6/2014			**2.2**	0.0	23.7		
SWMU-20	MW-17A	11/4/2014			**0.16**	0.4	26.0		
SWMU-20	MW-17A	4/28/2015			**1.6**	0.0	26.3		
SWMU-20	MW-17A	10/26/2015		0.17	**0.91**	0.0	29.0		-11.1
SWMU-20	MW-18A	05/15/2006	Natural Redox Baseline		**0.154**	0.4	64.8		
SWMU-20	MW-18A	11/12/2009	Downgradient Monitoring Triggered		**0.8**				
SWMU-20	MW-18A	05/17/2010			**1.0**	0.4	32.2		
SWMU-20	MW-18A	11/08/2010			**0.1**	0.0	14.2		
SWMU-20	MW-18A	5/3/2011			**<0.1**	0.0	31.5		
SWMU-20	MW-18A	8/1/2011			**1.1**	0.0	42.2		
SWMU-20	MW-18A	11/1/2011			**0.7**	0.0	93.3		
SWMU-20	MW-18A	5/3/2012			**<0.10**	0.0			
SWMU-20	MW-18A	9/4/2012			**<0.10**		19.5		
SWMU-20	MW-18A	11/13/2012			**<0.10**	0.0	21.5		
SWMU-20	MW-18A	5/20/2013			**<0.10**		19.6		
SWMU-20	MW-18A	11/19/2013			**<0.10**	0.6	15.0		
SWMU-20	MW-18A	5/6/2014			**<0.10**	0.0	26.1		
SWMU-20	MW-18A	11/4/2014			**<0.10**	0.4	21.0		
SWMU-20	MW-18A	4/28/2015			**0.11**	0.0	19.1		
SWMU-20	MW-18A	10/26/2015		0.10	**<0.10**	0.6	23.4		-7.1

TABLE 3
NITRATE CONCENTRATIONS AT DOWNGRADIENT MONITORING LOCATIONS
AOC-05 ANAEROBIC BIOREMEDIATION REMEDIAL ACTION
BOEING DEVELOPMENTAL CENTER

				Aquifer Redox Conditions					
				DO	**Nitrate**	Iron II	Sulfate	Methane	ORP
Area	Well	Date		(mg/L)	**(mg-N/L)**	(mg/L)	(mg/L)	(mg/L)	(mV)
SWMU-20	MW-21A	05/15/2006	Natural Redox Baseline		**0.136**	0.4	54.9		
SWMU-20	MW-21A	11/12/2009	Downgradient Monitoring Triggered		**<0.1**				
SWMU-20	MW-21A	05/17/2010			**0.2**	0.0	11.9		
SWMU-20	MW-21A	11/08/2010			**<0.1**	0.0	5.9		
SWMU-20	MW-21A	5/3/2011			**0.2**	0.0	52.1		
SWMU-20	MW-21A	8/1/2011			**0.1**	0.0	26.7		
SWMU-20	MW-21A	11/1/2011			**<0.1**	0.0	9.3		
SWMU-20	MW-21A	5/3/2012			**0.17**	0.0			
SWMU-20	MW-21A	9/4/2012			**<0.10**		6.7		
SWMU-20	MW-21A	11/13/2012			**0.16**	0.0	18.5		
SWMU-20	MW-21A	5/20/2013			**0.10**	0.5	13.5		
SWMU-20	MW-21A	11/19/2013			**<0.10**	0.0	15.6		
SWMU-20	MW-21A	5/6/2014			**<0.10**	0.0	7.6		
SWMU-20	MW-21A	11/4/2014			**<0.10**	0.0	5.1		
SWMU-20	MW-21A	4/28/2015			**<0.10**	0.0	5.3		
SWMU-20	MW-21A	10/26/2015		0.33	**0.11**	0.0	3.9		10.3

DO = dissolved oxygen
mg/L = milligrams per liter
mg/NL = mg/L as nitrogen
mV = millivolt
ORP = oxidation reduction potential
Nitrate column bolded for emphasis of target compound. Other results included for aquifer redox evaluation.
= not analyzed