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July 10, 2013

U.S. Army Engineer District, Nashville
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Subject: ***Submittal of the Final Remedial Investigation Report for Acid Area 1***
Former Plum Brook Ordnance Works, Sandusky, Ohio
Contract No. W912P5-12-D-0001: Shaw Project Number 146394

Dear Ms. Coleman:

In accordance with the requirements of Task Order No. DO-02 of Contract No. W912P5-12-D-0001 to Shaw Environmental & Infrastructure, Inc., a CB&I company, we are pleased to submit this Final Remedial Investigation Report for Acid Area 1 at the Former Plum Brook Ordnance Works (PBOW) located in Sandusky, Ohio. This report represents the full compilation and summary for the Remedial Investigation for Acid Area 1 (DERP-FUDS Project No. G05OH001823). This report was prepared consistent with the following: the site characterization report, baseline human health risk assessment, and screening-level ecological risk assessment that were prepared and finalized for Acid Area 1; the agreements among the PBOW Project Delivery Team members; and communications with the U.S. Army Corps of Engineers regarding the scope of this report.

Enclosed for your records are four copies of this report and a complete electronic copy is attached to each hard copy on compact disk (CD). Copies have also been sent to those on the distribution list as indicated for their records.

Should you have any questions or require additional information regarding this submittal, please do not hesitate to contact me at (865) 694-7496.

Sincerely,

Steven. T. Downey, PE, PMP
Project Manager

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Former Plum Brook Ordnance Works, Sandusky, Ohio

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Final
Remedial Investigation Report
Acid Area 1
FUDS Project No. G05OH001823

Former Plum Brook Ordnance Works
Sandusky, Ohio

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List of Acronyms

AA1	Acid Area 1
amsl	above mean sea level
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
CD	compact disk
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CSEM	conceptual site exposure model
DERP	Army Defense Environmental Restoration Program
DoD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FUDS	Formerly Used Defense Sites
HI	hazard index
HQ	hazard quotient
ICI	International Consultants Incorporated
ILCR	incremental lifetime cancer risk
IT	IT Corporation
Jacobs	Jacobs Engineering Group, Inc.
LRD	Great Lakes and Rivers Division
µg/L	micrograms per liter
mg/L	milligrams per liter
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	no-observed-adverse-effects level
NWI	National Wetland Inventory
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
ppm	parts per million
PRG	preliminary remediation goal

List of Acronyms *(Continued)*

RBC	risk-based criteria
RDX	cyclotrimethylenetrinitramine
RfD	reference dose
RI	remedial investigation
SCR	site characterization report
SDWR	Secondary Drinking Water Regulations
Shaw	Shaw Environmental, Inc.
SI	site inspection
SLERA	screening-level ecological risk assessment
SSAP	site-specific sampling and analysis plan
SVOC	semivolatile organic compound
T&E	threatened or endangered
TAL	target analyte list
TCE	trichloroethene
TDS	total dissolved solids
TNT	trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTC	TNT Area C
TRV	toxicity reference value
USACE	U.S. Corps of Engineers
VOC	volatile organic compound

Executive Summary

A remedial investigation (RI) was conducted for Acid Area 1 (AA1) at Plum Brook Ordnance Works, Sandusky, Ohio. The results of the RI have been previously reported in the following three finalized documents:

- Jacobs Engineering Group, Inc. (Jacobs), 2010, ***Final Baseline Human Health Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.
- Jacobs Engineering Group, Inc. (Jacobs), 2010, ***Final Screening Level Ecological Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.
- Jacobs Engineering Group, Inc. (Jacobs), 2009, ***Final Site Characterization Report, Remedial Investigation Part 1 at Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.

This RI summarizes the findings of these three reports, which are appended. No additional investigation results, evaluation, or information is included in this RI report. However, recommendations are provided based on this previously provided information. Thus, the purposes of this RI report are to 1) place all RI-related reports under a single cover, and 2) record a recommendation as to whether or not performance of a feasibility study is warranted.

Site Characterization. A site inspection (SI) of AA1 conducted in 1998 identified surface and subsurface soil contamination above screening levels. An RI was performed April 2007 through May 2008 to further evaluate soil contamination and to evaluate any impacts to the groundwater, surface water, and sediment in the vicinity of AA1.

RI surface and subsurface soil samples were collected at AA1 to define lateral and vertical contamination in the soil. Groundwater was also investigated. Eight temporary piezometers were installed in the overburden/shale unit and water level measurements were conducted over a 12-month period. Three overburden/shale monitoring wells and three bedrock limestone monitoring wells were installed. Twelve surface water samples and 15 sediment samples were collected from four drainage ditches associated with AA1.

The following samples were collected and sent for laboratory analysis:

- Surface soil – 38 samples (15 SI samples, 23 RI samples)
- Subsurface soil – 37 samples (15 SI samples, 22 RI samples)
- Overburden/shale groundwater – One sample from each of five wells in November 2007 and one sample from each of the five wells in May 2008
- Limestone bedrock monitoring wells – One sample from each of five wells in November 2007 and one sample from each of the five wells in May 2008
- Surface water – 12 samples
- Sediment – 15 samples from adjacent drainage ditches.

Chemicals detected in surface soils (<1.5 feet below ground surface [bgs]) at concentrations exceeding residential and background screening levels include the polychlorinated biphenyls (PCB) Aroclor 1260; polycyclic aromatic hydrocarbons (PAH); and the metals lead, antimony, and vanadium. PCBs were the most common contaminant in the surface soil. The highest concentrations of PCBs were found to occur within the footprint of the former storage tanks, and elevated concentrations were also found around the footprint of the former process buildings. Of the metals, only lead was detected at concentrations appreciably above background levels.

Detections of chemicals exceeding screening levels in subsurface soil include Aroclor 1254; Aroclor 1260; the volatile organic compounds tetrachloroethene (PCE) and trichloroethene (TCE); the metals lead, aluminum, vanadium, and cadmium. The PCBs were detected in samples collected at 3 to 5 feet bgs from two locations that coincided with elevated concentrations in surface soil. The detections of TCE and PCE were both from a single sample collected at the 8 to 10 feet bgs interval. The detected concentrations of metals in AA1 subsurface soil were not appreciably greater than background soil levels.

Only metals were detected at concentrations exceeding preliminary remediation goal (PRG) values in overburden/shale groundwater. Of these, only iron and manganese concentrations exceeded reporting limits. These metals are not related to former site operations, and their presence at concentrations exceeding screening levels is likely associated with suspended soil particulates in the samples.

In limestone bedrock groundwater, the only organic compounds detected at concentrations exceeding reporting limits are benzene, toluene, ethyl benzene, total xylenes, and naphthalene; these were also detected at concentrations exceeding the PRGs. These compounds are petroleum

hydrocarbon components that occur naturally in the Delaware and Columbus Limestone groundwater units. A few metals were also detected in limestone groundwater, but only iron and manganese concentrations exceeded reporting limits. As stated previously with respect to overburden/shale groundwater, these metals are not related to former site operations.
From the 12 surface water samples collected, TCE (reported in one sample) is the only organic chemical detected at a concentrations exceeding the reporting limit and the PRG. Various non-site-related metals were also detected at concentrations exceeding PRGs.

PCBs are the only organic compounds detected in the sediment samples at concentrations that exceed the PRGs and reporting limits. Nine of the 15 sediment samples contained PCBs, lead, and/or benzo(a)pyrene at concentrations exceeding screening values. The concentrations of PCBs in sediment are considerably less than those detected in the surface soil and tend to decrease downstream away from the site. A few metals were also detected at concentrations that exceeded PRGs. Lead exceeded the PRGs at only two sediment sampling locations, and the concentrations are considerably less than those found in the surface soils.

Baseline Human Health Risk Assessment. A baseline human health risk assessment (BHHRA) was performed using the RI analytical results and the analytical results from soil samples collected previously during the SI. These data were used to evaluate the following human receptors (media evaluated in parentheses):

- Current/future groundskeeper (surface soil)
- Future indoor worker (surface soil, bedrock groundwater)
- Current/future construction worker (surface soil, subsurface soil, surface water, sediment)
- Future resident (surface soil, subsurface soil, surface water, sediment, bedrock groundwater)
- Current/future adult hunter (surface soil, including venison pathway)
- Current/future hunter's child (surface soil [venison pathway only]).

Cancer risks are calculated as incremental lifetime cancer risk (ILCR) values, and noncancer hazards are calculated as hazard index (HI) values. The overall HI and ILCR values are summarized by environmental medium and receptor in the following bullets. Exceedances of the PBOW cancer risk goal (ILCR>1E-5) are shown in bold type, and exceedances of the noncancer hazard criterion (HI>1) or the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) risk management range (1E-6 to 1E-4) are shown in bold italics. Receptors with

neither an ILCR nor HI value that exceeds the PBOW cancer risk goal or the HI criterion for a given medium are not shown.

Surface Soil

- Current/future groundskeeper: ILCR = 1E-5; HI = 0.2
- Future indoor worker: ILCR = 6E-6; HI = 0.07
- Current/future construction worker: ILCR = 8E-7; HI = 0.5
- Future resident: *ILCR = 6E-5*; ***child HI = 2***; adult HI = 0.4
- Current/future hunter: ILCR = 1E-6; HI = 0.02
- Current/future hunter's child: ILCR = 7E-10; HI = 0.0001

Subsurface Soil

- Current/future construction worker: ILCR = 5E-7; HI = .3
- Future resident: **ILCR = 4E-5; *child HI = 2***; adult HI = 0.3

Groundwater

- Future indoor worker: *ILCR = 9E-5*; ***HI = 2***
- Future resident: ***ILCR = 4E-4***; ***child HI = 14***; ***adult HI = 6***

Surface Water

- Current/future construction worker: ILCR = 3E-8; HI = 0.03
- Future resident: ILCR = 7E-7; child HI = 0.02; adult HI = 0.01

Sediment

- Current/future construction worker: ILCR = 2E-7; HI = 0.09
- Future resident: ILCR = 4E-6; child HI = 0.08; adult HI = 0.01.

The site-related cancer risk-driving chemicals in AA1 surface soil were Aroclor 1254 and Aroclor 1260. Aroclor 1254 was the only noncancer hazard-driving chemical in AA1 surface soil.

The site-related cancer risk driving chemicals in AA1 subsurface soil were Aroclor 1254 and Aroclor 1260. Aroclor 1254 is the only site-related chemical that contributed appreciably to the noncancer hazard in AA1 subsurface soil.

The risks and hazards associated with AA1 limestone bedrock groundwater are regarded as unrealistic because exposure is unlikely. This unlikelihood of exposure is because of low yield of the bedrock aquifer and the presence of naturally occurring petroleum hydrocarbons in this limestone unit. Also, all of the risk-driving chemicals and hazard-driving chemicals in AA1

limestone bedrock groundwater are naturally occurring inorganics and naturally occurring petroleum-related organic chemicals; these are not associated with former PBOW activities.

The cancer risks for all receptors evaluated in the BHHRA for exposure to AA1 surface water and sediment are less than the PBOW cancer risk goal and are either within or less than the NCP risk management range. Noncancer hazards are less than the HI goal of 1.

Screening-Level Ecological Risk Assessment. A screening-level ecological risk assessment (SLERA) was performed using the RI analytical results for soil and sediment and the soil sample results from samples collected previously during the SI. Only soil samples collected from depth intervals ranging from 0 to 5 feet below ground surface were used in the SLERA.

Ecological reconnaissance surveys were conducted as part of the SLERA. The predominant vegetation types were upland old fields, shrub thickets, successional woods, marsh, and scrub/shrub wetlands. Small areas of scrub/shrub wetland vegetation were identified in the eastern and west-central portions of AA1. Also, a small marsh was identified just northwest of AA1, and marsh/shrub habitat was observed along some of the drainage ditches, especially the drainage ditch just south of AA1 and a ditch that flows to the north. No threatened or endangered plant or animal species were observed during site reconnaissance.

The following terrestrial species were evaluated for exposure to contaminants in AA1 soil: deer mouse (small omnivorous mammal), short-tailed shrew (small insectivorous mammal), Eastern cottontail rabbit (medium-sized terrestrial herbivorous mammal), marsh wren (small insectivorous bird), raccoon (medium-sized omnivorous mammal), white-tailed deer (large herbivorous mammal), and red-tailed hawk (large carnivorous bird). These were evaluated for direct (e.g., ingestion of soil) and food web exposure pathways. Two aquatic receptors, the raccoon and mallard duck (medium-sized avian omnivore), were selected to evaluate exposure to surface water and sediment.

Ecological hazards in a SLERA are characterized by the derivation of a hazard quotient (HQ) value, HQs less than or equal to 1 represent no probable hazard. Although the Ohio Environmental Protection Agency considers all HQs above 1 to be potentially significant, the HQ values include much uncertainty and are highly conservative. Therefore, it should be understood that HQs greater than 1 do not mean that adverse ecological effects are occurring at the site or may occur in the future. Generally, HQ values less than 10 indicate a low potential for adverse ecological effects.

All of the HQ values were less than 10, indicating low potential for adverse ecological impacts. Among the terrestrial receptors, only two site-related chemicals of potential ecological concern (COPEC) had HQ values greater than 1. These are Aroclor 1254 and Aroclor 1260. The highest HQ for Aroclor 1260 was 8 in the marsh wren, and the highest HQ for Aroclor 1254 was 3, also in the marsh wren. All HQ values for the Eastern cottontail rabbit, white-tailed deer, raccoon (terrestrial pathways), and red-tailed hawk were less than 1.

Of the two aquatic receptors, only the raccoon had any COPECs with HQ values greater than 1, including 2-methylnaphthalene (HQ = 4), anthracene (HQ = 7), fluoranthene (HQ = 5), and pyrene (HQ=8). However, it is likely that the presence of these PAHs in sediment is the result of exhaust emissions and nearby road and railroad runoff, including leakage from vehicles, as well as from the breakdown of petroleum chemicals from the asphalt. The presence of PAHs in sediment does not appear to be resultant from former PBOW activities.

Recommendations. Based on the RI results, including the BHHRA and SLERA, the U.S. Army Corps of Engineers recommends that a feasibility study be performed for AA1 soils.

1.0 Introduction

The U.S. Army is conducting studies of environmental impacts attributable to releases associated with historical operations of a property previously owned by the U.S. Department of Defense (DoD), the former Plum Brook Ordnance Works (PBOW) in Sandusky, Erie County, Ohio. PBOW is an Army Defense Environmental Restoration Program (DERP) project under the Great Lakes and Rivers Division (LRD) Formerly Used Defense Sites (FUDS) program. The Louisville District Office of the U.S. Corps of Engineers (USACE) is the program management district for the LRD FUDS program. Management support for PBOW is provided by the USACE Huntington District Office, and technical oversight is provided by the USACE Nashville District Office.

This remedial investigation (RI) has been performed to determine if there have been any environmental impacts associated with former DoD activities that present an unacceptable risk to human health or the environment associated with the former Acid Area 1 (AA1), which together with Acid Areas 2 and 3 comprise DERP-FUDS Project No. G05OH001823.

This RI report was conducted under Delivery Order No. DX09 of Contract No. W912QR-08-D-0013 to Shaw Environmental & Infrastructure, Inc. (Shaw) (a CB&I company). It summarizes the information presented previously in the following reports:

- Jacobs Engineering Group, Inc. (Jacobs), 2010a, ***Final Baseline Human Health Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.
- Jacobs Engineering Group, Inc. (Jacobs), 2010b, ***Final Screening Level Ecological Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.
- Jacobs Engineering Group, Inc. (Jacobs), 2009a, ***Final Site Characterization Report, Remedial Investigation Part 1 at Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.

It should be noted that this RI report generally presents and summarizes information directly as it was conveyed in these final approved reports performed by Jacobs. No new data are presented in this RI report. It is noted that Section 2.4 includes an updated evaluation of groundwater quality based on more recent PBOW documents (e.g., Shaw, 2008; 2012).

1.1 Report Organization

As part of the RI effort, the AA1 site was previously investigated and evaluated in a site characterization report (SCR), baseline human health risk assessment (BHHRA), and screening-level ecological risk assessment (SLERA). This RI report summarizes these three reports and presents recommendations based on their findings. The SCR, BHHRA, and SLERA are appended to this report in their entirety (Appendices A through C) in electronic format on compact disk (CD).

The remainder of this chapter provides a description and history of the PBOW facility and of the former AA1. This description of AA1 discusses its relationship to the PBOW remedial activities and briefly describes the history and current associated conditions. More specific information is included in the respective SCR, BHHRA, and SLERA reports that are appended to this RI report. Chapter 2.0 of this report summarizes the physical setting of PBOW and AA1. This discussion of physical setting includes the geography, topography, drainage, and geology, including hydrogeology and natural groundwater quality.

Chapter 3.0 summarizes the SCR, Chapter 4.0 summarizes the BHHRA, and Chapter 5.0 summarizes the SLERA results and conclusions. Chapter 6.0 presents site-specific recommendations for site management decisions. These recommendations primarily discuss whether or not a remedial action is warranted. These recommendations do not identify a specific technological approach, but are provided to help site managers form a basis for determining whether a feasibility study (FS) is required, or for proceeding directly to a no-action proposed plan. References used in the RI are listed in Chapter 7.0.

1.2 Facility Location and Description

The former 9,000-acre PBOW facility was used for the manufacture of nitroaromatics during World War II. The National Aeronautics and Space Administration (NASA) operates and maintains the site as the Plum Brook Station, which is a satellite facility of the John H. Glenn Research Center, located at Lewis Field in Cleveland, Ohio. PBOW is located approximately 4 miles south of Sandusky, Ohio, and 59 miles west of Cleveland. Although primarily in Perkins and Oxford Townships, the eastern edge of PBOW extends into Huron and Milan Townships. PBOW is bounded on the north by Bogart Road, on the south by Mason Road, on the west by Patten Tract Road, and on the east by U.S Highway 250. The areas surrounding PBOW are mostly agricultural and residential. Public access is prohibited at PBOW except during the annual deer hunting season, which is by permit only. Figure 1-1 shows the geographical location of the former PBOW site.

1.3 Facility History and Background

The PBOW facility was constructed on property comprising 9,009 acres in early 1941 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), 2,4-dinitroluene, and pentolite (International Consultants Incorporated [ICI], 1995). Production of explosives at PBOW began in December 1941 and continued until 1945. It is estimated that more than 1 billion pounds of nitroaromatic explosives were manufactured at PBOW during the 4-year operating period. The three explosive manufacturing areas were designated TNT Area A (TNTA), TNT Area B (TNTB), and TNT Area C (TNTC). Twelve process lines were used in the manufacture of TNT: four lines at TNTA, three lines at TNTB, and five lines at TNTC.

After plant operations ceased, the manufacturing process lines were decontaminated by the Army in late 1945. During decontamination, all structures, equipment, and manufacturing debris were either removed and salvaged or removed and burned. After the property was certified as decontaminated, 3,230 acres of the property were initially transferred to the Ordnance Department, then to the War Assets Administration on September 6, 1946. In 1949, PBOW was transferred to the General Services Administration. This transfer did not include the Plum Brook Depot area, also known as the magazine area, which consists of 2,800 acres. The Department of the Army reacquired the 3,230 acres in 1954. In 1955, the Army completed further decontamination of the manufacturing process lines. This effort included removal of contaminated surface and subsurface soil around the buildings and wooden and ceramic waste disposal lines containing TNT. Thousands of pounds of TNT were discovered in catch basins; this TNT was removed and burned at the burning grounds. The Army continued cleanup efforts until 1963.

Two property use agreements were entered into by the Army and the National Advisory Committee of Aeronautics, the predecessor of NASA, in 1956 and 1958, respectively. Accountability and custody for the entire portion of the former PBOW property (6,030 acres) that had been under the accountability and custody of the Department of the Army were transferred to NASA on March 15, 1963. NASA performed further decontamination efforts during 1964. The NASA decontamination process included removing contaminated surface soil above the drain tiles, flumes, etc.; destruction of all buildings by fire; then removal of all soil, debris, sumps, and above-grade portions of concrete foundations. Portions of the concrete foundations located below grade were left buried, and some that had been previously slightly above grade were covered with fill material. All materials, including the soil in those areas, were flashed; the area was then rough-graded. The decontamination process was also to have included the burning of excavated nitroaromatic-filled pipelines (Dames & Moore, Inc., 1997a).

NASA has operated and maintained the former PBOW property since 1963, and the facility is currently the Plum Brook Station, which supports the NASA John H. Glenn Research Center at Lewis Field, Cleveland, Ohio, as a satellite operation. Most of the aerospace testing facilities built in the 1960s at PBOW are currently on standby or inactive status. However, NASA has constructed newer research facilities on site since the 1960s. On April 18, 1978, NASA declared approximately 2,152 acres of PBOW as excess. This excess included former buffer areas that had not been used by the Army and were thus not subject to decontamination efforts. The Perkins Township Board of Education acquired 46 acres of the excess acreage and uses this area as a bus transportation area. The General Services Administration retains ownership of the remaining excess acreage and currently has a use agreement with the Ohio National Guard for 604 acres of this land. The details of land transactions are listed in the site management plan (ICI, 1995).

1.4 Acid Area 1 Description and History

AA1 is one of three acid production areas at PBOW; the others are Acid Area 2 and Acid Area 3. AA1 is located near the center of PBOW approximately 240 feet south of Maintenance Road and is bounded on the eastern side by Taylor Road. A smaller, less traveled road, Power House Road, divides the central portion of the site (Figure 1-2). AA1 covers an area of approximately 17 acres. The ground surface is essentially a flat, open field covered with tall grass and low shrubs. A minimal slope is present which grades toward the north-central portion of the site. Small wooded areas have developed throughout AA1 and tend to be thickest in the northeastern portion of the site. The areas outside of the site boundary have similar growth (Jacobs, 2009a).

During the TNT manufacturing processes at PBOW, all three acid areas were used to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. Based on information presented in the SCR (Appendix A), the following five main processes for acid production likely took place at each of the acid areas:

- Weak nitric acid production
- Strong nitric acid production
- Reprocessing of spent sulfuric acid to produce strong sulfuric acid
- Oleum (sulfuric acid saturated with sulfur trioxide) production
- Mixed acid (strong nitric acid and oleum) production.

Buildings, storage tank areas, roads, and rail lines required for the production, reprocessing, nitration, and transfer of acid are identified at AA1 and shown on Figure 1-3. A complete description of the acid production operations is included in the SCR (Jacobs, 2009a).

2.0 Physical Setting

2.1 Physiography and Topography

PBOW is located within the Eastern Lake section of the Central Lowland Province, near the southwestern shore of Lake Erie. The region is characterized by lake plains, outwash plains, and till plains with occasional small hills produced during the retreat of the Wisconsin glaciation ice sheet. Approximately two-thirds of Erie County was once covered by a glacial lake. Processes associated with the lake produced features such as beach ridges and wave-cut cliffs.

The area of PBOW was originally a flat lake bottom which resulted from glacial melt waters. Across PBOW, the topography is relatively flat with a gentle north-northeast slope towards Lake Erie. Specifically, the land surface at AA1 is flat. Elevations at the site range from 638.3 to 642.8 feet above mean sea level (amsl) (Jacobs, 2009a).

The AA1 site physical features include an open field with four separate drainage features. One borders the southern site boundary, two originate on the western portion of the site and drain to the west, and a fourth originates in the center of the site and drains to the north. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. The remains of an old railroad grade with a few railroad ties and loose track are still evident at the site. A paved service road completes a loop around the perimeter of the site (Jacobs, 2009a).

2.2 Geology

2.2.1 PBOW Geology

Dominant soil materials of Erie County are derived from glacial till, outwash (gravel and sand), and lacustrine (very fine sand, silt, and clay) deposits. Some soil types have been formed from more recent deposits of alluvium and weathering of parent rock. Within PBOW, the soil origins are listed as lacustrine. The glacial drift is less than 20 feet thick on average, with bedrock exposed in many places (Jacobs, 2009a).

The bedrock formations in northern Ohio consist of Devonian and Silurian carbonates (limestone and dolomite) and clastics (shale, siltstone, and sandstone). The regional dip is to the southeast at approximately 35 feet per mile, with younger rocks subcropping to the east. The Silurian and Devonian Formations unconformably overlie sedimentary sequences of Ordovician and Cambrian age, which in turn unconformably overlie the Pre-Cambrian crystalline Greenville Basement.

At PBOW, four Devonian formations subcrop beneath glacial drift cover (Shaw, 2003). From oldest to youngest, these formations are Delaware Limestone, Plum Brook Shale, Prout Limestone, and the Huron Shale member of the Ohio Shale. Further details of PBOW-specific geology are presented in the SCR (Appendix A).

2.2.2 AA1 Geology

Overburden thickness at AA1 ranges from 20 feet near the center of the southern site boundary to 26 feet in the northwestern corner. Throughout the majority of AA1, the overburden soil above the bedrock is characterized as mainly clay and silty clay with a fairly continuous layer of silt in the upper 10 feet. A localized sand lens, less than 1 foot thick, is present on the western side of AA1 at a depth of approximately 19 feet (Jacobs, 2009a).

Bedrock below the overburden soil at AA1 is the Plum Brook Shale. Thickness of the shale ranges from 12 feet in the northwest corner to 19.5 feet near the southeast corner of AA1. The Delaware Limestone underlies the Plum Brook Shale (Jacobs, 2009a).

2.3 Hydrogeology

2.3.1 PBOW Groundwater

Groundwater at PBOW includes the shallow overburden/shale and the limestone bedrock aquifers. PBOW is located within a transition between the two aquifers; the shale is absent to the northwest. Both aquifers are overlain by a veneer of glacial drift, generally less than 20 feet thick, that is considered a poor source of groundwater. Flow in the overburden/shale is toward the local surface drainages, with a generally northerly trend. Groundwater flow in the Delaware Limestone is generally toward the north but is influenced by major fracture zones (Shaw, 2003).

2.3.2 AA1 Groundwater

Groundwater underlying AA1 includes both the overburden/shale and the limestone bedrock aquifers. During the spring of 2008, groundwater elevations in the overburden/shale unit ranged from 633.8 to 640.1 feet amsl. Depths to the shallow groundwater ranged from 1.6 to 5.6 feet below ground surface (bgs). The shallow groundwater underlying AA1 flows to the northwest; however, local drainage ditches serve to control the flow of the shallow groundwater (Jacobs, 2009a).

Regional groundwater elevation contours for the deeper Delaware Limestone aquifer indicate a linear feature running northeast-southwest through PBOW which acts as a preferential flowpath

for the groundwater at AA1 (Shaw, 2003). This feature is parallel to the bedrock strike and may represent a fracture system and/or karst development. The AA1 site is located approximately 1,000 feet southeast of the axis of this feature. Groundwater elevations in the bedrock ranged from 603.5 to 607.7 feet amsl in May 2008 (Jacobs, 2009a), and groundwater is interpreted to flow from the site in a northwestern direction toward the linear feature.

2.4 Groundwater Quality and Use

2.4.1 Groundwater Quality

Two groundwater aquifer systems are utilized for drinking water in the region: a carbonate aquifer to the west and a shale aquifer to the east (Shaw, 2005). PBOW is located within the transition of the two systems. The limestone unit typically yields an adequate volume of groundwater for a drinking water source but is regionally regarded by the Ohio Department of Natural Resources (ODNR) (1962) as being of low quality because of high mineral content.

The two main water-bearing zones underlying the PBOW facility are located in the overburden/shale unit and the limestone bedrock and are thus called the overburden/shale and bedrock water-bearing zones. The overburden and shale groundwater units exhibit similar water levels, suggesting substantial vertical communication, and are considered one hydrogeologic unit.

Overburden/Shale Groundwater. Groundwater in the overburden is in discontinuous pockets during dry time periods (Shaw, 2005; IT Corporation [IT], 1997, 1999, 2001a). Also, the shallow overburden groundwater generally has low yields over most of PBOW due to the high percentage of silt and clay and minimal soil thickness above bedrock. Because of these conditions, the overburden/shale groundwater yields insufficient volume for potable use in many areas of the underlying PBOW. Additionally, groundwater from background wells in competent shale bedrock was found to have elevated concentrations of chloride, sulfate, iron, manganese, and total dissolved solids (TDS) (Shaw, 2006). Some of these concentrations, especially those of sulfate and TDS, were found at levels that far exceed the respective U.S. Environmental Protection Agency (EPA) Office of Groundwater Secondary Drinking Water Regulations (SDWR) or health advisories (EPA, 2012a). The SDWRs are nonenforceable levels that are based on aesthetic properties (e.g., taste, odor, or color) or cosmetic effects (e.g., skin or tooth discoloration). The following bulleted items compare concentrations of these analytes in samples from off-site upgradient background shale unit groundwater wells to the respective Office of Drinking Water SDWRs or health advisories.

- ***Chloride*** – Fifty percent of the background wells exceeded the chloride SDWR of 250 milligrams per liter (mg/L) or parts per million (ppm). The maximum background concentration (3,540 ppm) was 14 times higher than the SDWR.

- ***Sulfate*** – Eleven percent of the background wells exceeded the sulfate SDWR of 250 ppm. The maximum background concentration (514 ppm) was approximately twice the SDWR.

- ***Iron*** – Thirty-two percent of the background wells exceeded the iron SDWR of 0.3 ppm. The maximum background concentration (1.55 ppm) was approximately 5 times higher than the SDWR.

- ***Manganese*** – Sixty-one percent of the background wells exceeded the manganese SDWR of 0.05 ppm. The maximum background concentration (0.728 ppm) was over 14 times higher than the SDWR.

- ***Sodium*** – One hundred percent of the background wells exceeded the sodium health advisory level of 20 ppm. The maximum background concentration (1,390 ppm) was approximately 70 times higher than the sodium health advisory level. (Note that no SDWR exists for sodium.)

- ***TDS*** – Eighty-two percent of the background wells exceeded the TDS SDWR of 500 ppm. The maximum background concentration (6,850 ppm) was nearly 14 times higher than the SDWR.

Based on naturally occurring high TDS and other analytes as described in the preceding list, this groundwater unit is consistent with the EPA guidelines for Class III nonpotable groundwater. Therefore, overburden/shale groundwater is generally not a suitable drinking water source, based on both low yield and poor natural quality.

This low yield in the overburden/shale groundwater generally found underlying much of PBOW was observed in the vicinity of AA1. Groundwater level measurements were collected from eight temporary piezometers. Seven water level measurements were conducted over a 12-month period (April 21, 2007 through May 2, 2008) from the temporary piezometers. Shallow groundwater levels at the site ranged from 1.6 feet bgs (May 2008) in monitoring well AA1-GW-002 to 9.5 feet bgs (October 2007) in piezometer PZ-02 during this period. Piezometer hydrographs show water levels reached a high point during May 2008.

Limestone Bedrock Groundwater. The limestone bedrock water-bearing zone yields groundwater year round, although specific locations may not produce water or produce water at a minimal flow rate due to limited or tight bedrock fractures in some areas. During periods of low precipitation, only limited migration of contaminants would occur in the overburden due to reduced infiltration. Limestone bedrock groundwater underlying most of PBOW is of poor

natural quality, largely due to naturally occurring petroleum hydrocarbons and hydrogen sulfide gas emissions.

The presence of natural petroleum-derived hydrocarbon seeps is common along the walls of area quarries (Shaw, 2005). Petroleum hydrocarbons were observed at depth during the drilling of bedrock well AA1-BEDGW-002. Hydrogen sulfide was also noted to have been encountered while drilling wells AA1-BEDGW-003 and AA1-BEDGW-004. These observations provide evidence that petroleum hydrocarbons are naturally occurring in this general area of PBOW (Jacobs, 2009a).

Consistent with the findings of naturally occurring petroleum hydrocarbons in the limestone wells, benzene was detected in the groundwater of all four AA1 bedrock monitoring wells during each of the four groundwater sampling events beginning in November 1997 until May 2008. Including quality control samples, naturally occurring benzene was detected in all 11 of the groundwater samples collected from the AA1 limestone bedrock monitoring wells. Limestone bedrock groundwater samples exhibited benzene concentrations up to 140 micrograms per liter (µg/L), which exceeds the promulgated Safe Drinking Water Act maximum contaminant level of 5 µg/L for benzene (EPA, 2012a).

TDS concentrations in each groundwater sample collected from the limestone monitoring wells also exceeded the Safe Drinking Water Act SDWR of 500 mg/L. The maximum TDS concentration was 7,140 mg/L, more than 14 times the SDWR. The predominant components of TDS are common salts; very small particulates; ionic forms of common elements such as calcium, magnesium, sodium, iron, sulfate, and strontium; and elevated TDS (Ohio Environmental Protection Agency [OEPA], 2009). The elevated TDS within the limestone bedrock that underlies PBOW likely results from the reducing conditions that mobilize metals. In addition, naturally occurring long-chained petroleum hydrocarbon molecules may also contribute to TDS in PBOW bedrock groundwater.

In summary, the limestone unit generally provides an adequate quantity of groundwater for hypothetical potable use. However, the natural quality of this water would fail drinking water standards with respect to naturally occurring benzene that consistently exceeds the maximum contaminant level and TDS limit. The elevated benzene is related to naturally occurring petroleum hydrocarbons, and the high TDS is likely associated with naturally occurring reducing conditions.

2.4.2 Groundwater Use

Upwards of 170 private drinking water wells permitted by the Erie County Health Department are located within 4 miles of PBOW. USACE conducted a private well survey for the area within 1 mile of the downgradient PBOW boundary. Only five private wells were identified within the 1-mile radius. Two of these were identified as being used to irrigate lawns and gardens and to wash cars; the other three wells were not used at all (Appendix A of Shaw [2006]). Groundwater is not used within the PBOW facility.

2.5 Surface Water

2.5.1 PBOW Surface Water

PBOW lies in the eastern region of the Pickeral Creek–Pipe Creek Basin, which in turn, lies within the St. Lawrence River drainage basin. The Huron River Basin lies approximately 3.5 miles east of PBOW. Sandusky Bay and Lake Erie are approximately 4.5 miles north of the site.

Eleven streams pass through or originate within PBOW and are a part of four drainage areas: 1) Sawmill Creek (southern PBOW), 2) Plum Brook (central PBOW), 3) Pipe Creek (western PBOW), and 4) Storrs-Hemminger Ditch. All streams flow north or northeasterly into Sandusky Bay. Numerous ponds lie within and around PBOW.

The Erie County Health Department does not permit the use of surface water for private drinking water supply, and no surface water within PBOW is used as a drinking water supply.

2.5.2 AA1 Surface Water

Four drainage ditches are associated with AA1: one on the southern perimeter of the site, two originating on the western portion of the site and draining to the west, and one originating in the center of the site and draining to the north. This northern drainage ditch includes a tributary originating east of the site and drains to the northwest, bisecting the northeast corner of the site (Figure 1-3). Also, a low-lying ponded area was identified near the eastern end of the site; this area has no drainage outlet (Jacobs, 2009a).

Three of the four drainage ditches are considered ephemeral and flow only during the wet season and following precipitation events, remaining essentially dry during the summer months. The northern drainage ditch that receives runoff water from the center of AA1 is a tributary to Plum Brook and usually contains water throughout the year. Flowing water was present at most of the surface water sample locations in May 2007, as 12 of the planned 15 samples were able to be collected (Jacobs, 2009a).

3.0 Site Characterization and Evaluation

This chapter provides a summary of the sampling, analyses, results, and evaluation of the environmental media (i.e., soil, overburden/shale groundwater, limestone bedrock groundwater, surface water, and sediment) associated with AA1 based chiefly on samples collected during the RI field activities. This information has been presented in the AA1 SCR (Jacobs, 2009a), which is included with this report as Appendix A.

This chapter also includes references to the samples collected as part of the 1998 site inspection (SI), as these data were also reviewed and evaluated with the RI data in the text of the SCR. These are briefly summarized in Section 3.1. Identification of the samples and the recommendations from the SI present a context for the performance of the RI and for some of the specific sampling locations selected and analyses performed in the RI.

Please note that this chapter provides no data or other information that have not been previously presented in the AA1 SCR (Appendix A).

3.1 Previous Investigation and Evaluation

Prior to the RI, a records review was conducted to investigate whether any previous investigations had been conducted at any of the Acid Areas. Based upon the findings, an SI of AA1 was conducted in 1998 by IT (IT, 1998). The SI included the drilling of 15 soil borings, collection of 2 soil samples (surface and subsurface) from each boring, installation of 1 overburden/shale and 1 bedrock monitoring well, and collection of 2 rounds of groundwater samples from the newly installed wells. Surface soil samples were collected from a depth of 0.5 to 1.5 feet bgs to represent 0 to 1 foot of native material. Surface soil samples were analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), polychlorinated biphenyls (PCB), target analyte list (TAL) metals, and nitroaromatics. Subsurface soil samples were analyzed for VOCs, SVOCs, metals, and nitroaromatics.

The analytical results were compared to risk-based criteria (RBC) derived from EPA (1998) Region 3 values as described in the SI (IT, 1998). Based on this screening evaluation, the PCB Aroclor 1260 and nitroaromatic compound 4-amino-2,6-dinitrotoluene were present in shallow soils at concentrations greater than RBCs. Subsurface soil samples were not analyzed for PCBs; therefore, it was not known if PCBs were present at depth. There were no detected inorganic contaminants in surface and subsurface soil exceeding both the RBCs and the established background values.

One shallow overburden well (AA1-GW-002) and one bedrock well (AA1-BEDGW-001) were installed at AA1 in 1997. Groundwater samples were collected from these wells during two sampling rounds, one in November 1997 and the other in May 1998. Sampling results indicate VOCs, SVOCs, and explosives were detected in the bedrock groundwater at levels above RBCs.

Based upon analytical conclusions, further sampling was recommended for SVOCs and PCBs in surface soil and nitroaromatics and metals in the subsurface soil. The SI results are summarized in the SCR (Appendix A) and were further evaluated in the BHHRA (Chapter 4.0 and Appendix B) and SLERA (Chapter 5.0 and Appendix C). The SI results are presented in Tables 4-1 through 4-4 and 5-2 through 5-5 of the attached SCR.

3.2 Remedial Investigation Characterization and Evaluation

This section summarizes the 2007 through 2008 RI sampling of environmental media at AA1, the analytical results, and an evaluation of these results as presented in the SCR (Jacobs, 2009a). Additional details are provided in the SCR, which is included as Appendix A.

3.2.1 Samples and Analyses

The RI samples were collected consistent with the sitewide sampling and analysis plan (Jacobs, 2004a) and site-specific sampling and analysis plan (SSAP) (Jacobs, 2004b) for AA1. Soil, groundwater, surface water and sediment sampling locations are shown on Figure 3-1.

A total of 45 surface and subsurface soil samples were collected as part of the RI for analysis of the full analytical suite (VOCs, SVOCs, PCBs, nitroaromatics, and metals). This includes 23 surface soil and 22 subsurface soil samples (no nitroaromatics were detected in subsurface soil). Surface soil is defined as samples collected from within the interval of 0.5 to 1.5 feet bgs and subsurface soil is defined as samples collected from depths greater than 1.5 feet bgs. The objective of the soil sampling was to evaluate the presence of soil contamination at additional former site facilities not previously tested during the SI (Jacobs, 2009a).

Eight temporary piezometers were installed following the guidelines listed in the SSAP (Jacobs, 2004b) to determine shallow groundwater gradients and to determine the location of permanent shallow monitoring wells. Groundwater analytical samples were not collected (Jacobs, 2009a).

Three shallow overburden wells (AA1-GW-003, AA1-GW-004, and AA1-GW-005) and three bedrock monitoring wells (AA1-BEDGW-002, AA1-BEDGW-003, and AA1-BEDGW-004) were installed at AA1 in accordance with the SSAP (Jacobs, 2004b) (Figure 3-1). Newly

installed overburden monitoring wells were placed to characterize upgradient, on-site, and downgradient groundwater and to evaluate the presence of chemical contamination in groundwater in the vicinity of AA1. Bedrock wells were placed in upgradient, source area, and downgradient locations based upon other nearby bedrock wells and the 2002 Delaware Limestone groundwater flow map from the *2002 Groundwater Data Summary and Evaluation Report* (Shaw, 2003). Groundwater samples were collected from the 6 newly installed wells and 4 existing wells (10 total monitoring wells). The existing wells included shallow monitoring wells AA1-GW-002 and MK-MW19 and bedrock wells AA1-BEDGW-001 and MNTA-BEDGW-001(Jacobs, 2009a).

Following a thorough reconnaissance of possible surface water and sediment sampling locations at AA1, 15 specific locations were selected and sampled for sediment (Figure 3-1). Twelve surface water samples were collocated with 15 sediment samples in the four drainage ditches. For each drainage ditch, at least one sample was proposed upgradient of the site, one on site or adjacent to the site, and one downgradient of the site. Three surface water samples that were initially planned were not collected because of dry conditions. These locations include the upgradient ponded area on the west side of the site (SW-06), the ponded area on the east side of the site (SW-13), and the upgradient location of the eastern tributary to the northern ditch (SW-15) (Jacobs, 2009a).

The following list summarizes the sample depth, number of samples, and analyses collected for the RI:

- Surface soil (0.5 to 1.5 feet bgs) – 23 samples
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals.

- Subsurface soil (3 to 5 or 8 to 10 feet bgs) – 22 samples
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals
  - 16 collected from a depth of 3 to 5 feet bgs
  - 6 collected from a depth of 8 to 10 feet bgs.

- Overburden/shale monitoring wells – five wells, two rounds (November 2007 and May 2008).
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, TAL metals (unfiltered), TAL metals (filtered – round 1 only), cyanide, total organic carbon, turbidity, alkalinity, total suspended solids, total dissolved solids, nitrate, chloride, sulfate, and hardness.
  - Iron (Fe++) and manganese (Mn++) were measured in field using Hach test kits.
  - Wells sampled include AA1-GW-002, AA1-GW-003, AA1-GW-004, AA1-GW-005, and MK-MW19.

- Limestone bedrock monitoring wells – five wells, two rounds (November 2007 and May 2008)
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, TAL metals (unfiltered), TAL metals (filtered – round 1 only), cyanide, total organic carbon, turbidity, alkalinity, total suspended solids, total dissolved solids, nitrate, chloride, sulfate, and hardness.
  - Iron (Fe++) and manganese (Mn++) were measured in field using Hach test kits.
  - Wells sampled include AA1-BEDGW-001, AA1-BEDGW-002, AA1-BEDGW-003, AA1-BEDGW-004, and MNTA-BEDGW-001.

- Surface Water – 12 samples
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals.

- Sediment – 15 samples
  - All samples analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals.

All analytical data from these samples were reviewed for accuracy and completeness. One hundred percent of the data analyzed were subjected to data validation following the guidelines in the Engineering Manual 200-1-6, *Chemical Quality Assurance for HTRW Projects* (USACE, 1997); EPA *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA, 1999), EPA *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA, 1994), and sampling and analysis plans (Jacobs, 2004a,b). Data were evaluated against specific criteria to verify the achievement of precision, accuracy, representativeness, completeness, and comparability goals established to meet the project data quality objectives. Additional information on data evaluation, data validation, and data quality are provided in the SCR (Appendix A).

3.2.2 Characterization of AA1

3.2.2.1 Local Soils

Soil at AA1 consists of clay and silty clay with a fairly continuous silty layer in the upper 10 feet (SCR Figure 2-1). This silty layer ranges in thickness from 1.5 to 8 feet, being thickest on the eastern and western ends of the site and thinning toward the center. There is a localized sand lens less than 1 foot in thickness on the western boundary at a depth of 19 feet. The remainder of the overburden is clay. The soil at AA1 is mapped as Udorthents, loamy, 0 to 6 percent slopes (Udb), which represents areas that have been altered during construction (Jacobs, 2009a).

3.2.2.2 Local Geology

Bedrock units in AA1 consist of the Plum Brook Shale (member of the Olentangy Shale) and the underlying Delaware Limestone, both of Devonian age. The Plum Brook Shale at AA1 was

encountered at an average depth of 23.8 feet bgs. In general, the shale was medium gray in color, calcareous, thinly bedded, friable, and loose. Thickness of the shale ranges from 12 feet at the northwest corner of the site to 19.5 feet at the southeast corner. Below the shale, the Delaware Limestone was encountered. It was found at depths ranging from 37.3 feet (602.1 feet amsl) in bedrock well AA1-BEDGW-003 to 46 feet bgs (598.6 feet amsl) in well AA1-BEDGW-002. The limestone was typically light gray in color, massive, shaley, and fossiliferous, and exhibited occasional vugs. Hydrocarbon was noted on two of the borelogs, AA1-BEDGW-001 and AA1-BEDGW-002, as well as the detection of the hydrogen sulfide odor.

3.2.2.3 Local Hydrogeology

Eight temporary piezometers were installed in the overburden/shale unit at AA1. Seven water level measurement events were conducted from April 21, 2007 through May 2, 2008. Based on the results of these measurements, it was determined that the overburden/shale groundwater generally flows in a west to northwest direction from AA1 and that the local drainage ditches highly influence groundwater flow direction (Figure 3-2). Depths to groundwater measured in the temporary piezometers and shallow monitoring wells ranged from a high of 1.57 feet bgs (637.03 feet amsl) in well AA1-GW-002 on May 2, 2008 (wet season) to a low of 9.53 feet bgs (629.72 feet amsl) in PZ-02 on October 15, 2007 (dry season) (Jacobs, 2009a).

Three bedrock wells at AA1 were installed in June and July 2007 as part of RI activities. Water level measurements were collected from four bedrock wells at AA1 and from one well located within the maintenance area north of the site. The upgradient and on-site wells AA1-BEDGW-002 and AA1-BEDGW-003 did not provide any useful data, as well AA1-BEDGW-002 had not fully recharged during the time of the investigation and well AA1-BEDGW-003 exhibited radically fluctuating water levels due to hydrogen sulfide gas percolating through the water. The sitewide bedrock groundwater contour map provided in the 2004 Groundwater Data Summary and Evaluation Report (Shaw, 2005) was used to evaluate gradients and flow patterns. Based on these maps, bedrock groundwater at AA1 flows to the west-northwest. This map shows a linear feature on a regional scale, running northeast-southwest through PBOW, which acts as a preferential flowpath for the groundwater at AA1 (Shaw, 2003). This feature is parallel to the bedrock strike and may represent a fracture system and/or karst development. Groundwater elevations drop steeply toward this zone on either side. The AA1 site is located approximately 1,000 feet southeast of the axis of this linear feature (Jacobs, 2009a).

3.2.2.4 Summary of Analytical Results

The analytical results of the RI samples described in Section 3.2.1 are summarized in this section along with the analytical samples collected during the SI in 1998. As part of this evaluation,

analytes detected in the respective environmental media were compared to EPA Region 9 October 1994 residential preliminary remediation goals (PRG) (EPA, 2004) and background screening concentrations (BSC) as points of reference only. (Note that non-cancer-based PRG values were adjusted to a hazard quotient [HQ] of 0.1.) Analytes detected in AA1 RI soil samples are presented in Tables 4-1 through 4-4 of the SCR. SCR Tables 5-2 and 5-3 show analytes of the shallow groundwater and SCR Tables 5-4 and 5-5 present analytes detected in the limestone bedrock groundwater. Analytes detected in surface water are presented in SCR Tables 6-1 and 6-2, while analytes detected in sediment are presented in SCR Tables 6-3 and 6-4 (Appendix A). The respective PRG values are included in these tables. PRGs do not infer a regulatory limit or mandated cleanup level, nor is the identification of an exceedance intended to indicate an unacceptable human health risk or a need for remedial action. A formal evaluation of human health risks was performed in the BHHRA (Appendix B), which includes further information on PRGs.

The evaluation of the analytical results of the samples and analyses (Section 3.2.1), as presented in the SCR, are summarized below for each medium.

Surface Soil (0.5 to 1.5 feet). A total of 38 surface soil samples have been collected at AA1. Fifteen surface soil samples were collected for the 1998 SI at a depth of 0.5 to 1.5 feet bgs to represent the 0 to 1 foot interval of native material, and 23 surface soil samples were collected for the 2007 RI at a depth of 0.5 to 1.5 feet bgs. Analytical results of detected chemicals are included in SCR Tables 4-1 and 4-2 (Appendix A). Distributions and concentrations of contaminants exceeding the PRGs in the surface soil are presented on Figure 3-3. Specific compounds exceeding the PRGs and established background values for inorganics include the following (Jacobs, 2009a):

- Benzo(a)pyrene - 6 locations
- Benzo(a)anthracene - 1 location
- Benzo(b)fluoranthene - 1 location
- Dibenz(a,h)anthracene - 1 location
- Indeno(1 ,2,3-cd)pyrene - 1 location
- Aroclor 1254 - 20 locations
- Aroclor 1260 - 24 locations
- Lead - 17 locations
- Antimony - 1 location
- Vanadium - 1 location.

Subsurface Soil (>1.5 feet). A total of 37 subsurface soil samples were collected at AA1. Fifteen subsurface soil samples were collected during the SI at depth intervals of 2 to 4, 6 to 8, or 8 to 10 feet bgs and 22 subsurface samples were collected for the RI at depths of 3 to 5 or 8 to 10

feet bgs. Analytical results of detected chemicals are included in SCR Tables 4-3 and 4-4 (Appendix A). Distributions and concentrations of compounds exceeding the PRGs in soil are presented on Figure 3-4. Specific compounds exceeding the October 2004 EPA Region 9 residential PRGs (EPA, 2004) include the following (Jacobs, 2009a):

- Benzo(a)pyrene - 1 location
- Tetrachloroethene (PCE) - 1 location
- Trichloroethene (TCE) - 1 location
- Aroclor 1254 - 2 locations
- Aroclor 1260 - 2 locations
- Aluminum - 6 locations
- Cadmium - 1 location
- Lead - 2 locations
- Vanadium - 3 locations.

Piezometer Overburden/Shale Groundwater Summary. Eight temporary piezometers were installed from April 19 through 21, 2007 within AA1 to determine the depth, gradient, and groundwater flow direction of the shallow overburden groundwater. No overburden/shale groundwater samples were collected (Jacobs, 2009a).

Monitoring Well Overburden/Shale Groundwater Sample Summary. Two rounds of groundwater samples were collected from the AA1 shallow monitoring wells, one in November 2007 (dry season) and one in May 2008 (wet season). Groundwater data were also collected in 1997 and 1998 from two existing monitoring wells; on-site well AA1-GW-002 and downgradient well MK-MW19. Groundwater samples were collected using the low-flow groundwater sampling methodology when possible (Jacobs, 2009a).

Two overburden/shale wells (monitoring wells AA1-GW-004 and AA1-GW-005) exhibited conditions that did not allow for low-flow sampling. Groundwater recharge rates from monitoring well AA1-GW-004 were too low to perform purging and sampling at low flow rates within a 10-hour period during the Round 1 dry season sampling only. This well was pumped dry and allowed to recover overnight. Additional purging and water parameter measurements (to ensure water quality representativeness under stable conditions) were attempted the following day, prior to sampling; however, the water level dropped below the top of the pump within 10 minutes. It was decided to collect the samples using the low-flow bladder pump without further collection of water parameter measurements to ensure full sample aliquots. During the wet season sampling, the water column was significantly higher and the well had sufficient yields to allow low-flow sampling. This well was sampled using low-flow technique during the Round 2 (wet season) event (Jacobs, 2009a).

Monitoring well AA1-GW-005 was sampled with a disposable bailer during both sampling events. During the dry season sampling event in November 2007, there was not sufficient water column to collect the full suite of samples. Therefore, this sample was analyzed only for VOC and total metals; aliquots for SVOCs, PCBs, explosives, dissolved metals, and cyanide analyses could not be collected from this well in the first round. During the Round 2 (wet season) sampling in May 2008, low-flow sampling was attempted with a bladder pump, but due to poor well yield, the well was purged dry and sampled 2 days later after a sufficient water column had recovered to allow for collection of the full suite of analytes (Jacobs, 2009a).

Analytical results of detected chemicals in the bedrock aquifer are included in SCR Tables 5-2 and 5-3. The distributions of detections that exceed the PRGs are shown on Figure 3-5. Specific compounds exceeding the October 2004 EPA Region 9 residential PRGs (EPA, 2004) and established background values (Shaw, 2005) for inorganics include the following (Jacobs, 2009a):

- Manganese (all four wells)
- Iron (AA1-GW-002 and AA1-GW-005)
- Arsenic (AA1-GW-002 and AA1-GW-005, both round 1 only, nondetect round 2)
- Thallium (AA1-GW-002 and AA1-GW-003, both round 1 only, nondetect round 2)
- Vanadium (AA1-GW-005, round 1 only, nondetect round 2).

Bedrock Groundwater Sample Summary. Two rounds of groundwater sampling were also performed at the five AA1 bedrock monitoring wells (MNTA-BEDGW-001, AA1-BEDGW-001, AA1-BEDGW-002, AA1-BEDGW-003, and AA1-BEDGW-004), the first in November 2007 (dry season) and the second in May 2008 (wet season). Groundwater data were also collected in 1997 and 1998 from two existing monitoring wells: on-site well AA1-BEDGW-001 and downgradient well MNTA-BEDGW-001. Groundwater samples from monitoring wells were collected using the low-flow groundwater sampling methodology where groundwater yield was adequate. Because of low yield in wells MNTA-BEDGW-001, AA1-BEDGW-002, and AA1-BEDGW-003, low-flow sample collection methods were successful only for monitoring wells AA1-BEDGW-001 and AA1-BEDGW-004.

Monitoring well AA1-BEDGW-002 was not sampled in November 2007 during the dry season event due to an insufficient water column, preventing any development activities. During the dry season sampling event, groundwater was purged from the well with a bailer to serve as a limited well development. The water column was allowed to recover until sampling in May 2008, but it had to be sampled with a bailer due to a limited water column and very low well yields.

Monitoring wells MNTA-BEDGW-001 and AA1-BEDGW-003 were sampled prior to meeting purge volume requirements or water parameter stabilization due to low well yields. In addition to the low well yield, bedrock well AA1-BEDGW-003 was sampled prior to meeting purge volume requirements and stabilization due to unsafe conditions related to the high volume of hydrogen sulfide gas (Jacobs, 2009a).

Analytical results of detected chemicals in the bedrock aquifer are included in SCR Tables 5-4 and 5-5. The distributions of detections that exceed the PRGs are shown on Figure 3-5. Specific compounds exceeding the October 2004 EPA Region 9 residential PRGs (EPA, 2004) and established background values (Shaw, 2005) for inorganics include the following (Jacobs, 2009a):

- Well AA1-BEDGW-001
  - 2,4,6-TNT (Round 1 only)
  - 2-Nitrotoluene (Round 1 only, not detected in Round 2)
  - Cyclotrimethylenetrinitramine (RDX) (Rounds 1 and 2)
  - Benzene (Rounds 1 and 2)
  - Xylene (Rounds 1 and 2)
  - Naphthalene (Rounds 1 and 2)
  - Cyanide (Round 1, not detected in Round 2)
  - Manganese (Round 1 only)
  - Thallium (Round 1 only)
  - Vanadium (Round 1 only)

- Well AA1-BEDGW-002
  - RDX (Round 2, Round 1 not sampled)
  - Nitrobenzene (Round 2, Round 1 not sampled)
  - Benzene (Round 2, Round 1 not sampled)
  - Ethylbenzene (Round 2, Round 1 not sampled)
  - Toluene (Round 2, Round 1 not sampled)
  - Xylene (Round 2, Round 1 not sampled)
  - Naphthalene Round 2, Round 1 not sampled)
  - Arsenic (Round 2, Round 1 not sampled)

- Well AA1-BEDGW-003
  - Benzene (Rounds 1 and 2)
  - Xylene (Rounds 1 and 2)
  - Naphthalene (Rounds 1 and 2)
  - Nitrite (Round 1 only, not detected in Round 2)
  - Thallium (Round 1 only, not detected in Round 2)

- Well AA1-BEDGW-004
  - 1,4-Dichlorobenzene (Round 1 only, not detected Round 2)
  - Benzene (Rounds 1 and 2)

  - Toluene (Rounds 1 and 2)
  - Xylene (Rounds 1 and 2)
  - Naphthalene (Rounds 1 and 2)
  - TCE (Round 1 only, not detected round 2)
  - Thallium (Round 1 only, not detected in Round 2).

- Well MNTA-BEDGW-001
  - Benzene (Rounds 1 and 2)
  - Xylene (Rounds 1 and 2)
  - Naphthalene (Rounds 1 and 2)
  - Nitrogen, Nitrite (Round 2 only, not analyzed in Round 1)
  - Thallium (Round 1 only, not detected in Round 2)
  - Toluene (Round 1 only)
  - Vanadium (Round 2 only, not detected in Round 1)

Surface Water Summary. Twelve surface water samples were collected and analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals. Contaminants detected include VOCs, SVOCs, nitroaromatics, and metals. Analytical results of chemicals detected in the surface water are shown in SCR Tables 6-1 and 6-2 (Appendix A). The distribution of detections that exceed the PRGs is shown on Figure 3-6. Specific compounds exceeding the October 2004 EPA Region 9 residential PRGs (EPA, 2004) include the following (Jacobs, 2009a):

- Iron - 9 locations
- Manganese - 10 locations
- Arsenic - 3 locations
- Thallium - 2 locations
- Aluminum - 1 location
- Vanadium - 1 location
- TCE - 2 locations
- Carbon tetrachloride - 1 location.

Sediment Summary. Fifteen sediment samples were collected and analyzed for VOCs, SVOCs, PCBs, nitroaromatics, and TAL metals. Contaminants detected include VOCs, SVOCs, PCBs, nitroaromatics, and metals. Analytical results of chemicals detected in the surface water are shown in SCR Tables 6-3 and 6-4 (Appendix A). The distribution of detections that exceed the PRGs is shown on Figure 3-7. Specific compounds exceeding the October 2004 EPA Region 9 residential PRGs (EPA, 2004) include the following (Jacobs, 2009a):

- PCB (Aroclor 1260) - 5 locations
- PCB (Aroclor 1254) - 4 locations
- Benzo(a)pyrene - 6 locations
- Lead - 2 locations
- Aluminum - 5 locations

- Vanadium - 1 location
- Nickel - 1 location
- N-Nitroso-di-n-propylamine - 1 location.

4.0 Baseline Human Health Risk Assessment

This chapter provides a summary of the AA1 BHHRA report (Jacobs, 2010a), which is included as Appendix B. It is important to note that this site-specific risk assessment, including the evaluation of future land use and groundwater use, was performed to satisfy administrative requirements, including those described by FUDS regulations (USACE, 2004). This chapter provides no data or other information that has not been previously presented in the full BHHRA or SCR (Appendix A) reports.

The BHHRA evaluates potential human health risks associated with exposure to soil, bedrock groundwater, surface water and, sediment associated with AA1 at the former PBOW.
This summary identifies the chemicals of potential concern (COPC); summarizes the receptors, media, and exposure pathways evaluated; summarizes the risk characterization; and presents the BHHRA conclusions. The BHHRA was performed consistent with EPA guidance and with the procedures established in the BHHRA for TNTA and TNTC soil (IT, 2001b), the BHHRA for groundwater at PBOW (Shaw, 2006) and, most specifically, the AA1 BHHRA work plan (Jacobs, 2009b).

4.1 Identification of Chemicals of Potential Concern

A screening procedure was conducted on the RI and SI (IT, 1998) analytical data from each AA1 environmental medium. This screening process is used to identify COPCs, which are the detected chemical analytes carried through the full risk assessment process. The objectives of COPC screening are to focus the risk assessment on those chemicals that may contribute significantly to overall risk and to remove from quantification those chemicals whose contribution is clearly inconsequential. COPC screening includes a risk-based screen which also considers status as a human nutrient, a frequency-of-detection evaluation, and a background screen.

The COPC screening process resulted in the generation of a data summary table that includes each medium quantitatively evaluated in the BHHRA. This table generated during the BHHRA is included as Table 4-1 of this RI report. Table 4-1 includes the following information for each chemical detected in surface soil, subsurface soil, limestone bedrock groundwater, surface water, and sediment:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of detection limits

- Arithmetic mean of site concentrations
- Appropriate risk-based screening concentration
- Appropriate BSC
- Selection/exclusion of chemical as a COPC.

Additional details of this data summary, including the estimation of the upper confidence limit values and exposure point concentrations for COPCs, are discussed in the BHHRA (Appendix B).

- ***Surface Soil*** – arsenic, cobalt, lead, Aroclor 1254, Aroclor 1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

- ***Subsurface Soil*** – arsenic, cobalt, Aroclor 1254, Aroclor 1260, benzo(a)pyrene, and PCE

- ***Bedrock Groundwater*** – cyanide, 2-nitrotoluene, RDX, TNT, arsenic, manganese, thallium, bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, naphthalene, benzene, ethylbenzene, methylene chloride, TCE, and xylenes

- ***Surface Water*** – arsenic, cobalt, iron, manganese, thallium, carbon tetrachloride, 1,1-dichloroethane, and TCE

- ***Sediment*** – arsenic, cobalt, Aroclor 1254, Aroclor 1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-c,d)pyrene, and N-nitroso-di-n-propylamine.

4.2 Exposure Assessment

Exposure is the contact of a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPCs found at or migrating from a site (EPA, 1989). The AA1 BHHRA characterizes potential exposures to COPCs in AA1 environmental media as portrayed by the conceptual site exposure model (CSEM). These environmental media include soil, groundwater, surface water, and sediment.

The CSEM provides the basis for identifying and evaluating the potential risks to human health in the BHHRA. The CSEM, graphically depicted on Figure 4-1, includes the receptors appropriate to all plausible site-use scenarios and the potential exposure pathways. This presentation of all possible pathways by which a potential receptor may be exposed, including all sources, release and transport pathways, and exposure routes, facilitates consistent and comprehensive evaluation of risk to human health and helps to ensure that potential pathways are not overlooked. The elements of a CSEM include the following:

- Source
- Source media (i.e., initially contaminated environmental media)
- Contaminant release mechanisms
- Contaminant transport pathways
- Intermediate or transport media
- Exposure media
- Receptors
- Routes of exposure.

Contaminant release mechanisms and transport pathways are not relevant for direct receptor contact with a contaminated source medium (e.g., ingestion or dermal contact).

The receptors and pathways on Figure 4-1 reflect scenarios developed from information regarding site background and history, topography, climate, and demographics as presented by Dames and Moore, Inc. (1997b) and the sitewide groundwater investigation (IT, 1997). No current or future exposure by off-site residents is evaluated. Most of the off-site residents are serviced by municipal water from surface water sources. Although there are numerous private groundwater wells in the vicinity, including several within 1 mile of the facility boundary, none of these is used as a potable source. Based on the investigations of other PBOW sites, natural hydrocarbons and hydrogen sulfide are known to be present within the bedrock limestone, and shale formation groundwater generally provides low yields and is of low quality (Shaw, 2008); however, the groundwater underlying AA1 was not summarily excluded for consideration as a tap water source based on natural water quality parameters or general assumptions concerning yield. Therefore, given the presence of numerous off-site wells and the assumption of unrestricted future land use on the site, the development of groundwater for on-site residential (or on-site worker) use as tap water was evaluated for purposes of this BHHRA. Groundwater quality and use are discussed further in Section 2.4.

Exposure associated with the COPCs was evaluated using the following receptors. The media that were quantitatively evaluated for each receptor are listed in parentheses:

- Current/future groundskeeper (surface soil)

- Future indoor worker (surface soil, bedrock groundwater)

- Current/future construction worker (surface soil, subsurface soil, surface water, sediment)

- Future resident (surface soil, subsurface soil, surface water, sediment, bedrock groundwater)

- Current/future adult hunter (surface soil, including venison pathway)
- Current/future hunter's child (surface soil [venison pathway only]).

The resident was evaluated for noncancer hazards separately for the young child (ages 1 through 6 years) and adult life stages, and the noncancer hazard results are presented separately for the child and adult residents. Cancer risk results for the child and adult resident were evaluated separately but are combined in this report to present cancer risks associated with the 30-year residential child/adult exposure duration.

Based on the groundwater investigation, the overburden/shale groundwater unit underlying AA1 is not regarded as a potential source of potable water because of the high clay content and limited discontinuous permeable zones resulting in low yields, and the water is of naturally poor quality. Therefore, the BHHRA did not quantify risks associated with hypothetical future use of groundwater from the overburden/shale unit (Jacobs, 2009b).

The analytical results of the limestone bedrock groundwater were evaluated for risk in the BHHRA assuming potable use. The BHHRA described the use of water from this unit as questionable because of low yields and naturally poor groundwater quality associated with the presence of naturally occurring petroleum hydrocarbons and hydrogen sulfide gas. The low yield is evidenced by the inability to collect groundwater samples using the low-flow method in three of the five AA1 limestone bedrock monitoring wells. Hydrogen sulfide was present in three of the wells, and petroleum was found at depth in two of the wells during installation (Jacobs, 2009a). Please note that naturally occurring hydrogen sulfide gas is common in many PBOW limestone wells as well as in limestone bedrock wells throughout the region. Emissions of hydrogen sulfide gas from these wells may result in nuisance odors and, at elevated levels, potential health concerns. The presence of hydrogen sulfide gas, which has direct and indirect corrosive effects, results in the rapid deterioration of metal components of well materials, pumps, and plumbing. Therefore, groundwater from the limestone unit underlying the AA1 is regarded as nonpotable, despite the assumption made in the BHHRA that it may hypothetically be developed as a drinking water source. The assumption of potability for the limestone bedrock groundwater was made in the BHHRA because OEPA maintained that this assumption should initially be made under baseline conditions where no prior use restrictions are in place.

The equations for the calculations of intake values for each exposure pathway, exposure assumptions, and the calculation of exposure point concentrations of COPCs for modeled pathways (e.g., venison, airborne concentrations) are presented in the BHHRA (Appendix B).

4.3 Risk Characterization

Risk characterization is the process of applying numerical methods and professional judgment to determine the potential for adverse human health effects to result from the presence of site-specific chemicals. This is done by combining the intake rates estimated during the exposure assessment with the appropriate toxicity information identified in the toxicity assessment (see Chapter 4.0 of the BHHRA in Appendix B). Noncancer hazards and cancer risks are characterized separately, including COPCs that induce both types of effects.

Quantitative expressions are calculated during risk characterization that describe the probability of developing cancer (i.e., incremental lifetime cancer risk [ILCR]), or the nonprobabilistic comparison of estimated dose with a reference dose (RfD) for noncancer effects (i.e., HQ and hazard index [HI]). Quantitative estimates are developed for individual chemicals, exposure pathways, and exposure media for each receptor. These quantitative risk characterization expressions, in combination with qualitative information, are used to guide risk management decisions. Risk characterization is applied only to COPCs.

4.3.1 Cancer Risk

The risk from exposure to potential chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime and is called the ILCR. Equations for calculating the ILCR are presented in the BHHRA (Appendix B).

Total ILCRs in the range of 1E-6 to 1E-4 are regarded as acceptable (EPA, 1990); this range is referred to as the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA, 1990) risk management range. Risks less than this range are regarded as negligible. A target cancer risk goal of 1E-5 is used by OEPA and was selected by the PBOW Project Delivery Team as a basis to consider remedial action. Use of this 1E-5 goal represents a departure from the Army's practice of generally using a cancer risk exceeding a value of 1E-4 (the upper end of the NCP risk management range) to trigger remedial action considerations.

4.3.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects of chemicals are evaluated by comparing an exposure level or intake with an RfD. The HQ, defined as the ratio of intake to RfD, is estimated by dividing the intake of a chemical by the RfD as described in the BHHRA (Appendix B). Chemical noncancer hazards are evaluated using chronic RfD values. An HQ of unity indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects. In the case of simultaneous exposure of a receptor to multiple

chemicals, or to a given chemical by multiple pathways, an HI is calculated as the sum of the HQs.

A total HI is calculated as the sum of all HI values, including all media and all COPCs, for a given receptor. Calculating a total HI as the sum of HQ values is based on the assumption that the potential for noncancer effects is additive. EPA (1989), however, acknowledges that the assumption of additivity is probably appropriate only for chemicals that induce adverse effects by the same mechanism. Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ, as described in Appendix B.

4.3.3 Risk Characterization Results

Cancer and noncancer risk characterization results were evaluated in the BHHRA for each environmental medium and each receptor scenario using the methods summarized in Sections 4.3.1 and 4.3.2 and described in Appendix B. The cancer risks and noncancer hazards for each receptor exposed to AA1 are presented in Table 4-2.

The overall HI and ILCR values are summarized by environmental medium and receptor in the following bullets. Exceedances of the PBOW cancer risk goal (ILCR>1E-5) are shown in bold type, and exceedances of the noncancer hazard criterion (HI>1) or the NCP risk management range (1E-6 to 1E-4) are shown in bold italics:

Surface Soil

- Current/future groundskeeper: ILCR = 1E-5; HI = 0.2
- Future indoor worker: ILCR = 6E-6; HI = 0.07
- Current/future construction worker: ILCR = 8E-7; HI = 0.5
- Future resident: *combined child/adult ILCR = 6E-5*; ***child HI = 2***; adult HI = 0.4
- Current/future hunter: ILCR = 1E-6; HI = 0.02
- Current/future hunter's child: ILCR = 7E-10; HI = 0.0001

Subsurface Soil

- Current/future construction worker: ILCR = 5E-7; HI = 0.3
- Future resident: **combined child/adult ILCR = 5E-5;** ***child HI = 2***; adult HI = 0.3

Groundwater

- Future indoor worker: *ILCR = 9E-5*; ***HI = 2***
- Future resident: ***combined child/adult ILCR = 4E-4***; ***child HI = 14***; ***adult HI = 6***

Surface Water

- Current/future construction worker: ILCR = 3E-8; HI = 0.03
- Future resident: combined child/adult ILCR = 7E-7; child HI = 0.02; adult HI = 0.01

Sediment

- Current/future construction worker: ILCR = 2E-7; HI = 0.09
- Future resident: combined child/adult ILCR = 4E-6; child HI = 0.08; adult HI = 0.01.

Please note that the BHHRA reported elevated risks and hazards for the resident associated with PCE in indoor air via the subsurface soil-to-air pathway. The ILCR and HI in the BHHRA were calculated using provisional toxicity values for PCE, as no verified toxicity values were available. Since submittal of the BHHRA, EPA has verified new toxicity values for PCE, which were posted on the Integrated Risk Information System in February 2012 (EPA, 2012b). As a result, the maximum detected concentration of PCE in subsurface soil (1.6 mg/kg) is less than the current November 2012 Regional Screening Level for PCE in residential soil (22 mg/kg) (EPA, 2012c), which is based on a cancer risk of 1E-6 using the recently verified toxicity values. Because the maximum detected concentration of PCE is less than the Regional Screening Level, the soil-to-to indoor air results for PCE are not reflected in the above ILCR and HI results for the resident exposed to subsurface soil.

4.3.4 BHHRA Conclusions

The conclusions are presented separately by environmental medium.

Surface Soil. Under potential future and/or current surface soil exposure scenarios (i.e., groundskeeper, indoor worker, resident, construction worker, hunter, and hunter's child), the PBOW cancer risk goal is exceeded only for the future resident. None of these potential receptors have a surface soil ILCR that exceeds the NCP risk management range. With respect to noncancer effects, only the HI value associated with the child resident exceeds the HI criterion of 1, indicating that adverse noncancer health effects cannot be regarded as unlikely for the child, assuming future residential use. Please note that there are currently no residences on or planned for the AA1 property. The HI values for AA1 surface soil are less than a value of 1 for all other receptors, indicating that adverse health effects are regarded as unlikely under these scenarios.

The site-related cancer risk-driving chemicals in AA1 surface soil identified in the BHHRA were Aroclor 1260 and Aroclor 1254. The site-related, hazard-driving surface soil chemical identified in the BHHRA was Aroclor 1254.

Subsurface Soil. Of the receptors evaluated in the BHHRA for exposure to subsurface soil (i.e., future resident and future/current construction worker), only the future resident has an ILCR value that exceeds the PBOW cancer risk goal. This value does not exceed the NCP risk management range. The child resident has an HI value that exceeds the HI criterion of 1. However, the only site-related chemical that contributed appreciably to this HI is Aroclor 1254, which has an HI value (0.8) that does not exceed the HI criterion. Therefore, based on exposure only to site-related chemicals in AA1 subsurface soil, adverse health effects would not be expected for any receptor. It should be recognized that exposure only to subsurface soil, rather than some combination of surface soil and subsurface soil, is not plausible. As stated previously with respect to surface soil, there are currently no residences on or planned for the AA1 property, so there is currently no exposure to subsurface soil within AA1. The site-related cancer risk-driving chemicals in AA1 subsurface soil identified in the BHHRA were Aroclor 1260 and Aroclor 1254. Aroclor 1254 is the only site-related COPC that contributes significantly to the noncancer hazard.

Groundwater. The PBOW cancer risk goal was exceeded by the ILCR values associated with AA1 bedrock groundwater for each of the receptors evaluated (i.e., future resident and future indoor worker) in the BHHRA. However, the ILCR for indoor worker AA1 groundwater exposure did not exceed the NCP risk management range. The HI values also exceeded the HI criterion for each receptor. However, the risks and hazards associated with AA1 groundwater are regarded as implausible because exposure is unlikely due to low yield of the bedrock aquifer. In addition, the data quality of the samples was low due to high turbidity associated with the bailer sampling method, which had to be used in three of the five wells due to low water yield. The risk-driving and hazard-driving chemicals in AA1 groundwater are naturally occurring metals (i.e., arsenic, manganese, and thallium) and naturally occurring petroleum-related organic chemicals (i.e., benzene) that are not associated with former PBOW activities. In summary, exposure is regarded as implausible and, regardless, the risk-driving and hazard-driving analytes are not related to former site activities.

Surface Water. The cancer risks for all receptors evaluated in the BHHRA for exposure to AA1 surface water (i.e., current/future construction worker and future resident) are less than the PBOW cancer risk goal and the NCP risk management range. Noncancer hazards are all less than the HI criterion of 1, indicating that exposure to chemicals in surface water would not result in adverse human health effects.

Sediment. The cancer risks for all receptors evaluated in the BHHRA for exposure to AA1 sediment (i.e., current/future construction worker and future resident) are less than the PBOW cancer risk goal and are either within or less than the NCP risk management range. Noncancer hazards are all less than the HI criterion of 1, indicating that exposure to chemicals in AA1 sediment would not result in adverse human health effects.

5.0 Screening-Level Ecological Risk Assessment

This chapter provides a summary of the SLERA report (Jacobs, 2010b), which is included as Appendix C. It is important to note that this site-specific ecological risk assessment was performed to satisfy administrative requirements, including those described by FUDS regulations (USACE, 2004). This chapter provides no data or other information that has not been previously presented in the full SLERA or SCR (Appendix A) report.

The SLERA was performed to evaluate and provide an estimate of current and future ecological hazard associated with exposure to potential releases to soil, surface water, and sediment associated with AA1. This SLERA summary provides an ecological site description, identifies chemicals of potential ecological concern (COPEC), identifies ecological receptors, characterizes exposure, characterizes ecological risks, and presents the conclusions of the SLERA.

The SLERA is consistent with EPA guidance and with the procedures established in the SLERA for TNTA and TNTC soil (IT, 2001c) and, most specifically, the AA1 SLERA work plan (Jacobs, 2009b).

5.1 Ecological Site Description

This ecological site description includes a general discussion of site background and the area of concern, surface water resources, wetlands, and vegetative communities; a species inventory; and a discussion of threatened and endangered (T&E) species. Ecological characterization of the study area was based on a compilation of existing ecological information and site reconnaissance activities discussed in Sections 5.1.1 and 5.1.2. Information was obtained on the presence of state- and federally listed, endangered T&E species; species of special concern; and wildlife and fisheries resources. A botanist searched for T&E plant species during the reconnaissance visits. A checklist of biological species present at the site was developed using existing SI reports, environmental data sources, and information gathered during the site reconnaissance. Information on unique and special-concern habitats, preserves, wildlife refuge parks, and natural areas within the general vicinity was also obtained.

5.1.1 Site Background

PBOW is part of the Lake Plains region. Across PBOW, the land slopes gently to the north-northeast towards Lake Erie. The Lake Plains region itself is over 69 percent cropland, 2.7 percent pasture land, and 10.5 percent forest (ODNR, 1985). However, since the U.S. Army acquired the site in 1941 and removed the land from agricultural production, undeveloped portions of the former PBOW have become second generation forest and open fields. This has

resulted in PBOW becoming an island of forest and open fields within the greater context of primarily agricultural land in north-central Ohio.

AA1 comprises approximately 17 acres. The ground surface is relatively flat, with minimal slope to the north and northwest. The majority of the site is upland old fields, and four drainage features are present at AA1. Drainage ditches in the south, west-central, and northwest corner of the site drain to the west into Ransom Brook. A drainage feature in the north-central portion of the site drains to the north. AA1 previously had two sets of railroad tracks bisecting the site east to west; these have since been removed. AA1 also had access road and parking areas.

5.1.2 Site Reconnaissance

Ecological scientists performed site reconnaissance visits to AA1 in the spring and fall of 2008. These visits were performed at different times of year to identify early- and late-blooming plant species (especially T&E) and to identify migrating and nesting bird species. These site visits were also used to compile lists of other fauna observed at the site. No federally or state-listed species were observed. A full species list is presented in the SLERA (Appendix C).

Prior to arrival at PBOW, site personnel obtained maps and other relevant site information and determined the locations of potential ecological units such as streams, creeks, ponds, grasslands, forest, and wetlands on or near the site. Additionally, the biological inventory performed in 1994 at PBOW (ODNR, 1995) that identifies and indicates the locations of T&E species at the installation was reviewed. The locations of known or potential contaminant sources affecting the site and the probable gradient of the pathway by which contaminants may be released from the site to the surrounding environment were identified. Reconnaissance personnel used the site visit to evaluate the site for more subtle clues of potential effects from contaminant release. Information obtained during the reconnaissance trips was used to select representative receptors, refine exposure scenarios for the risk assessment, and identify protected species or habitats of special concern in the study area.

5.1.3 Surface Water

Four drainage features are present in the vicinity of AA1 (Figure 3-1). The ditch that originates in the north-central portion of the site and drains to the north typically has flowing water year-round. A second ditch is located approximately 40 feet south of the service road that forms the southern boundary of AA1. A third ditch originates in a swampy area in the western portion of AA1 and drains to the west into Ransom Brook. The fourth drainage ditch originates in a ponded area (resultant from a man-made dike) in the northwest corner of the site. Each of these ditches,

the wet area, and the ponded area dry up in the summer, except for the first ditch described in the north-central part of the site.

5.1.4 Wetlands

According to the National Wetland Inventory (NWI) maps for the area (U.S. Fish and Wildlife Service, 1977), there are no designated wetlands at AA1. It should be noted that the accuracy of NWI maps is limited, especially in relatively flat landscapes (such as PBOW), because minor depressions often contain isolated wetlands not easily identified through aerial photograph interpretation (the process used by the U.S. Fish and Wildlife Service in preparing NWI maps). During the vegetation survey, small areas of scrub/shrub wetland vegetation were identified in the eastern and west-central portions of AA1. Also, a small marsh was identified just northwest of AA1, and marsh/shrub habitat was observed along some of the drainage ditches, especially the drainage ditch just south of AA1 and the perennial ditch that flows to the north (Figure 5-1).

5.1.5 Vegetative Communities

Vegetative communities at the site were classified during spring and fall 2008 site reconnaissance trips. The vegetation community map shown on Figure 5-1 was generated based on information obtained during these reconnaissance visits. The predominant vegetation types were upland old fields, shrub thickets, successional woods, marsh, and scrub/shrub wetlands. Plant species identified are listed in Table 2-1 of the SLERA (Appendix C).
Vegetative stress attributable to chemical contamination was not observed at AA1.

5.1.6 Species Inventory

Based on information from ODNR (1995) and collected during the site reconnaissance, species lists were prepared for plants, mammals, birds, reptiles, amphibians, and fish. Note that no reptiles, amphibians, or fish were observed during reconnaissance at AA1; given the limited quality of surface water habitat associated with AA1, this area is not expected to support fish. These species lists are included in the SLERA.

A total of 151 plant species were documented at AA1 during the early summer and fall vegetation surveys. This comprises approximately 41 percent of the total number of species documented at PBOW either during the 1994 biological inventory (ODNR, 1995) or during vegetation surveys at other sites at the former PBOW.

White-tailed deer and signs of three other mammals (coyote, raccoon, and Eastern fox squirrel) were observed during the vegetation surveys. A total of 43 species of mammals may be found in

the region based on species range maps. It is likely that other species of mammals are present at AA1 but were not observed due to the short duration of the field visits.

A total of 129 species of birds may be found in the region based on species range maps and field observations, and 105 species have been recorded at the former PBOW by the ODNR during their multiyear studies. During the 2008 spring and fall site reconnaissance, 28 bird species were documented at AA1.

No T&E plant or animal species were observed during site reconnaissance. Further, based on the lack of sightings in the vicinity of PBOW, no T&E bird species are expected to be found at AA1. Likewise, the only T&E mammal (Ohio endangered) historically documented at PBOW, the Indiana bat, has widespread sightings throughout Ohio, but AA1 does not provide the preferred habitat (caves or trees with exfoliated bark)

5.2 Identification of Chemicals of Potential Ecological Concern

A screening process was performed on the analytical data from the RI and SI to identify COPECs that may pose a threat to ecological receptors. These data include all soil samples collected to a depth of 5 feet, surface water, and sediment samples. Groundwater was excluded because exposure to this AA1 medium is considered to be an incomplete pathway for ecological receptors. Sample locations are presented on Figure 3-1.

The COPEC selection process was performed to develop a subset of chemicals detected at the site that are not naturally occurring or are associated with non-site-related sources. These chemicals are also present at sufficient frequencies, concentrations, and spatial areas to possibly pose a potential risk to ecological receptors. Examples of screening criteria that were used include the following: analytical detection limit, frequency of detection less than 5 percent, comparability with background, status as a nutrient, and comparison with risk-based screening ecotoxicity values. This selection process and the screening values used for COPEC selection are described in the SLERA (Appendix C).

The results of the COPEC screening as presented in the SLERA (Appendix C) are shown in Table 5-1. The table presents the following information:

- Chemical name
- Frequency of detection
- Range of detected concentrations

- Range of detection limits
- Arithmetic mean (average) of site concentrations
- Distribution type
- Upper confidence limit of the mean of the concentration (only for chemicals selected as COPECs)
- Appropriate ecological screening value
- BSC
- COPEC selection conclusion: NO (with rationale for exclusion) or YES (selected)
- Ninety-fifth percent upper confidence limit on the arithmetic mean concentration.

Chemicals identified as COPECs were quantitatively evaluated in the predictive SLERA, which is summarized in Sections 5.3 through 5.6. The COPEC are listed below by environmental medium.

- ***Soil.*** 2,4-Dinitrotoluene, Aroclor 1254, Aroclor 1260, naphthalene, antimony, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and vanadium.
- ***Sediment.*** Acetone, carbon disulfide, p-cresol, 2-methylnaphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, Aroclor 1254, Aroclor 1260, chromium, lead, mercury, and nickel.
- ***Surface Water.*** 1,1,1-Trichloroethane, aluminum, barium, copper, iron, manganese, nickel, and zinc.

5.3 Selection of Ecological Receptors

Ecological assessment receptors were selected in the SLERA to focus the exposure characterization on species, groups of species, or functional groups that are directly related to the following assessment endpoints: the protection of long-term survival and reproductive capabilities for terrestrial invertebrates, herbivorous mammals, omnivorous mammals, insectivorous mammals and birds, and carnivorous birds.

As part of this receptor selection process, site biota were organized into major functional groups. For terrestrial communities, the major groups are plants and wildlife, including terrestrial invertebrates, mammals, and birds.

Seven representative terrestrial receptor species that are expected or possible in the area of AA1 (based on the ecological description of the site presented in Section 5.1) were selected as indicator species for the potential effects of COPECs. These indicator species represent two classes of vertebrate wildlife (mammals and birds) and a range of both body size and food habits and include herbivores, omnivores, and carnivores. The seven terrestrial species selected include the deer mouse (small omnivorous mammal), short-tailed shrew (small insectivorous mammal), Eastern cottontail rabbit (medium-sized terrestrial herbivorous mammal), marsh wren (small insectivorous bird), raccoon (medium-sized omnivorous mammal), white-tailed deer (large herbivorous mammal), and red-tailed hawk (large carnivorous bird).

Exposure to aquatic organisms within the ditches and wet areas is assumed to occur via direct exposure to contaminants in the water column and via prey exposed to contaminants in surface water and sediment. Potential uptake through the aquatic food chain is evaluated for the raccoon (also considered as a terrestrial receptor) and mallard (medium-sized avian aquatic omnivore).

A terrestrial food web is presented on Figure 5-2 and an aquatic food web is presented on Figure 5-3. Many of the species evaluated, particularly the deer mouse, cottontail rabbit, short-tailed shrew, and marsh wren, have limited home ranges which make them particularly vulnerable to exposure from site contaminants. The species selected to represent the various foraging guilds present at AA1 have the following desirable characteristics:

- Potential high abundance and wide distribution at the site.
- Sufficient toxicological information (with the exception of some bird species) is available in the literature for comparative and interpretive purposes.
- Importance with respect to the stability of the local ecological food chain and biotic community.
- Readily available exposure data, e.g., as summarized in the *Wildlife Exposure Factors Handbook* (EPA, 1993).

5.4 Exposure Characterization

A description of the nature, extent, and magnitude of potential exposure of assessment receptors to COPECs that are present at or migrating from the site is presented in this section, considering both current and reasonably plausible future use of the site. Exposure characterization is critical in further evaluating the risk of chemicals identified as COPECs during the screening process. The exposure assessment links the magnitude (concentration) and distribution (locations) of the contaminants detected in the media sampled during the investigation, evaluating pathways by

which chemicals may be transported through the environment, and determining the points at which organisms found in the study area may contact contaminants.

Ecological routes of exposure for biota may be direct (bioconcentration) or through the food web via the consumption of contaminated organisms (biomagnification). Direct exposure routes include dermal contact, absorption, inhalation, and ingestion. Examples of direct exposure include animals incidentally ingesting contaminated soil or sediment (e.g., during burrowing or dust-bathing activities), animals ingesting surface water, plants absorbing contaminants by uptake from contaminated sediment or soil, and dermal contact of aquatic organisms with contaminated surface water or sediment. Given the scarcity of available data for wildlife dermal and inhalation exposure pathways, potential risk from these pathways is not estimated in the SLERA. In addition, these pathways are generally considered to be incidental for most species, with the possible exceptions of burrowing animals and dust-bathing birds. Food web exposure can occur when terrestrial or aquatic fauna consume contaminated biota. Examples of food web exposure include animals at higher trophic levels consuming plants or animals that bioaccumulate contaminants.

Daily doses of COPECs for vertebrate receptors were calculated using standard exposure algorithms. These algorithms incorporate species-specific natural history parameters (i.e., feeding rates, water ingestion rates, dietary composition, etc.) as well as site-specific area use factors. These algorithms are presented and described in the SLERA (Appendix C).

Exposure to soil, surface water, and sediment is discussed in the following paragraphs. Surface water was not present in the drainage adjacent to the site, and groundwater is not a medium of concern for ecological receptors at this site.

Soil Exposure Pathway. Soil exposure pathways are potentially important for terrestrial plants and animals at the site. A depth of 0 to 5 feet bgs was evaluated to account for potential effects on deep-rooted plants and burrowing animals such as the shrew. Although the shrew itself may not actually burrow to a depth of 5 feet, there may be other mammals that burrow this deep. Also, for herbivores that feed on deep-rooted plants, the evaluation of exposure to soil from a depth of 0 to 5 feet bgs is appropriate because most feeder roots are located within this depth and contaminants may be translocated to parts of the plants eaten by animals (e.g., main roots and leaves).

Surface Water Exposure Pathway. Potential contaminant sources for surface water include over-ground transport from the vicinity of AA1 contaminated soil/sediment and groundwater,

and deposition of airborne contaminants. The release mechanisms include surface water runoff, groundwater discharge, and airborne deposition. Exposure routes for contaminated surface water include ingestion by terrestrial fauna and uptake and absorption by aquatic flora and fauna. Consumption of bioaccumulated contaminants constitutes a potential indirect exposure pathway for faunal receptors. Chemical bioavailability of some metals and other chemicals is controlled by water hardness, pH, and total suspended solids.

Sediment Exposure Pathway. Potential contaminant sources for sediment include over-ground transport from the AA1 and contaminated surface water, groundwater, and soil. The release mechanisms include surface water runoff, groundwater discharge, and airborne deposition. Potential receptors of chemicals in contaminated sediment include aquatic flora and fauna. Direct exposure routes for contaminated sediment include contact by benthic-dwelling organisms such as amphipod invertebrates, uptake by aquatic flora, and ingestion by aquatic fauna. Indirect exposure pathways from sediment include consumption of bioaccumulated contaminants by consumers in the food chain. Only direct exposure to aquatic sediment-dwelling organisms was evaluated in the SLERA due to limited aquatic habitat.

5.5 Risk Characterization

The risk characterization phase integrates information on exposure, exposure-effects relationships, and defined or presumed target populations. The result is a determination of the likelihood, severity, and characteristics of adverse effects to environmental stressors present at a site. Qualitative and semiquantitative approaches were used to estimate the likelihood of adverse effects occurring as a result of exposure of the selected site receptors to COPECs.

Food chain modeling was used to estimate exposure rates for the representative assessment receptors. These exposure rates were compared with toxicity reference values (TRV) to calculate HQs (Wentsel, et al., 1996). Only conservative TRVs based on a no-observed-adverse-effects level (NOAEL) were used in the food chain model. HQs are calculated by summing intake doses across all exposure pathways for each chemical for a given receptor and dividing by the TRV. HQs less than or equal to 1 represent no probable hazard. Although OEPA considers all HQs above 1 to be potentially significant, the following uncertainties regarding HQ interpretation are noted:

- HQs are not measures of risk.
- HQs are not population based.
- HQs are not linearly scaled.

- HQs are often produced that are unrealistically high and toxicologically impossible (e.g., estimated HQs greater than 1,000).
- Trace soil concentrations of inorganic chemicals (including concentrations well below background levels) can lead to HQ threshold exceedances.

Although OEPA considers HQs greater than 1 to be potentially significant, the following interpretation of HQ ranges from Wentsel, et al. (1996) takes into consideration the uncertainties inherent in HQs and provides a basis for possible recommendations:

- HQs from 1 to less than 10 represent a low potential for environmental effects.
- HQs from 10 to less than 100 represent a significant potential that effects could result from greater exposure.
- HQs greater than 100 represent the highest potential for expected effects.

Therefore, it should be understood that HQs greater than 1 do not mean that adverse ecological effects are occurring at the site or may occur in the future.

Table 5-2 summarizes the NOAEL-based HQs for the seven evaluated terrestrial assessment receptors and the two aquatic receptors, as presented in Section 5.3 of the SLERA (Appendix C).

5.6 SLERA Conclusions

All of the HQ values were less than 10, indicating low potential for adverse ecological impacts (Table 5-2). Among the terrestrial receptors, only two site-related COPECs had an HQ value greater than 1. These are Aroclor 1254 and Aroclor 1260. The highest HQ was 8, for Aroclor 1260 in the marsh wren, and the highest HQ for Aroclor 1254 was 3, also in the marsh wren. HQ values for the eastern cottontail rabbit, white-tailed deer, raccoon (terrestrial pathways), and red-tailed hawk were all less than 1.

Of the two aquatic receptors, only the raccoon had any COPECs with HQ values greater than 1, including 2-methylnaphthalene (HQ = 4), anthracene (HQ = 7), fluoranthene (HQ = 5), and pyrene (HQ=8) (Table 5-2). However, it is likely that the presence of these polynuclear aromatic hydrocarbons in sediment is the result of exhaust emissions and nearby road and railroad runoff, including leakage from vehicles, as well as from the breakdown of petroleum chemicals from the asphalt. The presence of polynuclear aromatic hydrocarbons in sediment does not appear to be resultant from former PBOW activities.

6.0 DERP-FUDS Project No. G05OH001823 (AA1) Recommendations

The purpose of the RI is to gather information concerning the site characteristics so that appropriate remedial alternatives may be developed in the FS. However, it is unnecessary to perform an FS if the BHHRA indicates that the human health risk goals are met under baseline conditions and the ecological risk assessment indicates a lack of adverse ecological effects (DoD, 2004; 2012).

Based on the RI results, including the BHHRA and SLERA, USACE recommends that an FS be performed for AA1 soils. The recommendation is based on potential human health concerns associated with exposure to surface soil and subsurface soil. The results of the BHHRA indicate that exposure to each of these media under a future residential exposure scenario would result in elevated cancer risks or elevated noncancer hazards that are associated with DoD-related contaminants.

7.0 References

Dames and Moore, Inc., 1997a, ***Final Report, Sitewide Groundwater Investigation, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Dames and Moore, Inc., 1997b, ***TNT Areas Site Investigation, Final Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** April.

International Consultants Incorporated (ICI), 1995, ***Site Management Plan, Plum Brook Ordnance Works, Sandusky, Ohio, Part B, Areas of Concern,*** U.S. Army Corps of Engineers, Huntington District, September.

IT Corporation (IT), 2001a, ***TNT Areas A and C Remedial Investigation, Volume I – Report of Findings, Final, Former Plum Book Ordnance Works, Sandusky, Ohio,*** November.

IT Corporation (IT), 2001b, ***TNT Areas A and C Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio, Volume 2, Baseline Human Health Risk Assessment,*** Final, November.

IT Corporation (IT), 2001c, ***TNT Areas A and C Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio, Volume 3, Ecological Risk Assessment,*** Final, November.

IT Corporation (IT), 1999, ***Final - Summary Report, Site-Wide Groundwater Monitoring (1997-1998), Former Plum Brook Ordnance Works, Sandusky, Ohio,*** June.

IT Corporation (IT), 1998, ***Site Investigations of Acid Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** December.

IT Corporation (IT), 1997, ***Site-Wide Groundwater Investigation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

Jacobs Engineering Group, Inc. (Jacobs), 2010a, ***Final Baseline Human Health Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.

Jacobs Engineering Group, Inc. (Jacobs), 2010b, ***Final Screening Level Ecological Risk Assessment, Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** July.

Jacobs Engineering Group, Inc. (Jacobs), 2009a, ***Final Site Characterization Report, Remedial Investigation Part 1 at Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.

Jacobs Engineering Group, Inc. (Jacobs), 2009b, ***Final Baseline Human Health Risk Assessment and Ecological Screening Level Risk Assessment Work Plan, Acid Area 1,*** Former Plum Brook Ordnance Works, Sandusky, Ohio, April.

Jacobs Engineering Group, Inc. (Jacobs), 2004a, ***Final Site-Wide Sampling and Analysis Plan, Former Plum Brook Ordnance Works, Sandusky, Ohio***, May.

Jacobs Engineering Group, Inc. (Jacobs), 2004b, ***Final Site-Specific Sampling and Analysis Plan, Remedial Investigation, Part 1, Acid Areas 2 & 3, Former Plum Brook Ordnance Works, Sandusky, Ohio***, October.

Ohio Department of Natural Resources (ODNR), 1995, ***Biological Inventory of Plum Brook Station, 1994***, prepared for Office of Environmental Programs, NASA Lewis Research Center, Cleveland, Ohio, prepared by ODNR under contract to The Bionetics Corporation, Brookpark, Ohio.

Ohio Department of Natural Resources (ODNR), 1985, ***Ohio Resources Inventory***, Joint Publication of ODNR, Division of Soil and Water Conservation, and USDA Soil Conservation Service, Columbus, Ohio, 28 pp.

Ohio Department of Natural Resources (ODNR), 1962, ***Availability of Underground Water, Pickeral Creek – Pipe Creek Area***, as referenced in Dames and Moore, Inc. (D&M), 1997c, ***TNT Areas Site Investigation, Final Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** April.

Ohio Environmental Protection Agency (OEPA), 2009, ***Drinking Water Quality Sampling to Support the Ohio Department of Health Childhood Cancer Investigation, City of Clyde and Surrounding Townships***, Division of Drinking and Ground Waters, April 9.

Shaw Environmental, Inc. (Shaw), 2012, ***Proposed Plan for Groundwater (Covering TNT and Red Water Pond Areas, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** March.

Shaw Environmental, Inc. (Shaw), 2008, ***Feasibility Study for Groundwater, TNT and Red Water Pond Areas, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, December.

Shaw Environmental, Inc. (Shaw), 2006, ***Baseline Human Health Risk Assessment of Groundwater, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

Shaw Environmental, Inc. (Shaw), 2005, ***2004 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio***, April.

Shaw Environmental, Inc. (Shaw), 2003, ***2002 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

U.S. Army Corps of Engineers (USACE), 2004, ***Formerly Used Defense Sites (FUDS) Program Policy***, Washington, D.C., ER-200-3-1, May 10.

U.S. Army Corp of Engineers (USACE), 1997, ***Chemical Quality Assurance for HTRW Projects,*** Engineering Manual 200-1-6, October.

U.S. Department of Defense (DoD), 2012, ***Defense Environmental Restoration Program (DERP) Management Manual, No. 4715.20***, March 9.

U.S. Department of Defense (DoD), 2004, ***Formerly Used Defense Sites Program Policy, Regulation No. 200-3-1, ER 200-3-1***, May 14.

U.S. Environmental Protection Agency (EPA), 2012a, ***2012 Edition of the Drinking Water Standards and Health Advisories,*** Office of Water, April, EPA 822-S-12-001.

U.S. Environmental Protection Agency (EPA), 2012b, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, on line.

U.S. Environmental Protection Agency (EPA), 2012c, ***Regional Screening Level Table, User's Guide (November 2012)***, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

U.S. Environmental Protection Agency (EPA), 2004, ***Preliminary Remediation Goals (PRG) Table***, Region 9, San Francisco, California, October.

U.S. Environmental Protection Agency (EPA), 1999, ***Contract Laboratory Program National Functional Guidelines for Organic Data Review,*** EPA540/R-99/008, October.

U.S. Environmental Protection Agency (EPA), 1998, ***Risk-Based Concentration Table,*** EPA Region 3, April.

U.S. Environmental Protection Agency (EPA), 1994, ***Contract Laboratory Program National Functional Guidelines for Inorganic Data Review***, EPA/540/R-94/013, July.

U.S. Environmental Protection Agency (EPA), 1993, ***Wildlife Exposure Factors Handbook***, Vols. I and II, Office of Research and Development, Washington, D.C., EPA/600/R-93/187a.

U.S. Environmental Protection Agency (EPA), 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," ***Federal Register*** 55(46): 8666-8865.

U.S. Environmental Protection Agency (EPA), 1989, ***Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)***, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/1-89/002.

U.S. Fish and Wildlife Service, 1977, National Wetland Inventory Map, based on aerial photographs in March 1977, Sandusky and Kimball, Ohio quadrangles.,

Wentsel, R.S., T.W. LaPoint, M. Simini, R.T. Checkai, D. Ludwig, and L.W. Brewer, 1996, ***Tri-Service Procedural Guidelines for Ecological Risk Assessments,*** U.S. Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Maryland.

TABLES

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Surface Soil												
GC2	Moisture, Percent	15	15	100	Percent		12.1	21.8	17.7			
GC2	pH	15	15	100	pH Units		6.8	8.1	7.48			
GC2	Sulfate (as SO4)	15	12	80	mg/kg	12 - 12	13.4	3910	651			
HE	1,3,5-Trinitrobenzene	25	1	4	µg/kg	80 - 250	300	300	59.3		2200000	
HE	2,4,6-Trinitrotoluene	25	1	4	µg/kg	80 - 250	300	300	59.3		19000	
HE	2,4-Dinitrotoluene	25	4	16	µg/kg	100 - 250	130	2500	174		120000	
HE	4-Amino-2,6-Dinitrotoluene	25	1	4	µg/kg	80 - 250	810	810	79.7		150000	
HE	4-Nitrotoluene	23	1	4	µg/kg	80 - 100	180	180	51.7		30000	
MET	Aluminum	38	38	100	mg/kg		155	14300	8100	15500	77000	
MET	Antimony	38	1	3	mg/kg	2.2 - 7.7	9.5	9.5	2.38	9.3	31	
MET	Arsenic	38	37	97	mg/kg	1.3 - 1.3	1.4	18.1	6.59	36.5	0.39	Y
MET	Barium	38	37	97	mg/kg	26 - 26	20.4	145	53.6	826	15000	
MET	Beryllium	38	25	66	mg/kg	0.57 - 0.64	0.23	0.86	0.427	1	160	
MET	Cadmium	38	20	53	mg/kg	0.23 - 0.64	0.28	1.7	0.48		70	
MET	Calcium	38	38	100	mg/kg		1040	166000	27200	52300		
MET	Chromium	38	37	97	mg/kg	1.3 - 1.3	2.3	50.7	14	29	280	
MET	Cobalt	38	33	87	mg/kg	5.7 - 6.4	1.5	26.5	6.88	116	23	Y
MET	Copper	38	37	97	mg/kg	2.8 - 2.8	3.7	57.6	16.5	56.2	3100	
MET	Iron	38	38	100	mg/kg		218	30400	16800	234000	55000	
MET	Lead	38	38	100	mg/kg		4.1	770	99.6	48.6	400	Y
MET	Magnesium	38	36	95	mg/kg	570 - 640	858	18100	4200	10400		
MET	Manganese	38	38	100	mg/kg		3	910	303	3506		
MET	Mercury	38	26	68	mg/kg	0.013 - 0.042	0.016	0.76	0.0769	0.1	6.7	
MET	Nickel	38	36	95	mg/kg	4.6 - 5.1	6.2	57.8	15.2	55.1	1600	
MET	Potassium	38	30	79	mg/kg	570 - 640	461	2580	936	3390		
MET	Selenium	38	3	8	mg/kg	0.57 - 0.77	0.65	1.1	0.382	2	390	
MET	Sodium	38	2	5	mg/kg	220 - 640	263	503	206			
MET	Thallium	38	1	3	mg/kg	0.38 - 1.3	0.77	0.77	0.39	1.3	5.1	
MET	Vanadium	38	36	95	mg/kg	5.7 - 6.4	9.4	51.7	23	40.9	550	
MET	Zinc	38	38	100	mg/kg		6.2	181	61.6	322	23000	

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Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Surface Soil (continued)												
PCB	PCB-1254 (Aroclor 1254)	38	22	58	µg/kg	5.1 - 2900	68	7100	1770		220	Y
PCB	PCB-1260 (Aroclor 1260)	38	31	82	µg/kg	5.1 - 41	45	18000	3350		220	Y
SV	1,2,4-Trichlorobenzene	38	3	8	µg/kg	0.12 - 420	0.22	0.74	79.9		87000	
SV	2,4-Dinitrotoluene	38	3	8	µg/kg	26 - 420	54	460	97.1		120000	
SV	2-Methylnaphthalene	38	8	21	µg/kg	39 - 420	40	410	120		310000	
SV	Acenaphthylene	38	1	3	µg/kg	21 - 420	150	150	89.9			
SV	Anthracene	38	3	8	µg/kg	29 - 420	26	120	89.7		17000000	
SV	Benzo(a)anthracene	38	11	29	µg/kg	40 - 420	36	660	123		150	Y
SV	Benzo(a)pyrene	38	9	24	µg/kg	25 - 420	21	850	105		15	Y
SV	Benzo(b)fluoranthene	38	6	16	µg/kg	33 - 420	94	1400	140		150	Y
SV	Benzo(g,h,i)perylene	38	4	11	µg/kg	77 - 420	88	570	120			
SV	Benzo(k)fluoranthene	38	6	16	µg/kg	42 - 420	75	580	112		1500	
SV	bis(2-Ethylhexyl)phthalate	38	6	16	µg/kg	38 - 410	39	210	74.8		35000	
SV	Chrysene	38	12	32	µg/kg	34 - 420	45	810	136		15000	
SV	Dibenz(a,h)anthracene	38	1	3	µg/kg	64 - 420	160	160	104		15	Y
SV	Fluoranthene	38	15	39	µg/kg	59 - 420	44	1200	169		2300000	
SV	Indeno(1,2,3-cd)pyrene	38	3	8	µg/kg	49 - 420	43	720	106		150	Y
SV	Naphthalene	38	3	8	µg/kg	34 - 420	64	160	97.5		3900	
SV	Phenanthrene	38	11	29	µg/kg	25 - 420	57	580	143			
SV	Phenol	38	1	3	µg/kg	38 - 420	45	45	92.7		18000000	
SV	Pyrene	38	12	32	µg/kg	42 - 420	52	960	152		1700000	
VOC	1,1,1-Trichloroethane	38	4	11	µg/kg	0.6 - 59	1.4	160	7.83		9000000	
VOC	2-Butanone (Methyl ethyl ketone)	38	1	3	µg/kg	0.94 - 100	20	20	10.2		28000000	
VOC	Acetone	38	12	32	µg/kg	8.6 - 150	45	170	38.5		61000000	
VOC	Benzene	38	12	32	µg/kg	0.43 - 35	0.43	3.8	3.45		1100	
VOC	Carbon Disulfide	38	14	37	µg/kg	1.2 - 96	1.4	30	9.1		670000	
VOC	Chloromethane	38	1	3	µg/kg	0.35 - 39	1.2	1.2	4.26		1700	
VOC	Cyclohexane	23	15	65	µg/kg	0.5 - 40	0.9	46	8.78		7200000	
VOC	Ethylbenzene	38	6	16	µg/kg	0.5 - 56	0.89	3	4.07		5700	
VOC	Methyl Acetate	23	5	22	µg/kg	1.1 - 120	2.1	460	41.5		78000000	

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Surface Soil (continued)												
VOC	Methylcyclohexane	23	17	74	µg/kg	0.28 - 15	0.8	3300	211			
VOC	Methylene Chloride	38	2	5	µg/kg	0.42 - 46	2.5	3.2	3.45		11000	
VOC	Toluene	38	10	26	µg/kg	0.79 - 67	1.2	56	6.05		5000000	
VOC	Trichloroethene (TCE)	38	2	5	µg/kg	0.57 - 63	1.2	1.7	4.27		2800	
VOC	Xylenes, Total	38	11	29	µg/kg	0.64 - 42	1.1	200	13.7		600000	
Subsurface Soil												
GC2	Moisture, Percent	15	15	100	Percent		15.9	21.2	18.8			
GC2	Nitrogen, Nitrate (as N)	15	1	7	mg/kg	5.9 - 6.3	58.6	58.6	6.78		130000	
GC2	pH	15	15	100	pH Units		6.3	8	7.53			
GC2	Sulfate (as SO4)	15	11	73	mg/kg	12 - 13	26.4	5440	806			
HE	2,4,6-Trinitrotoluene	24	1	4	µg/kg	80 - 250	150	150	55.5		19000	
HE	2,4-Dinitrotoluene	24	2	8	µg/kg	100 - 250	120	1800	138		120000	
HE	2-Amino-4,6-Dinitrotoluene	22	1	5	µg/kg	120 - 150	480	480	85		150000	
HE	4-Amino-2,6-Dinitrotoluene	24	1	4	µg/kg	80 - 250	430	430	67.1		150000	
HE	4-Nitrotoluene	22	1	5	µg/kg	80 - 100	110	110	47.4		30000	
MET	Aluminum	37	37	100	mg/kg		4700	19900	11900	15500	77000	
MET	Arsenic	37	37	100	mg/kg		3	15.4	7.87	36.5	0.39	Y
MET	Barium	37	36	97	mg/kg	24 - 24	26.1	290	71.5	826	15000	
MET	Beryllium	37	25	68	mg/kg	0.25 - 0.63	0.465	1.1	0.576	1	160	
MET	Cadmium	37	17	46	mg/kg	0.25 - 0.63	0.325	6.9	0.589		70	
MET	Calcium	36	36	100	mg/kg		1290	76800	29900	52300		
MET	Chromium	37	37	100	mg/kg		10.3	27.5	17.9	29	280	
MET	Cobalt	37	37	100	mg/kg		1.6	23.6	10.2	116	23	Y
MET	Copper	37	37	100	mg/kg		5.9	36.9	21.5	56.2	3100	
MET	Iron	37	37	100	mg/kg		2700	36000	21600	234000	55000	
MET	Lead	37	37	100	mg/kg		4.2	80.8	14.2	48.6	400	
MET	Magnesium	37	37	100	mg/kg		908	23700	8980	10400		
MET	Manganese	37	37	100	mg/kg		39.9	1070	416	3506		
MET	Mercury	37	19	51	mg/kg	0.015 - 0.042	0.017	0.081	0.0234	0.1	6.7	
MET	Nickel	37	37	100	mg/kg		5.8	47.2	25	55.1	1600	
MET	Potassium	37	36	97	mg/kg	600 - 600	643	4820	2030	3390		

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Subsurface Soil (continued)												
MET	Sodium	37	4	11	mg/kg	220 - 640	257	323	214			
MET	Vanadium	37	37	100	mg/kg		15.6	44.5	28.6	40.9	550	
MET	Zinc	37	37	100	mg/kg		25.8	271	68	322	23000	
PCB	PCB-1254 (Aroclor 1254)	22	8	36	µg/kg	3.6 - 5.3	3.9	1900	131		220	Y
PCB	PCB-1260 (Aroclor 1260)	22	12	55	µg/kg	4 - 5.3	4.2	4900	373		220	Y
SV	2,4-Dinitrotoluene	37	2	5	µg/kg	26 - 420	89	870	116		120000	
SV	2-Methylnaphthalene	37	1	3	µg/kg	38 - 420	52	52	96.2		310000	
SV	Benzo(a)anthracene	37	1	3	µg/kg	39 - 420	66.5	66.5	97		150	
SV	Benzo(a)pyrene	37	1	3	µg/kg	24 - 420	72	72	92.5		15	Y
SV	Benzoic acid	13	1	8	µg/kg	21 - 25	140	140	21.7		240000000	
SV	bis(2-Ethylhexyl)phthalate	37	4	11	µg/kg	39 - 420	48	140	93.4		35000	
SV	Chrysene	37	1	3	µg/kg	33 - 420	88.5	88.5	95.8		15000	
SV	Di-n-butylphthalate	37	1	3	µg/kg	32 - 420	120	120	96.4		6100000	
SV	Fluoranthene	37	1	3	µg/kg	57 - 420	120	120	104		2300000	
SV	Phenanthrene	37	4	11	µg/kg	28 - 420	75	150	100			
SV	Pyrene	37	2	5	µg/kg	42 - 420	115	120	102		1700000	
VOC	1,1,1-Trichloroethane	37	5	14	µg/kg	0.75 - 6.3	6.7	1800	85.8		9000000	
VOC	1,1,2-Trichloroethane	37	1	3	µg/kg	0.29 - 18	0.8	0.8	1.8		1100	
VOC	1,1-Dichloroethane	37	4	11	µg/kg	0.45 - 6.3	6	760	24.1		3400	
VOC	1,1-Dichloroethene	37	3	8	µg/kg	1 - 61	1.5	140	6.16		250000	
VOC	1,2-Dichloroethane	37	1	3	µg/kg	0.38 - 24	23	23	2.32		450	
VOC	2-Butanone (Methyl ethyl ketone)	37	7	19	µg/kg	1.2 - 72	2.7	11	7.89		28000000	
VOC	Acetone	37	16	43	µg/kg	4 - 85	13	480	52.7		61000000	
VOC	Benzene	37	8	22	µg/kg	0.42 - 24	0.62	5.3	2.47		1100	
VOC	Carbon Disulfide	37	4	11	µg/kg	1.2 - 66	2	4.2	3.47		670000	
VOC	cis-1,2-Dichloroethene	22	1	5	µg/kg	1 - 51	83	83	5.47		780000	
VOC	Cyclohexane	22	10	45	µg/kg	0.49 - 28	0.92	11	3.63		7200000	
VOC	Ethylbenzene	37	3	8	µg/kg	0.62 - 38	1.4	2.4	2.53		5700	
VOC	Methylcyclohexane	22	9	41	µg/kg	0.27 - 15	0.26	15	3.41			
VOC	Methylene Chloride	37	2	5	µg/kg	0.52 - 32	2.3	3.3	2.3		11000	

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Subsurface Soil (continued)												
VOC	Tetrachloroethene (PCE)	37	2	5	µg/kg	0.81 - 41	240	1600	51.7		570	Y
VOC	Toluene	37	9	24	µg/kg	0.78 - 44	1.5	9.5	3.37		5000000	
VOC	Total 1,2-Dichloroethene	15	2	13	µg/kg	5.9 - 6.3	4	7.4	3.43		700000	
VOC	Trichloroethene (TCE)	37	8	22	µg/kg	0.77 - 36	1.5	220	9.71		2800	
VOC	Xylenes, Total	37	4	11	µg/kg	0.58 - 36	3.3	6	2.83		600000	
Deep Groundwater												
GC2	Alkalinity, Total (as CaCO3)	7	7	100	mg/L		520	900	710			
GC2	Alkalinity, Carbonate (as CACO3)	4	4	100	mg/L		549	944	691			
GC2	Chloride (as Cl)	11	11	100	mg/L		337	3310	1940			
GC2	Cyanide	11	2	18	µg/L	5 - 10	16.6	594	58.2		730	Y
GC2	Hardness (as CACO3)	11	11	100	mg/L		362	2350	1350			
GC2	Nitrogen, Nitrite	4	4	100	mg/L		0.07	2.9	0.89		3.7	
GC2	Nitrogen, Nitrate-Nitrite	5	1	20	mg/L	0.25 - 0.25	0.28	0.28	0.156		3700	
GC2	Sulfate (as SO4)	11	11	100	mg/L		0.57	206	26.4			
GC2	Suspended Solids (residue, Non-filterable)	10	9	90	mg/L	4 - 4	4	330	52.4			
GC2	Total Dissolved Solids	10	10	100	mg/L		730	7100	3590			
GC2	Total Organic Carbon	11	11	100	mg/L		1.1	16	5.95			
GC2	Turbidity	7	7	100	NTU		1.1	273	85.5			
HE	2-Amino-4,6-Dinitrotoluene	9	2	22	µg/L	0.11 - 0.14	0.46	0.925	0.202		73	
HE	4-Amino-2,6-Dinitrotoluene	11	2	18	µg/L	0.074 - 0.3	0.082	0.55	0.115		73	
HE	1,3-Dinitrobenzene	11	1	9	µg/L	0.074 - 0.33	0.18	0.18	0.0727		3.7	
HE	2,4-Dinitrotoluene	11	1	9	µg/L	0.096 - 0.3	0.23	0.23	0.0832		73	
HE	2,6-Dinitrotoluene	11	3	27	µg/L	0.096 - 0.3	0.21	1.7	0.325		37	
HE	HMX	11	1	9	µg/L	0.074 - 0.75	0.21	0.21	0.117		1800	
HE	2-Nitrotoluene	11	2	18	µg/L	0.074 - 0.56	0.087	1.1	0.174		0.31	Y
HE	3-Nitrotoluene	11	6	55	µg/L	0.11 - 0.3	0.14	0.82	0.243		730	
HE	4-Nitrotoluene	9	1	11	µg/L	0.074 - 0.15	0.15	0.15	0.0635		4.2	
HE	Nitrobenzene	11	2	18	µg/L	0.081 - 0.3	0.24	0.52	0.119		3.4	
HE	RDX	11	5	45	µg/L	0.074 - 0.75	0.14	5.5	1.16		0.61	Y
HE	Tetryl	11	2	18	µg/L	0.074 - 0.3	0.11	2.4	0.283		150	
HE	1,3,5-Trinitrobenzene	11	1	9	µg/L	0.074 - 0.3	3.75	3.75	0.405		1100	
HE	2,4,6-Trinitrotoluene	11	2	18	µg/L	0.074 - 0.3	0.99	2.7	0.394		2.2	Y

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Deep Groundwater (continued)												
MET	Aluminum	6	1	17	µg/L	75 - 200	76.6	76.6	64.9	309	37000	
MET	Aluminum (total)	11	8	73	µg/L	75 - 75	89.9	504	168	309	37000	
MET	Arsenic	6	2	33	µg/L	3 - 30	6.5	19.6	7.6	7.4	0.045	Y
MET	Arsenic (total)	11	4	36	µg/L	3 - 3	4.7	21.2	6.35	7.4	0.045	Y
MET	Barium	6	6	100	µg/L		42.8	2800	1050	11800	7300	
MET	Barium (total)	11	11	100	µg/L		29.6	2950	788	11800	7300	
MET	Calcium	6	6	100	µg/L		81300	363000	244000	316000		
MET	Calcium (total)	11	11	100	µg/L		69800	371000	233000	316000		
MET	Chromium	6	1	17	µg/L	2 - 10	2	2	2.5		55000	
MET	Chromium (total)	11	3	27	µg/L	2 - 10	2.85	15.9	3.95		55000	
MET	Copper (total)	11	1	9	µg/L	4 - 25	26.2	26.2	5.15	19.8	1500	
MET	Iron	6	4	67	µg/L	30 - 100	45.7	372	101	1550	26000	
MET	Iron (total)	11	11	100	µg/L		90.6	2540	821	1550	26000	
MET	Mercury	6	1	17	µg/L	0.08 - 0.2	0.19	0.19	0.085		0.63	
MET	Mercury (total)	11	1	9	µg/L	0.08 - 0.2	0.18	0.18	0.0636		0.63	
MET	Potassium	6	6	100	µg/L		39900	91900	59100	116000		
MET	Potassium (total)	11	11	100	µg/L		36000	95900	62500	116000		
MET	Magnesium	6	6	100	µg/L		49900	348000	197000	217000		
MET	Magnesium (total)	11	11	100	µg/L		45700	351000	176000	217000		
MET	Manganese	6	6	100	µg/L		7	1010	421	636	880	Y
MET	Manganese (total)	11	11	100	µg/L		8.4	1160	287	636	880	Y
MET	Sodium	6	6	100	µg/L		395000	1210000	797000	1390000		
MET	Sodium (total)	11	11	100	µg/L		279000	1420000	816000	1390000		
MET	Lead	6	1	17	µg/L	1.5 - 9	2.5	2.5	1.79			
MET	Lead (total)	11	2	18	µg/L	1.5 - 3	1.6	4.4	1.23			
MET	Selenium (total)	11	2	18	µg/L	3 - 5	3.8	4	2.12		180	
MET	Thallium	6	3	50	µg/L	3 - 30	3.1	3.8	5.36		2.4	Y
MET	Thallium (total)	11	3	27	µg/L	3 - 10	3.5	4.7	2.86		2.4	Y
MET	Vanadium	6	1	17	µg/L	3 - 50	8.7	8.7	10.5		260	
MET	Vanadium (total)	11	2	18	µg/L	3 - 50	4.8	11	6.93		260	
MET	Zinc	6	2	33	µg/L	5 - 5	66.3	82.1	26.4	507	11000	
MET	Zinc (total)	11	7	64	µg/L	5 - 5	5.2	38.3	11.8	507	11000	

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Deep Groundwater (continued)												
SV	bis(2-Ethylhexyl)phthalate	11	4	36	µg/L	1.2 - 36	2	28	6.97		4.8	Y
SV	2,4-Dimethylphenol	11	4	36	µg/L	0.66 - 110	1.2	20	8.39		730	
SV	Isophorone	11	1	9	µg/L	0.51 - 16	2.9	2.9	1.64		71	
SV	3-Methylphenol	9	1	11	µg/L	0.72 - 22	8.4	8.4	2.44		1800	
SV	4-Methylphenol (p-Cresol)	11	1	9	µg/L	0.72 - 110	8.4	8.4	7.23		180	
SV	2-Methylnaphthalene	11	11	100	µg/L		0.81	290	42.8		150	Y
SV	Naphthalene	11	11	100	µg/L		1.3	93	22.7		0.14	Y
SV	Phenanthrene	11	2	18	µg/L	0.72 - 110	2.3	46	9.43			
SV	Phenol	11	3	27	µg/L	0.43 - 13	8.2	37	6.2		11000	
VOC	Acetone	10	3	30	µg/L	1.1 - 250	6.2	32.5	19.3		22000	
VOC	Bromodichloromethane	11	0	0	µg/L	0.086 - 25			1.51		1.1	
VOC	Bromochloromethane	9	0	0	µg/L	0.3 - 1.6			0.388			
VOC	Bromomethane	11	0	0	µg/L	0.26 - 50			3.03		8.7	
VOC	Benzene	11	11	100	µg/L		9.5	140	52.5	2.4	0.41	Y
VOC	Toluene	11	11	100	µg/L		24	240	86.3	1.7	2300	
VOC	Carbon Disulfide	11	2	18	µg/L	0.13 - 0.75	59	63	11.3		1000	
VOC	Methylcyclohexane	9	9	100	µg/L		44	490	180			
VOC	Cyclohexane	9	9	100	µg/L		140	530	301		13000	
VOC	Ethylbenzene	11	11	100	µg/L		7.45	140	44	0.87	1.5	Y
VOC	Isopropylbenzene (Cumene)	9	9	100	µg/L		4	28	13		680	
VOC	Methylene Chloride	11	4	36	µg/L	0.26 - 6.3	1.4	7.75	2.16		4.8	Y
VOC	Trichloroethene (TCE)	11	1	9	µg/L	0.28 - 25	1.8	1.8	1.84		1.7	Y
VOC	Xylenes, Total	11	11	100	µg/L		140	930	411	5.5	200	Y
Surface Water												
HE	2-Amino-4,6-Dinitrotoluene	12	1	8	µg/L	0.11 - 0.13	0.24	0.24	0.0738		73	
HE	4-Amino-2,6-Dinitrotoluene	12	1	8	µg/L	0.074 - 0.086	0.4	0.4	0.0694		73	
HE	RDX	12	3	25	µg/L	0.074 - 0.086	0.081	0.5	0.116		0.61	
HE	Tetryl	12	1	8	µg/L	0.072 - 0.086	0.24	0.24	0.0558		150	
MET	Aluminum	12	8	67	µg/L	100 - 100	317	10200	1300		37000	
MET	Arsenic	12	3	25	µg/L	3 - 3	4	49.3	6		0.045	Y
MET	Barium	12	12	100	µg/L		11.6	194	59.2		7300	
MET	Calcium	12	12	100	µg/L		84500	271000	152000			

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Surface Water (continued)												
MET	Cobalt	12	4	33	µg/L	3 - 3	6.15	12.8	4.05		11	Y
MET	Chromium	12	2	17	µg/L	2 - 2	2.1	12.7	2.07		55000	
MET	Copper	12	1	8	µg/L	4 - 4	21.9	21.9	3.66		1500	
MET	Iron	12	12	100	µg/L		76.7	50000	6170		26000	Y
MET	Mercury	12	1	8	µg/L	0.08 - 0.08	0.11	0.11	0.0458		0.63	
MET	Potassium	12	12	100	µg/L		957	46200	7360			
MET	Magnesium	12	12	100	µg/L		18100	64600	33600			
MET	Manganese	12	12	100	µg/L		64.6	8840	1330		880	Y
MET	Sodium	12	12	100	µg/L		3430	19300	7780			
MET	Nickel	12	9	75	µg/L	3 - 3	3.4	51.7	13.9		730	
MET	Lead	12	5	42	µg/L	1.5 - 1.5	1.6	29.9	3.96			
MET	Selenium	12	1	8	µg/L	3 - 3	3.8	3.8	1.69		180	
MET	Thallium	12	2	17	µg/L	3 - 3	3.7	4.3	1.92		2.4	Y
MET	Vanadium	12	2	17	µg/L	3 - 3	3.3	19	3.11		260	
MET	Zinc	12	7	58	µg/L	5 - 5	7	71.6	15.8		11000	
SV	Benzoic acid	7	1	14	µg/L	0.37 - 0.39	3.7	3.7	0.69		150000	
SV	Benzyl alcohol	8	1	12	µg/L	0.69 - 0.74	2.3	2.3	0.598		18000	
SV	2-Methylphenol (o-Cresol)	9	1	11	µg/L	0.77 - 0.81	0.95	0.95	0.455		1800	
SV	3-Methylphenol	9	2	22	µg/L	0.71 - 0.75	13	18	3.73		1800	
SV	4-Methylphenol (p-Cresol)	9	2	22	µg/L	0.71 - 0.75	13	18	3.73		180	
SV	Phenol	9	1	11	µg/L	0.42 - 0.45	0.65	0.65	0.264		11000	
VOC	Acetone	12	5	42	µg/L	1.1 - 1.1	2.9	22	4.08		22000	
VOC	Carbon tetrachloride	12	1	8	µg/L	0.14 - 0.14	0.46	0.46	0.103		0.2	Y
VOC	1,1-Dichloroethane	12	2	17	µg/L	0.15 - 0.15	2.6	3.9	0.604		2.4	Y
VOC	cis-1,2-Dichloroethene	12	1	8	µg/L	0.44 - 0.44	0.91	0.91	0.278		370	
VOC	2-Butanone (Methyl ethyl ketone)	12	1	8	µg/L	1.2 - 1.2	2.5	2.5	0.758		7100	
VOC	1,1,1-Trichloroethane	12	2	17	µg/L	0.15 - 0.15	4.9	14	1.64		9100	
VOC	Trichloroethene (TCE)	12	2	17	µg/L	0.28 - 0.28	1.7	4.9	0.667		1.7	Y
VOC	Chloroform	12	1	8	µg/L	0.1 - 0.1	0.15	0.15	0.0583		0.19	

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Sediment												
HE	2,4-Dinitrotoluene	15	2	13	µg/kg		240	490	98.3		120000	
HE	4-Nitrotoluene	15	2	13	µg/kg		110	320	66.2		30000	
HE	RDX	15	3	20	µg/kg		100	920	117		5500	
HE	Tetryl	15	1	7	µg/kg		100	100	47.8		240000	
HE	2,4,6-Trinitrotoluene	15	2	13	µg/kg		230	590	93.1		19000	
MET	Aluminum	15	15	100	mg/kg		5610	47600	14700	15500	77000	
MET	Arsenic	15	15	100	mg/kg		1.7	20.8	7.47	36.5	0.39	Y
MET	Barium	15	15	100	mg/kg		4.4	105	64.9	826	15000	
MET	Beryllium	15	15	100	mg/kg		0.36	13.8	1.79	1	160	
MET	Calcium	15	15	100	mg/kg		3140	114000	19600	52300		
MET	Cadmium	15	11	73	mg/kg		0.33	3.7	0.764		70	
MET	Cobalt	15	15	100	mg/kg		2.8	77.3	14.7	116	23	Y
MET	Chromium	15	15	100	mg/kg		2	34.4	16.4	29	280	
MET	Copper	15	15	100	mg/kg		9.8	51.7	21.5	56.2	3100	
MET	Iron	15	15	100	mg/kg		1470	54600	20000	234000	55000	
MET	Mercury	15	15	100	mg/kg		0.0205	2.2	0.202	0.1	6.7	
MET	Potassium	15	14	93	mg/kg		1090	4360	1820	3390		
MET	Magnesium	15	15	100	mg/kg		482	16200	5250	10400		
MET	Manganese	15	15	100	mg/kg		18.9	722	306	3506		
MET	Nickel	15	15	100	mg/kg		9.2	243	43.4	55.1	1600	
MET	Lead	15	15	100	mg/kg		5.6	77.3	27.7	48.6	400	
MET	Selenium	15	2	13	mg/kg		0.94	1.5	0.565	2	390	
MET	Vanadium	15	15	100	mg/kg		2	48.6	26.8	40.9	550	
MET	Zinc	15	15	100	mg/kg		28.5	286	93.9	322	23000	
PCB	PCB-1254 (Aroclor 1254)	15	14	93	µg/kg		4.6	750	186		220	Y
PCB	PCB-1260 (Aroclor 1260)	15	14	93	µg/kg		6.5	1800	268		220	Y
SV	Anthracene	15	2	13	µg/kg		41	61	23.5		17000000	
SV	bis(2-Ethylhexyl)phthalate	15	3	20	µg/kg		50	56	31.9		35000	
SV	Benzo(a)anthracene	15	8	53	µg/kg		104	350	121		150	Y
SV	Benzo(a)pyrene	15	6	40	µg/kg		91	310	77.9		15	Y
SV	Benzo(b)fluoranthene	15	12	80	µg/kg		59	500	164		150	Y

Table 4-1

Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Background	Toxicity Screening Level	COPC
Sediment (continued)												
SV	Benzo(g,h,i)perylene	15	1	7	µg/kg		180	180	59.3			
SV	Benzo(k)fluoranthene	15	10	67	µg/kg		68	380	146		1500	
SV	Chrysene	15	10	67	µg/kg		50	410	154		15000	
SV	Dibenzofuran	15	1	7	µg/kg		91	91	22			
SV	2,4-Dinitrotoluene	15	2	13	µg/kg		93	460	52		120000	
SV	Fluoranthene	15	9	60	µg/kg		100	640	223		2300000	
SV	Indeno(1,2,3-cd)pyrene	15	3	20	µg/kg		240	360	89.6		150	Y
SV	3-Methylphenol	15	1	7	µg/kg		270	270	36.2		3100000	
SV	4-Methylphenol (p-Cresol)	15	1	7	µg/kg		270	270	35.7		310000	
SV	2-Methylnaphthalene	15	1	7	µg/kg		280	280	41.5		310000	
SV	Naphthalene	15	1	7	µg/kg		210	210	35.2		3900	
SV	N-Nitroso-di-n-propylamine	15	1	7	µg/kg		620	620	78.3		69	Y
SV	Phenanthrene	15	9	60	µg/kg		46	310	95.3			
SV	Pyrene	15	10	67	µg/kg		65	540	205		1700000	
VOC	Acetone	15	8	53	µg/kg		19	260	72		61000000	
VOC	Benzene	15	6	40	µg/kg		0.76	7.8	1.36		1100	
VOC	Toluene	15	5	33	µg/kg		2.9	20	2.67		5000000	
VOC	Carbon Disulfide	15	7	47	µg/kg		2.6	30	5.59		670000	
VOC	Methylcyclohexane	15	7	47	µg/kg		0.55	37	4.82			
VOC	Chloroethane	15	4	27	µg/kg		2	9.65	2		15000000	
VOC	Cyclohexane	15	7	47	µg/kg		1.4	29	3.77		7200000	
VOC	1,1-Dichloroethane	15	1	7	µg/kg		2.3	2.3	0.48		3400	
VOC	cis-1,2-Dichloroethene	15	1	7	µg/kg		2.8	2.8	0.975		780000	
VOC	Ethylbenzene	15	3	20	µg/kg		0.835	3.5	0.747		5700	
VOC	2-Butanone (Methyl ethyl ketone)	15	7	47	µg/kg		2.7	53	7.38		28000000	
VOC	Trichloroethene (TCE)	15	2	13	µg/kg		2	4	0.88		2800	
VOC	Xylenes, Total	15	3	20	µg/kg		1.7	12	1.41		600000	

COPC - Chemical of potential concern.
HI - Explosives.
INO - Inorganics.
mg/kg - Milligrams per kilogram.
PAH - Polycyclic aromatic hydrocarbon.
MET - Metals.
GC2 - General chemistry parameters.
PCB - Polychlorinated biphenyl.
RDX - 1,3,5-Trinitroperhydro-1,3,5-triazome (cyclotrimethylenetrinitramine or cyclonite or hexogen or T4).
SV - Semivolatile organic compound.
µg/kg - Micrograms per kilogram.
VOC - Volatile organic compound.
NTU - Nephelometric turbidity unit.
mg/L - Milligrams per liter.
µg/L - Micrograms per liter.

Source: Revised Final Baseline Human Health Risk Assessment (Jacobs, 2010a).

Table 4-2

Summary of Cancer and Noncancer Risk Estimates from Potential Exposures at Acid Area 1 Plum Brook Ordnance Works, Sandusky, Ohio

Adult Residential Risks From Exposure to Groundwater

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E+00	2.E-04
Dermal Contact	4.E-01	1.E-05
Inhalation	5.E-01	6.E-06
Total	6.E+00	2.E-04

Child Residential Risks From Exposure to Groundwater

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+01	1.E-04
Dermal Contact	7.E-01	6.E-06
Inhalation	1.E+00	4.E-06
Total	1.E+01	1.E-04

Adult Residential Risks From Exposure to Surface Soil

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-01	1.E-05
Dermal Contact	2.E-01	1.E-05
Inhalation	9.E-05	4.E-09
Total	4.E-01	3.E-05

Child Residential Risks From Exposure to Surface Soil

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E+00	3.E-05
Dermal Contact	4.E-01	5.E-06
Inhalation	2.E-04	2.E-09
Total	2.E+00	4.E-05

Adult Residential Risks From Exposure to Subsurface Soil

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-01	1.E-05
Dermal Contact	7.E-02	6.E-06
Inhalation	NV[a]	NV
Total	3.E-01	2.E-05

Child Residential Risks From Exposure to Subsurface Soil

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+00	2.E-05
Dermal Contact	2.E-01	3.E-06
Inhalation[a]	NV	NV
Total	1.E+00	3.E-05

Adult Recreational Risks From Exposure to Surface Water

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA[b]	NA
Dermal Contact	1.E-02	5.E-07
Inhalation	NA	NA
Total	1.E-02	5.E-07

Child Recreational Risks From Exposure to Surface Water

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	2.E-02	2.E-07
Inhalation	NA	NA
Total	2.E-02	2.E-07

Adult Recreational Risks From Exposure to Sediment

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	8.E-03	1.E-06
Dermal Contact	5.E-03	4.E-07
Inhalation	NA	NA
Total	1.E-02	2.E-06

Child Recreational Risks From Exposure to Sediment

Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	7.E-02	3.E-06
Dermal Contact	1.E-02	2.E-07
Inhalation	NA	NA
Total	8.E-02	3.E-06

Table 4-2

Summary of Cancer and Noncancer Risk Estimates from Potential Exposures at Acid Area 1 Plum Brook Ordnance Works, Sandusky, Ohio

Indoor Worker Risks From Exposure to Groundwater		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	2.E+00	8.E-05
Dermal Contact	6.E-02	3.E-06
Inhalation	NA	NA
Total	2.E+00	9.E-05

Indoor Worker Risks From Exposure to Surface Soil		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	7.E-02	6.E-06
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	7.E-02	6.E-06

Adult Hunter Risks From Exposure to Surface Soil		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	8.E-03	7.E-07
Dermal Contact	9.E-03	7.E-07
Inhalation	NA	NA
Total	2.E-02	1.E-06

Adult Hunter Risks From Ingestion of Venison		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	8.E-05	2.E-09
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	8.E-05	2.E-09

Child Risks From Ingestion of Venison		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	1.E-04	7.E-10
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	1.E-04	7.E-10

Groundskeeper Risks From Exposure to Surface Soil		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	1.E-01	1.E-05
Dermal Contact	2.E-02	1.E-06
Inhalation	7.E-05	4.E-09
Total	2.E-01	1.E-05

Construction Worker Risks From Exposure to Surface Soil		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	4.E-01	6.E-07
Dermal Contact	1.E-01	2.E-07
Inhalation	7.E-05	7.E-11
Total	5.E-01	8.E-07

Construction Worker Risks From Exposure to Subsurface Soil		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	2.E-01	4.E-07
Dermal Contact	7.E-02	1.E-07
Inhalation	6.E-10	1.E-14
Total	3.E-01	5.E-07

Construction Worker Risks From Exposure to Surface		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	NA	NA
Dermal Contact	3.E-02	3.E-08
Inhalation	NA	NA
Total	3.E-02	3.E-08

Construction Worker Risks From Exposure to Sediment		
Exposure Route	**Hazard Quotient**	**Excess Cancer Risk**
Ingestion	8.E-02	2.E-07
Dermal Contact	2.E-02	3.E-08
Inhalation	NA	NA
Total	9.E-02	2.E-07

[a] "NV" indicates that this exposure route was not evaluated because no volatile COPCs were present in the subsurface soil samples. The BHHRA includes HI and ILCR values on a table that were apparently based on modeled inhalation risks of tetrachloroethene (PCE). However, the BHHRA states that inhalation risks were not modeled because no VOCs were identified as COPCs. A further review of PCE reveals that the maximum detected concentration in subsurface soil (1.6 mg/kg) is far less than the November 2012 Regional Screening Level (EPA, 2012) for residential soil (22 mg/kg) which is based on an ILCR of 1E-6. Therefore, PCE is not regarded as a COPC.

[a] "NA" indicates that the pathway is not applicable to the exposure route.

Source: Final Baseline Human Health Risk Assessment, Jacobs (2010a)

Table 5-1

Summary of Statistics and Identification of Ecological COPC for Constituents Detected in Environmental Media
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Average	Background	Toxicity Screening Level	COPEC[a]
GC2	Moisture, Percent	22	22	100	Percent		12.1	21.8	17.7			
GC2	Sulfate (as SO4)	22	16	73	mg/kg	12 - 13	13.4	3910	793			
GC2	pH	22	22	100	pH units		6.30	8.10	7.43			
HE	1,3,5-Trinitrobenzene	41	1	2	µg/kg	80 - 250	300	300	8370			
HE	2,4,6-Trinitrotoluene	41	2	5	µg/kg	80 - 250	150	300	8190			
HE	2,4-Dinitrotoluene	41	6	15	µg/kg	100 - 250	120	2500	9430		1000	Y
HE	2-Amino-4,6-Dinitrotoluene	39	1	3	µg/kg	120 - 150	480	480	12000			
HE	4-Amino-2,6-Dinitrotoluene	41	2	5	µg/kg	80 - 250	430	810	8210			
HE	4-Nitrotoluene	39	1	3	µg/kg	80 - 100	180	180	7990			
MET	Aluminum	61	61	100	mg/kg		155	19900	9470	15500		
MET	Antimony	61	1	2	mg/kg	2.2 - 7.7	9.50	9.50	381	9.30	0.142	Y
MET	Arsenic	61	60	98	mg/kg	1.3 - 1.3	1.40	18.1	8.86	36.5	5.70	
MET	Barium	61	59	97	mg/kg	24 - 26	20.4	145	130	826.	1.04	
MET	Beryllium	61	42	69	mg/kg	0.25 - 0.64	0.230	1.10	16.9	1.00	1.06	Y
MET	Cadmium	61	32	52	mg/kg	0.23 - 0.64	0.280	6.90	23.1		0.00222	Y
MET	Calcium	60	60	100	mg/kg		1040	166000	23400	52300		
MET	Chromium	61	60	98	mg/kg	1.3 - 1.3	2.30	50.7	17.3	29.0	0.400	Y
MET	Cobalt	61	56	92	mg/kg	5.7 - 6.4	1.50	26.5	53.0	116.	0.140	
MET	Copper	61	60	98	mg/kg	2.8 - 2.8	3.70	57.6	21.3	56.2	5.40	Y
MET	Iron	61	61	100	mg/kg		218	35100	18100	234000		
MET	Lead	61	61	100	mg/kg		4.10	770	68.0	48.6	0.0537	Y
MET	Magnesium	61	59	97	mg/kg	570 - 640	858	18100	6220	10400		
MET	Manganese	61	61	100	mg/kg		3.00	1070	327	3506		
MET	Mercury	61	40	66	mg/kg	0.013 - 0.042	0.0160	0.760	1.18	0.100	0.000510	Y
MET	Nickel	61	59	97	mg/kg	4.6 - 5.1	5.80	57.8	32.0	55.1	13.6	Y
MET	Potassium	61	52	85	mg/kg	570 - 640	461	4820	9220	3390		
MET	Selenium	61	4	7	mg/kg	0.57 - 1.5	0.650	1.10	59.9	2.00	0.0276	
MET	Sodium	61	4	7	mg/kg	220 - 640	263	503	32300			
MET	Thallium	61	1	2	mg/kg	0.38 - 1.3	0.770	0.770	65.8	1.30	0.0569	
MET	Vanadium	61	59	97	mg/kg	5.7 - 6.4	9.40	51.7	43.1	40.9	1.59	Y
MET	Zinc	61	61	100	mg/kg		6.20	271	64.3	322.	6.62	
PCB	PCB-1254 (Aroclor 1254)	54	27	50	µg/kg	4.0 - 2900	4.40	7100	12600		371.	Y
PCB	PCB-1260 (Aroclor 1260)	54	38	70	µg/kg	4.0 - 41	4.20	18000	2980		371.	Y
SV	1,2,4-Trichlorobenzene	61	3	5	µg/kg	0.12 - 420	0.220	0.740	13100			
SV	2,4-Dinitrotoluene	61	5	8	µg/kg	26 - 420	54.0	870	14000		1000	

Table 5-1

Summary of Statistics and Identification of Ecological COPC for Constituents Detected in Environmental Media
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Average	Background	Toxicity Screening Level	COPEC[a]
SV	2-Methylnaphthalene	61	8	13	µg/kg	39 - 420	40.0	410	15000		3240	
SV	Acenaphthylene	61	1	2	µg/kg	21 - 420	150	150	14400		682000	
SV	Anthracene	61	3	5	µg/kg	29 - 420	26.0	120	14200		1480000	
SV	Benzo(a)anthracene	61	12	20	µg/kg	40 - 420	36.0	660	13200		5210	
SV	Benzo(a)pyrene	61	10	16	µg/kg	25 - 420	21.0	850	11500		1520	
SV	Benzo(b)fluoranthene	61	6	10	µg/kg	33 - 420	94.0	1400	13800		59800	
SV	Benzo(g,h,i)perylene	61	4	7	µg/kg	77 - 420	88.0	570	16900		119000	
SV	Benzo(k)fluoranthene	61	6	10	µg/kg	42 - 420	75.0	580	14300		148000	
SV	Benzoic acid	24	1	4	µg/kg	22 - 26	140	140	2060			
SV	Chrysene	61	13	21	µg/kg	34 - 420	45.0	810	12900		4730	
SV	Di-n-butylphthalate	61	1	2	µg/kg	32 - 420	120	120	15100		150.	
SV	Dibenz(a,h)anthracene	61	1	2	µg/kg	64 - 420	160	160	17100		18400	
SV	Fluoranthene	61	16	26	µg/kg	59 - 420	44.0	1200	13300		122000	
SV	Indeno(1,2,3-cd)pyrene	61	3	5	µg/kg	49 - 420	43.0	720	14900		109000	
SV	Naphthalene	61	3	5	µg/kg	34 - 420	64.0	160	15100		99.4	Y
SV	Phenanthrene	61	12	20	µg/kg	25 - 420	57.0	580	13000		45700	
SV	Phenol	61	1	2	µg/kg	38 - 420	45.0	45.0	15500			
SV	Pyrene	61	13	21	µg/kg	42 - 420	52.0	960	13300		78500	
SV	bis(2-Ethylhexyl)phthalate	61	9	15	µg/kg	38 - 410	39.0	210	11300		925.	
VOC	1,1,1-Trichloroethane	61	7	11	µg/kg	0.60 - 59	1.40	160	453			
VOC	1,1,2-Trichloroethane	61	1	2	µg/kg	0.23 - 26	0.800	0.800	346			
VOC	1,1-Dichloroethane	61	2	3	µg/kg	0.36 - 40	6.00	33.0	415			
VOC	1,1-Dichloroethene	61	2	3	µg/kg	0.80 - 89	1.50	1.80	693			
VOC	2-Butanone (Methyl ethyl ketone)	61	8	13	µg/kg	0.94 - 100	2.70	20.0	1330		89600	
VOC	Acetone	61	20	33	µg/kg	4.0 - 150	20.0	270	1680		2500	
VOC	Benzene	61	16	26	µg/kg	0.42 - 35	0.430	5.30	385		255.	
VOC	Carbon Disulfide	61	15	25	µg/kg	1.2 - 96	1.40	30.0	715		94.1	
VOC	Chloromethane	61	1	2	µg/kg	0.35 - 39	1.20	1.20	611			
VOC	Cyclohexane	39	21	54	µg/kg	0.49 - 40	0.900	46.0	270			
VOC	Ethylbenzene	61	8	13	µg/kg	0.50 - 56	0.890	3.00	504		5160	
VOC	Methyl Acetate	39	5	13	µg/kg	1.1 - 120	2.10	460	605			
VOC	Methylcyclohexane	39	22	56	µg/kg	0.27 - 15	0.260	3300	171			
VOC	Methylene Chloride	61	3	5	µg/kg	0.42 - 46	2.30	3.20	442		4050	
VOC	Tetrachloroethene (PCE)	61	1	2	µg/kg	0.65 - 72	240	240	602			
VOC	Toluene	61	13	21	µg/kg	0.78 - 67	1.20	56.0	477		5450	
VOC	Total 1,2-Dichloroethene	22	2	9	µg/kg	5.7 - 6.4	4.00	7.40	497			
VOC	Trichloroethene (TCE)	61	5	8	µg/kg	0.57 - 63	1.20	35.0	535			
VOC	Xylenes, Total	61	14	23	µg/kg	0.63 - 42	1.10	200	341		10000	

Table 5-1

Summary of Statistics and Identification of Ecological COPC for Constituents Detected in Environmental Media
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Average	Background	Toxicity Screening Level	COPEC[a]
Surface Water												
HE	2-Amino-4,6-Dinitrotoluene	12	1	8	µg/L	0.11 - 0.13	0.240	0.240	0.0738			
HE	4-Amino-2,6-Dinitrotoluene	12	1	8	µg/L	0.074 - 0.086	0.400	0.400	0.0694			
HE	RDX	12	3	25	µg/L	0.074 - 0.086	0.0810	0.500	0.116			
HE	Tetryl	12	1	8	µg/L	0.072 - 0.086	0.240	0.240	0.0558			
MET	Aluminum	12	8	67	µg/L	100 - 100	317	10200	1300		87.0	Y
MET	Arsenic	12	3	25	µg/L	3.0 - 3.0	4.00	49.3	6.00		148.	
MET	Barium	12	12	100	µg/L		11.6	194	59.2		4.00	Y
MET	Calcium	12	12	100	µg/L		84500	271000	152000			
MET	Chromium	12	2	17	µg/L	2.0 - 2.0	2.10	12.7	2.07		42.0	
MET	Cobalt	12	4	33	µg/L	3.0 - 3.0	6.15	12.8	4.05			
MET	Copper	12	1	8	µg/L	4.0 - 4.0	21.9	21.9	3.66		1.58	Y
MET	Iron	12	12	100	µg/L		76.7	50000	6170		1.00	Y
MET	Lead	12	5	42	µg/L	1.5 - 1.5	1.60	29.9	3.96			
MET	Magnesium	12	12	100	µg/L		18100	64600	33600			
MET	Manganese	12	12	100	µg/L		64.6	8840	1330		120.	Y
MET	Mercury	12	1	8	µg/L	0.080 - 0.080	0.110	0.110	0.0458			
MET	Nickel	12	9	75	µg/L	3.0 - 3.0	3.40	51.7	13.9		28.9	Y
MET	Potassium	12	12	100	µg/L		957	46200	7360			
MET	Selenium	12	1	8	µg/L	3.0 - 3.0	3.80	3.80	1.69			
MET	Sodium	12	12	100	µg/L		3430	19300	7780			
MET	Thallium	12	2	17	µg/L	3.0 - 3.0	3.70	4.30	1.92			
MET	Vanadium	12	2	17	µg/L	3.0 - 3.0	3.30	19.0	3.11		19.0	
MET	Zinc	12	7	58	µg/L	5.0 - 5.0	7.00	71.6	15.8		59.0	Y
SV	2-Methylphenol (o-Cresol)	9	1	11	µg/L	0.77 - 0.81	0.950	0.950	0.455			
SV	3-Methylphenol	9	2	22	µg/L	0.71 - 0.75	13.0	18.0	3.73			
SV	4-Methylphenol (p-Cresol)	9	2	22	µg/L	0.71 - 0.75	13.0	18.0	3.73			
SV	Benzoic acid	7	1	14	µg/L	0.37 - 0.39	3.70	3.70	0.690			
SV	Benzyl alcohol	8	1	12	µg/L	0.69 - 0.74	2.30	2.30	0.598			
SV	Phenol	9	1	11	µg/L	0.42 - 0.45	0.650	0.650	0.264			
VOC	1,1,1-Trichloroethane	12	2	17	µg/L	0.15 - 0.15	4.90	14.0	1.64		11.0	Y
VOC	1,1-Dichloroethane	12	2	17	µg/L	0.15 - 0.15	2.60	3.90	0.604		47.0	
VOC	2-Butanone (Methyl ethyl ketone)	12	1	8	µg/L	1.2 - 1.2	2.50	2.50	0.758			
VOC	Acetone	12	5	42	µg/L	1.1 - 1.1	2.90	22.0	4.08			
VOC	Carbon tetrachloride	12	1	8	µg/L	0.14 - 0.14	0.460	0.460	0.103			
VOC	Chloroform	12	1	8	µg/L	0.10 - 0.10	0.150	0.150	0.0583			

Table 5-1

Summary of Statistics and Identification of Ecological COPC for Constituents Detected in Environmental Media
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Average	Background	Toxicity Screening Level	COPEC[a]
VOC	Trichloroethene (TCE)	12	2	17	µg/L	0.28 - 0.28	1.70	4.90	0.667		47.0	
VOC	cis-1,2-Dichloroethene	12	1	8	µg/L	0.44 - 0.44	0.910	0.910	0.278			
Sediment												
HE	2,4,6-Trinitrotoluene	15	2	13	µg/kg	80 - 100	230	590	93.1			
HE	2,4-Dinitrotoluene	15	2	13	µg/kg	100 - 130	240	490	98.3		14400	
HE	4-Nitrotoluene	15	2	13	µg/kg	80 - 95	110	320	66.2			
HE	RDX	15	3	20	µg/kg	80 - 95	100	920	117			
HE	Tetryl	15	1	7	µg/kg	80 - 100	100	100	47.8			
MET	Aluminum	15	15	100	mg/kg		5610	47600	14700	15500		
MET	Arsenic	15	15	100	mg/kg		1.70	20.8	7.47	36.5	6.00	
MET	Barium	15	15	100	mg/kg		4.40	105	64.9	826.		
MET	Beryllium	15	15	100	mg/kg		0.360	13.8	1.79	1.00		
MET	Cadmium	15	11	73	mg/kg	0.26 - 0.28	0.330	3.70	0.764			
MET	Calcium	15	15	100	mg/kg		3140	114000	19600	52300		
MET	Chromium	15	15	100	mg/kg		2.00	34.4	16.4	29.0	26.0	Y
MET	Cobalt	15	15	100	mg/kg		2.80	77.3	14.7	116.	50.0	
MET	Copper	15	15	100	mg/kg		9.80	51.7	21.5	56.2	16.0	
MET	Iron	15	15	100	mg/kg		1470	54600	20000	234000	20000	
MET	Lead	15	15	100	mg/kg		5.60	77.3	27.7	48.6	31.0	Y
MET	Magnesium	15	15	100	mg/kg		482	16200	5250	10400		
MET	Manganese	15	15	100	mg/kg		18.9	722	306	3506	460.	
MET	Mercury	15	15	100	mg/kg		0.0205	2.20	0.202	0.100	0.174	Y
MET	Nickel	15	15	100	mg/kg		9.20	243	43.4	55.1	16.0	Y
MET	Potassium	15	14	93	mg/kg	380 - 380	1090	4360	1820	3390		
MET	Selenium	15	2	13	mg/kg	0.73 - 2.3	0.940	1.50	0.565	2.00		
MET	Vanadium	15	15	100	mg/kg		2.00	48.6	26.8	40.9		
MET	Zinc	15	15	100	mg/kg		28.5	286	93.9	322.	120.	
PCB	PCB-1254 (Aroclor 1254)	15	14	93	µg/kg	4.9 - 4.9	4.60	750	186		60.0	Y
PCB	PCB-1260 (Aroclor 1260)	15	14	93	µg/kg	5.9 - 5.9	6.50	1800	268		5.00	Y
SV	2,4-Dinitrotoluene	15	2	13	µg/kg	29 - 47	93.0	460	52.0		14400	
SV	2-Methylnaphthalene	15	1	7	µg/kg	42 - 68	280	280	41.5		20.2	Y
SV	3-Methylphenol	15	1	7	µg/kg	33 - 53	270	270	36.2			
SV	4-Methylphenol (p-Cresol)	15	1	7	µg/kg	32 - 52	270	270	35.7		20.2	Y
SV	Anthracene	15	2	13	µg/kg	33 - 53	41.0	61.0	23.5		57.2	Y
SV	Benzo(a)anthracene	15	8	53	µg/kg	45 - 69	104	350	121		108.	Y
SV	Benzo(a)pyrene	15	6	40	µg/kg	28 - 45	91.0	310	77.9		150.	Y

Table 5-1

Summary of Statistics and Identification of Ecological COPC for Constituents Detected in Environmental Media
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

type	Analyte	Number of Samples	Number of Detects	Percent Detect	Units	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Average	Background	Toxicity Screening Level	COPEC[a]
SV	Benzo(b)fluoranthene	15	12	80	µg/kg	39 - 60	59.0	500	164		150.	Y
SV	Benzo(g,h,i)perylene	15	1	7	µg/kg	85 - 140	180	180	59.3		170.	Y
SV	Benzo(k)fluoranthene	15	10	67	µg/kg	49 - 74	68.0	380	146		240.	Y
SV	Chrysene	15	10	67	µg/kg	38 - 59	50.0	410	154		166.	Y
SV	Dibenzofuran	15	1	7	µg/kg	30 - 48	91.0	91.0	22.0			
SV	Fluoranthene	15	9	60	µg/kg	66 - 100	100	640	223		423.	Y
SV	Indeno(1,2,3-cd)pyrene	15	3	20	µg/kg	56 - 90	240	360	89.6		200.	Y
SV	N-Nitroso-di-n-propylamine	15	1	7	µg/kg	68 - 110	620	620	78.3			
SV	Naphthalene	15	1	7	µg/kg	39 - 64	210	210	35.2			
SV	Phenanthrene	15	9	60	µg/kg	28 - 43	46.0	310	95.3		204.	Y
SV	Pyrene	15	10	67	µg/kg	49 - 75	65.0	540	205		195.	Y
SV	bis(2-Ethylhexyl)phthalate	15	3	20	µg/kg	45 - 71	50.0	56.0	31.9			
VOC	1,1-Dichloroethane	15	1	7	µg/kg	0.52 - 1.2	2.30	2.30	0.480			
VOC	2-Butanone (Methyl ethyl ketone)	15	7	47	µg/kg	1.4 - 3.9	2.70	53.0	7.38			
VOC	Acetone	15	8	53	µg/kg	19 - 64	19.0	260	72.0		9.10	Y
VOC	Benzene	15	6	40	µg/kg	0.46 - 1.1	0.760	7.80	1.36			
VOC	Carbon Disulfide	15	7	47	µg/kg	1.3 - 3.1	2.60	30.0	5.59		0.860	Y
VOC	Chloroethane	15	4	27	µg/kg	1.1 - 3.0	2.00	9.65	2.00			
VOC	Cyclohexane	15	7	47	µg/kg	0.52 - 1.2	1.40	29.0	3.77			
VOC	Ethylbenzene	15	3	20	µg/kg	0.73 - 1.7	0.835	3.50	0.747			
VOC	Methylcyclohexane	15	7	47	µg/kg	0.29 - 0.68	0.550	37.0	4.82			
VOC	Toluene	15	5	33	µg/kg	0.83 - 2.0	2.90	20.0	2.67			
VOC	Trichloroethene (TCE)	15	2	13	µg/kg	0.82 - 1.9	2.00	4.00	0.880			
VOC	Xylenes, Total	15	3	20	µg/kg	0.68 - 1.6	1.70	12.0	1.41			
VOC	cis-1,2-Dichloroethene	15	1	7	µg/kg	1.2 - 3.3	2.80	2.80	0.975			

COPC - chemical of potential concern; GC2 - general chemistry parameters; HE - explosives; MET - metals; PCB - polychlorinated biphenyls; SV - semivolatile organics compounds; VOC - volatile organic compounds; mg/kg - milligram(s) per kilogram; µg/kg - microgram(s) per kilogram; µg/L - microgram(s) per liter

[a] A "Y" in this column indicates the that chemical is an ecological COPC.

Table 5-2

Hazard Quotients for All Wildlife Assessment Receptors
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

Contaminant of Potential Ecological Concern (COPEC)	Hazard Quotient Values							
	Short-Tailed Shrew	White-Tailed Deer	Marsh Wren	Deer Mouse	Eastern Cottontail Rabbit	Red-Tailed Hawk	Raccoon	Mallard
2,4-Dinitrotoluene	6.E-01	9.E-05	8.E-01	1.E+00	4.E-02	2.E-04	--[a]	--
Aluminum	--	--	--	--	--	--	--	4.E-05
Antimony	2.E-01	2.E-05	2.E-01	3.E-01	1.E-02	5.E-05	--	--
Barium	--	--	--	--	--	--	--	5.E-07
Beryllium	2.E-01	3.E-06	2.E-01	2.E-01	4.E-03	3.E-05	--	--
Cadmium	6.E-02	4.E-06	8.E-02	9.E-02	2.E-03	2.E-05	--	--
Chromium	5.E-02	2.E-06	2.E-02	3.E-02	2.E-03	3.E-06	1.E-03	4.E-04
Copper	2.E-02	9.E-06	1.E-02	9.E-02	4.E-03	1.E-05	--	3.E-07
Iron	--	--	--	--	--	--	--	2.E-04
Lead	2.E-01	2.E-05	1.E-01	3.E-01	1.E-02	3.E-05	1.E-03	4.E-04
Mangaense	--	--	--	--	--	--	--	2.E-06
Mercury	9.E-04	6.E-08	5.E-04	1.E-03	5.E-05	1.E-07	4.E-04	1.E-04
Nickel	5.E-03	3.E-07	2.E-03	4.E-03	3.E-04	5.E-07	4.E-04	3.E-05
Vanadium	**3.E+00**	4.E-05	**3.E+00**	**3.E+00**	5.E-02	5.E-04	--	--
Zinc	--	--	--	--	--	--	--	1.E-06
PCB-1254 (Aroclor 1254)	**2.E+00**	1.E-05	**3.E+00**	**2.E+00**	1.E-02	4.E-04	2.E-02	5.E-05
PCB-1260 (Aroclor 1260)	**7.E+00**	2.E-05	**8.E+00**	**6.E+00**	3.E-02	1.E-03	3.E-02	7.E-05
2-Methylnaphthalene	--	--	--	--	--	--	**4.E+00**	--
4-Methylphenol (p-Cresol)	--	--	--	--	--	--	6.E-05	--
Anthracene	--	--	--	--	--	--	**7.E+00**	--
Benzo(a)anthracene	--	--	--	--	--	--	5.E-05	--
Benzo(a)pyrene	--	--	--	--	--	--	4.E-05	--
Benzo(b)fluoranthene	--	--	--	--	--	--	7.E-05	--
Benzo(g,h,i)perylene	--	--	--	--	--	--	5.E-05	--
Benzo(k)fluoranthene	--	--	--	--	--	--	6.E-05	--
Chrysene	--	--	--	--	--	--	6.E-05	--
Fluoranthene	--	--	--	--	--	--	**5.E+00**	--
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	2.E-06	--
Phenanthrene	--	--	--	--	--	--	5.E-02	--
Pyrene	--	--	--	--	--	--	7.E-03	--
Acetone	--	--	--	--	--	--	2.E-05	8.E-05

Notes:

1. "--" indicates that the chemical is not a COPEC for that receptor.
2. Hazard quotient values shown in bold are greater than 1.

FIGURES

FIGURE 1-1
PBOW VICINITY MAP

ACID AREA No.1
REMEDIAL INVESTIGATION REPORT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

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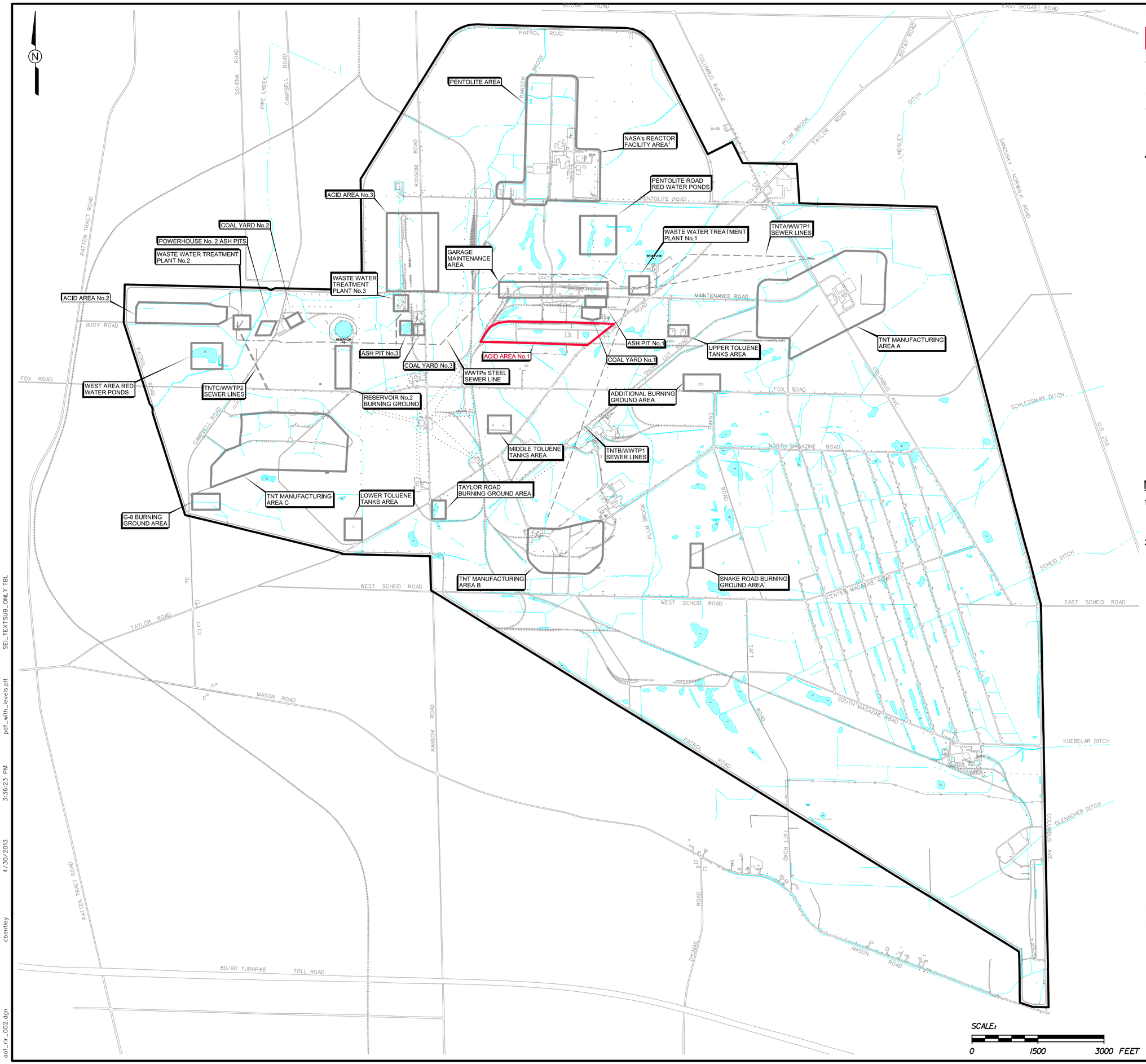

LEGEND:

- AREA OF CONCERN
- APPROXIMATE LOCATION OF SEWER LINES
- POND
- CREEK, DITCH, CONVEYANCE
- FORMER RAILROAD
- ROAD
- FENCE
- FACILITY BOUNDARY

NOTES:

1. SNAKE ROAD BURNING GROUND AREA WAS ALSO REFERRED TO AS "SNAKE ROAD BURN PIT", "SCHEID ROAD BURNING GROUNDS", AND "DISPOSAL AREA THREE".
2. REACTOR FACILITY CONSTRUCTED BY NASA POST WWII AND IS IDENTIFIED FOR LOCATION PURPOSES ONLY.

FIGURE 1-2
LOCATION OF ACID AREA No.1 AT PBOW

ACID AREA No.1
REMEDIAL INVESTIGATION REPORT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

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Legend

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings from Engineering Drawings
- Railway

200 100 0 200
Feet

N

Notes: *Aerial Photography from 1958.*
Data mapped to Ohio State Plane North NAD83, map units are feet.

JACOBS

Acid Area 1 — 1958 Aerial Photography

Plum Brook Ordnance Works
Sandusky, Ohio

11/20/08 JP X:\GIS\Projects\Plumbrook\Projects\AA1_Draft_RI\ArcGIS\Acid_Area1_1958_RI.mxd

Figure 1-3

SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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GENERAL SITE FEATURES

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 1-3

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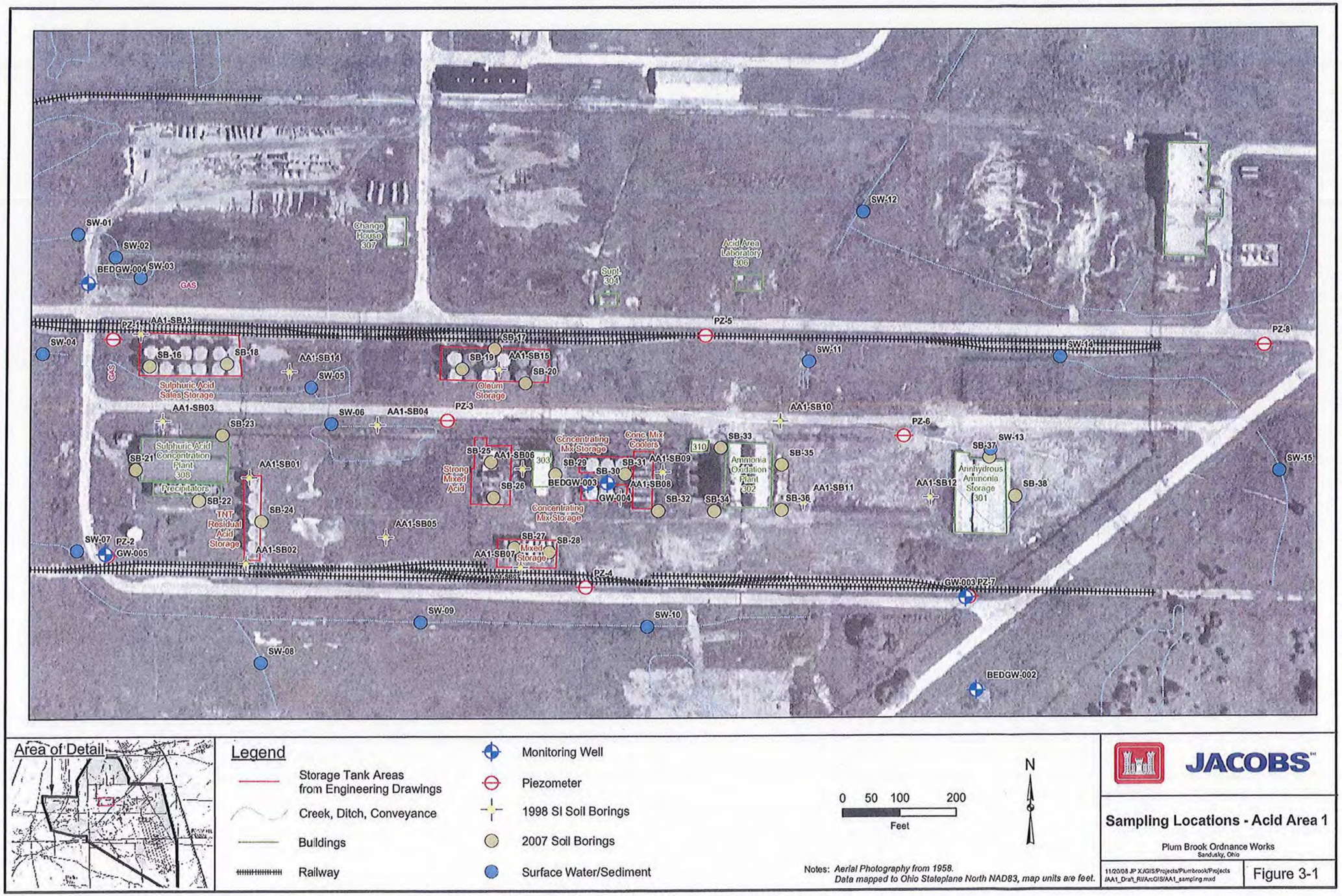

SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

SOIL BORING, TEMPORARY PIEZOMETER, OVERBURDEN/SHALE MONITORING WELL, BEDROCK MONITORING WELL, SURFACE WATER AND SEDIMENT SAMPLE LOCATION MAP

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-1

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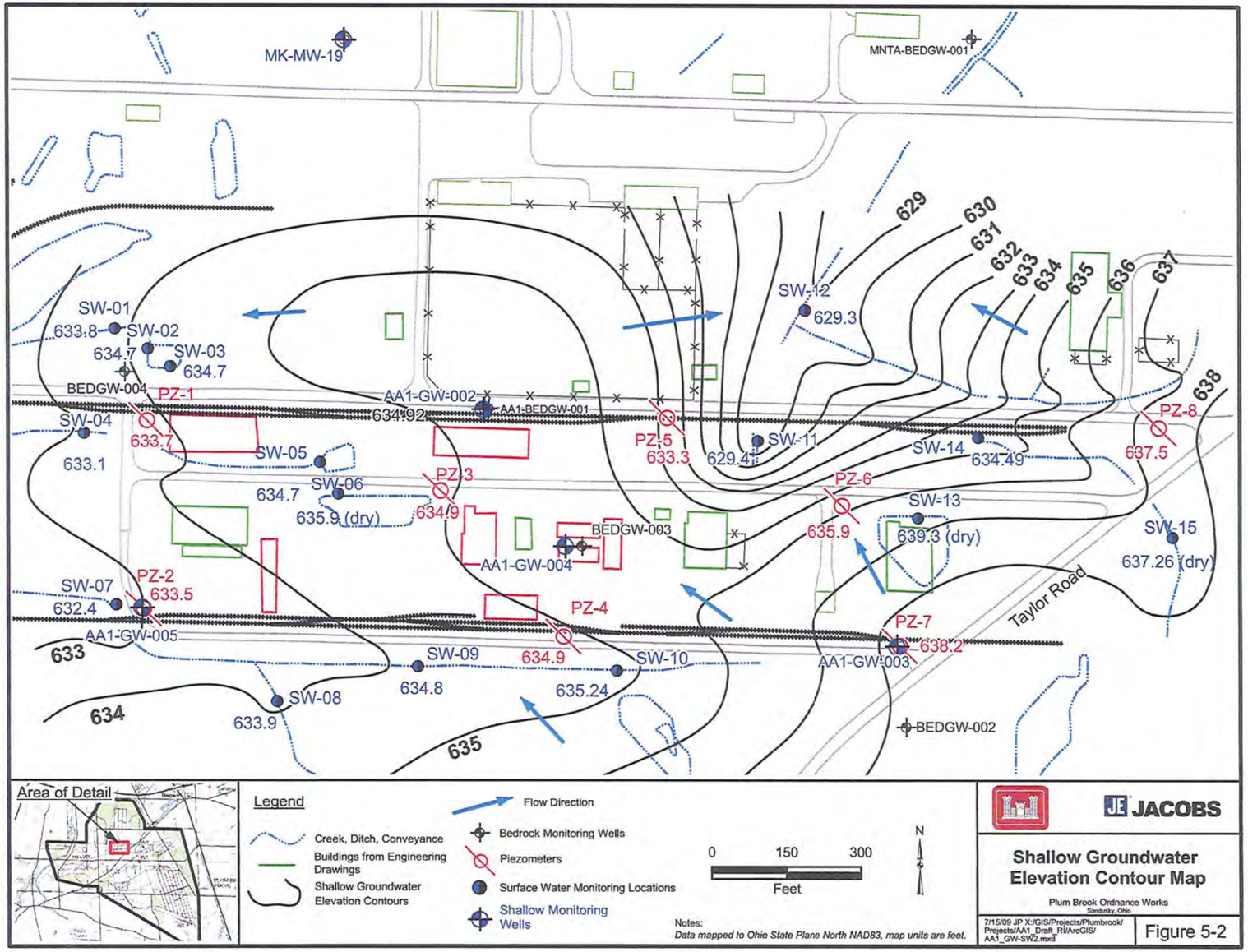

SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

OVERBURDEN/SHALE GROUNDWATER ELEVATION CONTOUR MAP (MAY 2007)

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-2

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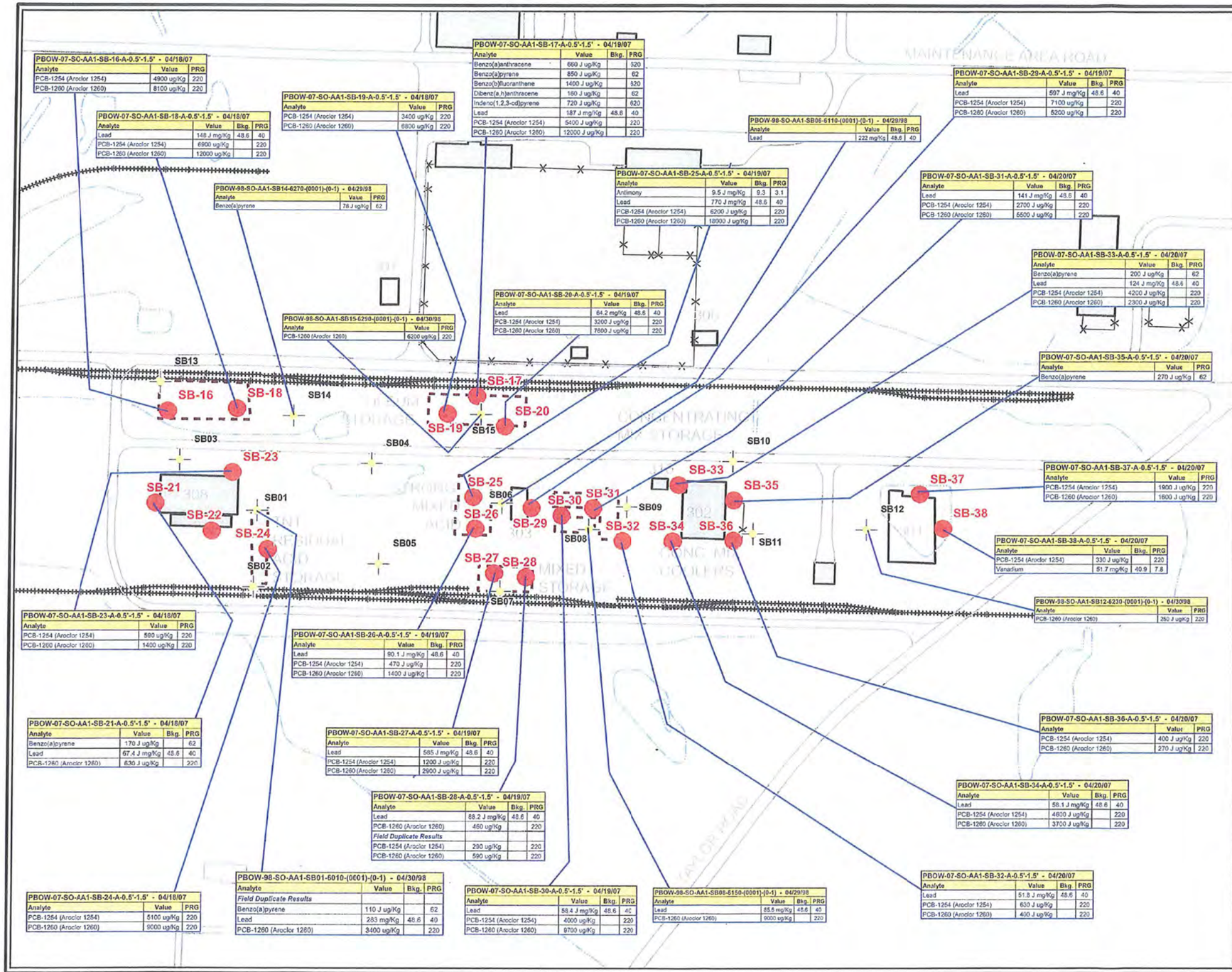

PBOW-07-SC-AA1-SB-16-A-0.5'-1.5' - 04/18/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	4900 ug/Kg	220
PCB-1260 (Aroclor 1260)	8100 ug/Kg	220

PBOW-07-SO-AA1-SB-18-A-0.5'-1.5' - 04/18/07			
Analyte	Value	Bkg.	PRG
Lead	148 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	6900 ug/Kg		220
PCB-1260 (Aroclor 1260)	12000 ug/Kg		220

PBOW-07-SO-AA1-SB-19-A-0.5'-1.5' - 04/18/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	3400 ug/Kg	220
PCB-1260 (Aroclor 1260)	6800 ug/Kg	220

PBOW-07-SO-AA1-SB-17-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Benzo(a)anthracene	660 J ug/Kg		620
Benzo(a)pyrene	850 J ug/Kg		62
Benzo(b)fluoranthene	1400 J ug/Kg		620
Dibenz(a,h)anthracene	160 J ug/Kg		62
Indeno(1,2,3-cd)pyrene	720 J ug/Kg		620
Lead	187 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	5400 J ug/Kg		220
PCB-1260 (Aroclor 1260)	12000 J ug/Kg		220

PBOW-07-SO-AA1-SB-29-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	597 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	7100 ug/Kg		220
PCB-1260 (Aroclor 1260)	5200 ug/Kg		220

PBOW-98-SO-AA1-SB06-6110-(0001)-(0-1) - 04/29/98			
Analyte	Value	Bkg.	PRG
Lead	222 mg/Kg	48.6	40

PBOW-98-SO-AA1-SB14-6270-(0001)-(0-1) - 04/29/98		
Analyte	Value	PRG
Benzo(a)pyrene	78 J ug/Kg	62

PBOW-07-SO-AA1-SB-25-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Antimony	9.5 J mg/Kg	9.3	3.1
Lead	770 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	6200 J ug/Kg		220
PCB-1260 (Aroclor 1260)	18000 J ug/Kg		220

PBOW-07-SO-AA1-SB-31-A-0.5'-1.5' - 04/20/07			
Analyte	Value	Bkg.	PRG
Lead	141 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	2700 J ug/Kg		220
PCB-1260 (Aroclor 1260)	5500 J ug/Kg		220

PBOW-07-SO-AA1-SB-33-A-0.5'-1.5' - 04/20/07			
Analyte	Value	Bkg.	PRG
Benzo(a)pyrene	200 J ug/Kg		62
Lead	124 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	4200 J ug/Kg		220
PCB-1260 (Aroclor 1260)	2300 J ug/Kg		220

PBOW-07-SO-AA1-SB-20-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	64.2 mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	3200 J ug/Kg		220
PCB-1260 (Aroclor 1260)	7600 J ug/Kg		220

PBOW-98-SO-AA1-SB15-6290-(0001)-(0-1) - 04/30/98		
Analyte	Value	PRG
PCB-1260 (Aroclor 1260)	6200 ug/Kg	220

PBOW-07-SO-AA1-SB-35-A-0.5'-1.5' - 04/20/07		
Analyte	Value	PRG
Benzo(a)pyrene	270 J ug/Kg	62

PBOW-07-SO-AA1-SB-37-A-0.5'-1.5' - 04/20/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	1900 J ug/Kg	220
PCB-1260 (Aroclor 1260)	1600 J ug/Kg	220

PBOW-07-SO-AA1-SB-38-A-0.5'-1.5' - 04/20/07			
Analyte	Value	Bkg.	PRG
PCB-1254 (Aroclor 1254)	330 J ug/Kg		220
Vanadium	51.7 mg/Kg	40.9	7.8

PBOW-98-SO-AA1-SB12-6230-(0001)-(0-1) - 04/30/98		
Analyte	Value	PRG
PCB-1260 (Aroclor 1260)	250 J ug/Kg	220

PBOW-07-SO-AA1-SB-23-A-0.5'-1.5' - 04/18/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	590 ug/Kg	220
PCB-1260 (Aroclor 1260)	1400 ug/Kg	220

PBOW-07-SO-AA1-SB-26-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	90.1 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	470 J ug/Kg		220
PCB-1260 (Aroclor 1260)	1400 J ug/Kg		220

PBOW-07-SO-AA1-SB-36-A-0.5'-1.5' - 04/20/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	400 J ug/Kg	220
PCB-1260 (Aroclor 1260)	270 J ug/Kg	220

PBOW-07-SO-AA1-SB-21-A-0.5'-1.5' - 04/18/07			
Analyte	Value	Bkg.	PRG
Benzo(a)pyrene	170 J ug/Kg		62
Lead	67.4 J mg/Kg	48.6	40
PCB-1260 (Aroclor 1260)	630 J ug/Kg		220

PBOW-07-SO-AA1-SB-27-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	585 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	1200 J ug/Kg		220
PCB-1260 (Aroclor 1260)	2900 J ug/Kg		220

PBOW-07-SO-AA1-SB-34-A-0.5'-1.5' - 04/20/07			
Analyte	Value	Bkg.	PRG
Lead	58.1 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	4600 J ug/Kg		220
PCB-1260 (Aroclor 1260)	3700 J ug/Kg		220

PBOW-07-SO-AA1-SB-28-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	88.2 J mg/Kg	48.6	40
PCB-1260 (Aroclor 1260)	460 ug/Kg		220
Field Duplicate Results			
PCB-1254 (Aroclor 1254)	290 ug/Kg		220
PCB-1260 (Aroclor 1260)	590 ug/Kg		220

PBOW-07-SO-AA1-SB-24-A-0.5'-1.5' - 04/18/07		
Analyte	Value	PRG
PCB-1254 (Aroclor 1254)	5100 ug/Kg	220
PCB-1260 (Aroclor 1260)	9000 ug/Kg	220

PBOW-98-SO-AA1-SB01-6010-(0001)-(0-1) - 04/30/98			
Analyte	Value	Bkg.	PRG
Field Duplicate Results			
Benzo(a)pyrene	110 J ug/Kg		62
Lead	283 mg/Kg	48.6	40
PCB-1260 (Aroclor 1260)	3400 ug/Kg		220

PBOW-07-SO-AA1-SB-30-A-0.5'-1.5' - 04/19/07			
Analyte	Value	Bkg.	PRG
Lead	58.4 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	4000 ug/Kg		220
PCB-1260 (Aroclor 1260)	9700 ug/Kg		220

PBOW-98-SO-AA1-SB08-5150-(0001)-(0-1) - 04/29/98			
Analyte	Value	Bkg.	PRG
Lead	85.5 mg/Kg	48.6	40
PCB-1260 (Aroclor 1260)	9000 ug/Kg		220

PBOW-07-SO-AA1-SB-32-A-0.5'-1.5' - 04/20/07			
Analyte	Value	Bkg.	PRG
Lead	51.8 J mg/Kg	48.6	40
PCB-1254 (Aroclor 1254)	630 J ug/Kg		220
PCB-1260 (Aroclor 1260)	400 J ug/Kg		220

Area of Detail

Legend

- 1998 SI Soil Borings
- Soil Boring

Note:
bgs = below ground surface
Bkg. = Background Sample (values are provided in units consistent with the reported sample values)
PRG = Preliminary Remediation Goal (values are provided in units consistent with the reported sample values)

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway

0 50 100 200 Feet

N

Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.

JACOBS

Distribution of Contaminants Exceeding PRG's in Surface Soil — Acid Area 1
Plum Brook Ordnance Works
Sandusky, Ohio

12/2/08 JP X:/GIS/Projects/Plumbrook/Projects /AA1_Draft_RI/ArcGIS/AA1_Surface_Soil.mxd

Figure 4-1

SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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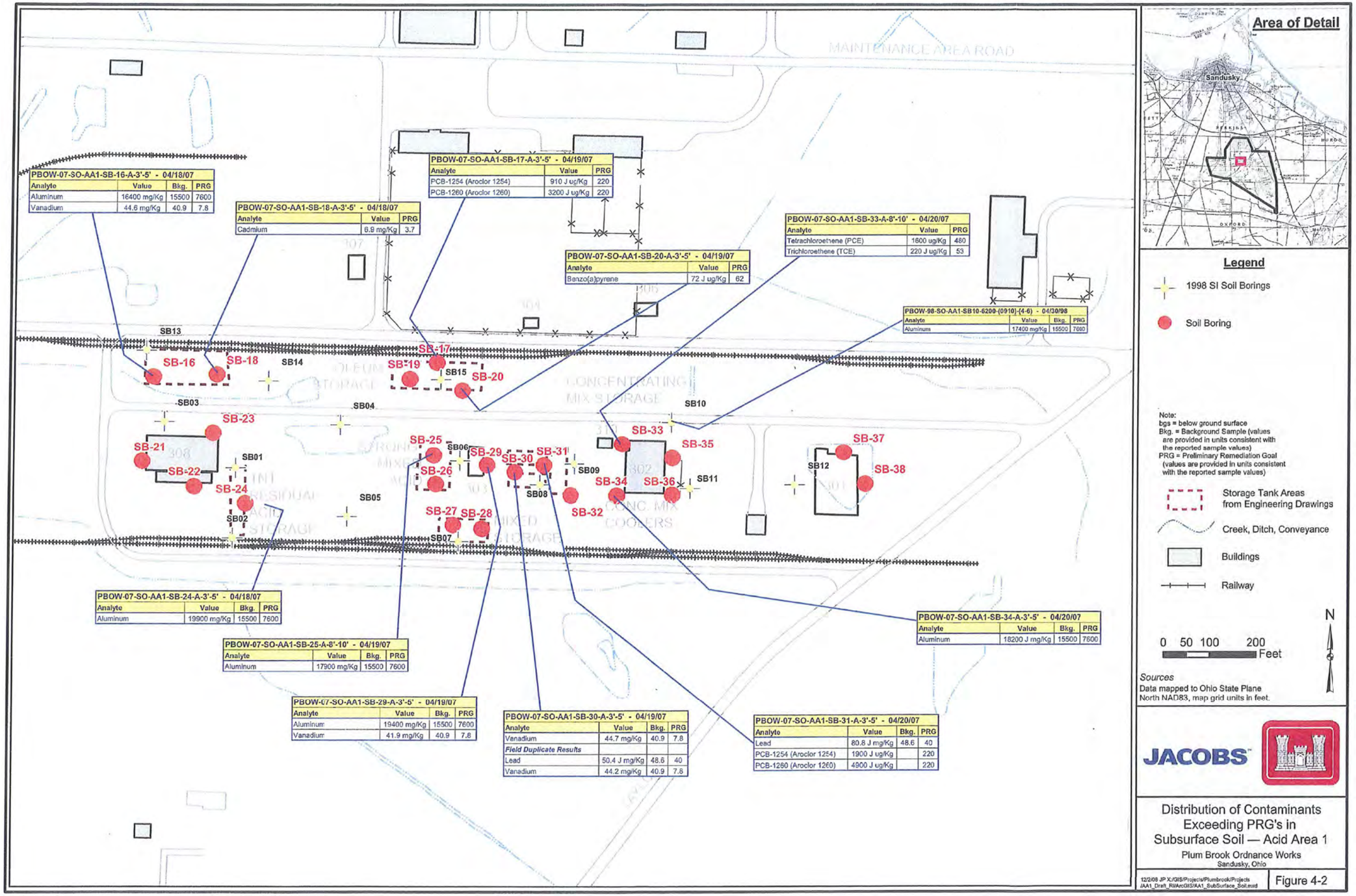
DISTRIBUTION OF CONTAMINANTS EXCEEDING PRGs IN SURFACE SOIL

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-3

aa1_rir_006.dgn 4/30/2013 3:57:19 PM cbentley pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL



SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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DISTRIBUTION OF CONTAMINANTS EXCEEDING PRGs IN SUBSURFACE SOIL

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-4

pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL
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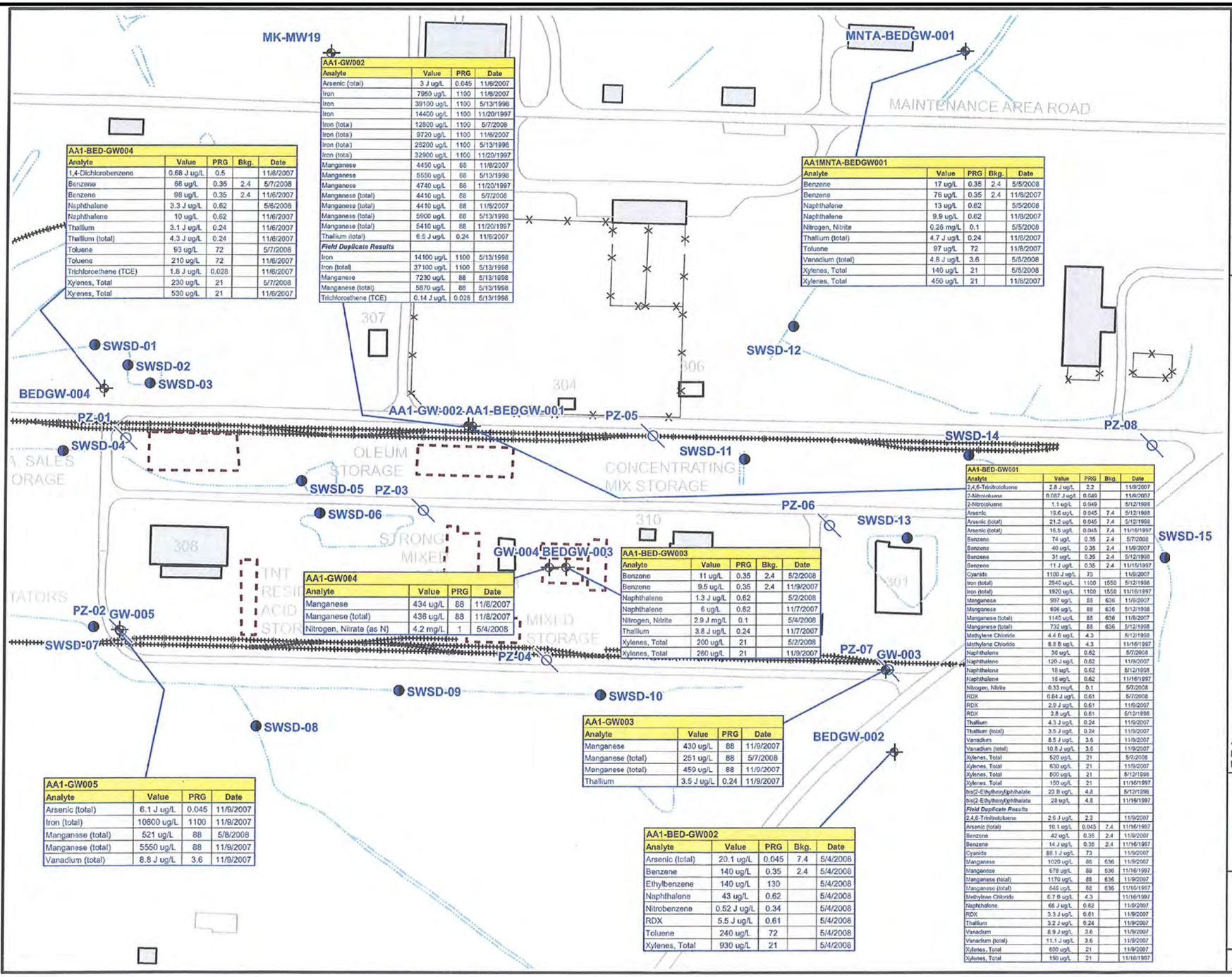
cbentley
aa1_rir_007.dgn



AA1-GW002			
Analyte	Value	PRG	Date
Arsenic (total)	3 J ug/L	0.045	11/6/2007
Iron	7950 ug/L	1100	11/8/2007
Iron	39100 ug/L	1100	5/13/1998
Iron	14400 ug/L	1100	11/20/1997
Iron (total)	12800 ug/L	1100	5/7/2008
Iron (total)	9720 ug/L	1100	11/6/2007
Iron (total)	26200 ug/L	1100	5/13/1998
Iron (total)	32900 ug/L	1100	11/20/1997
Manganese	4450 ug/L	88	11/8/2007
Manganese	5550 ug/L	88	5/13/1998
Manganese	4740 ug/L	88	11/20/1997
Manganese (total)	4410 ug/L	88	5/7/2008
Manganese (total)	4410 ug/L	88	11/8/2007
Manganese (total)	5900 ug/L	88	5/13/1998
Manganese (total)	5410 ug/L	88	11/20/1997
Thallium (total)	6.5 J ug/L	0.24	11/6/2007
Field Duplicate Results			
Iron	14100 ug/L	1100	5/13/1998
Iron (total)	37100 ug/L	1100	5/13/1998
Manganese	7230 ug/L	88	5/13/1998
Manganese (total)	5870 ug/L	88	5/13/1998
Trichloroethene (TCE)	0.14 J ug/L	0.028	5/13/1998

AA1-BED-GW004				
Analyte	Value	PRG	Bkg.	Date
1,4-Dichlorobenzene	0.68 J ug/L	0.5		11/8/2007
Benzene	68 ug/L	0.35	2.4	5/7/2008
Benzene	98 ug/L	0.35	2.4	11/8/2007
Naphthalene	3.3 J ug/L	0.62		5/6/2008
Naphthalene	10 ug/L	0.62		11/6/2007
Thallium	3.1 J ug/L	0.24		11/6/2007
Thallium (total)	4.3 J ug/L	0.24		11/6/2007
Toluene	93 ug/L	72		5/7/2008
Toluene	210 ug/L	72		11/6/2007
Trichloroethene (TCE)	1.8 J ug/L	0.028		11/6/2007
Xylenes, Total	230 ug/L	21		5/7/2008
Xylenes, Total	530 ug/L	21		11/6/2007

AA1MNTA-BEDGW001				
Analyte	Value	PRG	Bkg.	Date
Benzene	17 ug/L	0.35	2.4	5/5/2008
Benzene	76 ug/L	0.35	2.4	11/8/2007
Naphthalene	13 ug/L	0.62		5/5/2008
Naphthalene	9.9 ug/L	0.62		11/8/2007
Nitrogen, Nitrite	0.26 mg/L	0.1		5/5/2008
Thallium (total)	4.7 J ug/L	0.24		11/6/2007
Toluene	97 ug/L	72		11/8/2007
Vanadium (total)	4.8 J ug/L	3.6		5/5/2008
Xylenes, Total	140 ug/L	21		5/5/2008
Xylenes, Total	450 ug/L	21		11/8/2007

AA1-GW004			
Analyte	Value	PRG	Date
Manganese	434 ug/L	88	11/8/2007
Manganese (total)	438 ug/L	88	11/8/2007
Nitrogen, Nitrate (as N)	4.2 mg/L	1	5/4/2008

AA1-BED-GW003				
Analyte	Value	PRG	Bkg.	Date
Benzene	11 ug/L	0.35	2.4	5/2/2008
Benzene	9.5 ug/L	0.35	2.4	11/9/2007
Naphthalene	1.3 J ug/L	0.62		5/2/2008
Naphthalene	6 ug/L	0.62		11/7/2007
Nitrogen, Nitrite	2.9 J mg/L	0.1		5/4/2008
Thallium	3.8 J ug/L	0.24		11/7/2007
Xylenes, Total	200 ug/L	21		5/2/2008
Xylenes, Total	260 ug/L	21		11/9/2007

AA1-GW003			
Analyte	Value	PRG	Date
Manganese	430 ug/L	88	11/9/2007
Manganese (total)	251 ug/L	88	5/7/2008
Manganese (total)	459 ug/L	88	11/9/2007
Thallium	3.5 J ug/L	0.24	11/9/2007

AA1-GW005			
Analyte	Value	PRG	Date
Arsenic (total)	6.1 J ug/L	0.045	11/9/2007
Iron (total)	10800 ug/L	1100	11/9/2007
Manganese (total)	521 ug/L	88	5/8/2008
Manganese (total)	5550 ug/L	88	11/9/2007
Vanadium (total)	8.8 J ug/L	3.6	11/9/2007

AA1-BED-GW002				
Analyte	Value	PRG	Bkg.	Date
Arsenic (total)	20.1 ug/L	0.045	7.4	5/4/2008
Benzene	140 ug/L	0.35	2.4	5/4/2008
Ethylbenzene	140 ug/L	130		5/4/2008
Naphthalene	43 ug/L	0.62		5/4/2008
Nitrobenzene	0.52 J ug/L	0.34		5/4/2008
RDX	5.5 J ug/L	0.61		5/4/2008
Toluene	240 ug/L	72		5/4/2008
Xylenes, Total	930 ug/L	21		5/4/2008

AA1-BED-GW001				
Analyte	Value	PRG	Bkg.	Date
2,4,6-Trinitrotoluene	2.8 J ug/L	2.2		11/9/2007
2-Nitroaniline	0.087 J ug/L	0.049		11/9/2007
2-Nitrotoluene	1.1 ug/L	0.049		5/12/1998
Arsenic	19.6 ug/L	0.045	7.4	5/12/1998
Arsenic (total)	21.2 ug/L	0.045	7.4	5/12/1998
Arsenic (total)	16.5 ug/L	0.045	7.4	11/16/1997
Benzene	74 ug/L	0.35	2.4	5/7/2008
Benzene	40 ug/L	0.35	2.4	11/9/2007
Benzene	31 ug/L	0.35	2.4	5/12/1998
Benzene	11 J ug/L	0.35	2.4	11/16/1997
Cyanide	1100 J ug/L	73		11/9/2007
Iron (total)	2540 ug/L	1100	1550	5/12/1998
Iron (total)	1920 ug/L	1100	1550	11/16/1997
Manganese	997 ug/L	88	636	11/9/2007
Manganese	696 ug/L	88	636	5/12/1998
Manganese (total)	1140 ug/L	88	636	11/9/2007
Manganese (total)	732 ug/L	88	636	5/12/1998
Methylene Chloride	4.4 B ug/L	4.3		5/12/1998
Methylene Chloride	8.8 B ug/L	4.3		11/16/1997
Naphthalene	36 ug/L	0.62		5/7/2008
Naphthalene	120 J ug/L	0.62		11/9/2007
Naphthalene	18 ug/L	0.62		5/12/1998
Naphthalene	16 ug/L	0.62		11/16/1997
Nitrogen, Nitrite	0.53 mg/L	0.1		5/7/2008
RDX	0.64 J ug/L	0.61		5/7/2008
RDX	2.9 J ug/L	0.61		11/9/2007
RDX	2.8 ug/L	0.61		5/12/1998
Thallium	4.3 J ug/L	0.24		11/9/2007
Thallium (total)	3.5 J ug/L	0.24		11/9/2007
Vanadium	8.5 J ug/L	3.6		11/9/2007
Vanadium (total)	10.8 J ug/L	3.6		11/9/2007
Xylenes, Total	520 ug/L	21		5/7/2008
Xylenes, Total	630 ug/L	21		11/9/2007
Xylenes, Total	500 ug/L	21		5/12/1998
Xylenes, Total	150 ug/L	21		11/16/1997
bis(2-Ethylhexyl)phthalate	23 B ug/L	4.8		5/12/1998
bis(2-Ethylhexyl)phthalate	28 ug/L	4.8		11/16/1997
Field Duplicate Results				
2,4,6-Trinitrotoluene	2.6 J ug/L	2.2		11/9/2007
Arsenic (total)	18.1 ug/L	0.045	7.4	11/16/1997
Benzene	42 ug/L	0.35	2.4	11/9/2007
Benzene	14 J ug/L	0.35	2.4	11/16/1997
Cyanide	88.1 J ug/L	73		11/9/2007
Manganese	1020 ug/L	88	636	11/9/2007
Manganese	678 ug/L	88	636	11/16/1997
Manganese (total)	1170 ug/L	88	636	11/9/2007
Manganese (total)	646 ug/L	88	636	11/16/1997
Methylene Chloride	6.7 B ug/L	4.3		11/16/1997
Naphthalene	66 J ug/L	0.62		11/9/2007
RDX	3.3 J ug/L	0.61		11/9/2007
Thallium	3.2 J ug/L	0.24		11/9/2007
Vanadium	8.9 J ug/L	3.6		11/9/2007
Vanadium (total)	11.1 J ug/L	3.6		11/9/2007
Xylenes, Total	600 ug/L	21		11/9/2007
Xylenes, Total	150 ug/L	21		11/16/1997

Legend

- Surface Water or Sediment Sampling Locations
- Monitoring Wells
- Piezometers

Note:
bgs = below ground surface
Bkg. = Background Sample (values are provided in units consistent with the reported sample values)
PRG = Preliminary Remediation Goal (values are provided in units consistent with the reported sample values)

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway

0 50 100 200 Feet

N

Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.

JACOBS

Distribution of Contaminants Exceeding PRG's in Groundwater — Acid Area 1
Plum Brook Ordnance Works
Sandusky, Ohio

1/20/09 JP X:/GIS/Projects/Plumbrook/Projects /AA1_Draft_RI/ArcGIS/AA1_Groundwater2.mxd

Figure 5-3

SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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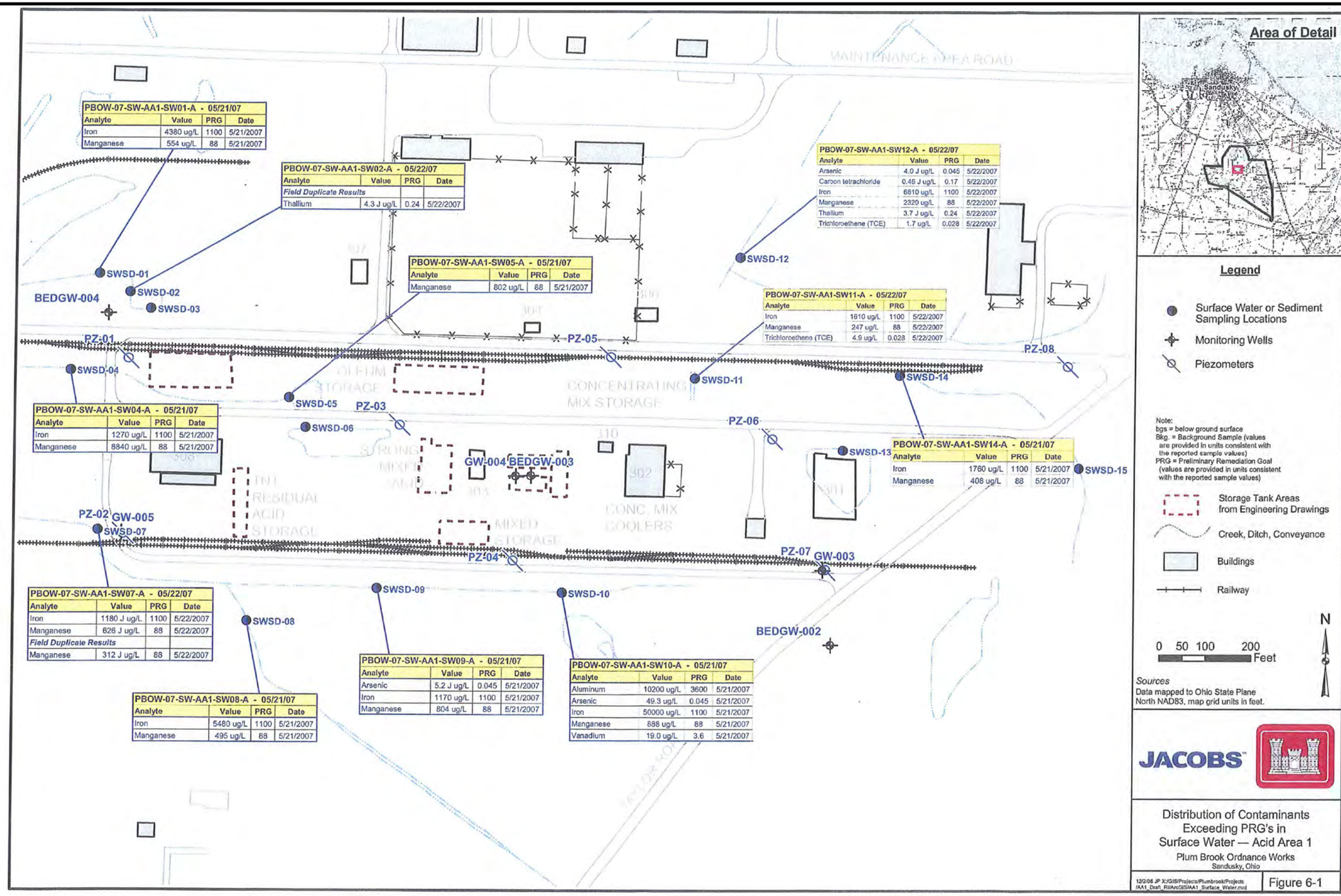
DISTRIBUTION OF CONTAMINANTS EXCEEDING PRGs IN GROUNDWATER

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-5

aa1_rir_008.dgn cbentley 4/30/2013 4:20:05 PM pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL



SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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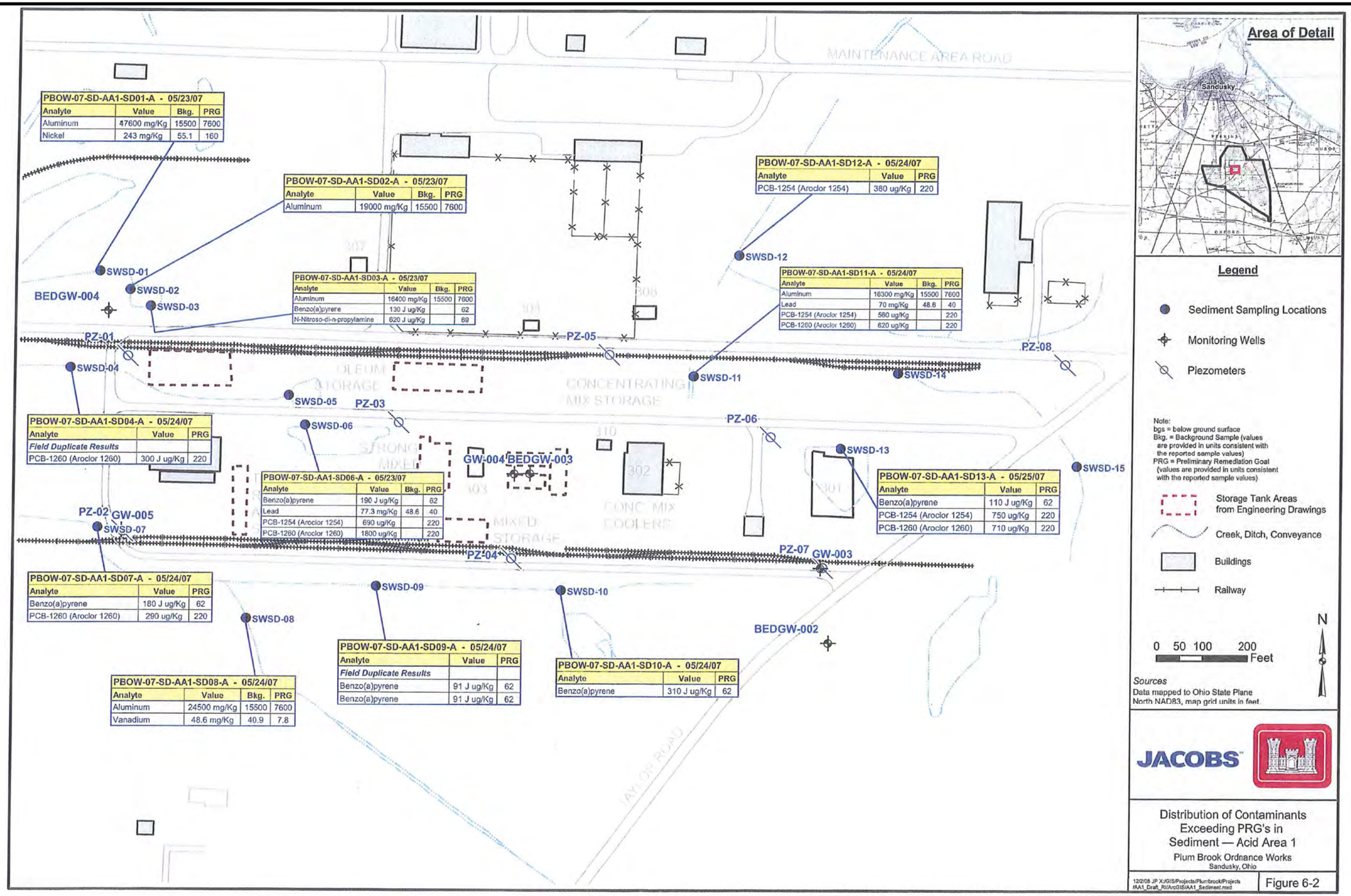
DISTRIBUTION OF CONTAMINANTS EXCEEDING PRGs IN SURFACE WATER

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-6

pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL 4:24:14 PM 4/30/2013 cbentley aa1_rir_009.dgn



SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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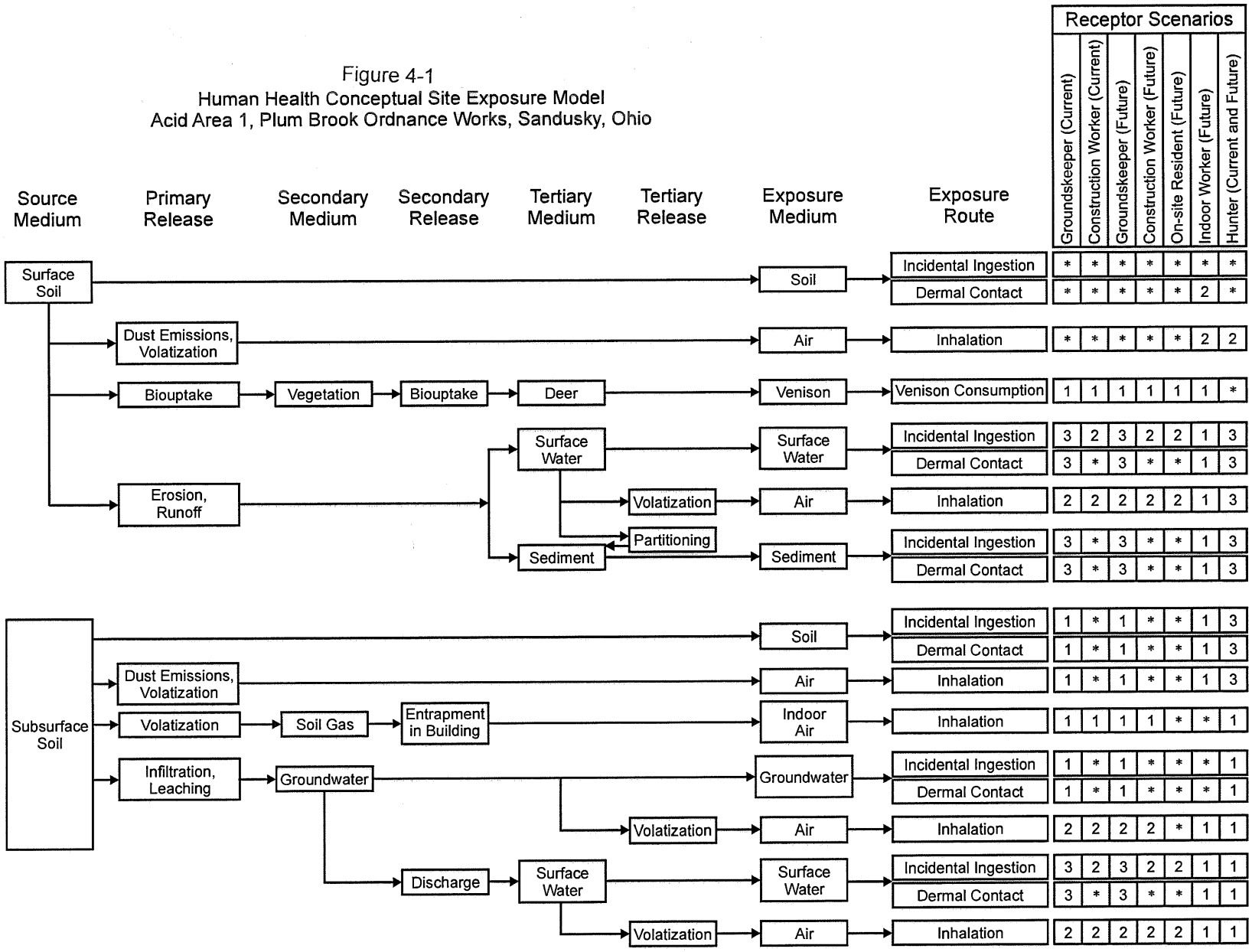
DISTRIBUTION OF CONTAMINANTS EXCEEDING PRGs IN SEDIMENT

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 3-7

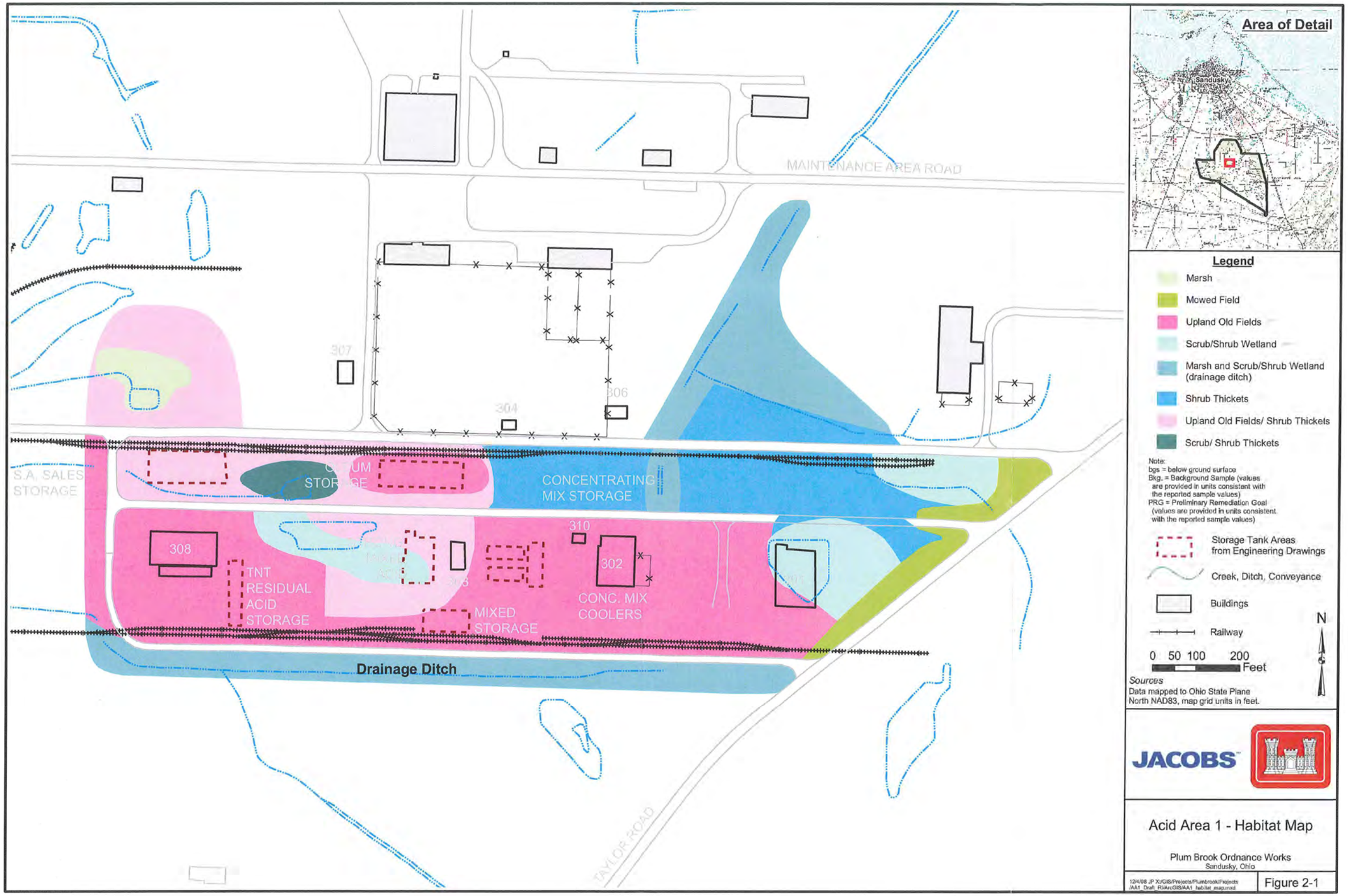
pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL 4:28:25 PM 4/30/2013 cbentley aa1_rir_010.dgn

Figure 4-1
Human Health Conceptual Site Exposure Model
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio



* = Complete exposure route quantified in the risk assessment.
1 = There is no plausible pathway for exposure in this medium.
2 = Although theoretically complete, this pathway in not quantified as explained in text.
3 = Contact with this medium, although plausible, is not part of this receptor's normal or expected activities; therefore, contact would be sporadic and is not quantified.

Source: Jacobs, 2010a



SOURCE: FINAL SITE CHARACTERIZATION REPORT (JACOBS, 2009).

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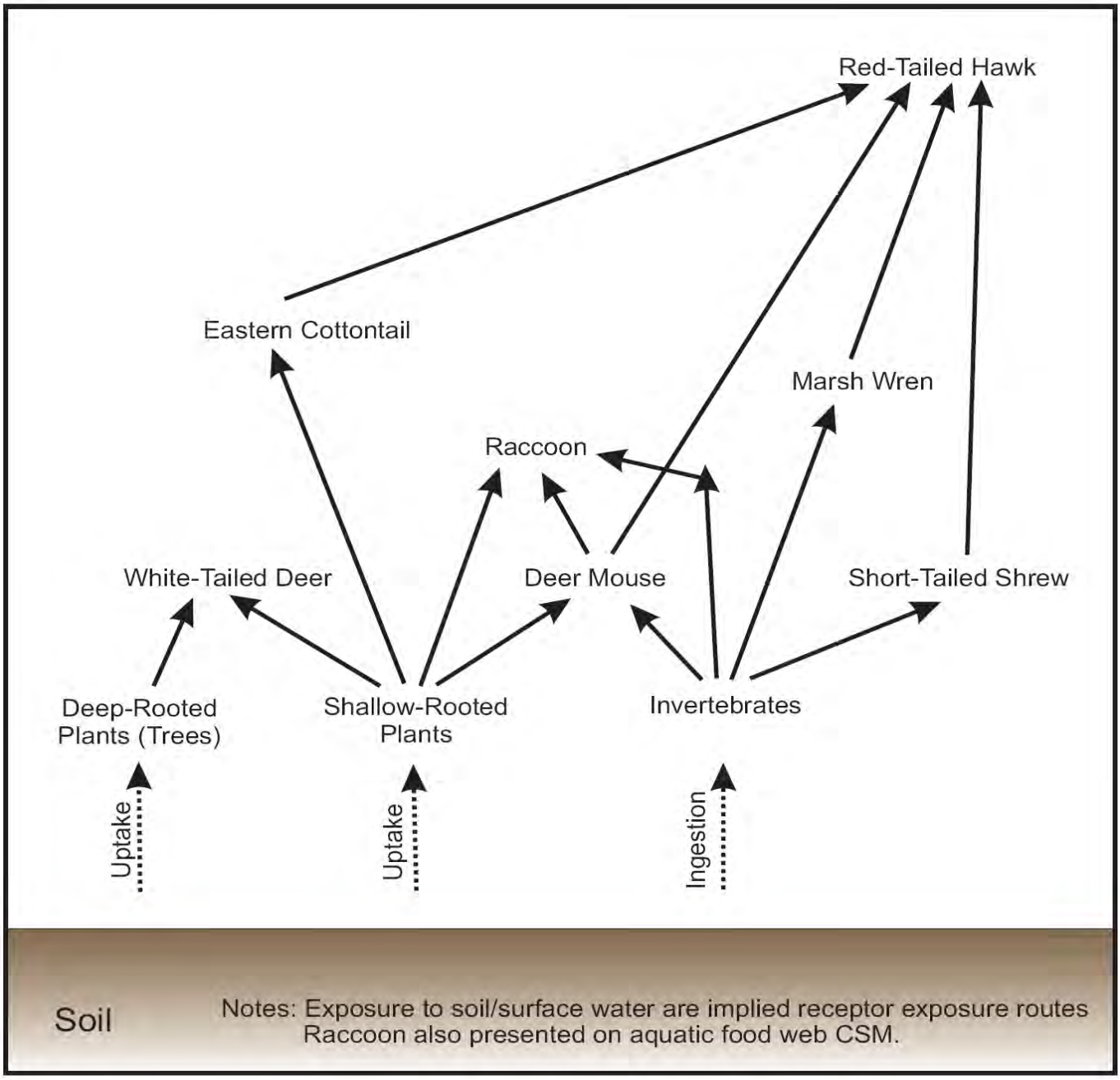
HABITAT MAP

ACID AREA No. 1 REMEDIAL INVESTIGATION REPORT

FIGURE 5-1

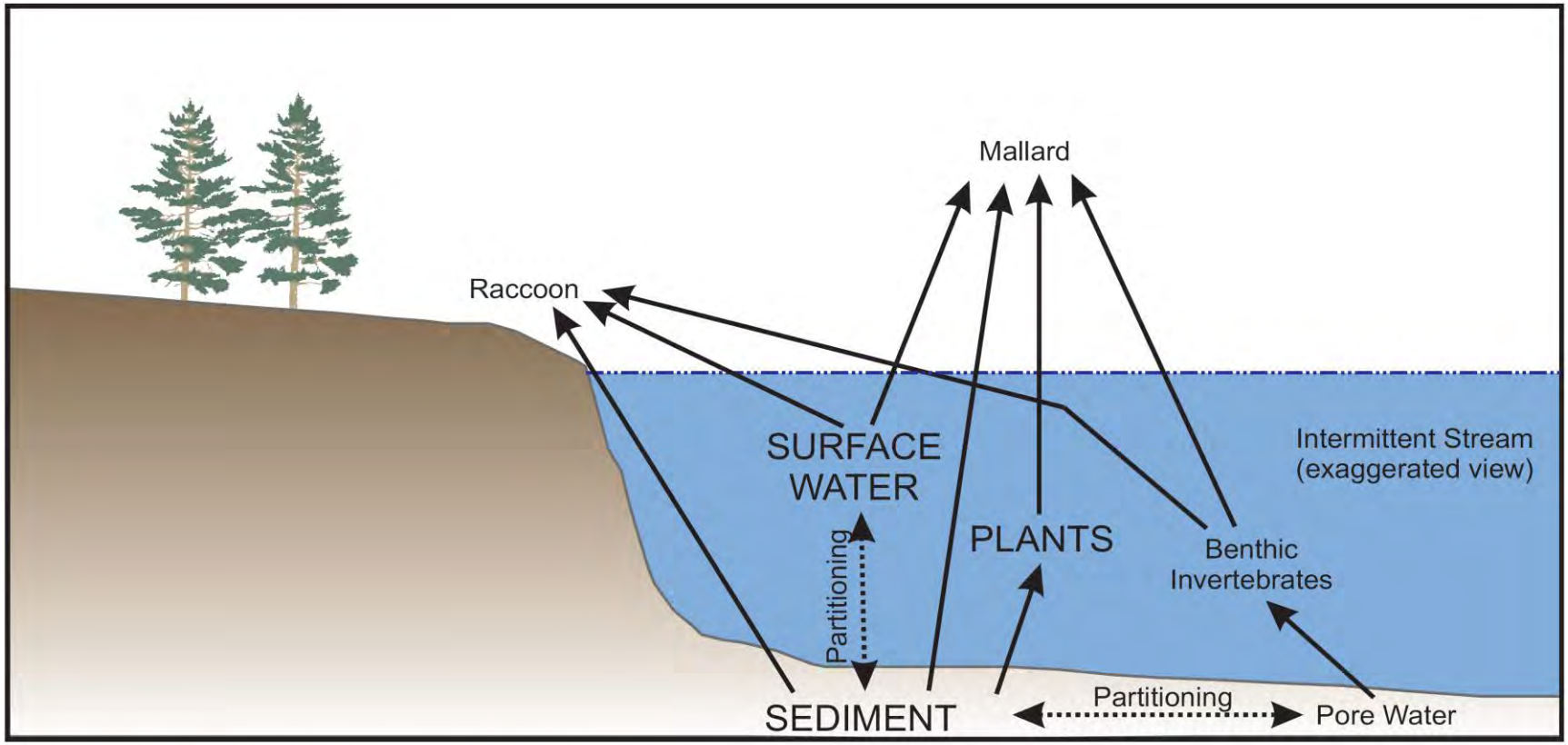
aa1_rir_011.dgn cbentley 4/30/2013 4:31:56 PM pdf_with_levels.plt SEL_TEXTSUB_ONLY.TBL

Figure 5-2
Simplified Terrestrial Food Web Conceptual Site Model
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio



Source: Jacobs, 2010b

Figure 5-3
Simplified Aquatic Food Web Conceptual Site Model
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio



Notes: Raccoon also presented on terrestrial food web CSM.

Source: Jacobs, 2010b

APPENDIX A

ACID AREA 1 SITE CHARACTERIZATION REPORT
(ELECTRONIC DELIVERABLE ONLY)

APPENDIX B

ACID AREA 1 BASELINE HUMAN HEALTH RISK ASSESSMENT
(ELECTRONIC DELIVERABLE ONLY)

APPENDIX C

ACID AREA 1 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT
(ELECTRONIC DELIVERABLE ONLY)