PBOW
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October 19, 2004

Commander
U.S. Army Engineer District, Nashville
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Nashville, Tennessee 37203

Background Monitoring Well Selection
For the Phase II Groundwater Remedial Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Dear Mrs. Ingram:

Seven possible background bedrock groundwater monitoring wells at the above noted facility, have been sampled on a quarterly basis beginning in September-October 2001, to determine the background concentration of inorganics in bedrock groundwater. Shaw is providing this technical memorandum for review and approval from PBOW Team Members of wells that were selected, prior to report preparation. Prior review and approval of this background monitoring well data set will reduce subsequent comments and revisions to the 2004 Groundwater Data Summary and Evaluation Report, scheduled for November 2004.

Please submit any external comments within **2 weeks or by November 1, 2004** to Mrs. Linda Ingram at the USACE office in Nashville, Tennessee. Use email address Linda.Ingram@lrn02.usace.army.mil or you may send a written response to the following address:

Department of the Army
Nashville District, Corps of Engineers
ATTN: CELRN-EC-R-M (Mr. Linda Ingram)
P.O. Box 1070
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Should you have any questions or require additional information regarding this submittal, please do not hesitate to call me at (865) 694-7496.

Sincerely,

Steven T. Downey, P.E.
Project Manager

Enclosures

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Evaluation and Selection of Background Groundwater Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio
September 2004

1.0 Introduction

Seven new and existing monitoring wells have been sampled to determine the background concentrations of inorganics in bedrock groundwater at the Former Plum Brook Ordnance Works (PBOW), Sandusky, Ohio. The purpose of this technical memorandum is to qualitatively evaluate the suitability of these wells for determining background concentrations and to obtain approval from PBOW Team Members prior to report preparation. Prior review and approval of a background data set will reduce subsequent comments and revisions to the Draft 2004 Groundwater Data Summary and Evaluation Report, scheduled for November 2004.

Data from the following 5existing wells (installed prior to November 2001) and 2 newly installed wells (installed in August 2003) were evaluated to determine whether groundwater data collected from these wells was representative of background conditions. Evaluation criteria included well yield, groundwater flow direction, water quality parameters, and the presence of groundwater contamination.

2.0 Potential Background Monitoring Well Locations

For evaluating background bedrock groundwater, monitoring wells furthest upgradient of known PBOW contaminant sources is required. In general, bedrock groundwater flow at the PBOW site is in the northeast direction, toward Lake Erie. This interpretation is based on consistent observations of quarterly groundwater elevation data collected over the past 2 years. Potential upgradient background monitoring wells include those installed as part of historical site investigations and those installed as part of the focused background investigation. In all, the following wells were evaluated:

- BG8-BEDGW-001
- PB-BED-MW24
- PB-BED-MW25
- PB-BED-MW26
- PB-BED-MW28
- PB-BED-MW29.

Locations of all potential background wells evaluated in this document are shown on Figure 1.

Wells BG8-BEDGW-001 and PB-BED-MW20 have been used for previous groundwater investigations and are upgradient of known PBOW contaminant sources. Bedrock monitoring well BG8-BEDGW-001 is located in the extreme western part of the PBOW facility, south of the G-8 Burning Ground Area and TNT Manufacturing Area C. Monitoring well PB-BED-MW20 is located in the extreme southern portion of the PBOW facility west of the intersection of Taft and Patrol Roads.

To supplement these existing background wells and better provide for site-wide bedrock groundwater coverage, monitoring wells PB-BED-MW24, PB-BED-MW25, and PB-BED-MW26 were installed in August 2001. Bedrock monitoring well PB-BED-MW24 is located in the extreme western part of the PBOW facility, southwest of Acid Area No. 2 and west of the West Area Red Water Ponds. Bedrock well PB-BED-MW25 is located in the extreme southwest part of the PBOW facility, southeast of the Lower Toluene Tanks Area and well PB-BED-MW26 is located in the extreme southwest part of the PBOW facility.

Evaluation of background PBOW bedrock groundwater from the identified wells began in the fall of 2001. Groundwater samples were attempted to be collected by the low-flow (minimal drawdown) sampling methodology if recharge of bedrock groundwater allowed, and if not, were collected by bailer. Groundwater sampling was performed on a quarterly basis in relation to a calculated "wet" and "dry" climatological season for the PBOW site. Based on historical rainfall records and evapotranspiration rates, the wet season (time the greatest volume of groundwater potentially present) for the Sandusky area was determined to be during the months of January through June and the dry season (time the least amount of groundwater potentially present) was identified as July through December. After the first year (4 quarters) of groundwater sampling, analytical data was reviewed. Low levels of nitroaromatics in the bedrock groundwater were intermittently detected in wells PB-BED-MW20 (nitrobenzene-April 2002), PB-BED-MW24 (nitrobenzene, RDX, and 2,6-DNT-April 2002), and PB-BED-MW25 (nitrobenzene-April 2002). Since these wells were located on PBOW property, it was thought the low levels of nitroaromatics may be site related. Based on discussions with the Ohio Environmental Protection Agency, two additional rounds of groundwater sampling were conducted in October 2002 and April 2003 to verify the detection of nitroaromatics in these wells. Nitroaromatics (nitrobenzene, TNT and RDX) were again detected in the groundwater from these three wells. Monitoring well PB-BED-MW20 detected RDX in the groundwater in April 2003, PB-BED-MW24 detected TNT in April 2003, and PB-BED-MW25 detected nitrobenzene in October 2002. With the additional groundwater

elevation data from these wells, the data was used to refine the groundwater flow maps for the site. These flow maps indicated that well PB-BED-MW24 was potentially downgradient of the West Area Red Water Pond.

To determine if these wells were truly background and upgradient of the PBOW site, off-site monitoring wells PB-BED-MW28 and PB-BED-MW29 were installed in August 2003 hydraulically upgradient (south) of PBOW. Monitoring well PB-BED-MW28 is located south of the PBOW facility on property owned by NASA, near the intersection of Taft and Mason Roads. This well is upgradient of well PB-BED-MW20. Monitoring well PB-BED-MW29 is situated southwest of the PBOW facility on private property, located west of Ransom Road and south of West Scheid Road. This well is located upgradient of PB-BED-MW25. Following installation of these new bedrock wells, four (4) additional rounds of groundwater sampling were conducted from all potential background wells.

As part of the investigation to determine off-site groundwater quality, monitoring well PB-BED-MW30 was installed in March 2004 northwest of PB-BED-MW24, east of the intersection of Bouy and Patten Tract Roads. Water level from this well in addition to one private well further to the north, confirmed that well PB-BED-MW24 is indeed downgradient of the West Area Redwater Pond.

3.0 Review Criteria

New and existing background bedrock monitoring wells were evaluated using site data to determine whether groundwater samples collected from these wells is representative of background bedrock concentrations of inorganic compounds entering the PBOW facility. This data included criteria such as well yield, groundwater flow direction, water quality parameters, and the presence of groundwater contamination. A brief description of these review criteria are presented in the following paragraphs.

3.1 Well Yield

Well yield is an important factor in determining whether the fracture encountered during drilling is providing groundwater in sufficient quantities that would be available for transport of any potential groundwater contamination. More importantly, the yield dictates whether the well can be sampled using low-low (minimal drawdown) methods, thus providing more representative groundwater sample results. Well yield was evaluated during drilling to determine the interval to install the well screen and during well sampling.

3.2 Groundwater Flow Direction

Groundwater flow maps were completed to determine the overall groundwater flow regime at PBOW. Current groundwater flow directions are depicted on the August 2004 overburden/shale bedrock contour map (Figure 1). Flow directions of the bedrock groundwater in the Delaware Limestone are shown on the August 2004 Delaware Limestone groundwater contour map (Figure 2). These maps were reviewed to determine whether each well used in the evaluation was upgradient of potential groundwater contamination.

3.3 Water Quality Parameters

Water quality parameters, collected during purging and sampling using a flow-through cell, were evaluated to determine if there were anomalous data or indicators of potential sampling problems. A summary of water quality measurements is shown on Table 1.

3.4 Presence of Groundwater Contamination

The presence of groundwater contamination, particularly site-related contaminants (i.e., nitroaromatics), may alter groundwater geochemistry. For example, anaerobic degradation of organic compounds may lead to lower dissolved oxygen and more negative oxidation-reduction potential, leading to higher dissolved inorganics. A summary of the background groundwater analytical results is provided as Table 2.

4.0 Results

The following sections summarize all available data for each of the potential background wells.

4.1 BG8-BEDGW-001

Monitoring well BG8-BEDGW-001 is screened within the Olentangy Shale bedrock at a depth of 4.75 to 19.75 feet bgs. Based on groundwater elevation data collected and corresponding flow maps, groundwater flow in this area of PBOW is to the north-northwest (Figure 1), indicating this well is upgradient of known PBOW areas of potential contamination. A total of 12 groundwater sampling events (10 by low-flow [minimal drawdown] and 2 by bailer) have been conducted at the well beginning in November 1997 (dry season) and ending in June 2004 (wet season). Nitroaromatics have never been detected in any of the groundwater samples from the well. Sporadic detections of acetone, 2-butanone, carbon disulfide, chloromethane, methylene chloride, xylenes and bis(2-ethylhexyl)phthalate have been reported. Approximately half of these organic compounds were "B" qualified, indicating the compound was also detected in the associated laboratory blank, suggesting these reported detections are not site related. The remaining detected

organic compound concentrations were less than 1 microgram per liter (μg/l). The analytical data does not indicate that this well has been impacted by PBOW-related activities.

Review of groundwater quality data indicates anomalous readings for three sampling events. An elevated pH of 13.03 S.U. was observed on September 27, 2001. The pH range for all other sampling events from this well was 5.97 to 7.80 S.U. At a pH of 13.03 S.U., concentrations of iron and manganese would be expected to be low. Review of the data does not indicate these to be anomalously low compared to other results from this well. Elevated pH readings were also observed in other wells sampled during this time period, suggesting that these readings are due to equipment error and are not indicative of geochemical changes in groundwater. Elevated Eh and dissolved oxygen readings were recorded on April 3, 2002 and March 11, 2004. Redox values recorded for all other sampling periods are negative for this well, indicating reducing conditions. Corresponding dissolved oxygen readings are also typically low, ranging from 0.0 ppm to 1.92 ppm. Conversely, the Eh values for April 3, 2004 and March 11, 2004 were 220 mV and 42.8 mV, and DO values were 6.74 ppm and 5.51 ppm, respectively. Note that the DO value for April 3, 2003 was obtained from the purging log. The DO meter malfunctioned during sampling, and the reading was the last recorded. Regardless, the data suggest a possible seasonal effect occurring. Review of the dissolved inorganics data indicate lower concentrations of redox-sensitive compounds, specifically iron and manganese. Even though some anomalies of groundwater quality criteria are noted and some organics were reported at low concentrations, the observed values do not appear to indicate site-related conditions. Therefore, well BG8-BEDGW-001 is recommended to be included in the background data set. Further evaluation of the seasonal trends will be completed as part of the 2004 Groundwater Data Summary and Evaluation Report.

4.2 PB-BED-MW20

Monitoring well PB-BED-MW20 is screened within the Ohio Shale at a depth of 28.5 to 48.5 bgs. Based on groundwater elevation data collected and corresponding flow maps, groundwater flow in this area of PBOW is to the east (Figure 1), indicating this well is upgradient of known PBOW areas of potential contamination. A total of 12 groundwater sampling events (8 by low-flow [minimal drawdown], and 4 by bailer) have been conducted at the well beginning in November 1997 (dry season) and ending in June 2004 (wet season). Low concentrations of nitrobenzene (0.088J μg/l), RDX (0.17J μg/l), and 4-amino-2,6-DNT (0.19J μg/l) were each detected in 1 of 12 sampling events. These three nitroaromatics were detected in groundwater samples collected during the months of April 2002 (wet season), April 2003 (wet season), and September 2003 (dry season), respectively. The RDX detection is interpreted to be false positive result based on the following information. RDX has only been detected sporadically in PBOW soil and groundwater

samples. In total, RDX has been detected in 4 of 880 soil samples and 11 of 421 groundwater samples collected at the site from 1996 through 2004. There is no information to indicate that RDX was ever used or was otherwise present at the site. RDX is not known to be a contaminant of any reactants used in TNT manufacturing, a by-product of TNT manufacturing, or a degradation product of any compounds formerly used or manufactured at PBOW. RDX is not a nitroaromatic and is structurally quite dissimilar from nitroaromatics such as TNT and related compounds, some of which are substrates or breakdown products of TNT (e.g., di- and mono- substituted nitroaromatics and aminonitroaromatics). Similar sporadic detections of RDX have been reported at the West Virginia Ordnance Works, a TNT manufacturing facility similar to PBOW. Confirmation sampling and analysis at that site verified that RDX was not present.

Natural gas was encountered in well PB-BED-MW20 during nearly every sampling event. During groundwater purging of the well when the water table was lowered, escaping gas was evident. The 2-inch riser would sometimes violently shake, gurgling and bubbling of water could be heard, and the explosive meter would measure maximum limits. Also, based on discussions with NASA personnel, an abandoned natural gas well is located nearby at Taft Road and the security fence. While hydrogen sulfide is common in nearly all the bedrock wells, natural gas (presumably methane), has not been observed in any other wells onsite.

Other organic compounds sporadically detected include acetone, bromomethane, 2-butanone, chloromethane, ethyl benzene, methylene chloride, xylenes, bis(2-ethylhexyl)phthalate, and 2-methylnaphthalene. Of these detections, acetone and methylene chloride were commonly "B" qualified, indicating the compound was also detected in the associated laboratory blank. This suggests the reported values may not be site related. In addition, 2-butanone and BEHP, although not "B" qualified, are also common laboratory contaminants. Other organic compounds benzene, carbon disulfide, and toluene were detected in the groundwater in more than half of the sampling events. As previously discussed, these detections are likely the result of natural petroleum hydrocarbons present in the bedrock at PBOW. All of the detected organic compounds exhibited concentrations slightly above or less than 1 μg/l, except acetone (5.3 μg/l in April 2002) and 2-butanone (9.8 μg/l in July 2002).

Review of water quality parameter data indicate that two anomalous results for Eh and/or DO. The positive Eh readings were observed in April of 2002 and 2003. Review of the redox-sensitive inorganics (i.e., iron) indicate much lower concentrations of iron during these two periods. In addition, dissolved oxygen was elevated during April 2003. These readings, coupled with the lower concentration of iron, suggest a possible seasonal trend in this well. Samples collected in

May 1998 also show a lower concentration of iron, supporting this seasonal trend. It should be noted however that Eh data was not available for this sample.

As noted above, the well exhibited high concentrations of natural gas. Review of the inorganic analytical data indicate that the dissolved iron concentrations were approximately one to two orders of magnitude higher than other background wells. In addition, manganese was also elevated by a factor of two over other wells.

In summation, most of the organic groundwater detections are interpreted to be influenced by the presence of natural gas in the rock formation or are common laboratory contaminants. The low levels of nitroaromatics were detected sporadically and were not reproducible over the quarterly sampling. In addition, the low concentrations of the nitroaromatics likely will not have a significant impact on the inorganic data. However, the presence of natural gas (methane), atypical for the PBOW site, likely influences the concentration of inorganics. Therefore, monitoring well PB-BED-MW20 should not be used to determine background groundwater concentrations for PBOW in general, even though the presence of methane is associated with natural geologic conditions. Should any other bedrock wells exhibit the presence of natural gas, the data from PB-BED-MW20 could be used for comparison purposes for that well only. Further, only those samples collected by low-flow should be used to determine the range in background concentrations.

4.3 PB-BED-MW24

Monitoring well PB-BED-MW24 is screened within the Delaware Limestone at a depth of 25.5 to 40.5 feet below ground surface (bgs). Based on groundwater elevation data collected and corresponding flow maps, groundwater flow in this area of PBOW is to the west-northwest (Figure 2). A total of 10 groundwater sampling events (9 by low-flow [minimal drawdown] and 1 by bailer) have been conducted at the well beginning in October 2001 (dry season) and ending in June 2004 (wet season). Nitroaromatics 2,6-DNT (µg/l), nitrobenzene (0.33 µg/l), RDX (0.22J µg/l), and 2,4,6-TNT (0.081J µg/L) were each detected in 1 of the 10 groundwater sampling events for this well. 2,6-DNT, nitrobenzene, and RDX were reported only in the sample taken during April 2002, and 2,4,6-TNT (0.081J µg/l) was reported only in the sample collected during April 2003. After installation of off-site monitoring well PB-BED-MW30 and review of potentiometric flow map data, it was concluded that well PB-BED-MW24 was actually downgradient of a known contamination source, the West Area Red Water Pond. Therefore, monitoring well PB-BED-MW24 is not considered a background well. Groundwater analytical results from this well will be evaluated with other site-related wells in the upcoming data summary report.

4.4 PB-BED-MW25

Monitoring well PB-BED-MW25 is screened within the Olentangy Shale bedrock at a depth of 27.5 to 37.5 feet bgs. Based on groundwater elevation data collected and corresponding flow maps, groundwater flow in this area of PBOW is to the northeast (Figure 1), indicating this well is upgradient of known PBOW areas of potential contamination. A total of 10 low-flow (minimal drawdown) groundwater sampling events have been conducted at the well beginning in October 2001 (dry season) and ending in June 2004 (wet season).

The nitroaromatic compound nitrobenzene has been detected in 2 of the 10 PB-BED-MW25 groundwater samples. During April 2002 it was detected at a concentration of 0.076J µg/l and in October 2002 at a concentration of 0.12J µg/l. The source of the nitrobenzene is unclear, but nitrobenzene has wide industrial use and is present in numerous consumer products; perhaps, its presence may be associated with the application of pesticides or fertilizer on local farm fields. Sporadic detections of acetone, carbon disulfide, chloroform, 4-methyl-2-pentanone, methylene chloride, benzene, ethyl benzene, toluene, xylenes (BTEX) and bis(2-ethylhexyl)phthalate have been reported. Three of these organic compounds (acetone, methylene chloride, and bis[2-ethylhexyl]phthalate) exhibited analytical results that were "B" qualified, indicating the compound was also detected in the associated laboratory blank. This suggests that these reported concentrations are not site related. Natural petroleum hydrocarbon (oil) and natural gas are known to be associated with the limestone and shale bedrock in northern Ohio. The low levels of BTEX and carbon disulfide (less than 1.5 µg/l) are believed to be related to the natural petroleum and gas. The remaining detected organic compounds (chloroform and 4-methyl-2-pentanone) were only detected during one sampling event and exhibited analytical results 1.1 and 0.3 µg/l, respectively. A potential source of chloroform is from release of chlorinated tap water into the environment through surface discharge or through septic systems. Although there are low levels of organics, the analytical data does not indicate that this well has been impacted by PBOW-related activities.

Review of groundwater quality data indicates an anomalous pH reading for one sampling event. An elevated pH of 10.58 S.U. was observed on October 5, 2001 with the pH for all other sampling events from this well ranging from 6.56 to 8.46 S.U. At an elevated pH (i.e., greater than 10 S.U.), the solubility of iron and manganese is low. Review of the data indicates iron at a concentration of 795 µg/l (unfiltered) and 713 µg/l (filtered) and manganese at a concentration of 89 µg/l (filtered) and 87 µg/l (filtered). The iron concentrations from the October 2002 sampling were anomalously high compared to the other sampling events for this well while manganese concentrations were within the range of those detected during other events. Elevated pH readings were also observed in

other wells sampled during the fall 2001 groundwater sampling, suggesting that these readings are due to equipment error and are not indicative of geochemical changes in groundwater.

With the exception of turbidity, the remaining water quality parameter readings were relatively consistent over the sampling intervals and do not indicate any possible errors. Field recorded turbidity readings were less than 6 NTUs for all samples collected. However, laboratory measured turbidity (Table 2) for these same samples ranged from 2 to 112 NTUs. The reason for this discrepancy is unclear.

The sporadic detections of nitrobenzene should not preclude this well from being used to determine background conditions in bedrock groundwater. While the source of the nitrobenzene could be from PBOW, the lack of other nitroaromatics (TNT or DNT) in samples from this well suggests that nitrobenzene is not site-related (note also, as mentioned above, that nitrobenzene has wide industrial applications and is present in numerous consumer products). Further, the low reported concentrations likely do not have a significant impact to groundwater geochemistry. The primary effects of organics in groundwater are lower dissolved oxygen and more reducing conditions. The bedrock groundwater is naturally under reducing conditions due to the presence of naturally occurring petroleum hydrocarbons, and thus, these sporadic nitrobenzene detections likely would not significantly change the geochemistry.

4.5 PB-BED-MW26

Monitoring well PB-BED-MW26 is screened within the Ohio Shale bedrock at a depth of 42.75 to 57.75 feet bgs. This well has insufficient yield for use in background monitoring. A single sample was collected by bailer only in January 2002,with sufficient volume to analyze only for unfiltered metals. Results of the unfiltered metals sample exhibited very high analytical results when compared to the results from other background wells. Since January 2002, sufficient water has not been available for further analysis. During a September 2002 meeting between the USACE, OEPA, NASA, and Shaw, it was decided to eliminate monitoring well PB-BED-MW26 from the background data set due to insufficient yield, having never been properly developed, and showing unrepresentative groundwater analytical results caused by the high turbidity in the groundwater that accompanies attempts at sampling by bailer from a limited water column.

4.6 PB-BED-MW28

Monitoring well PB-BED-MW28 is screened within the Ohio Shale bedrock at a depth of 21.65 to 41.65 feet bgs. Based on information from potentiometric flow maps, the well monitors groundwater upgradient of the PBOW site with groundwater flow in a northeast-easterly direction

toward the site (Figure 1). A total of 4 groundwater sampling events performed by the low-flow (minimal drawdown) sampling methodology have been conducted at the well beginning in September 2003 (dry season) and ending in June 2004 (wet season). Nitroaromatics have never been detected in the groundwater from the well. Sporadic detections of acetone, carbon disulfide, chloromethane, ethyl benzene, methylene chloride, trichloroethene, and xylenes have been reported and benzene and toluene were detected during all four of the sampling events. The sporadic detection of methylene chloride was "B" qualified, indicating that it was also detected in the associated laboratory blank. All of the compounds except acetone, benzene, and toluene were detected at concentrations less than 1 µg/l. Acetone was detected at a concentration of 2.1 µg/l in March 2004, benzene was detected at concentrations of 2.4 µg/l, 2.2 µg/l, 1.7 µg/l, and 1.1 µg/l during the months of September 2003, December 2003, March 2004, and June 2004, respectively, and toluene was detected at a concentration of 1.7 µg/l in September 2003. Natural petroleum hydrocarbon (oil) and natural gas are known to be associated with the shale bedrock in northern Ohio. The low levels of BTEX and carbon disulfide (1.3 µg/l) are believed to be related to the natural petroleum and natural gas in the organic rich shale in which the well is screened. The detection of trichloroethene (TCE) (0.59J µg/l) in the September 2003 is most likely related to local farming operations in the area.

Review of groundwater quality data indicates anomalous readings for only the Eh measurements. Positive readings indicating oxidizing conditions were obtained in December 2003 (7.5 mV-dry season) and March 2004 (75.3 mV-wet season) while negative measurements indicating reducing conditions were obtained in September 2003 (-95.2 mV-dry season) and June 2004 (-131.9 mV-wet season). Corresponding dissolved oxygen readings for all 4 events were typically low, ranging from 0.00 to 0.45 ppm. The Eh data suggest a possible seasonal effect occurring. Review of the dissolved inorganics data indicate higher concentrations of redox-sensitive compounds, specifically iron and manganese, during the fall and winter with lower concentrations observed in the spring and summer results. This likely is due to additional groundwater recharge occurring during the spring. Further evaluation of the seasonal trends will be completed as part of the 2004 Groundwater Data Summary and Evaluation Report.

The purpose of the background evaluation is to determine the water quality entering the PBOW site, regardless of any impacts from offsite areas. Given that this well's location is approximately 1,200 feet upgradient of the site, there is no concern of impacts by PBOW site activities; this is corroborated by a lack of nitroaromatics detections. Therefore, well PB-BED-MW28 well is recommended for use in the background data set.

4.7 PB-BED-MW29

Monitoring well PB-BED-MW29 is screened within the Olentangy Shale bedrock at a depth of 27.65 to 37.65 feet bgs. Based on information from potentiometric flow maps, the well monitors groundwater upgradient of the PBOW site with groundwater flow in a north-northeastly direction toward the site (Figure 1). A total of 4 groundwater sampling events performed by the low-flow (minimal drawdown) sampling methodology have been conducted at the well beginning in September 2003 (dry season) and ending in June 2004 (wet season). Nitroaromatics have never been detected in the groundwater from the well. Sporadic detections of acetone, chloroform, chloromethane, methylene chloride, and toluene have been reported and benzene, carbon disulfide, ethyl benzene, and xylenes were each detected in at least three of the four sampling events. Sporadic hits acetone and methylene chloride were "B" qualified, indicating that they were also detected in the associated laboratory blank. All of the compounds except acetone, carbon disulfide, and total xylenes were detected at a concentration less than 1 µg/l. Acetone was detected at concentrations of 17 µg/l, 2.1 µg/l, and 9.1 µg/l in September 2003, March 2004, and June 2004 respectively, carbon disulfide was detected at a concentration of 13 µg/l during the month of December 2003, and total xylenes were detected at concentrations of 5.5 µg/l, 5.1 µg/l, 4.5 µg/l, and 3.7 µg/l during the months of September and December 2003 and March and June 2004, respectively. Natural petroleum hydrocarbon (oil) and natural gas are known to be associated with the shale bedrock in northern Ohio. The low levels of BTEX and carbon disulfide are believed to be related to the natural petroleum and natural gas in the organic rich shale in which the well is screened.

Review of groundwater quality data indicates no particular anomalous readings. The Eh measurement during the month of June 2004 was recorded as a negative reading compared to three positive measurement readings during the previous sampling months. As with PB-BEDGW-028, Eh shows a seasonal trend. Concentrations of redox-sensitive compounds, specifically iron also shows a seasonal trend.

The purpose of the background evaluation is to determine the water quality entering the PBOW site, regardless of any impacts from offsite areas. Given that this well's location is approximately 1,200 feet upgradient of the site, there is no concern of impacts by PBOW site activities, as corroborated by a lack of nitroaromatics detections. Therefore, well PB-BED-MW29 is recommended for use in the background data set.

5.0 Summary

Based on a review of all available site data, the following wells are recommended for inclusion in the PBOW background data set that will be used in determining the background concentrations of inorganics in bedrock groundwater:

- BG8-BEDGW-001 (10 samples)
- PB-BED-MW25 (10 samples)
- PB-BED-MW28 (4 samples)
- PB-BED-MW29 (4 samples)

It should be noted that only samples from the above wells collected using low-flow (minimal drawdown) will be used in the statistical evaluation of background analytical data. The number of samples shown in parenthesis represent only the samples collected using low-flow sampling. All other samples collected by bailer will not be used in determining the background concentration of inorganics.

The following wells are recommended for exclusion from the PBOW background well data set, with the reasons for exclusion provided in parentheses:

- PB-BED-MW20 (excluded due to the presence of methane)
- PB-BED-MW24 (excluded because location is now interpreted as being downgradient from a contamination source; also, presence of multiple nitroaromatics)
- PB-BED-MW26 (insufficient well yield).

It is noted that well PB-BED-MW20 might be useful as a background well for qualitative comparison for any on-site wells that are impacted by natural gas.

Table 1

Final Field Measurements of Groundwater Samples
Background Well Review
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Time	Low-Flow Sampled	PID (ppm)	H_2S (ppm)	Eh (mV)	pH	Conductivity (µmhos/cm)	Turbidity (NTU)	Dissolved O_2 (ppm)	Temperature (°C)	Volume Purged (gal)
Background Bedrock Wells (1997 through March 2004)												
BG8-BEDGW-001	11/17/1997	NA	No	0	NM	-245.3	7.21	3.31	321	6.83	10.5	30
	5/15/1998	NA	No	0.1	NM	-36.2	7.80	151	10	8.00	13.0	27.73
	9/27/2001	1220	Yes	0.0	NM	-339	13.03	3.75	0.0	0.00	12.65	2.97
	1/16/2002	1450	Yes	0.0	0.0	-79	7.38	0.856	2.8	0.00	10.69	2.22
	7/12/2002	0920	Yes	0	0	-258	7.21	3.68	10.3	0.41	13.45	5
	10/18/2002	1050	Yes	0.0	0.0	-307	5.97	3.88	16.5	1.73	14.2	4.0
	4/10/2003	1545	Yes	1.1	0.0	-64.5	7.79	0.656	2.3	NM	8.61	3
	9/18/2003	1550	Yes	0.0	0	-307.9	6.84	3.429	0.0	1.92	15.72	2
	12/10/2003	1620	Yes	0.0	0	-50.8	7.23	0.988	0.0	0.31	11.11	3
	3/11/2004	1405	Yes	0.0	0	42.8	7.16	0.983	0.0	5.51	9.21	2.7
	6/16/2004	1600	Yes	0.0	0.0	-102.8	7.18	0.648	0.0	1.90	15.82	1.8
PB-BED-MW20	11/17/1997	NA	No	0	NM	-24.7	6.74	48.5	563	4.14	9.4	27
	5/28/1998	NA	No	0.1	NM	NM	6.65	38.1	999	12.80	13.0	58
	9/26/2001	1415	No	0.0	NM	-73	8.95	53.60	53.5	0.00	10.54	10.33
	1/15/2002	1415	Yes	1.6	0.0	-55	6.83	52.60	15.0	0.00	7.22	1
	4/4/2002	1013	Yes	0.0	NM	51	7.07	53	0.0	0.00	10.37	1.9
	7/10/2002	1600	Yes	0	0	-57	6.73	52.9	NR	0.00	13.85	3.5
	10/17/2002	1510	No	0.0	0.0	-32	5.69	56.3	10.8	3.38	11.60	24
	4/11/2003	1050	Yes	0.9	0.0	64.3	6.96	49.75	3.7	9.23	10.17	2.8
	9/18/2003	0845	Yes	0.0	0	-9.6	6.43	49.71	0.0	0.38	11.97	1.8
	12/10/2003	1200	Yes	0.0	0	-30.2	6.68	51.46	0.1	0.46	8.86	1.5
	3/10/2004	1525	Yes	0.0	0	-55.7	6.70	48.57	0.0	0.00	10.91	0.75
	6/17/2004	1515	Yes	0	0.0	-53.5	6.68	48.96	0.0	0.54	25.98	1.5
PB-BED-MW24	10/9/2001	0935	Yes	NM	NM	-144	9.38	1.81	73.3	5.32	11.20	2.99
	1/17/2002	1005	Yes	114	0.0	-333	6.82	1.99	2.5	0.00	9.69	2.11
	4/3/2002	1730	Yes	76.0	0.0	-318	7.06	1.98	0.0	NM	10.71	1.8
	7/12/2002	1405	Yes	84.1	>500	-358	6.66	1.88	350	0.00	12.93	4.5
	10/19/2002	1110	No	58.2	>50	-297	6.30	1.85	22.3	5.52	12.20	4.5
	4/9/2003	1530	Yes	5.6	>200	-337.7	6.64	1.753	0.0	0.00	9.98	3.3
	9/17/2003	1320	Yes	62.9	>500	-323.0	6.14	1.637	0.0	4.88	13.00	3.25
	12/10/2003	1035	Yes	58.3	>50	-331.7	6.61	1.408	0.0	-1.99	10.06	3.2
	3/10/2004	1305	Yes	56.8	156	-310.3	6.54	1.700	3.4	0.00	10.84	2.1
	6/16/2004	1330	Yes	47.5	>200	-321.9	6.63	1.334	0.0	0.00	14.65	3.3

Table 1

Final Field Measurements of Groundwater Samples
Background Well Review
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Time	Low-Flow Sampled	PID (ppm)	H_2S (ppm)	Eh (mV)	pH	Conductivity (µmhos/cm)	Turbidity (NTU)	Dissolved O_2 (ppm)	Temperature (°C)	Volume Purged (gal)
Background Bedrock Wells (1997 through March 2004), continued												
PB-BED-MW25	10/5/2001	0920	Yes	0.0	0.01	-237	10.58	1.89	5.7	2.41	11.90	3.67
	1/16/2002	1030	Yes	0.0	0.0	-291	7.23	2.42	5.8	0.00	10.54	4.44
	4/3/2002	1120	Yes	NM	NM	-333	8.46	2.62	2.7	0.01	10.90	8
	7/11/2002	1115	Yes	0	0	-302	7.19	1.86	1.9	0.00	12.92	8
	10/17/2002	1035	Yes	0.0	0.0	-290	6.56	2.96	2.1	1.69	12.00	6.0
	4/10/2003	1035	Yes	0.0	0.0	-333.8	7.22	2.817	3.7	NM	10.93	5.5
	9/18/2003	1220	Yes	0.3	0.0	-296.2	6.98	1.707	0.0	0.22	13.91	5.5
	12/11/2003	1355	Yes	0.0	0	-325.6	7.11	1.509	0.0	0.10	10.82	3.6
	3/11/2004	0915	Yes	0.0	0.0	-303.4	7.01	1.605	0.0	0.00	10.85	5.2
	6/17/2004	0945	Yes	0.0	0.0	-275.5	7.09	1.672	0.0	0.26	13.59	4.8
PB-BED-MW26	10/10/2001	NA	NA	3.6	NM	No sample collected due to insufficient water volume.						
	1/15/02[a]	1030	No	2.2	0.21	-59	6.87	31.0	999	8.04	8.69	0.5
	4/9/2002	NA	NA	NM	NM	No sample collected due to insufficient water volume.						
	7/12/2002	NA	NA	3.1	0	No sample collected due to insufficient water volume.						
	10/16/2002	NA	NA	6.0	0.0	No sample collected due to insufficient water volume.						
	4/8/2003	NA	NA	NM	NM	No sample collected due to insufficient water volume.						
	9/3/2003	NA	NA	NM	NM	No sample collected due to insufficient water volume.						
	12/10/2003	NA	NA	NM	NM	No sample collected due to insufficient water volume.						
	3/10/2004	NA	NA	15.6	0.00	No sample collected due to insufficient water volume.						
	6/17/2004	NA	NA	14.6	20	No sample collected due to insufficient water volume.						
PB-BED-MW28	9/17/2003	0915	Yes	0.0	0	-95.2	7.50	1.408	0.0	0.21	13.88	1.50
	12/9/2003	1320	Yes	0.0	0	7.5	7.54	1.391	0.0	0.45	10.28	1.5
	3/9/2004	1410	Yes	0.0	0	75.3	8.50	1.739	0.0	0.00	10.01	2.5
	6/15/2004	1330	Yes	0.0	0	-131.9	7.89	1.228	0.4	0.33	15.01	4
PB-BED-MW29	9/16/2003	1520	Yes	0.0	0	6.5	6.66	10.30	25.0	0.22	15.80	3.9
	12/9/2003	1535	Yes	8.0	0	3.0	6.82	8.490	1.9	0.39	10.00	1.37
	3/10/2004	1015	Yes	0.0	0	34.4	6.73	9.207	10.2	0.0	9.13	1.8
	6/16/2004	0955	Yes	0.0	0	-52.9	6.78	9.125	0.3	0.19	13.65	3

Table 1

Final Field Measurements of Groundwater Samples
Background Well Review
Former Plum Brook Ordnance Works, Sandusky, Ohio

Notes:

Water quality measurements were recorded immediately before sample collection. PID and H_2S readings taken as monitoring well lid removed.

O_2 - Oxygen.

[a]Water quality reading collected from last purged groundwater due to a limited water volume. Reading was not recorded in a flow through cell. Well was purged on 1/15/02 and sample was collected on 1/17/02 at 0820.