October '97 Volume 1.4

# PBOW RAB

## Final Site-Wide Groundwater Investigation Report Available

The Sitewide Groundwater Investigation - Final Report, is now available for review at the Firelands College Library. A copy of the Executive Summary and the Conclusions and Recommendations are included with this newletter. The reports are part of the permanent record for the investigations and clean-up of the former Plum Brook Ordnance Works Site.

## September RAB Meeting Minutes

Minutes of Restoration Advisory Board Meeting
Plum Brook Ohio Ordnance Works

The third meeting of the Plum Brook Ordnance Works Restoration Advisory Board was convened at 7:00 p.m., 9 September 1997 at the Firelands College Library. Diane Folk, DOD Co-Chair and Project Manager opened the meeting.

Attendees were as follows:

Diane Folk
Lisa Ohlemacher
Mark Bohne
David Speer
Starr Truscott
Jan Bohne
George Parker
Richard A. Pitsinger
Mary Thompson

Ms. Folk relayed to the group that Mr. Ralph Roshong had called and said that he wished to resign from the Board. Mr. Roshong cited the irregularity of the meetings as well as conflicts with other more regularly scheduled meetings.

The members commented on how they had enjoyed the tour that was conducted by Mr. Peacook (NASA Representative) in May of the Plum Brook Project.

The Draft Site-Specific Sampling and Analysis Plan Sitewide Investigation of Groundwater, Former Plum Brook Ordnance Works was received from the IT Corporation and a copy is located in the Library, Firelands College. Ms. Folk said that she had recently received updates and had brought copies to insert and update the plan.

Ms. Folk stated that members of the IT Corporation, Knoxville, TN was presently on the Plum Brook site conducting sampling of the wells and drilling additional wells. A large portion of the work is in the Red Water Area.

Previous findings were discussed by the group and the following excerpts read (Pg VI 2, Revision No. 1 dated July 1997):

In 1994, the USACE Nashville District conducted the most recent sitewide groundwater investigation of the overburden and bedrock hydrostratigraphic units at PBOW Dames & Moore, 1996). Eleven overburden groundwater monitoring wells and eight bedrock wells were installed during the 1994 investigation. Groundwater samples were collected from 16 overburden wells and 8 bedrock wells. All groundwater samples were analyzed for nitroaromatic compounds, nitrates, and total and dissolved metals. Samples from Bedrock wells were also analyzed for VOCs and base/neutral and acid extractables (BNA) to acquire baseline groundwater quality information of the bedrock aquifer.

The overburden unit, composed of glacial outwash materials, has a thickness ranging from a few feet in the south to greater than 40 feet in some locations in the north. The bedrock unit consists of Devonian limestone



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and shale that dip to the southeast at approximately 35 feet per mile.

In general, groundwater flows in a northerly direction, towards Lake Erie, in both the unconsolidated overburden material and consolidated bedrock. On the western side of the site groundwater in the overburden water-bearing zone flows to the northwest, while groundwater in the bedrock aquifer flows to the northeast.

The results of the groundwater quality analyses indicated significant levels of explosive residues in the groundwater in the overburden aquifer in the immediate vicinity of both former Red Water Pond areas. Low levels of explosives, several VOCs, and BNAs were also detected in several bedrock wells.

The specific objectives of the sitewide groundwater level investigation was then discussed:

1. Determine if there are hazardous substances present at the site in a manner that constitutes unacceptable risk to human health and the environment.

2. Define site physical features and characteristics (aquifer background conditions).

3. Evaluate fate and transport pathways (groundwater modeling).

4. Determine current and future routes of exposure.

5. Evaluation of fate and transport pathways will not be completely satisfied during this investigation, but sufficient groundwater information will be collected so that a scope of work for groundwater modeling can be completed if required to determine fate and transport of hazardous substances in site groundwater. Additionally, the collected data can be used to conduct a human health and ecological risk assessment, if necessary.

Ms. Folk stated that the field activities include:

8 new bedrock wells
4 new overburden wells

Sampling 12 existing bedrock wells
Sampling 35 existing overburden

Mr. Pitsinger asked how the water could be treated. Ms. Folk used an example of how the Corps has treated water at the West Virginia Ordnance Works site through the use of a groundwater pump and treat system.

Mr. Speers asked if there were boring logs on the wells that are presently open. Ms. Folk said "yes" and the logs would be an appendix to the report.

Ms. Folk told the group that she would bring some pictures of the Keystone Arsenal in November '97. The Arsenal is now privately owned and the owner will not allow anyone on the property.

Mr. Bohne asked if anyone had seen the video entitled Planet Neighborhood. Ms Folk said that she would see if she could borrow a copy of it for the group.

Ms. Folk said that she would try and find some information and provide it to the RAB on pilot projects depicting innovative technology. She also will try to provide answers for the following:

Where was acid mixed on the site?

How many TNT plants were in the world?

More information on what is being done about the piping that is wrapped in absestos and located on Plum Brook Station.

Administrative Items:

Meeting adjourned at 8:30 p.m.

**It is my intention to research the questions listed above and provide answers at the November restoration advisory board meeting.**

**Diane**

## NEXT MEETING

**November 19, 1997**
**Firelands College Library**
**Library Classroom - 7:00 pm**

**Diane Perry Folk, Project Manager**

**E-mail address:**
INET:DIANEF@MAIL.ORH.USACE.ARMY.MIL

TELEPHONE - (304) 529-5507

# Executive Summary

IT Corporation (IT) conducted a sitewide groundwater investigation (GWI) at the former Plum Brook Ordnance Works (PBOW) from September through October 1996 under contract to the U.S. Army Corps of Engineers (USACE) Nashville District. The PBOW is an approximately 9,000-acre site near Sandusky, Ohio and was used during World War II for manufacturing explosives. The site is currently owned and operated by the National Aeronautics and Space Administration (NASA) as a science research facility.

This work was conducted under the Defense Environmental Restoration Program (DERP) Formerly Used Defense Sites (FUDS) and included installation of overburden monitoring wells, redevelopment of existing monitoring wells, collection of groundwater samples, laboratory analysis of groundwater samples, evaluation of analytical and field data, and preparation and submittal of reports. The objectives of the sitewide GWI at PBOW were to acquire supplementary data of the sitewide groundwater levels and contaminants to add to an existing database, and to fill in existing data gaps in groundwater levels and contamination in western portion of PBOW. This report presents summaries of field activities, findings, conclusions, and recommendations derived from the data acquired during this sitewide GWI.

***Sitewide Hydrogeology.*** Two major water-bearing zones exist at PBOW. The overburden water-bearing zone consists of glacial till and lacustrine deposits with varying thickness. The bedrock water-bearing zone is mainly developed in a limestone/dolomite formation containing some evaporite. General groundwater flow direction in both water-bearing zones is to the north and northeast. However, the local flow regime in the overburden may be different depending on soil thickness, topography, and surface water features and exhibits strong seasonal dependence. Some overburden wells may become dry at certain times of the year. The groundwater flow regime in the bedrock water bearing zone is believed to be influenced by the orientation and connectivity of solutionally enlarged fractures. The difference in water level elevations in both water-bearing zones indicates a predominant downward flow, but water in the shallow depth can also move upward and be lost to evapotranspiration. Data gaps were identified with respect to groundwater quality and water level elevations, especially in the middle and eastern portion of the facility.

***West Area Red Water Ponds.*** The overburden water-bearing zone exhibits impacts by nitroaromatic compounds in the central portion of the West Area Red Water Ponds (WARWP)

area, while inorganic compounds are present at concentrations exceeding the RBCs throughout this area. Detected metals in groundwater in the WARWP area will require further evaluation to determine whether these are due to site contamination.

The bedrock water-bearing zone has been impacted by nitroaromatic and organic compounds north of the WARWP area, but does not exhibit impacts by any constituents in the central portion of the WARWP area. Inorganic compounds have also exceeded the RBCs north of the WARWP area, but these exceedances will require further evaluation to determine their source.

***Pentolite Road Red Water Pond.*** The overburden water-bearing zone in the Pentolite Road Red Water Pond area has been impacted by nitroaromatic compounds, while the bedrock water-bearing zone exhibits impacts by benzene, toluene, ethyl benzene, and xylene (BTEX), semi-volatile organic compounds (SVOC), and nitroaromatic compounds. This area has been considered as a source area of nitroaromatic contamination because of its past land use. Although the Pentolite Road Red Water Pond area water-bearing zones exhibit larger suites of inorganic compounds at concentrations exceeding the RBCs than other areas of PBOW, further evaluation is necessary to determine whether they are attributable to site contamination.

***TNT Area A.*** Groundwater sampling results indicate that the overburden water-bearing zone has been impacted by nitroaromatic contaminants in the vicinity of MK-MW22 in the western part of TNT Area A (TNTA). The bedrock water-bearing zone exhibits impacts by BTEX and nitroaromatic compounds in the northeastern part of TNTA. Further evaluation is, however, necessary to determine whether detected inorganic in the two water-bearing zones are attributable to site contamination

***TNT Area B.*** The overburden water-bearing zone has been impacted by nitroaromatic compounds downgradient of TNT Area B (TNTB). Further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions. The bedrock water-bearing zone within this area has not been investigated.

***TNT Area C.*** The overburden water-bearing zone in TNT Area C (TNTC) has not been impacted by organic compounds, nitroaromatic compounds, or pesticides and polychlorinated biphenyls (PCB). A small number of metals were detected and exceeded the risk-based concentration (RBC) in the dissolved phase, but further evaluation is needed to determine whether these detections are attributable to site contamination. The bedrock water-bearing zone

has been impacted by nitroaromatic and organic compounds in TNTC. Inorganic compounds have also exceeded the RBC in TNTC area, but these exceedances will require further evaluation to determine their source.

***Sitewide Groundwater Quality.*** Analysis of groundwater samples collected from wells across the PBOW has shown that the overburden water-bearing zone has been impacted by nitroaromatic compounds with the exception of TNTC. Nitroaromatic compounds were also detected in six of the eight bedrock wells sampled, indicating that nitroaromatic contamination is evident in both water-bearing zones. Organic compounds (volatile organic compounds [VOC] and SVOCs) at concentrations exceeding the RBCs were present exclusively in overburden water-bearing zones in the two red water pond areas. At least one BTEX compound was detected in all bedrock wells, except BED-MW14 and -MW20. Free product was found in BED-MW16 located near the central toluene tank area. A variety of metals were present in groundwater samples from both water-bearing zones and some of them exceeded the RBCs. However, it is not clear whether these elevated metals are attributable to site contamination or are naturally occurring constituents. Hydrogen sulfide ($H_2S$) gas was encountered in three bedrock wells indicating a possible reducing environment in the bedrock zone. Pesticides and PCBs were not detected in any wells sampled during this investigation. Groundwater samples collected from five overburden wells and one bedrock well contained cyanide. However, the presence of cyanide in water samples is attributable to suspended solids since cyanide was not detected in filtered samples.

Overall groundwater quality in both water-bearing zones at PBOW showed evidence of impacts from past use of the site, including manufacturing explosives by the former PBOW in the 1940s and post-PBOW operations by NASA. Based on the GWI conducted at PBOW, additional sampling efforts are recommended. These efforts include additional well installation, quarterly water level measurements, seasonal groundwater sampling, and delineation of the lateral extent of contamination in the two red water pond areas as well as geochemical study of bedrock water quality to determine the source of $H_2S$.

# 6.0 Conclusions and Recommendation

This section presents conclusions and recommendations from the GWI at the former PBOW based on the analytical results presented in Chapter 4.0 and hydrogeology discussed in Chapter 5.0. With the exception of groundwater flow condition, conclusions concerning groundwater quality are presented by geographic area and monitored water-bearing zone.

## 6.1 Conclusions

The following conclusions are derived from the results of the current GWI within the former PBOW.

### 6.1.1 Groundwater Flow

Groundwater across PBOW site exists in both overburden and bedrock water-bearing zones. The general groundwater flow direction in both water-bearing zones is to the north and northeast. However, local flow regime in the overburden may be different depending on soil thickness, topography, and surface water features and exhibits strong seasonal dependence. Some overburden wells may become dry at certain times of the year. The groundwater flow regime in the bedrock is believed to be influenced by solutionally enlarged fractures. The difference in water level elevations in both water-bearing zones indicates a predominantly downward flow, but water in the shallow depth can also move upward and be lost to evapotranspiration

### 6.1.2 West Area Red Water Ponds and TNT Area C

Eleven overburden and three bedrock wells were sampled in the vicinity of the WARWP and TNTC. Two (TNTC-MW03 and MK-MW10) of the 11 overburden wells exhibited low levels of VOCs, but did not exceed RBCs. Nitroaromatic compounds were detected under the SVOC analysis at concentrations exceeding the RBCs in IT-MW02 and WA-MW02; SVOCs were also detected in TNTC-MW03 but did not exceed the RBCs. Similarly, IT-MW02 and WA-MW02 both exhibited nitroaromatic compounds at concentrations exceeding the RBCs under the explosives analysis. Explosives were also detected in IT-MW06, but the concentrations did not exceed the RBCs. Each of the 11 overburden wells also exhibited inorganic compounds at concentrations exceeding the RBCs. RBC exceedances in overburden wells are summarized as follows:

- ***IT-MW06.*** Aluminum, arsenic, barium, chromium, iron, lead, and manganese
- ***IT-MW08.*** Manganese and vanadium

- ***IT-MW02.*** 1,3,5-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, 4,6-dinitro-2-methylphenol, RDX, iron, lead, and manganese

- ***WA-MW01.*** Iron and manganese

- ***WA-MW02.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 3-nitroaniline, 4-amino-2,6-DNT, aluminum, arsenic, chromium, iron, manganese, nickel, and vanadium

- ***MK-MW10.*** Aluminum, arsenic, chromium, iron, lead, and manganese

- ***MK-MW11.*** Iron, lead, and manganese

- ***TNTC-MW03.*** Aluminum, arsenic, barium, chromium, iron, lead, manganese, nickel, and vanadium

- ***TNTC-MW04.*** Aluminum, arsenic, chromium, iron, lead, manganese, and vanadium

- ***TNTC-MW05.*** Iron, lead, and manganese

- ***TNTC-MW06.*** Chromium, iron, and manganese

With the exception of nitroaromatic compounds and total cyanide (RBC not established) in IT-MW02 and WA-MW02, detected constituents exceeding RBC values were limited to inorganic compounds in the 11 overburden wells. Of the metals exceeding RBCs, only lead, manganese, nickel, and vanadium were detected in any of the wells at concentrations exceeding the RBCs in the dissolved phase; two of the wells (MK-MW10 and MK-MW11) did not exhibit dissolved metals at concentrations exceeding the RBCs.

Based on the analytical results for the overburden wells, it is evident that IT-MW02 and WA-MW02 have been impacted by nitroaromatic compounds by past site activities. In addition, nine wells (IT-MW06, IT-MW08, IT-MW02, WA-MW01, WA-MW02, TNTC-MW03, TNTC-MW04, TNTC-MW05, and TNTC-MW06) exhibit inorganic compounds at concentrations exceeding the RBCs in the dissolved phase, which may be due to site contamination or naturally occurring conditions; background levels for inorganic compounds in groundwater have not been established. Because dissolved metals were not detected in MK-MW10 and MK-MW11, the total metals RBC exceedances in these wells are attributed to suspended solids in the groundwater samples.

Two of the three sampled bedrock wells exhibited VOCs at concentrations exceeding the RBCs: BED-MW13 and BED-MW19. SVOCs were detected in each of the three wells, but only BED-MW13 exhibited an SVOC compound at a concentration exceeding the RBC. Nitroaromatic compounds exceeded the RBCs in BED-MW13 and BED-MW19. Although each of the three bedrock wells had detectable levels of inorganic compounds, only BED-MW13 and BED-MW19 had levels exceeding their respective RBCs. RBC exceedances in bedrock wells are summarized as follows:

- ***BED-MW13.*** Benzene, toluene, 2-methylnaphthalene, 4-amino-2,6-DNT, nitrobenzene, barium, and vanadium
- ***BED-MW14.*** None
- ***BED-MW19.*** Benzene, nitrobenzene, and barium.

Based on the analytical results from the three bedrock wells, it is evident that BED-MW13 and BED-MW19 have been impacted by explosives and organic contaminants from past site activities. BED-MW14 also exhibits impacts by these constituents, but at levels below the RBCs. Bedrock wells BED-MW13 and BED-MW19 also exhibit at least one inorganic compound exceeding the RBCs, but these levels are not necessarily attributable to site contamination as background levels have not been established. In addition, BED-MW13 exhibited strong $H_2S$ gas that could be hazardous during well sampling.

In general, it is concluded that the overburden water-bearing zone in TNTC has not been impacted by organic compounds, nitroaromatic compounds, or pesticides and PCBs. A small number of metals have exceeded the RBCs in the dissolved phase, but further evaluation is needed to determine whether these detections are attributable to site contamination. The overburden water-bearing zone exhibits impacts by nitroaromatic compounds in the central portion of the WARWP area, while inorganic compounds are present at concentrations exceeding the RBCs throughout this area. However, as with TNTC, detected metals in groundwater in the WARWP area will require further evaluation to determine whether these are due to site contamination.

The bedrock water-bearing zone has been impacted by nitroaromatic and organic compounds in TNTC and north of the WARWP area, but does not exhibit impacts by any constituents in the central portion of the WARWP area. Inorganic compounds have also exceeded the RBCs in

TNTC and north of the WARWP area, but these exceedances will require further evaluation to determine their source.

### *6.1.3 Pentolite Road Red Water Pond Area*

Four overburden and two bedrock wells were sampled in the vicinity of the Pentolite Road Red Water Pond area. None of the four overburden wells exhibited VOCs at concentrations exceeding the RBCs, although IT-MW05 had detectable concentrations of chlorobenzene and toluene. Nitroaromatic compounds exceeded the RBCs in PR-MW07, PR-MW08, and PR-MW09 under the SVOC and explosives analyses. SVOCs and explosives were not detected in IT-MW05. Inorganic compounds exceeded the RBCs in each of the four overburden wells. RBC exceedances in the four overburden wells are summarized as follows:

- ***IT-MW05.*** Arsenic, barium, iron, and manganese
- ***PR-MW07.*** 1,3,5-TNB, 1,3-DNB, 2,4,-DNT, 2,6-DNT, RDX, chromium, cobalt, copper, iron, manganese, nickel, and vanadium
- ***PR-MW08.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 2,6-DNT, 4,6-dinitro-2-methylphenol, RDX, antimony, cadmium, chromium, cobalt, copper, iron, manganese, nickel, and vanadium
- ***PR-MW09.*** 1,3,5-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, antimony, chromium, cobalt, copper, iron, manganese, nickel, and vanadium.

Based on the analytical results for the overburden wells, it is evident that PR-MW07, PR-MW08, and PR-MW09 have been impacted by nitroaromatic compounds by past site activities. Each of the four wells also exhibit inorganic compounds at concentrations exceeding the RBCs, with greater impacts evident in the PR-series wells. However, background concentrations have not been established for metals in groundwater at PBOW, and it is unclear whether these RBC exceedances are due to site contamination.

Both of the sampled bedrock wells exhibited VOCs and SVOCs at concentrations exceeding the RBCs. Both wells also exhibited nitroaromatic compounds, but only the detections in BED-MW15 exceeded the respective RBCs. Inorganic compounds were detected in each well at concentrations exceeding the RBCs. In addition, petroleum product was observed in BED-MW16. RBC exceedances in the two bedrock wells are summarized as follows:

- ***BED-MW15.*** Benzene, chloroform, ethyl benzene, toluene, bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, 1,3,5-TNB, 1,3-DNB, RDX, antimony, and barium

- ***BED-MW16.*** Benzene, chloroform, ethyl benzene, toluene, total xylenes, 2-methylnaphthalene, antimony, barium, chromium, lead, manganese, and vanadium.

Based on the analytical results from the two bedrock wells, it is evident that BED-MW15 and BED-MW16 have been impacted by organic contaminants from past site activities. In addition, BED-MW15 also exhibits impacts by nitroaromatic compounds. Both wells also exhibit at least two inorganic compounds at concentrations exceeding the RBCs, but these levels are not necessarily attributable to site contamination as background levels have not been established. In addition, BED-MW16 also contained floating petroleum product that may be the source of dissolved benzene, toluene, ethyl benzene, and xylene (BTEX) detected in both bedrock wells in this area.

In general, it is concluded that the overburden water-bearing zone in the Pentolite Road Red Water Pond area has been impacted by nitroaromatic compounds, while the bedrock water-bearing zone exhibits impacts by BTEX, SVOCs, and nitroaromatic compounds. Although the Pentolite Road Red Water area water-bearing zones exhibit larger suites of inorganic compounds at concentrations exceeding the RBCs than other areas of PBOW, further evaluation is necessary to determine whether they are attributable to site contamination.

### *6.1.4 TNT Area A*

Five overburden and two bedrock wells were sampled in the vicinity of TNTA. None of the five overburden wells exhibited concentrations of VOCs or SVOCs that exceeded the RBCs. Two wells had detectable levels of nitroaromatic compounds, but only MK-MW22 exhibited explosives at concentrations exceeding the RBCs. All of the overburden wells exhibited inorganic compounds at concentrations exceeding the RBCs. The RBC exceedances for each of the five wells is summarized as follows:

- ***TNTA-MW10.*** Arsenic, iron, and manganese
- ***TNTA-MW11.*** Arsenic, iron, and manganese
- ***MK-MW22.*** 1,3,5-TNB, 4-amino-2,6-DNT, nitrobenzene, iron, and manganese
- ***MK-MW23.*** Arsenic
- ***MK-MW24.*** Iron, lead, manganese, and vanadium.

Based on the analytical results for the overburden wells, it is evident that MK-MW22 has been impacted by nitroaromatic compounds from past site activities. Each of the five wells also exhibit at least one inorganic compound at concentrations exceeding the RBCs. However, background concentrations have not been established for metals in groundwater at PBOW, and it is unclear whether these RBC exceedances are due to site contamination.

VOCs were detected at concentrations exceeding the RBCs in both bedrock wells during the GWI, and SVOCs were detected but did not exceed RBCs. Nitroaromatic compounds were also detected at concentrations exceeding the RBCs in BED-MW17 and BED-MW18. Several inorganic compounds were detected at concentrations exceeding the RBCs in both wells. RBC exceedances in the two bedrock wells are summarized as follows:

- ***BED-MW17.*** Benzene, toluene, nitrobenzene, antimony, arsenic, barium, iron, and lead
- ***BED-MW18.*** Benzene, ethyl benzene, 4-amino-2,6-DNT, antimony, barium, and manganese.

The analytical results from the two monitoring wells indicate that both BED-MW17 and BED-MW18 have been impacted by organic and nitroaromatic compounds from past site activities. Although several metals were detected at concentrations exceeding the RBCs, only one (arsenic) was present in the dissolved sample and only in BED-MW17, which suggests that the other metals RBC exceedances are attributable to suspended solids in the unfiltered sample and are not necessarily due to site contamination. However, site background levels of inorganic compounds have not been developed for groundwater at PBOW. $H_2S$ gas was detected in both bedrock wells, indicating a possible strong reducing environment in the bedrock zone.

It is concluded that the overburden water-bearing zone has been impacted by nitroaromatic contaminants in the vicinity of MK-MW22 in the western part of TNTA. The bedrock water-bearing zone exhibits impacts by BTEX and nitroaromatic compounds in the northeastern part of TNTA. Further evaluation is, however, necessary to determine whether detected inorganic in the two water-bearing zones are attributable to site contamination.

### *6.1.5 TNT Area B*

Two overburden wells and one bedrock well were sampled in the vicinity of TNTB. Neither overburden well exhibited organic contaminants at concentrations exceeding the RBCs. Nitroaromatic compounds were not detected in MK-MW16, but exceeded RBCs in MK-MW17.

Several inorganic compounds also exceeded the RBCs in both wells. The RBC exceedances for each well are summarized as follows:

- ***MK-MW16.*** Aluminum, iron, lead, manganese, and nickel
- ***MK-MW17.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,6-DNT, 4-amino-2,6-DNT, arsenic, iron, manganese, and nickel.

Based on the analytical results from the two overburden wells, it is evident that MK-MW17 has been impacted by nitroaromatic compounds from past site activities. Although several metals exceeded the RBCs in both wells, only manganese and nickel exceeded the RBCs in the dissolved phase in MK-MW16. This indicates that the RBC exceedances of aluminum, iron, and lead in this well are attributable to suspended solids in the unfiltered sample. As background concentrations have not been established for metals in groundwater at PBOW, it is unclear whether the inorganic compounds detected at concentrations exceeding the RBCs are attributable to site contamination.

It is concluded that the overburden water-bearing zone has been impacted by nitroaromatic compounds downgradient of TNTB. Further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions

### *6.1.6 PB-BED-MW20*

The upgradient bedrock well, BED-MW20, was sampled during the GWI. Analytical results from this well indicate that it has not been impacted by organic or explosive compounds from past activities. Five metals did exceed RBCs from this well, but only vanadium was detected in both the total and dissolved samples. Therefore, the RBC exceedances of total antimony, barium, iron, and manganese are attributed to suspended solids in the unfiltered sample. Because background concentrations of metals have not been established for groundwater at PBOW, the RBC exceedance of vanadium requires further evaluation to determine whether it is due to natural conditions.

It is, therefore, concluded that the bedrock water-bearing zone upgradient in relation to other bedrock wells at PBOW does not exhibit impacts by organic or nitroaromatic compounds. However, further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions

## 6.2 Recommendations

Based on the analytical results and conclusions of the sitewide GWI, the following recommendations are made:

- Installation and sampling of additional monitoring wells at various locations are recommended to more accurately define the nature and extent of contaminants in groundwater in the overburden and bedrock water-bearing zones. Specifically, additional overburden and bedrock wells are recommended as follows:

### Bedrock Wells

- One at the G-8 Burning Ground (corner of Campbell Street and Patrol Road) to provide water quality data upgradient of the WARWP and TNTC.

- One near MK-MW16 (TNTB) to provide upgradient water quality data for TNTB and one near MK-MW17 (TNTB) to provide downgradient water quality data for TNTB.

- One in the Maintenance Area to provide upgradient water quality data for the Pentolite Road Red Water Pond area.

- One each (three total) in Acid Areas 1, 2, and 3 to provide bedrock water-bearing zone water quality data in these areas.

- One in the Additional Burn Ground (intersection of Fox Road and Snake Road) to provide groundwater quality data upgradient of TNTA, the Pentolite Road Area, and the Maintenance Area.

### Overburden Wells

- One each (three total) in Acid Areas 1, 2, and 3 to provide overburden water-bearing zone water quality data in these areas. These wells should be placed close to the proposed bedrock well in each area to form a well pair so that appropriate test can be performed to determine the vertical hydraulic gradient.

- One in the Additional Burn Ground (intersection of Fox Road and Snake Road) to provide groundwater quality data upgradient of TNTA, the Pentolite Road Red Water Pond area, and the Maintenance Area. This well should also be placed close to the bedrock well as a well cluster.

- Groundwater level measurements should be collected from all PBOW wells on a quarterly basis for a period of 1 year to determine groundwater gradient variations.

- Selected monitoring wells should be sampled once during the wet season and once during the dry season to determine possible impacts on contaminant migration at the site.

- Existing and new monitoring wells should be evaluated to determine their suitability as background wells; once selected, analytical data from background wells shall be statistically evaluated to determine naturally occurring background concentrations for inorganic compounds so that metals in groundwater samples can be fully evaluated

- All future groundwater data shall be collected in order to support (1) sitewide groundwater flow and transport modeling and (2) a human health risk assessment.

The outlined recommendations will be addressed during the sitewide groundwater level investigation recently contracted to IT. Data collected from the upcoming investigation will be combined with data collected during this GWI and previous GWIs conducted by others in order to provide a comprehensive sitewide groundwater quality evaluation. In addition, the following recommendations should be considered in scoping future studies at the PBOW site:

- Additional groundwater sampling of the overburden water-bearing zone in the vicinity of the two red water pond areas to delineate the lateral extent of nitroaromatic contamination. Hydropunch is the recommended methodology for this additional sampling effort.

- Geochemical evaluation of bedrock chemical data to determine the source of the $H_2S$ gas detected in the bedrock water-bearing zone and possible impact on contaminant migration.