**DEPARTMENT OF THE ARMY**
**US ARMY INSTALLATION MANAGEMENT COMMAND**
**US ARMY ENVIRONMENTAL COMMAND**
**2455 REYNOLDS ROAD**
**JOINT BASE SAN ANTONIO FORT SAM HOUSTON, TX 78234-7588**

AMIM-AEC-M (1200C) June 2, 2021

SUBJECT: Submittal of Final Remedial Investigation/Feasibility Study for Site-Wide Groundwater at the Badger Army Ammunition Plant WDNR BRRTS #02-57-001002

Mr. Steve Martin
Wisconsin Department of Natural Resources
GEF2 Central Office
PO Box 7921
Madison, WI 53707-7921

Dear Mr. Martin:

Enclosed is the Final Remedial Investigation/Feasibility Study (RI/FS) for Site-Wide Groundwater at the former Badger Army Ammunition Plant (BAAP). This RI/FS presents updated groundwater investigation results, human health risk assessment findings, and the analysis of remedial alternatives for contaminated groundwater at the BAAP.

The Final RI/FS was prepared by SpecPro Professional Services, LLC (SPS) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and the Defense Environmental Restoration Program (DERP) requirements.

The Army received comments from the public, United States Geological Survey, and Wisconsin Department of Natural Resources on the Draft Final RI/FS dated November 5, 2019. Appendix K of the enclosed Final RI/FS addresses the comments received by the above parties.

Site-wide groundwater investigations have identified four groundwater plumes: Propellant Burning Ground (PBG) Plume, Central Plume, Deterrent Burning Ground (DBG) Plume, and Nitrocellulose Production Area (NC Area) Plume.

The Feasibility Study identifies and provides a detailed evaluation of potential remedial alternatives that could reduce, control or mitigate exposure to groundwater. The Feasibility Study does not recommend or select remedial alternatives. The Army's preferred alternative or remedy for each groundwater plume will be presented in a Proposed Plan, scheduled to be completed in 2021.

Please do not hesitate to contact me at 210-466-1351 if you have any questions.

Sincerely,

Digitally signed by
LYNCH.BRYAN.PATRICK.1021561
254
Date: 2021.06.02 13:02:15 -05'00'

Bryan P. Lynch
Commander's Representative

Enclosure
Copy furn: Gregory Rudloff, USEPA - Region 5
SpecPro Professional Services, LLC

**FINAL**

# REMEDIAL INVESTIGATION/FEASIBILITY STUDY FOR SITE-WIDE GROUNDWATER AT THE FORMER BADGER ARMY AMMUNITION PLANT, BARABOO, WISCONSIN

**Prepared for:**
**U.S. Army Environmental Command**
**2950 Connell Road**
**JBSA – Fort Sam Houston, TX 78232**

**JUNE 2021**


**Prepared by:**
**SpecPro Professional Services, LLC**
**S7560 U.S. Highway 12**
**North Freedom, WI 53951**

# EXECUTIVE SUMMARY

This Remedial Investigation/Feasibility Study (RI/FS) presents updated groundwater investigation results, human health risk assessment findings, and the analysis of remedial alternatives for contaminated groundwater at the former Badger Army Ammunition Plant (BAAP). The RI/FS is prepared in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the Defense Environmental Restoration Program (DERP) requirements.

BAAP was constructed in 1942 to produce smokeless gunpowder and solid rocket propellant as munitions components for World War II. The former BAAP is located on the Sauk Prairie, between the Baraboo Range and the Wisconsin River. Because of production and waste disposal practices that were common at the time, soil and groundwater at the former BAAP were impacted. The Department of the Army (Army) has transferred a majority of the total 7,275 acres of BAAP to other Federal agencies.

The Army began assessing potential waste management areas that may be sources of soil and groundwater contamination in 1980. When the Army applied for a Resource Conservation and Recovery Act (RCRA) permit in 1988, the State of Wisconsin did not have authorization to implement certain elements of RCRA, also known as the Hazardous and Solid Waste Amendments of 1984, so the Army operated under a dual federal-state permit, where the Wisconsin Department of Natural Resources (WDNR) regulated the RCRA operating and/or closure requirements and the United States Environmental Protection Agency (USEPA) addressed RCRA corrective action requirements.

RCRA closure and post-closure requirements were managed through an *In-Field Conditions Report* (IFCR), which WDNR issued in 1987. As required by the IFCR, the Army has been conducting groundwater monitoring of both monitoring wells and residential wells since 1987. The current site-wide groundwater monitoring program follows the IFCR dated September 4, 2013 and subsequent revisions up through July 24, 2018. Currently, the Army is sampling 166 monitoring wells and 54 residential wells at varying frequencies.

In 2011, the Army submitted a Revised Alternative Feasibility Study, Groundwater Remedial Strategy report to the WDNR. The selected groundwater remedy was Monitored Natural Attenuation (MNA). Due to the relatively long remedial timeframe for the MNA remedy to achieve the proposed cleanup levels, the proposed remedy included construction and operation of a municipal drinking water system that would provide residents in the communities surrounding the former BAAP with drinking water while groundwater contamination continued to diminish over time. During an evaluation by the Army's Office of General Counsel it was determined the Army did not have the legal or funding authority to procure and operate a municipal water system as identified in the 2011 Revised Alternative Feasibility Study.

While a draft Decision Document (DD) for Site-Wide Groundwater was being prepared in 2012, the Army identified several areas where the draft DD did not meet both legal and policy requirements. Specifically, a human health risk assessment was not prepared, incorrect legal standards were identified for the selected groundwater remedy and key components of the proposed response action were outside the Army's authority. In 2017, the Army coordinated with the WDNR and informed the public regarding the need to align the Badger Site-Wide Groundwater remedy selection to comply with legal, policy, and funding authorities. The Army communicated the need to reevaluate the groundwater remedy at BAAP in a letter dated July 25, 2017.

**Remedial Investigation**

The Army has conducted numerous site investigations and remedial actions at the former BAAP property. Groundwater investigation activities at BAAP began in 1980. Site-wide groundwater investigations identified four groundwater plumes: Propellant Burning Ground (PBG) Plume, Central Plume, Deterrent Burning Ground (DBG) Plume, and Nitrocellulose Production Area (NC Area) Plume.

The regional groundwater flow direction in the BAAP area is south-southeast towards the Wisconsin River. The Wisconsin River acts as a discharge point for groundwater east and south of BAAP. Based on historical groundwater sampling data, groundwater is contaminated by chlorinated solvents and explosives.

The Army has replaced seven residential drinking water wells due to groundwater impacts associated with the BAAP groundwater plumes. Three residential wells were impacted by the PBG Plume where volatile organic compounds (VOCs) were detected above WDNR Natural Resources (NR) 140 Enforcement Standards (ES). Three residential wells were impacted by the Central Plume where total dinitrotoluene (DNT) concentrations exceeded the NR 140 ES. The final residential well that was replaced was impacted by the DBG Plume where total DNT concentrations exceeded the NR 140 ES. All seven residential wells withdrew water from the shallow sand and gravel aquifer.

Remedial activities addressing source areas for the four groundwater contaminant plumes have been implemented. Soil remedial actions addressed the source areas to the maximum extent possible and minimized the potential exposure to human health based on anticipated future land use at the former BAAP. The Army has received site closure from the WDNR on all soil related investigations and remedial actions at BAAP.

**Risk Assessment**

A groundwater human health risk assessment (HHRA) was conducted in 2018. The HHRA evaluated whether groundwater contamination originating from the BAAP poses a current or hypothetical future risk to human health. The HHRA evaluated two potential ways people could be exposed to chemicals in groundwater, through vapor intrusion and domestic use of groundwater. The HHRA is based on conservative screening level risk calculations using maximum groundwater chemical concentrations detected in each groundwater plume. These conservative calculations overestimate the actual risk.

Based on previous vapor intrusion investigations, groundwater contamination at the BAAP does not pose a current or potential future risk to area residents due to vapor intrusion from any of the four groundwater plumes.

The groundwater risk evaluation was conducted to estimate the potential risk associated with the domestic use of groundwater. Groundwater quality data (residential wells and monitoring wells) from 2015, 2016, 2017 and 2018 were used for the initial screening level risk evaluation to represent current and hypothetical future groundwater quality. The default risk-based screening values provided in the

USEPA's Regional Screening Levels (RSLs) Resident Tapwater Generic Table (November 2018) were used to calculate both the cancer and non-cancer risks. The Tapwater RSLs incorporate exposure to chemicals in groundwater associated with ingestion (drinking water and food preparation), as well as dermal contact (hand washing and bathing) and inhalation (bathing, food preparation, and dishwashing) during use of the groundwater. When making risk management decisions, the Army considered a cumulative cancer risk above $1x10^{-6}$ (one in a million) for off-site residential wells and groundwater monitoring wells (current risk) and $1x10^{-4}$ (one in ten thousand) for on-site groundwater monitoring wells (hypothetical future) where existing property transfer documents are restricting access to groundwater. For both the off-site and on-site risk evaluations, the RI/FS identifies potential remedies when the cumulative non-cancer risk hazard index exceeds 1.0.

The risk-based contaminants of concern (COCs) identified in the PBG Plume were chloroform, carbon tetrachloride (CTET), ethyl ether, trichloroethene (TCE), and 2,6-DNT. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). For the PBG Plume, the risk evaluation identified unacceptable cancer risks and non-cancer hazards associated with current (off-site) groundwater access, as well as hypothetical future (on-site) cancer and non-cancer risk above the risk management criteria.

The risk-based COCs identified in the DBG Plume were chloroform, 1,1,2-trichloroethane (1,1,2-TCA), TCE, and total DNT. For the DBG Plume, the risk evaluation identified unacceptable cancer risks and non-cancer hazards associated with current (off-site) groundwater access, as well as hypothetical future (on-site) non-cancer risk above the risk management criteria.

The risk-based COCs identified in the Central Plume were 1,2-dichloroethane, benzene, chloroform, and 2,6-DNT. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The risk evaluation indicated that the Central Plume has current (off-site) cancer risk above the risk management criteria.

There were no risk-based COCs identified in the NC Area Plume. The current and future hypothetical cancer risks and non-cancer hazards associated with the NC Area Plume are below the risk management criteria.

The COCs that are identified in the RI have an associated current or hypothetical future risk. The Feasibility Study evaluates potential response actions for the identified risks.

**Feasibility Study**

The FS identifies and provides a detailed evaluation of potential remedial alternatives that could reduce, control or mitigate exposure to groundwater COCs. Remedial alternatives considered in the FS must be protective of human health and the environment for the PBG Plume, DBG Plume, and Central Plume and meet Applicable, or Relevant and Appropriate Requirements (ARARs), which are CERCLA threshold criteria for remedy selection. The HHRA did not identify COCs for the NC Area Plume. Therefore, remedial alternatives are not being considered for the NC Area Plume.

The FS includes remedial action objectives (RAOs), which provide a general description of what the cleanup will accomplish, serves as the basis for evaluating each remedial alternative, and provides an understanding of how the unacceptable risks will be addressed by each remedial alternative. Groundwater RAOs require the remedy to protect human health by preventing exposure to contaminated groundwater, to restore groundwater to the extent practicable, and minimize the impact of the contaminant plumes on the environment. Specifically, the RAOs for any individual plume are achieved when the risk-based groundwater COCs are below cleanup levels. The FS includes the identification and evaluation of general response actions (GRAs), remedial technologies, and process options with respect to effectiveness, implementability, and cost. Appropriate remedial technologies and process options were carried forward and combined to develop remedial alternatives for each individual plume. The remedial alternatives and a brief description are listed below.

**Remedial Alternatives – PBG Plume**

Based on site conditions and the screening of process options, six remedial alternatives were developed for the PBG Plume to address the presence of contaminants in groundwater at the BAAP.

***Alternative 1: No Action***

The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. It would have no impact on the contaminant plume, require no groundwater monitoring but would include on-site groundwater access restrictions.

***Alternative 2: Monitored Natural Attenuation and Alternate Water Supply***

The Monitored Natural Attenuation (MNA) and Alternate Water Supply Alternative would include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 3: Active Groundwater Remediation – Pump and Treat***

The Active Groundwater Remediation – Pump and Treat Alternative would target areas remediating the impacted groundwater with elevated 2,6-DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). It would include groundwater removal through four extraction wells and treatment units located both on-site and off-site. It would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation***

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target remediating the impacted groundwater with elevated 2,6-DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). It would include in-situ biochemical treatment utilizing permanent injection wells and temporary injection points to administer the biochemical product into the contaminant plume. The injection locations would be located both on-site and off-site. It would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 5: Well Replacement – Plume Area***
The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer residential wells, meeting replacement criteria, near the PBG Plume with deeper bedrock aquifer wells. It would also include continued groundwater monitoring and on-site groundwater access restrictions.

***Alternative 6: Source Area Treatment***
The Source Area Treatment Alternative would target remediating the impacted groundwater with elevated 2,6-DNT concentrations directly downgradient of the source areas. It would include in-situ biochemical treatment utilizing permanent injection wells to administer the biochemical product into the contaminant plume. In addition, the alternative would include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

**Remedial Alternatives – DBG Plume**

Based on site conditions and the screening of process options, six remedial alternatives were developed for the DBG Plume to address the presence of contaminants in groundwater at the BAAP.

***Alternative 1: No Action***
The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. It would have no impact on the contaminant plume, require no groundwater monitoring but would include on-site groundwater access restrictions.

***Alternative 2: Monitored Natural Attenuation and Alternate Water Supply***
The MNA and Alternate Water Supply Alternative would include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 3: Active Groundwater Remediation – Pump and Treat***
The Active Groundwater Remediation – Pump and Treat Alternative would target remediating the impacted groundwater with elevated total DNT concentrations. It would include groundwater removal through three extraction wells and treatment units located both on-site and off-site. The alternative would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation***
The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target remediating the impacted groundwater with elevated total DNT concentrations. It would include in-situ biochemical treatment utilizing temporary injection points to administer the biochemical product into the contaminant plume. The temporary injection points would be located both on-site and off-site. It would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 5: Well Replacement – Plume Area***

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer residential wells, meeting replacement criteria, near the DBG Plume with deeper bedrock aquifer wells. It would also include continued groundwater monitoring and on-site groundwater access restrictions.

***Alternative 6: Source Area Treatment***

The Source Area Treatment Alternative would target remediating the impacted groundwater with elevated total DNT concentrations directly downgradient of the source area. It would include in-situ biochemical treatment utilizing temporary injection points to administer the biochemical product into the contaminant plume. In addition, the alternative would include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

**Remedial Alternatives – Central Plume**

Based on site conditions and the screening of process options, five remedial alternatives were developed for the Central Plume to address the presence of contaminants in groundwater at the BAAP.

***Alternative 1: No Action***

The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. It would have no impact on the contaminant plume, require no groundwater monitoring but would include on-site groundwater access restrictions.

***Alternative 2: Monitored Natural Attenuation and Alternate Water Supply***

The MNA and Alternate Water Supply Alternative would include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 3: Active Groundwater Remediation – Pump and Treat***

The Active Groundwater Remediation – Pump and Treat Alternative would target remediating the impacted groundwater with elevated 2,6-DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). It would include groundwater removal through eight extraction wells and treatment units. The alternative would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation***

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target remediating the impacted groundwater with elevated 2,6-DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). It would include in-situ biochemical treatment utilizing temporary injection points to administer the biochemical product into the contaminant plume. The temporary injection points would be located both on-site and off-site. It would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

***Alternative 5: Well Replacement – Plume Area***

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer residential wells, meeting replacement criteria, near the Central Plume with deeper bedrock aquifer wells. It would also include continued groundwater monitoring and on-site groundwater access restrictions.

Each alternative was evaluated based on criteria identified the USEPAs 1994 National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and includes overall protection of human health and the environment, compliance with Applicable or Relevant and Appropriate Requirements (ARARs), long-term effectiveness and permanence, reduction in toxicity, mobility and volume, short-term effectiveness, implementability, and cost.

The Army's preferred alternative or remedy will be presented in the Proposed Plan; the remedy will be based on the results of this RI/FS. The Proposed Plan will briefly summarize the remedial investigation and the remedial alternatives evaluated in this RI/FS, highlighting the key factors that led to identifying the preferred alternative. The Army will submit the Proposed Plan to the regulatory agencies and then the public for review. After this review, the Army will release a Decision Document that documents the selected remedy, certifies that the remedy selection process was carried out in accordance with CERCLA, and addresses public comments on the Proposed Plan.

# CERTIFICATION PAGE

Certification Statement

In accordance with NR 712.09, a registered professional engineer, a hydrogeologist, or a scientist from the State of Wisconsin shall certify this report. The required certification statements are presented, and signed and sealed as follows:

"I, **Joel L. Janssen**, hereby certify that I am a Professional Geologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code."

6/2/21

Joel L. Janssen, P.G. License No. 1325 — Date

Geologist, SpecPro Professional Services, LLC


"I, **Brian S. Jacobs**, hereby certify that I am a professional engineer in the State of Wisconsin, registered in accordance with the requirements of ch. A-E 4, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A-E 8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code."

06/02/21

Brian S. Jacobs, P.E. License No. 35309-006 — Date

Engineer, SpecPro Professional Services, LLC

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| | |
|---|---|
| **1,1,1-TCA** | 1,1,1-Trichloroethane |
| **1,1,2-TCA** | 1,1,2-Trichloroethane |
| **2,4-DNT** | 2,4-Dinitrotoluene |
| **2,6-DNT** | 2,6-Dinitrotoluene |
| **µg/l** | Micrograms per liter |
| **Army** | Department of the Army |
| **ARAR** | Applicable or relevant and appropriate requirement |
| **atm** | Atmosphere-meters |
| **ATSDR** | Agency for Toxic Substances and Disease Registry |
| **bgs** | Below ground surface |
| **BAAP** | Badger Army Ammunition Plant |
| **BEST** | Biologically Enhanced Subsurface Treatment |
| **BIA** | Bureau of Indian Affairs |
| **BNA** | Base Neutral Acid |
| **BSD** | Bluffview Sanitary District |
| **CERCLA** | Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also known as Superfund: Amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). |
| **cm/sec** | Centimeters per second |

| | |
|---|---|
| **COC** | Contaminant of Concern |
| **COPC** | Contaminant of Potential Concern |
| **CSM** | Conceptual Site Model |
| **CTET** | Carbon Tetrachloride |
| **DBG** | Deterrent Burning Ground |
| **DD** | Decision Document |
| **DERP** | Defense Environmental Restoration Program |
| **DNT** | Dinitrotoluene |
| **DoD** | Department of Defense |
| **EBS** | Enhanced Biodegradation System |
| **ES** | Enforcement Standard |
| **EVO** | Emulsified Vegetable Oil |
| **°F** | Degrees Fahrenheit |
| **FS** | Feasibility Study |
| **ft/ft** | Feet per foot |
| **FUDS** | Formerly Used Defense Sites |
| **GAC** | Granular Activated Carbon |
| **GEMS** | Groundwater and Environmental Monitoring System (WDNR) |
| **gpm** | Gallons per minute |
| **GRA** | General Response Action |
| **HDPE** | High-Density Polyethylene |
| **HHRA** | Human Health Risk Assessment |
| **HI** | Hazard Index |
| **HQ** | Hazard Quotient |
| **HWTTU** | Hazardous Waste Thermal Treatment Unit |
| **IFCR** | In-Field Conditions Report |
| **IRM** | Interim Remedial Measures |
| **MCL** | Maximum Contaminant Level |
| **MCLG** | Maximum Contaminant Level Goal |
| **MIRM** | Modified Interim Remedial Measures |
| **mg/l** | Milligrams per liter |
| **MNA** | Monitored Natural Attenuation |
| **MSL** | Mean Sea Level |
| **OSWER** | Office of Solid Waste and Emergency Response |
| **NC** | Nitrocellulose |
| **NC Area** | Nitrocellulose Production Area |
| **NCP** | National Oil and Hazardous Substances Contingency Plan |
| **NG** | Nitroglycerin |
| **NPS** | National Park Service |
| **NR** | Natural Resources |
| **NPDWR** | National Primary Drinking Water Regulations |
| **NSDWR** | National Secondary Drinking Water Regulations |
| **O&M** | Operation and Maintenance |
| **PAL** | Preventive Action Limit |
| **PBG** | Propellant Burning Ground |
| **PDS** | Prairie du Sac |

| | |
|---|---|
| **PP** | Proposed Plan |
| **ppt** | Inches of Precipitation |
| **PSTS** | Pilot-Scale Treatability Study |
| **RA** | Remedial Action |
| **RAO** | Remedial Action Objective |
| **RCRA** | Resource Conservation and Recovery Act |
| **RI** | Remedial Investigation |
| **RI/FS** | Remedial Investigation/Feasibility Study |
| **RME** | Reasonable Maximum Exposure |
| **ROD** | Record of Decision |
| **RSL** | Regional Screening Level |
| **SMCL** | Secondary Maximum Contaminant Level |
| **SPS** | SpecPro Professional Services, LLC |
| **SVE** | Soil Vapor Extraction |
| **SVOC** | Semi-volatile Organic Compounds |
| **TBC** | To be considered |
| **TCE** | Trichloroethene or Trichloroethylene |
| **THQ** | Total Hazard Quotient |
| **USACE** | United States Army Corps of Engineers |
| **USDA** | United States Department of Agriculture |
| **USEPA** | United States Environmental Protection Agency |
| **USGS** | United States Geological Survey |
| **VOC** | Volatile Organic Compounds |
| **WDHFS** | Wisconsin Department of Health and Family Services |
| **WDNR** | Wisconsin Department of Natural Resources |
| **WDOT** | Wisconsin Department of Transportation |
| **Wis. Adm. Code** | Wisconsin Administrative Code |
| **WPDES** | Wisconsin Pollutant Discharge Elimination System |
| **WP&L** | Wisconsin Power and Light |
| **WWTP** | Wastewater Treatment Plant |

# 1.0 INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) was prepared by SpecPro Professional Services, LLC (SPS), for the Department of Army (Army) for investigation and remediation activities at the former Badger Army Ammunition Plant (BAAP) in Sauk County, Wisconsin. This RI/FS presents updated groundwater investigation results and the analysis of remediation alternatives for contaminated groundwater at the BAAP in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

Environmental cleanup decision-making under CERCLA follows a prescribed sequence: Remedial Investigation (RI), Feasibility Study (FS), Proposed Plan (PP), and Record of Decision (ROD). Under the Defense Environmental Restoration Program (DERP), the Department of Defense (DoD) has conducted investigation and cleanup activities at BAAP. The DoD Manual, DERP Management, dated March 9, 2012 outlines the policies and procedures the Army must follow when conducting environmental restoration.

The RI serves as the mechanism for collecting data to characterize site conditions, determine the nature and extent of the contamination, and assess risks to human health and the environment from this contamination.

This RI/FS was prepared to serve as a principal source for decision-making relating to remediation of groundwater impacts from the BAAP. The report provides a summary of historic and current groundwater investigation and remediation efforts by the Army and describes the development and re-evaluation of groundwater remedial action alternatives for the BAAP.

The Army's preferred alternative or remedy will be presented in the PP; the remedy will be based on the results of this RI/FS. The PP will briefly summarize the remedial investigation and the alternatives evaluated in this RI/FS, highlighting the key factors that led to identifying the preferred alternative. The Army will submit the Proposed Plan to the regulatory agencies and then the public for review. After this review, the Army will release a Decision Document (DD) that documents the selected remedy, certifies that the remedy selection process was carried out in accordance with CERCLA, and addresses public comments on the Proposed Plan. Included within the DD is the Army's ROD.

The In-field Conditions Report (IFCR), issued by the Wisconsin Department of Natural Resources (WDNR) in 1987, and subsequent amendments, calls for groundwater monitoring and reporting at the BAAP. The current site-wide groundwater monitoring program follows the IFCR dated September 4, 2013 and subsequent revisions up through July 24, 2018.

The initial site-wide RI and FS were completed in 1993 and 1994 (ABB-ES, 1993 and 1994). Soil and groundwater remedial alternatives were analyzed, selected, and approved by the Army and state and federal regulators for the PBG and Deterrent Burning Ground (DBG) areas, and their associated groundwater contaminant plumes. In addition to the PBG and DBG areas and their associated plumes, the Central Plume and Nitrocellulose Production Area (NC Area) Plume have since been identified through further groundwater investigations; however, remedial investigations and actions were previously completed in these areas. These activities were documented and reported to the WDNR. These efforts have met soil remediation action goals and have received regulatory closure. Investigation of groundwater has been ongoing at the BAAP from 1980 to the present. The interim groundwater remedial action for the Propellant Burning Ground (PBG) Plume began in 1990 and continued through 2015. Groundwater monitoring associated with the current sites addressed under Resource Conservation and Recovery Act (RCRA) closure will continue indefinitely (30 years or more) until the WDNR approves case closure.

In December of 2011, the Army completed and submitted to the WDNR, a Revised Alternative Feasibility Study, Groundwater Remedial Strategy report. The selected groundwater remedy was Monitored Natural Attenuation (MNA). Due to the relatively long remedial timeframe for the MNA remedy to achieve the proposed cleanup levels, the proposed remedy included construction and operation of a municipal drinking water system that would provide residents in the communities surrounding the former BAAP with drinking water while groundwater contamination continued to diminish over time. During an evaluation by the Army's Office of General Counsel it was determined the Army did not have the legal or funding authority to procure and operate a municipal water system as identified in the 2011 Revised Alternative Feasibility Study.

While a draft Decision Document (DD) for Site-Wide Groundwater was being prepared in 2012, the Army identified several areas where the draft DD did not meet both legal and policy requirements. Specifically, a human health risk assessment was not prepared, incorrect legal standards were identified for the selected groundwater remedy and key components of the proposed response action were outside the Army's authority.

Since 2012, the Army has monitored groundwater, which included installing new monitoring wells and continued evaluation of the contaminant plumes through groundwater monitoring. In addition, the Army has completed the systematic shutdown of the Interim Remedial Measures (IRM) and Modified Interim Remedial Measures (MIRM) being conducted at the Propellant Burning Ground. A summary of the Army’s actions to address the WDNR’s conditions of approval is provided in Appendix A.

In 2017, the Army coordinated with the WDNR and the public regarding the need to align with Badger Site-Wide Groundwater remedy selection to comply with legal, policy, and funding authorities. The Army communicated the need to reevaluate the groundwater remedy in a letter dated July 25, 2017. This RI/FS includes the HHRA which is based on groundwater data collected from 2015 through 2018.

# 2.0 SITE BACKGROUND

## 2.1 Site Description

The BAAP, located in south-central Wisconsin within Sumpter and Merrimac Townships in Sauk County, was constructed in 1942 to produce smokeless gunpowder and solid rocket propellant as munitions components for World War II by the Army. BAAP is located on the Sauk Prairie, between the Baraboo Range and the Wisconsin River.

Production of nitric acid, sulfuric acid, oleum (also known as fuming sulfuric acid), nitrocellulose (NC), and nitroglycerin (NG) occurred in support of munitions components production. Production periods were as follows: World War II (1942 to 1945), Korean War (1951 to 1958), and Vietnam Conflict (1966 to 1975). A portion of the BAAP property was transferred post-World War II under the Formerly Used Defense Sites (FUDS) program. BAAP was maintained on stand-by status during the non-production eras and determined to be excess in 1997. Excess hazardous substances were disposed at primarily two locations on-site: the PBG and the DBG. The production and waste disposal practices during operational periods were burning and burial (landfilling), and this impacted the soil and groundwater at the BAAP with multiple contaminants.

After the closure, BAAP land consisted of 7,275 acres that the Army has transferred and divided between the United States Department of Agriculture (USDA), Wisconsin Department of Transportation (WDOT), United States Department of Health Services on behalf of the Bluffview Sanitary District (BSD), Bureau of Indian Affairs (BIA) on behalf of the Ho-Chunk Nation and the National Park Service (NPS) on behalf of the WDNR. The property that comprised BAAP is being used as agricultural and grazing land (USDA), Highway 78 (WDOT), recreational land (NPS/WDNR), agricultural and industrial land (Ho-Chunk), and a wastewater treatment plant (BSD). The Army still maintains ownership of two cemeteries on the former BAAP.

The primary land use to the north of the BAAP is recreational at Devil's Lake State Park, managed by the WDNR. This area is not impacted by past activities at BAAP as it is hydrologically upgradient. Lake Wisconsin and the Wisconsin River, to the south and southeast of the BAAP, are hydraulically connected to the groundwater beneath the BAAP. Lake Wisconsin was formed in 1914 by the Wisconsin Power and Light (WP&L) dam on the Wisconsin River, near Prairie du Sac (see Figure 1).

Agricultural and residential property is located to the east, south, and west of the BAAP. The agricultural and residential property is in the townships of Merrimac, Prairie du Sac, and Sumpter. The 2016 United States Census estimated the Township of Merrimac population at 1,010 residents, the Township of Prairie du Sac population at 1,132 residents, and the Township of Sumpter population at 1,224 residents.

## 2.2 Site History

### *2.2.1 Production and Standby Periods*

During World War II, BAAP employed approximately 7,500 workers and produced approximately 271 million pounds of single- and double-base propellant. Oleum and smokeless powder production began in 1943. Rocket paste powder production began in 1945. The solvent less extrusion smokeless propellant process was installed in 1944 and 1945. A portion of the BAAP property was transferred during 1945 under the FUDS program. From 1945 to 1951, the BAAP was in standby status.

BAAP was reactivated for the Korean War in 1951. Reactivation activities were completed by 1954. Facilities for the manufacture of Ball Powder® propellant were constructed during 1954 and 1955. A facility to recycle old cannon powder as a source of NC for the new propellant was also constructed in 1954 and 1955. BAAP remained in production until the Korean War ended and the propellant magazines were full, approximately 1958. During the Korean War, approximately 286 million pounds of single- and double-base propellant were manufactured with a peak production employment of 5,022 employees. The BAAP was in standby status again from 1958 to 1966.

BAAP was reactivated in 1966 for the Vietnam Conflict. The BAAP manufactured Ball Powder® propellant, rocket propellant, and smokeless propellant from 1966 to 1975. In 1972, construction included new sewage treatment systems, new acid production, and new nitroglycerin (NG) production facilities. During the Vietnam Conflict, approximately 487 million pounds of single- and double-base propellant were manufactured with a peak production employment of 5,400 employees. The BAAP was placed in standby status in 1975 and was declared excess in 1997, which began the dismantling/demolition process.

### *2.2.2 Waste Disposal Practices*

The PBG area has been identified as a source area of groundwater contamination. The PBG Plume source area includes Landfill #1, PBG Waste Pits, 1949 Pit, and the Racetrack Area (see Figure 1). During production periods, the PBG Waste Pits, 1949 Pit, and the Racetrack Area were used for disposal of waste and excess production chemicals, primarily solvents [benzene, carbon tetrachloride (CTET), and trichloroethene (TCE)], and explosives [dinitrotoluene (DNT)]. Excess chemicals and munitions components were placed in open pits and burned to dispose of them. Ash, asphalt, concrete, slag, wood, and other metallic and nonmetallic wastes were disposed of in Landfill #1. Additional information about source area investigations, remedial actions, and regulatory acceptance is provided in Section 3.1.

The DBG area has been identified as a source area of groundwater contamination. The DBG Plume source area includes the DBG Waste Pits, Landfill #3, and Landfill #5 (see Figure 1). During production periods, the DBG Waste Pits were used to dispose of waste and excess production chemicals, primarily explosives (DNT). Excess chemicals and munitions components were placed in open-topped metal tanks and burned to dispose of them. Coal ash, construction rubble, trash, and burned garbage were disposed of in Landfill #3. Coal ash, demolition debris, laboratory waste, and office waste were disposed of in Landfill #5. Additional information about source area investigations, remedial actions, and regulatory acceptance is provided in Section 3.2.

The Nitroglycerin (NG) Production and Rocket Paste Production areas have been identified as source areas of groundwater contamination for the Central Plume (see Figure 1). Process wastewater was conveyed in open ditches from the north-central to the south side of BAAP where it subsequently flowed to the Settling Ponds and Spoils Disposal Areas, and eventually to the Wisconsin River (see Figure 1). The wastewater may have contained various production chemicals (i.e., DNT, lead, nitrocellulose, and nitroglycerin). Additional information about source area investigations, remedial actions, and regulatory acceptance is provided in Section 3.3.

The Smokeless Powder and Nitrocellulose (NC) Production areas have been identified as source areas of groundwater contamination for the NC Area Plume (see Figure 1). The Smokeless Powder and NC Production areas manufactured single-base propellant across approximately 800 acres of land. DNT was a component of the manufacturing process. Process wastewater (containing production waste) was conveyed through a network of underground piping that lead to an open ditch near the sanitary wastewater treatment plant (WWTP), see Figure 1. The process wastewater may have leaked into the soil beneath the piping network or beneath the production buildings. Additional information about source area investigations, remedial actions, and regulatory acceptance is provided in Section 3.4.

Sanitary wastewater was conveyed through a network of underground piping and treated at the on-site sanitary WWTP, see Figure 1. Some remote production areas treated sanitary wastewater in small leaching systems.

### *2.2.3 Demolition and Restoration*

Environmental investigation and restoration activities began at the BAAP in 1977. Between 2002 and 2012, most of the structures at the BAAP were demolished and placed into the on-site Landfills 3118 and 3646, located on the east-central portion of the BAAP (see Figure 1). Landfills 3118 and 3646 are State of Wisconsin licensed facilities that were permitted to accept asbestos, demolition debris, and contaminated soil. Landfills 3118 and 3646 were closed in 2008 and 2013 in accordance with State of Wisconsin regulatory approval, respectively. Demolition activities included: removal of all process chemicals, equipment, piping, process and storage tanks, munitions and explosives. Many of the concrete slabs that laid underneath these structures have been removed and have either been disposed of or recycled for beneficial reuse.

## 2.3 Environmental Setting

### *2.3.1 Topography*

The land surface features at the BAAP is the result of glaciation. The BAAP is located on the southern edge of the Baraboo Range, also commonly referred to as the Baraboo Hills. The terminal moraine, deposited by the leading edge of the last glacier as it moved from east to west, extends from north to south across the central portion of the BAAP. The topography in the eastern two-thirds of the BAAP consists of gently rolling hills with numerous depressions. The western third of the BAAP is an outwash plain that is nearly level to gently sloping towards the southwest.

### *2.3.2 Climate*

The climate in the BAAP area is typically continental with some influence from the Great Lakes system. Average annual temperatures in the region vary from 39 degrees Fahrenheit (°F) to 50°F. The freeze-free season is typically 80 to 180 days. From 1971 to 2000, the Southwest Wisconsin Divisional Climate Summary included the following averages: Winter: 19.7°F, 3.44 inches of precipitation (ppt); Spring: 45.8°F, 9.24 ppt; Summer: 69.2°F, 13.14 ppt; Fall: 48.0°F, 8.10 ppt (Wisconsin State Climatology Office Website, 2010). Precipitation for the area averages approximately 30 inches annually. Typically, 70% of this rainfall occurs during the growing season; April through September. The one year and ten year predicted maximum 24-hour rainfall totals for Sauk County are 2.3 and 4.1 inches, respectively.

### *2.3.3 Surface Water Hydrology*

Surface drainage consists of overland flow to the west, south, and east. Much of the run-off collects in isolated depressions on-site and infiltrates or evaporates. The ditches in the northwest portion of the BAAP drain toward the Ballistics Pond and subsequently to the west of the BAAP and Highway 12 (see Figure 1). The surface water from the Nitroglycerin, Rocket Paste, and Magazine Areas, located in the central and southeast areas of the BAAP, discharges to the Settling Ponds in the south-central portion of BAAP (see Figure 1). The Settling Ponds are manmade areas that received wastewater from production but are now almost entirely dry except in severe rain events. The Settling Ponds area drains to the south and east and discharged into Gruber's Grove Bay, on Lake Wisconsin (see Figure 1).

### *2.3.4 Geology*

A thick sequence of unconsolidated sediments was deposited during multiple glaciation events. A glacial terminal moraine transects the BAAP from north to south, as shown in Figure 2. Figure 2 is a map depicting the geological features at the surface. This map was adapted from the Geology of Sauk County by Attig and Clayton, 1990. Bisecting BAAP from north to south is the terminal moraine shown in dark green (gj) and classified as thick till of the Johnstown Moraine. Thinner glacial till, shown in light green (gd), is found east of the terminal moraine.

On the far eastern side of BAAP is a unit classified as a collapsed meltwater-stream sediment (sc). West of the terminal moraine is stream sediment (sj) of the Johnstown Moraine, shown in pink. There is also a unit of stream sediment (ss) shown cutting through the terminal moraine in the southern portion of BAAP. This stream sediment unit is younger than the Johnstown sediment, contains ice rafted boulders, and was deposited by floodwater during the drainage of glacial Lake Wisconsin during the Elderon Phase of glaciation.

Based on the borings advanced at BAAP, the glacial till varies in thickness from 10 to 90 feet. Outwash sand and gravel or fluvial deposits (stream sediment) lie beneath the till. The water table does not intersect the till beneath BAAP, only the outwash is in contact with the groundwater. West of the terminal moraine, a thick sequence of glacial outwash sand and gravel was deposited (sj). Glacial tills to the east are primarily silty sands with cobbles and boulders. Several feet of clay and silt (loess) overlie the glacial sediments.

Figures 3 and 4 are generalized geologic cross sections that show thickness of the unconsolidated sediment (sand and gravel) overlying bedrock. These two cross sections were adapted from figures in *Hydrogeology and Simulation of Groundwater Flow in Sauk County, Wisconsin* (Gotkowitz et al, 2005). The unconsolidated sediment and bedrock unit thicknesses were derived by reviewing boring logs from wells at and near BAAP. Bedrock geology at BAAP is dominated by the Eau Claire Formation (Cambrian age) beneath most of BAAP, with some Precambrian metamorphosed quartzite, granite, and rhyolite. The Eau Claire Formation consists of sandstone/shale/siltstone/dolomite. The Baraboo Range to the north of the BAAP contains Precambrian conglomerate and quartzite, which are part of the Baraboo Syncline, rising approximately 500 feet above the BAAP. The bedrock surface dips steeply toward the south, where soil deposits quickly thicken to a maximum of approximately 250 feet. Along the northern BAAP boundary, soil deposits are thin or absent and bedrock outcrops are common. Figure 5 illustrates the bedrock surface beneath and surrounding BAAP. This bedrock surface map was based on available monitoring well, production well, and residential well construction logs. The bedrock surface drops 200 feet in the northern third of BAAP and flattens out in the southern two-thirds of BAAP.

Figure 3 shows the Bluffview Well #3 on the far left penetrating the entire Eau Claire Formation and entering the Baraboo quartzite. A layer of shale is shown to underlie the western half of BAAP. The shale layer acts as an aquitard, which retards groundwater in the sand and gravel aquifer and the upper sandstone aquifer from moving downward into the lower sandstone aquifer. The Eau Claire Formation is shown to thin out to the east and acts as both an aquitard and an aquifer based on the thickness of the sandstone. The Bluffview Well #3 draws its water from the Eau Claire Formation.

Figure 4 is a cross section that runs from the Baraboo Range south to the Village of Prairie du Sac (PDS). This section also shows the Bluffview Well #3 on the far left and the PDS Well #3 on the far right. The PDS Well #3 penetrates through the Eau Claire Formation and a layer of shale before entering the Mt. Simon Formation (sandstone). The shale layer is shown to be present from just north of the Bluffview Well #3 down to PDS. The shale layer was also found in the Bluffview Well #4 well located at the Bluffview Sanitary District's sanitary WWTP. This shale layer acts as an aquitard, which restricts groundwater from migrating deeper into the Mt. Simon Formation. Based on the well log, the PDS Well #3 has a water depth at the ground surface, whereas the local water table is located 45 feet below ground. This implies that the PDS Well #3 is a flowing or artesian well. The thick sequence of the Eau Claire Formation and the shale layer protect the PDS Well #3 from contaminants on the surface and in the sand and gravel aquifer. Monitoring well PBN-1405F is shown at the BAAP boundary and penetrates through the layer of shale. PBN-1405F was installed in 2014 by the Army to verify that contaminants have not migrated through the shale layer.

Geologic cross sections depicting stratigraphic relationships between the various soil units, bedrock units, and water table are orientated in Figure 6. Figures 7, 8, 9, 10, and 11 are geologic cross sections that are orientated through the PBG area. Figures 12 and 13 are geologic cross sections that are orientated through the DBG area. Figure 14 is a geologic cross section orientated through the Central Plume area. Figure 15 is a geologic cross section orientated through the NC Area Plume area. The terminal moraine is shown in many sections, represented as glacial till (SP-SM or SM-SP), and consists mostly of varying grain sizes of sand with fines and some gravel/cobbles/boulders. Based on the cross sections, the glacial till is not present beneath the water table. Beneath the glacial till lies sand of varying grain sizes that was deposited by glacial fluvial processes (glacial outwash). The sand outwash contains many pockets of gravel with some being localized and others interconnecting. The gravel layers have been encountered up to 40 feet thick. A uniform layer of gravel exists near the bedrock surface, south of the PBG. A layer of clay and silt (CL-ML), up to 30 feet thick, is present in the DBG area. As shown in Figure 12, the fine-grained layer appears to pinch out approximately 1,300 feet east of the DBG. Both Figure 12 and 13 show the fine-grained unit located beneath the water table. The bedrock shown in each cross section consists of the Eau Claire Formation.

### *2.3.5 Hydrogeology*

Two major aquifers and one minor aquifer are present beneath the BAAP: the surficial sand and gravel aquifer, the Eau Claire Formation, and the deeper Mt. Simon Formation (sandstone aquifer), respectively. The sand and gravel aquifer and the Eau Claire are un-confined to semi-confined and possibly hydraulically connected. The Eau Claire Formation varies between 80 to 280 feet below ground surface (bgs). The Mt. Simon Formation is located approximately 400 feet bgs and is mostly present to the east and south of BAAP. The general direction of groundwater flow is south to southeast. Steep gradients exist along the northern boundary of the BAAP. The gradient flattens substantially in the central and southern portions of the BAAP. Recharge to the sand and gravel aquifer is limited by infiltration through a fine-grained loess unit (silt/clay) in some areas.

As previously mentioned, Figures 3 and 4 shows that the Eau Claire Formation contains at least one uniform shale layer that acts as an aquitard, which retards groundwater in the sand and gravel aquifer from moving downward into the lower sandstone aquifer (Mt. Simon Formation). The Eau Claire Formation also contains many thinner layers of shale and thick sequences of dolomite that act as an aquitard.

The regional groundwater flow direction in the BAAP area is south-southeast towards the Wisconsin River as depicted in *Water-Table Elevation Map of Sauk County, Wisconsin* (Gotkowitz and Zeiler, 2003) and *Hydrogeology and Simulation of Groundwater Flow in Sauk County, Wisconsin* (Gotkowitz et al, 2005). This direction of flow correlates well with the groundwater contours generated by collecting water levels in the BAAP monitoring wells. Figure 16 depicts the groundwater contours at BAAP during September 2017. Figure 17 depicts the groundwater contours near the PBG during September 2017.

The Wisconsin River acts as a discharge point for groundwater east and south of BAAP. As depicted in *Water Resources of Wisconsin Lower Wisconsin River Basin* (Hindall and Borman, 1974) groundwater on both the west and east sides of the Wisconsin River discharges into the Wisconsin River. The Lake Wisconsin reservoir, caused by the hydroelectric dam on the Wisconsin River, influences groundwater flow across the BAAP. Lake Wisconsin is north of the dam where there is an approximate 40-foot surface water drop. The water level in Lake Wisconsin is elevated above the water table for much of the southeastern portion of the BAAP. Anywhere the elevation in Lake Wisconsin is higher than the water table, the water in Lake Wisconsin will discharge to the groundwater. Subsequently, Lake Wisconsin discharges to the groundwater in the Gruber's Grove Bay area and continues to discharge to the groundwater until it reaches the WP&L dam. The net result is groundwater flow parallel to Lake Wisconsin with discharge to the Wisconsin River south of the dam. Groundwater in the northeast portion of the BAAP is higher in elevation than Lake Wisconsin; therefore, the groundwater discharges to Lake Wisconsin in this area.

# 3.0 SOURCE INVESTIGATIONS AND REMEDIAL MEASURES

The Army has conducted numerous investigations and remedial actions at the former BAAP property. Groundwater investigation activities at BAAP began in 1980 and continue today. The Army proposed and the WDNR approved the site-wide groundwater investigations for RCRA licensed units which included the PBG, DBG, Central Plume, and NC Area Plume areas. Figure 18 shows the locations of the monitoring wells, the four groundwater plumes, and the source areas for each plume.

The RCRA licensed units served as source areas of the four groundwater contaminant plumes being addressed through the Army's CERCLA authority. These remedial activities have been well documented and documentation has been provided to the WDNR. The closure activities conducted by the Army have minimized the potential exposure to contaminated soil at BAAP. The Army has received closure approval from the WDNR on all soil related investigations and response actions at BAAP.

## 3.1 Propellant Burning Ground

The PBG is located in the southwestern portion of the BAAP. The PBG is comprised of the following areas: Waste Pits, 1949 Pit, Racetrack/Hazardous Waste Thermal Treatment Unit (HWTTU) area, and Landfill #1. The location and layout of the PBG is shown in Figure 19.

The PBG Waste Pits consisted of three waste pits (WP-1, WP-2, and WP-3) and an open burning area. The Waste Pits were approximately 40 feet in diameter and 12 to 15 feet deep. The PBG Waste Pits became active sometime between 1942 and 1949 and were last used in 1983. Approximately 2,280 cubic yards of soil were removed from the Waste Pits, from ground surface to approximately 23 feet deep in 1999. The soil was transported off-site and incinerated by a licensed hazardous waste contractor. The PBG Waste Pits were filled with clean soil to grade.

The 1949 Pit was a waste disposal area active between 1949 and 1962 located adjacent to the PBG Waste Pits (see Figure 19). The 1949 Pit contains approximately 58,080 cubic yards of waste, propellant, and construction materials. The area was no longer used, covered, and vegetated by 1968. A clay and geomembrane barrier cap was installed at the 1949 Pit in 1998 to inhibit the movement of contaminants in the soil. The *1949 Pit Phase One Cap, Final Construction Report* (Olin Corporation, 1999) was submitted and approved by the WDNR in 1999.

The Racetrack/HWTTU area consisted of an oval gravel road, three refuse pits, and burning plates, as well as the HWTTU. In 1995, three-fourths of the Racetrack/HWTTU area was closed with a soil cover to prevent contact with residual lead in the soil. The *Final Documentation Report For Soil Cover Construction Racetrack And Thermal Treatment Unit Closure* (Olin Corporation, 1996) was approved by the WDNR. Contaminated soil from the remaining portion of the Racetrack area was excavated and disposed in 1997 and the WDNR letter dated December 2, 1997 indicated that no additional remedial actions were required for this area.

Landfill #1 is a closed demolition debris disposal facility located northeast of the PBG that was used between 1942 and 1959. The area was covered with soil and vegetated by 1974. The facility contains approximately 19,500 cubic yards of ash, slag, asphalt, concrete, wood, and other metallic and nonmetallic wastes. To reduce infiltration, a composite cap including two feet of clay and geomembrane barrier cap was installed and completed in September 1997. The *Landfill #1 Final Cap Construction Report* was submitted to WDNR in January 1998. Regulatory approval of the Landfill #1 cap was received in a Liability, Clarification and Current Environmental Conditions letter report dated August 27, 2014.

DNT and organic solvent-containing materials are known to have been disposed of at the PBG through open burning and burial during production periods. Subsequently, localized impacts to soil consisted of 2,4-DNT, 2,6-DNT, polycyclic aromatic hydrocarbons, benzene, CTET, TCE, arsenic, chromium, lead, selenium, and zinc above soil cleanup remedial action objectives.

A soil vapor extraction (SVE) system operated at the PBG Waste Pits from 1997 to 1999. SVE wells were installed within each of the three waste pits. Approximately 1,600 pounds of solvent-related volatile organic compounds (VOCs) were successfully removed from within the vadose zone. The SVE system was shut down after achieving satisfactory removal of VOCs from the waste pits.

A pilot biotreatment system was installed at Waste Pit 1 in 1999. A Pilot-Scale Treatability Study was conducted in 2000 to evaluate the effectiveness of bacterial degradation of DNT by naturally occurring bacteria in the soil (in-situ). The system extracted groundwater beneath Waste Pit 1, treated the water with phosphate, and reinjected it into the soil column above the waste pit. Oxygen was added to the vadose zone by injecting air through the former SVE system wells, which now served as air injection wells. Carbohydrate (ethanol) injection wells for the control of nitrate byproduct were installed downgradient, but never used. Monitoring results indicated the indigenous bacteria were aerobically biodegrading DNT in the soil column successfully; therefore, the Army decided to go full-scale with the biotreatment system.

The Biologically Enhanced Subsurface Treatment (BEST) system was installed in 2000 to reduce the soil and groundwater contaminants beneath the PBG Waste Pits. The BEST system operated from 2001 to 2005. From 2001 through 2003, additional air injection wells were installed to aid bacterial degradation of DNT in the groundwater. The air injection wells were in operation until 2006. Evaluation of the BEST system indicated effective DNT reduction in soil and groundwater occurred during the operation of the system.

In 2005, Shaw Environmental, Inc. (Shaw) investigated the PBG source area to evaluate the existing soil conditions beneath each PBG Waste Pit (WP-1, WP-2 and WP-3) and evaluate the BEST system performance. Investigation activities are presented in further detail in the *January 2005 Field Activities Technical Memorandum, Propellant Burning Ground* (Shaw Environmental, Inc., 2005). This investigation included drilling borings through each waste pit and collecting soil samples for laboratory analysis. These soil borings and samples were collected at pre-specified intervals corresponding to previous borings, thus allowing for direct comparison to previous concentrations of VOCs and DNTs. Soil sample results for DNT were compared to previous soil samples collected beneath the waste pits during 1991, 1997, 2002, and

2003. Appendix B contains a site map and tables comparing the DNT concentrations from the January 2005 memorandum prepared by Shaw. This investigation determined that DNT concentrations had been reduced and CTET, chloroform, TCE, and other VOCs were no longer present in the soil beneath the PBG Waste Pits. A summary of the VOC soil sample results is provided in Table 1. No additional soil sampling has been conducted.

Based in the soil boring data provided in the *January 2005 Field Activities Technical Memorandum*, the DNT contaminated soil beneath the PBG Waste Pits has vertically migrated into the groundwater. Table 5 in Appendix B provides a comparison of the DNT soil results beneath Waste Pit 2.

In 2006, a draft Alternative Feasibility Study was completed to re-evaluate the interim remedial actions for soils at the PBG and determine the final remedy. The selected remedy included the previous remedial actions: soil vapor extraction, partial soil excavation and incineration, and full-scale bioremediation. The final remedy chosen included removal of the bioremediation system, installation of an impermeable cap, and continued groundwater monitoring and remediation. On March 17, 2008, the WDNR approved the final remedy for the PBG subsurface soil.

Removal of the BEST system was completed in 2008. The PBG Waste Pits were then capped with a clay and geomembrane barrier cap, according to regulatory requirements. The *Construction Documentation Report, PBG Phase 2, Cap and Construction* (SpecPro, Inc., 2009) report was submitted to the WDNR and approved in a letter report dated March 25, 2009.

Based on the 2005 Shaw soil investigation data, the DNT soil contaminant mass was calculated to be 34,810 pounds. This DNT contaminated soil is located beneath the PBG Waste Pit cap. Input parameters and calculations are provided in Table 2.

The Waste Pits, 1949 Pit, Racetrack/HWTTU, and Landfill #1 areas are regularly inspected. Signage, fencing, and vegetation are inspected and maintained. Cap and cover areas are inspected annually for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR and United States Environmental Protection Agency (USEPA).

In addition to the annual inspection and in accordance with condition of the final approval, the U.S. Army Corps of Engineers (USACE) completed a five-year review of the PBG in 2013 and 2019. Results of the 2013 review were provided to the WDNR on June 26, 2013. The 2013 five-year review focused on groundwater contaminant concentration trends, cap maintenance activities, and possible modifications to the maintenance and monitoring of the PBG site remedy. These three items were evaluated for the period from 2008 to 2012. The 2013 five-year review concluded that concentration trends for some individual wells were either increasing or probably increasing but the overall plume stability was found to be stable, decreasing, or did not exhibit a trend. The 2013 five-year review also concluded that maintenance records showed that the PBG cap system was being properly maintained and in acceptable condition. Results of the 2019 five-year review are not currently available.

**Table 1**
**Propellant Burning Ground - Volatile Organic Compounds Soil Sample Results (2005)**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | Volatile Organic Compounds | | |
|---|---|---|---|---|
| **Sample Number** | **Sample Interval (ft bgs)** | **Carbon Tetrachloride** | **Trichloroethylene** | **Chloroform** |
| PBB 0501 010 | 20 - 30 | <0.060 | <0.060 | <0.060 |
| PBB 0501 022 | 21 - 22 | <0.060 | <0.060 | <0.060 |
| PBB 0501 026 | 25 - 26 | <0.060 | <0.060 | <0.060 |
| PBB 0501 030 | 20 - 30 | <0.060 | <0.060 | <0.060 |
| PBB 0501 031 | 30 - 31 | <0.060 | <0.060 | <0.060 |
| PBB 0501 040 | 30 - 40 | <0.060 | <0.060 | <0.060 |
| PBB 0501 041 | 40 - 41 | <0.060 | <0.060 | <0.060 |
| PBB 0501 050 | 40 - 50 | <0.060 | <0.060 | <0.060 |
| PBB 0501 051 | 50 - 51 | <0.060 | <0.060 | <0.060 |
| PBB 0501 060 | 50 - 60 | <0.060 | <0.060 | <0.060 |
| PBB 0501 061 | 60 - 61 | <0.060 | <0.060 | <0.060 |
| PBB 0501 070 | 60 - 70 | <0.060 | <0.060 | <0.060 |
| PBB 0501 071 | 70 - 71 | <0.060 | <0.060 | <0.060 |
| PBB 0501 080 | 70 - 80 | <0.060 | <0.060 | <0.060 |
| PBB 0501 080 | 90 - 91 | <0.060 | <0.060 | <0.060 |
| PBB 0501 090 | 80 - 90 | <0.060 | <0.060 | <0.060 |
| PBB 0501 091 | 90 - 91 | <0.060 | <0.060 | <0.060 |
| PBB 0501 100 | 90 - 100 | <0.060 | <0.060 | <0.060 |
| PBB 0502 010 | 104 - 105 | <0.060 | <0.060 | <0.060 |
| PBB 0502 023 | 22 - 23 | <0.060 | <0.060 | <0.060 |
| PBB 0502 029 | 28 - 29 | <0.060 | <0.060 | <0.060 |
| PBB 0502 030 | 20 - 30 | <0.060 | <0.060 | <0.060 |
| PBB 0502 035 | 34 - 35 | <0.060 | <0.060 | <0.060 |
| PBB 0502 040 | 30 - 40 | <0.060 | <0.060 | <0.060 |
| PBB 0502 050 | 40 - 50 | <0.060 | <0.060 | <0.060 |
| PBB 0502 053 | 52 - 53 | <0.060 | <0.060 | <0.060 |
| PBB 0502 060 | 50 - 60 | <0.060 | <0.060 | <0.060 |

**Table 1**
**Propellant Burning Ground - Volatile Organic Compounds Soil Sample Results (2005)**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Sample Number | Sample Interval (ft bgs) | Carbon Tetrachloride | Trichloroethylene | Chloroform |
|---|---|---|---|---|
| PBB 0502 070 | 60 - 70 | <0.060 | <0.060 | <0.060 |
| PBB 0502 080 | 70 - 80 | <0.060 | <0.060 | <0.060 |
| PBB 0502 080 | 80 - 90 | <0.060 | <0.060 | <0.060 |
| PBB 0502 090 | 80 - 90 | <0.060 | <0.060 | <0.060 |
| PBB 0502 100 | 90 - 100 | <0.060 | <0.060 | <0.060 |
| PBB 0502 105 | 104 - 105 | <0.060 | <0.060 | <0.060 |
| PBB 0503 010 | 60 - 70 | <0.060 | <0.060 | <0.060 |
| PBB 0503 013 | 12 - 13 | <0.060 | <0.060 | <0.060 |
| PBB 0503 020 | 10 - 20 | <0.060 | <0.060 | <0.060 |
| PBB 0503 030 | 20 - 30 | <0.060 | <0.060 | <0.060 |
| PBB 0503 040 | 30 - 40 | <0.060 | <0.060 | <0.060 |
| PBB 0503 050 | 40 - 50 | <0.060 | <0.060 | <0.060 |
| PBB 0503 055 | 54 - 55 | <0.060 | <0.060 | <0.060 |
| PBB 0503 060 | 50 - 60 | <0.060 | <0.060 | <0.060 |
| PBB 0503 070 | 60 - 70 | <0.060 | <0.060 | <0.060 |
| PBB 0503 080 | 70 - 80 | <0.060 | <0.060 | <0.060 |
| PBB 0503 090 | 80 - 90 | <0.060 | <0.060 | <0.060 |
| PBB 0503 100 | 90 - 100 | <0.060 | <0.060 | <0.060 |
| PBB 0503 105 | 100 - 105 | <0.060 | <0.060 | <0.060 |

ft bgs - feet below ground surface
All results are expressed in milligrams per kilogram (mg/kg)
Samples collected by Shaw Environmental, Inc., in January 2005
Samples were analyzed by CT Laboratories using method SW8260B
Boring PBB 0501 was drilled beneath Propellant Burning Ground (PBG) Waste Pit 1.
Boring PBB 0502 was drilled beneath PBG Waste Pit 2.
Boring PBB 0503 was drilled beneath PBG Waste Pit 3.

**Table 2**
**DNT-Impacted Soil Contaminant Mass Estimate**
**Propellant Burning Ground and Deterrent Burning Ground Source Areas**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Source Location | Average Concentration (mg/Kg) | Interval Depth (ft bgs) | Interval Thickness (ft) | Length (ft) | Width (ft) | Total Volume (ft3) | Mass Volume (lbs) |
|---|---|---|---|---|---|---|---|
| **Propellant Burning Ground** | | | | | | | |
| Waste Pit #1 (upper zone) | 7,776 | 22 - 31 | 9 | 50 | 40 | 18,000 | 17,493 |
| Waste Pit #1 (lower zone) | 45.6 | 31 - 91 | 60 | 50 | 40 | 120,000 | 684 |
| Waste Pit #2 (upper zone) | 3,746 | 23 - 43 | 20 | 40 | 30 | 24,000 | 11,236 |
| Waste Pit #2 (lower zone) | 191 | 43 - 105 | 62 | 40 | 30 | 74,400 | 1,776 |
| Waste Pit #3 (upper zone) | 1,618 | 13 - 20 | 7 | 30 | 20 | 4,200 | 849 |
| Waste Pit #3 (lower zone) | 528 | 20 - 90 | 70 | 30 | 20 | 42,000 | 2,772 |
| Total DNT Soil Contaminant Mass | | | | | | | **34,810** |
| **Deterrent Burning Ground** | | | | | | | |
| Waste Pit #1 | 1,950 | 10 - 30 | 20 | 70 | 35 | 49,000 | 11,942 |
| Waste Pits #2 and #3 | 1,050 | 20 - 50 | 30 | 280 | 40 | 336,000 | 44,093 |
| Total DNT Soil Contaminant Mass | | | | | | | **56,035** |

cm - centimeters
cm3 - cubic centimeters
ft - feet
ft3 - cubic feet
lbs - pounds
mg/Kg - milligrams per kilogram
bgs - below ground surface
Deterrent Burning Ground estimate is based on data from 1991 to 1998.
Propellant Burning Ground estimate is based on data from 2005.
Soil bulk density = 125 lbs/ft3 = 0.002002 Kg/cm3
Mass volume (lbs) = average concentration (mg/kg) x soil bulk density (kg/cm3) x 28,317 (cm3/ft3) x total volume (ft3) x (1 kg/$10^6$ mg) x 2.204586 (lb/kg)

### *3.1.1 Interim Remedial Measures/Modified Interim Remedial Measures*

Groundwater contamination in monitoring wells at the PBG was first detected in 1982 (Tsai, 1988). In 1989, the Army evaluated interim remedial measures (IRM). The goals of the early groundwater remedial action were to: 1) curb the advancement of the plume, 2) reduce contaminants within the plume, and 3) be compliant with local, state, and federal regulations.

The IRM groundwater pump and treat system began operations during June 1990 by pumping approximately 350 gallons per minute (gpm). The IRM groundwater treatment system originally consisted of one source control well (SCW-1) and three boundary control wells (BCW-1, BCW-2, and BCW-3) located within the BAAP boundary. The groundwater was treated with liquid phase granular activated carbon (GAC) treatment. BCW-4 was installed in 1993 but was never connected to the IRM. By April 1998, BCW-1, BCW-2, and BCW-3 were shut down and SCW-1 and SCW-2R (installed in 1997) were pumping approximately 310 gpm. Figure 19 shows the locations of the former IRM extraction wells and the former boundary control wells.

Extracted groundwater from the IRM extraction wells was pumped through a GAC system that removed VOCs and DNT from the water by adsorption. The treated water then flowed through a pipeline and discharged into Lake Wisconsin near Gruber's Grove Bay.

An evaluation of the IRM was conducted in 1993 to address new regulatory requirements. This evaluation concluded that the PBG Plume was not being entirely captured by the IRM system. The PBG Plume was extending beneath and east of the three original boundary control wells. A groundwater treatment system was designed to augment the existing IRM system.

This augmented groundwater treatment system called the MIRM system began operations on June 20, 1996. The MIRM groundwater treatment system originally consisted of six boundary extraction wells (EW-161, EW-162, EW-163, EW-164, EW-165, and EW-166) pumping a combined 3,000 gpm. These MIRM extraction wells were located along the southern BAAP boundary (see Figure 19). Four additional extraction wells (EW-167, EW-168, EW-169, and EW-170) were installed along the axis of the plume in 2005 (see Figure 19). The pumping of these extraction wells was refined over the years to optimize removal of groundwater contaminants including the replacement of EW-163 with EW-163R and EW-170 with EW-170R. Until use of the MIRM was discontinued in 2015, the five pumping MIRM extraction wells (EW-163R, EW-167, EW-168, EW-169, and EW-170R) extracted groundwater from the PBG Plume at a combined rate of approximately 2,400 gpm. The water from the MIRM extraction wells flowed through air strippers for treatment of VOCs then passed through a GAC system to remove DNT and additional VOCs. The treated water then flowed through a pipeline and discharged into Lake Wisconsin.

Since the PBG Waste Pits were capped in 2008, the DNT concentrations in monitoring wells near the PBG Waste Pits have dropped significantly. The mass of DNT being removed from the groundwater by the IRM system had also reduced dramatically, indicating the IRM system had effectively removed most of the available contaminant mass in the groundwater near the source area. This implied that further operation of the IRM system would not be cost-effective. The Army submitted an *Interim Remedial Measures Shutdown Plan (Badger Technical Services*

*(BTS, LLC), October 2012* that outlined a systematic approach to restoring natural groundwater conditions so that PBG Plume dynamics and attenuation could be evaluated. Based on the WDNR's December 11, 2012 approval letter, the IRM was shut down on December 17, 2012. The Army's June 17, 2014 letter to the WDNR summarized the monitoring activities conducted during 2013 and 2014 and requested that the IRM system be dismantled. The WDNR's August 4, 2014 letter approved the dismantling of the IRM system. During 2014, the IRM extraction wells were abandoned and the IRM treatment building was demolished.

Like the IRM, the MIRM system had reached its limitations of effective contaminant removal and its operation would no longer be cost efficient. To that end, the Army submitted a *Modified Interim Remedial Measures Shutdown Plan (Badger Technical Services, LLC), January 2014* that outlined a systematic approach to restoring natural groundwater conditions so that PBG Plume dynamics and attenuation could be evaluated. Based on the WDNR's August 4, 2014 approval letter, the MIRM was completely shut down on August 31, 2015. The Army's June 27, 2016 letter to the WDNR summarized the monitoring activities conducted between 2014 and 2016 and requested that the MIRM system be dismantled. The WDNR's July 15, 2016 letter approved the dismantling of the MIRM system. During 2016, the MIRM extraction wells were abandoned. Ownership of the MIRM treatment building was transferred from the Army to the BSD in July 2016.

## 3.2 Deterrent Burning Ground

The DBG area consists of seven acres and is located in the northeastern portion of BAAP. The DBG area was used as a sand borrow pit from the 1940s until the early 1960s, and a waste disposal site from the 1940s to the 1970s. The DBG consisted of three burn areas within a man-made depression, approximately three acres in size and 20 feet deep.

Coal ash from the power plant, construction rubble, trash, and burned garbage were deposited in Landfill #3, which is part of the DBG. From 1966 through 1971 the remaining portion of the DBG was used for open burning in open-topped metal tanks of deterrent, a liquid organic extract from surplus propellant, composed mostly of DNT and di-n-butyl phthalate, as well as minor amounts of diphenylamine, benzene, and nitrocellulose. Structural timbers, asphalt shingles, cardboard, paper, and office waste were also burned in the pits. Subsurface soils at the DBG were found to be impacted with DNT, n-nitrosodiphenylamine, arsenic, and chromium. The majority of the impacts were found in the shallowest portion of the pit, with arsenic and chromium in limited areas of the site. Investigations also showed DNT spread vertically in the subsurface soils and reached groundwater.

Landfill #5 is located to the northeast of the DBG. During operations, the landfill reportedly received solid waste, including office waste, demolition debris, laboratory waste, and coal ash from the power plant between 1979 and 1988. No hazardous materials were reported to have been disposed in Landfill #5. In 1988, the landfill was closed with a clay barrier cap which received regulatory approval from the WDNR on September 20, 1989.

An interim corrective action consisting of the removal and off-site incineration of DBG waste pit soil occurred in 1999 and 2000. Impacted soil from the three pits was excavated to a depth of approximately 15 feet. The total volume of the excavated and incinerated soil was approximately 4,260 cubic yards. Each pit was backfilled with clean fill to pre-excavation grades. This removed the surface soil contaminated with the highest DNT levels and metals.

In 2001, the backfilled area was covered with an interim geomembrane cap, facilitating additional soil and groundwater studies to better understand site conditions. On April 24, 2002, the *Draft Alternative Feasibility Study - Deterrent Burning Ground Waste Pits Subsurface Soil* (Stone & Webster, Inc., 2002) was submitted to request a permit modification to perform the remedial action, including partial excavation and incineration (completed in 2000), geosynthetic clay and geomembrane barrier cap installation, institutional controls, and groundwater monitoring. In accordance with conditions set forth in the WDNR *Final Determination of Remedy for the Deterrent Burning Ground*, dated October 14, 2002, an Enhanced Biodegradation System (EBS) and a geosynthetic clay and geomembrane barrier cap were installed at the DBG during 2003. The cap also encompassed Landfill #3. Due to limited groundwater contamination and the low risk to potential receptors, active groundwater remediation was not required by the WDNR.

The EBS was installed beneath the cap in the area of the three DBG waste pits. The EBS was designed to enhance naturally occurring biodegradation of DNT in subsurface soil by maintaining soil moisture, nutrients and soil gas oxygen beneath the cap. Water and nutrients were introduced into the soil column through a network of piping. The water infiltration rate was kept below the average annual percolation rate.

The Army suspended all operation and monitoring associated with the EBS following the infiltration event in June 2008. This decision was based on the lack of a water resource sufficient to provide the volume needed for continued treatment, problems with the soil moisture and respirometry monitoring equipment and a lack of consistent evidence to show that the EBS was effectively enhancing degradation beyond what was occurring naturally. The WDNR was notified of the EBS discontinuance in a letter report from the Army dated November 17, 2011. This letter provided information on the operation and monitoring of the EBS from 2003 to 2008.

Based on investigation data presented in the *Draft Alternative Feasibility Study - Deterrent Burning Ground Waste Pits Subsurface Soil* (Stone & Webster, Inc., 2002), the DNT soil contaminant mass was calculated to be 56,035 pounds. This DNT contaminated soil is located beneath the engineered cap. Input parameters are provided in Table 2. Concentrations and volume data were used to derive a mass volume in pounds. It should be noted that the soil data used in the calculation was collected from soil borings conducted between 1991 to 1998. No additional soil sampling has been conducted since 1998. Based in the soil boring data, DNT isoconcentration map, and cross sections provided in the *Draft Alternative Feasibility Study*, the DNT contaminated soil beneath the DBG cap is estimated to be 26 feet above the water table. This separation distance implies that the water table (groundwater surface) does not currently intersect with soil contaminated with DNT. Prior to the cap being constructed in 2003, rainwater would have mixed with contaminated soil in the DBG waste pits and vertically infiltrated down towards the groundwater table.

The DBG cap and Landfill #5 areas are regularly inspected. Signage, fencing, and vegetation are inspected and maintained. Cap areas are inspected annually for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR and USEPA.

In accordance with the condition of the final approval, the USACE completed a five-year review of the DBG in 2013 and 2019. Results of the 2013 review were provided to the WDNR on June 26, 2013. The 2013 five-year review focused on groundwater contaminant concentration trends, cap maintenance activities, and new technologies potentially applicable to address remaining impacted soil beneath the DBG cap. The 2013 five-year review concluded that most of the groundwater concentration trends were either stable or decreasing with some individual wells indicating increasing or probably increasing trends. The 2013 five-year review concluded that maintenance records showed that the DBG cap system was being properly maintained and in acceptable condition. No new technologies were identified that were not previously evaluated during the remedy selection or could be implemented without negatively impact to the DBG cap. Results of the 2019 five-year review are not currently available.

## 3.3 Central Plume Area

Based on the knowledge of groundwater flow and monitoring results, the detection of DNT in groundwater during 2004 at the Water's Edge Subdivision indicated another source of DNT groundwater contamination existed besides the PBG and DBG. The Water's Edge Subdivision is located on the north side of Gruber's Grove Bay and at the southern portion of the Central Plume (shown in inset B on Figure 20). Based on the groundwater flow direction and the groundwater contaminant detections, the source of 2,6-DNT contaminated groundwater was believed to be in the north-central portion of BAAP where nitroglycerin, rocket paste, and rocket propellant were produced (see Figure 1). However, several investigations/excavations to date have not determined a specific source of DNT contamination (e.g., landfill or disposal area). It is believed that the broad production area may have caused the groundwater impacts. In 2004, 2,6-DNT was first detected within two residential wells located in the Water's Edge Subdivision. The 2,6-DNT concentration in two residential wells exceeded the Chapter NR 140 Enforcement Standard (ES). In 2005, the Army replaced these two residential wells, WE-RM385 and WE-RR541.

In 2006, the USDA installed a well (USDA 6) in the southeast portion of BAAP to provide water to cows. The USDA 6 well is located approximately 4,300 feet north of the Water's Edge Subdivision (see Figure 20). Sampling results indicated 2,6-DNT exceeded the Chapter NR 140 ES. The following is a summary of the DNT source investigations that were conducted in the Central Plume area.

### *3.3.1 DNT Source Investigation*

Groundwater data and historical production standard operating procedures were reviewed. Based on these reviews, the investigation of the source of DNT contamination focused on the Rocket Paste production area (see Figure 1). Containers of production chemicals, which contained DNT, were transported by rail to each Pre-Mix House from the Bag Loading House. Nitrocellulose and nitroglycerin were added to the chemical mixture in each Pre-Mix House. The resulting slurry was then pumped to the Final Mix Houses. The Rocket Paste production area was not connected to the main industrial sewer network, so production related wash waters were discharged to open ditches. The surface water from the Nitroglycerin, Rocket Paste, and Magazine Areas, located in the central and southeast areas of the BAAP, discharges to the Settling Ponds in the south-central portion of BAAP (see Figure 1). The Settling Ponds are manmade areas that received wastewater from production. The Settling Ponds area drains to the south and east and discharged into Gruber's Grove Bay (see Figure 1).

From 2007 to 2010, multiple soil boring investigations were conducted at locations where releases of DNT may have occurred. Soil samples were analyzed for semi-volatiles including DNT. Soil removal activities were conducted around production buildings and along ditches and drainage pathways leading from the Rocket Paste and Nitroglycerin production areas. In addition, sewer removal and adjacent soil excavation was completed in this area. All contaminated soil and sewer piping were disposed of in the on-site licensed Landfill 3646. The WDNR was provided with multiple reports on the investigation and remediation activities. The WDNR provided the Army with multiple case closure letters. Based on these activities, there remains no source of DNT contaminated soil in the Central Plume.

## 3.4 Nitrocellulose Production Area

Based on the groundwater flow direction and the groundwater contaminant detections, the source of DNT contaminated groundwater is believed to be from the northwestern section of BAAP where nitrocellulose (NC) was manufactured. The completed NC was used to manufacture single-base propellants such as smokeless powder or double-base propellants such as rocket grains or Ball Powder. DNT was added to the manufacturing process in various production buildings. Investigations have determined that there are several potential sources of DNT contamination and it appears that the broad production area may have caused the groundwater impacts.

During 2007, the Army conducted a site-wide investigation into potential sources of DNT contamination in the groundwater. Several monitoring wells, including RIM-0705, were installed within the NC Production Area. Groundwater sampling determined that DNT was present within RIM-0705. This prompted soil investigations into the source of the DNT contamination. The following is a summary of the DNT source investigations that were conducted in the NC Production Area.

### *3.4.1 DNT Source Investigation*

The former DNT Screen House (located just north of monitoring well RIM-0705) was used in the production of smokeless powder. Containers of solid DNT were brought to the DNT Screen House and the solid DNT was broken up and screened to remove foreign material. The screened DNT was then distributed to mixing operations within NC Production Area. As part of the daily operating procedures in the DNT Screen House, accumulated residue on the floors was washed into a floor drain, which discharged out to a concrete process sewer sump. During 2008, 2009, and 2010, soil investigations were conducted within and beneath the sump along with the soil surrounding and beneath the DNT Screen House. These investigations determined that DNT contaminated soil was present. Remediation activities during 2008, 2009, and 2010 included the removal of sewer piping along with the surrounding contaminated soil, removal of the concrete sump along with the surrounding contaminated soil, and the contaminated soil surrounding and beneath the DNT Screen House. All contaminated soil and sewer piping were disposed of in the on-site licensed Landfill 3646.

Nine Hydro-jet Houses (located north of the DNT Screen House) were used during production of smokeless powder. During 2008, 2009, and 2010, soil investigations were conducted beneath the building basement concrete slabs. These investigations determined that DNT contaminated soil was present beneath the concrete slabs. Expansion joints and cracks within the concrete slabs were believed to be migration pathways for the DNT to penetrate beneath the basement slabs. Remediation activities during 2010 included the removal of the concrete slabs and the surrounding contaminated soil. All contaminated soil and concrete were disposed of in the on-site licensed Landfill 3646.

Additional soil investigation and removal activities were conducted around other NC Production Area buildings and the sewer piping network.

The WDNR was provided with multiple reports on the investigation and remediation activities. The WDNR provided the Army with multiple case closure letters. Based on these activities, there remains no source of DNT contaminated soil near the NC Production Area.

# 4.0 GROUNDWATER CHARACTERIZATION

## 4.1 Groundwater Quality Regulations

Both the USEPA and WDNR have published groundwater quality regulations related to groundwater associated with public drinking water systems and residential wells.

### *4.1.1 Federal Groundwater Quality Regulations*

The regulatory requirements described below, are the most relevant requirements as they relate to groundwater access for domestic purposes. These requirements are considered to be protective of human health.

#### 4.1.1.1 *National Primary Drinking Water Regulations*

Through the Safe Water Drinking Act, the USEPA has established National Primary Drinking Water Regulations (NPDWRs) that set mandatory water quality standard for drinking water contaminants. These are enforceable standards called “maximum contaminant levels” (MCLs) which are established to protect the public against consumption of drinking water contaminants that present a risk to human health. A copy of the NPDWRs (May 2009) is provided in Appendix C.

Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to Maximum Contaminant Level Goals (see below) as feasible using the best available treatment technology and taking cost into consideration. For this reason, MCLs are not always risk based values and may be higher than purely risk-based goals or screening criteria. MCLs are enforceable standards for public water systems.

Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

#### 4.1.1.2 *National Secondary Drinking Water Regulations*

The USEPA has also established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards for 15 contaminants. These are non-enforceable standards called "secondary maximum contaminant levels" (SMCLs). They are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL. A copy of the NSDWRs (May 2009) is provided in Appendix C.

#### 4.1.1.3 *Tapwater Regional Screening Level*

The USEPA has developed tapwater regional screening levels (RSLs) using risk assessment guidance from CERCLA. The tapwater RSLs are risk-based concentrations derived from standardized equations combining exposure information assumptions with USEPA toxicity data. The screening levels are considered by the USEPA to be protective for humans (including sensitive groups) over a lifetime. These values are derived solely on the basis of risk and do not consider the cost or feasibility of treating groundwater to these risk-based limits. A copy of the tapwater RSLs (November 2017) is provided in Appendix C.

The tapwater RSLs were developed considering potential exposure to chemicals in groundwater associated with domestic use of the groundwater as a drinking water source, as well as other normal domestic water uses, such as bathing, doing laundry, and washing dishes. Exposure to chemicals in groundwater are incorporated into the tapwater RSLs for both ingestion and dermal contact with the water, as well as inhalation of the portion of the chemicals in groundwater that are volatilized from the water as it is used (e.g., for bathing).

### *4.1.2 State Groundwater Quality Standards*

Chapter NR 140 establishes groundwater quality standards referred to as Enforcement Standards (ES) and Preventive Action Limits (PAL) for groundwater beneath the State of Wisconsin. These Chapter NR 140 groundwater quality standards are also used for evaluating groundwater monitoring data. The Chapter NR 140 ESs and PALs are listed within Table 1 - Public Health Groundwater Quality Standards and Table 2 - Public Welfare Groundwater Quality Standards (see Appendix C). The Public Welfare Groundwater Quality Standards listed in Table 2 (e.g., sulfate) are guidelines established to address cosmetic and aesthetic effects of substances present in drinking water supplies (e.g., taste). A copy of the Chapter NR 140 Groundwater Quality standards (February 2017) is provided in Appendix C.

#### 4.1.2.1 *Enforcement Standards*

The groundwater NR 140 ESs are protective of public health and welfare on the premise that the groundwater may be ingested through use as drinking water. All NR 140 ESs listed in Table 1 of Chapter NR 140 are Public Health Groundwater Quality Standards. The Chapter NR 140 ES concentrations are equal to or more stringent than the federal MCLs. Further references to groundwater standard exceedances will reference the NR 140 ES.

#### 4.1.2.2 *Preventive Action Limits*

The Chapter NR 140 PALs serve “to inform the WDNR of potential groundwater contamination problems (and to) establish the level of groundwater contamination at which the WDNR is required to commence efforts to control the contamination”. The Chapter NR 140 PALs are used early in the investigation process given the uncertainty over the nature and extent of contamination. The Chapter NR 140 ESs are used to define contaminants potential of concern and areas warranting remedial action where the current or future groundwater is used for drinking water purposes.

### 4.2 Groundwater Sampling Program

The Army has been monitoring the nature and extent of groundwater contamination since the early 1980s. Based on the current understanding of the BAAP groundwater plumes, not all monitoring wells are currently being used to define the current plume areas. Figure 18 identifies monitoring well locations which were initially installed to characterize groundwater quality and which wells are being monitored by the Army to define the nature and extent of groundwater contamination.

Any area outside the property transferred with groundwater access restrictions may be used for residential use. Figure 20 identifies the residential well locations currently being monitored by the Army. Both Figures 18 and 20 show the boundaries of the four groundwater contamination plumes.

Figure 21 displays the current monitoring well and residential well sampling frequencies, groundwater plumes, and groundwater flow directions. The groundwater plumes are displayed in two ways on Figure 21: areas that exceed the Chapter NR 140 PAL and areas that exceed the Chapter NR 140 ES. Groundwater areas exceeding the Chapter NR 140 PALs are provided for informational purposes since this data is not used for remedy selection. These plume boundaries displayed on Figure 21 are approximate and based on DNT and VOC groundwater data collected during 2018. The DBG Plume boundaries do not include sulfate groundwater data. The sulfate data will be discussed in Section 4.5.2.2 of this report.

The current groundwater sampling program including monitoring wells and residential wells is being conducted according to sampling plans agreed upon by the Army and WDNR. Sampling plans are routinely modified based on requests from the WDNR.

A total of 166 monitoring wells are sampled at varying frequencies: 5 quarterly (four times per year), 119 semi-annual (twice per year), 35 annual (once per year), and 7 biennial (once every two years); see Figure 21. Table 3 provides the location, well construction information, and sample frequency for the 166 monitoring wells currently being sampled by the Army. Appendix D details the groundwater sampling program. Table 4 provides the location and well construction information for the 137 monitoring wells that are not currently being sampled. There are currently 303 monitoring wells associated with BAAP (see Figure 18).

A total of 54 residential wells are sampled at varying frequencies: 2 quarterly (four times per year) and 52 annually; see Figure 21. Table 5 provides the well construction information and sample frequency for the 54 residential wells currently being sampled by the Army. Table 6 provides the well construction information for the residential wells that are not currently being sampled and shown on Figure 20. Well construction and depth information was not available for many residential wells due to the lack of information provided on well logs. Information regarding the construction and depths of residential wells near BAAP in 1993 was included in the *Final Remedial Investigation Report* (ABB Environmental Services, Inc., 1993).

Concurrent with this RI/FS report preparation, yet independent of this effort, the United States Geological Survey (USGS) is performing a comprehensive review of the BAAP groundwater monitoring program. The intention of the review is to evaluate the existing program and determine if modifications could be made to strengthen the value of the data generated from the monitoring effort. No modifications are being proposed, at this time, to the previously approved monitoring program; however, results of the USGS evaluation may result in suggested modifications to enhance the program.

**Table 3**
**Monitoring Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1111 | 751 | 3038 | 1/2/80 | 487,414 | 2,044,310 | 99.0 | 848.79 | 846.80 | 4.0 | 20.3 | n/a | OW | Sand | A | Annual | Central |
| NLN-8203A | 258 | 3118 | 5/5/82 | 494,954 | 2,045,545 | 115.5 | 884.12 | 881.80 | 4.0 | 10.0 | n/a | OW | Sand | A | Annual | Central |
| NLN-8203B | 259 | 3118 | 5/6/82 | 494,946 | 2,045,534 | 127.5 | 884.87 | 882.70 | 4.0 | 2.0 | n/a | PZ | Sand | B | Annual | Central |
| NLN-8203C | 260 | 3118 | 5/5/82 | 494,954 | 2,045,532 | 138.5 | 885.17 | 882.70 | 4.0 | 2.0 | n/a | PZ | Sand | C | Annual | Central |
| NPM-8901 | 506 | 3487 | 10/25/89 | 497,388 | 2,041,526 | 100.0 | 862.92 | 861.50 | 4.0 | 20.0 | n/a | OW | Sand | A | Annual | Central |
| RIM-1003 | 491 | 3487 | 5/3/10 | 492,555 | 2,043,661 | 114.3 | 885.06 | 882.78 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| RIM-1004 | 494 | 3487 | 5/5/10 | 489,552 | 2,044,244 | 70.5 | 836.40 | 833.60 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| RIN-0701C | 443 | 3487 | 10/12/07 | 497,385 | 2,041,541 | 180.0 | 863.86 | 860.76 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-0702C | 444 | 3487 | 10/16/07 | 494,729 | 2,042,699 | 201.0 | 887.98 | 885.81 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-0703C | 445 | 3487 | 10/17/07 | 489,062 | 2,044,835 | 207.0 | 857.55 | 854.83 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-1002A | 492 | 3487 | 5/4/10 | 492,556 | 2,046,082 | 92.2 | 862.81 | 860.46 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| RIN-1002C | 493 | 3487 | 6/1/10 | 492,569 | 2,046,079 | 179.8 | 862.95 | 860.86 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-1003A | 495 | 3487 | 5/5/10 | 489,061 | 2,044,797 | 90.5 | 857.10 | 854.66 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| RIN-1004B | 498 | 3487 | 5/13/10 | 486,645 | 2,044,721 | 146.7 | 859.31 | 856.74 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | Central |
| RIN-1005A | 496 | 3487 | 5/17/10 | 489,311 | 2,045,864 | 60.5 | 828.61 | 826.74 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| RIN-1005C | 497 | 3487 | 5/17/10 | 489,317 | 2,045,865 | 147.0 | 828.75 | 826.49 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-1501B | 538 | 3487 | 10/23/15 | 492,538 | 2,046,945 | 123.5 | 845.87 | 842.86 | 2.5 | 10.0 | n/a | PZ | Sand | B | Annual | Central |
| RIN-1501C | 539 | 3487 | 10/27/15 | 492,538 | 2,046,939 | 165.2 | 845.86 | 842.80 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-1501D | 540 | 3487 | 10/30/15 | 492,578 | 2,046,076 | 237.8 | 863.54 | 860.86 | 2.5 | 5.0 | n/a | PZ | Sand | D | Annual | Central |
| RIN-1502B | 541 | 3487 | 9/22/15 | 489,765 | 2,046,626 | 103.4 | 824.29 | 821.41 | 2.5 | 5.0 | n/a | PZ | Sand | B | Annual | Central |
| RIN-1502C | 542 | 3487 | 9/25/15 | 489,768 | 2,046,631 | 143.1 | 824.40 | 821.44 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| RIN-1502D | 543 | 3487 | 10/2/15 | 489,772 | 2,046,636 | 213.3 | 824.33 | 821.35 | 2.5 | 5.0 | 213 | PZ | Sand | D | Annual | Central |
| RPM-8901 | 507 | 3487 | 10/16/89 | 494,718 | 2,042,698 | 124.3 | 888.62 | 886.20 | 4.0 | 19.5 | n/a | OW | Sand | A | Annual | Central |
| NLN-1001A | 331 | 3646 | 4/21/10 | 495,613 | 2,044,708 | 111.5 | 882.62 | 880.28 | 4.0 | 15.0 | n/a | OW | Sand | A | Annual | Central |
| NLN-1001C | 332 | 3646 | 4/19/10 | 495,615 | 2,044,701 | 154.5 | 882.52 | 880.36 | 4.0 | 5.0 | n/a | PZ | Sand | C | Annual | Central |
| SEN-0501A | 580 | 4330 | 1/27/05 | 484,159 | 2,043,454 | 32.0 | 784.56 | 784.64 | 3.8 | 15.0 | n/a | OW | Sand | A | Semi-Annual | Central |
| SEN-0501B | 581 | 4330 | 1/27/05 | 484,158 | 2,043,458 | 87.0 | 784.71 | 784.87 | 3.8 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | Central |
| SEN-0501D | 582 | 4330 | 1/27/05 | 484,156 | 2,043,462 | 190.0 | 784.98 | 785.22 | 3.8 | 10.0 | 194 | PZ | Sand | D | Semi-Annual | Central |
| SEN-0502A | 583 | 4330 | 1/28/05 | 484,107 | 2,044,412 | 33.0 | 786.46 | 786.47 | 3.8 | 15.0 | n/a | OW | Sand | A | Semi-Annual | Central |
| SEN-0502D | 584 | 4330 | 1/12/05 | 484,103 | 2,044,417 | 187.0 | 786.24 | 786.76 | 3.8 | 10.0 | 190 | PZ | Sand | D | Semi-Annual | Central |
| SEN-0503A | 585 | 4330 | 1/26/05 | 484,524 | 2,044,148 | 55.5 | 809.56 | 809.63 | 3.8 | 15.0 | n/a | OW | Sand | A | Semi-Annual | Central |
| SEN-0503B | 586 | 4330 | 1/25/05 | 484,518 | 2,044,150 | 110.0 | 809.17 | 809.39 | 3.8 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | Central |
| SEN-0503D | 587 | 4330 | 1/19/05 | 484,514 | 2,044,152 | 213.0 | 809.31 | 809.31 | 3.8 | 10.0 | 214 | PZ | Sand | D | Semi-Annual | Central |
| ELM-8901 | 216 | 2813 | 1/18/89 | 501,113 | 2,043,592 | 165.0 | 922.57 | 920.50 | 4.0 | 19.5 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELM-8907 | 220 | 2813 | 4/18/89 | 500,500 | 2,044,492 | 150.3 | 916.21 | 913.70 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELM-8908 | 221 | 2813 | 4/1/89 | 500,503 | 2,044,033 | 145.0 | 906.05 | 903.00 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELM-8909 | 222 | 2813 | 4/13/89 | 501,298 | 2,043,256 | 155.0 | 921.86 | 919.60 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELM-9501 | 234 | 2813 | 6/27/95 | 498,219 | 2,046,902 | 69.0 | 843.28 | 840.70 | 4.0 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-0801B | 455 | 2813 | 4/15/08 | 498,220 | 2,046,894 | 105.0 | 843.87 | 841.37 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| ELN-0801C | 456 | 2813 | 4/15/08 | 498,213 | 2,046,896 | 150.5 | 843.82 | 841.42 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |

**Table 3**
**Monitoring Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELN-0801E | 457 | 2813 | 10/23/08 | 498,221 | 2,046,909 | 207.7 | 842.70 | 840.10 | 2.5 | 5.0 | 187 | PZ | Rock | E | Semi-Annual | DBG |
| ELN-0802A | 458 | 2813 | 10/28/08 | 498,661 | 2,045,219 | 107.5 | 878.47 | 876.20 | 2.5 | 15.0 | n/a | OW | Sand | A | Biennial | DBG |
| ELN-0802C | 459 | 2813 | 10/30/08 | 498,663 | 2,045,211 | 180.8 | 878.47 | 876.10 | 2.5 | 5.0 | n/a | PZ | Sand | C | Biennial | DBG |
| ELN-1001B | 460 | 2813 | 5/11/10 | 497,078 | 2,047,480 | 96.1 | 809.31 | 806.98 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| ELN-1001C | 461 | 2813 | 5/12/10 | 497,094 | 2,047,476 | 160.2 | 809.24 | 806.58 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| ELN-1001E | 462 | 2813 | 6/23/10 | 497,110 | 2,047,472 | 245.5 | 809.34 | 806.46 | 2.5 | 5.0 | 230 | PZ | Rock | E | Semi-Annual | DBG |
| ELN-1002A | 463 | 2813 | 6/8/10 | 496,066 | 2,049,181 | 70.3 | 835.13 | 832.55 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-1002B | 464 | 2813 | 6/9/10 | 496,056 | 2,049,188 | 116.2 | 835.15 | 832.39 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| ELN-1002C | 465 | 2813 | 6/15/10 | 496,075 | 2,049,195 | 164.1 | 835.15 | 832.13 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| ELN-1002E | 466 | 2813 | 6/17/10 | 496,063 | 2,049,200 | 236.5 | 834.75 | 831.97 | 2.5 | 5.0 | 219 | PZ | Rock | E | Semi-Annual | DBG |
| ELN-1003A | 467 | 2813 | 7/7/10 | 497,862 | 2,048,208 | 31.2 | 801.87 | 799.89 | 2.5 | 15.0 | n/a | OW | Sand | A | Quarterly | DBG |
| ELN-1003B | 468 | 2813 | 7/6/10 | 497,867 | 2,048,198 | 96.5 | 801.40 | 798.74 | 2.5 | 5.0 | n/a | PZ | Sand | B | Quarterly | DBG |
| ELN-1003C | 469 | 2813 | 7/6/10 | 497,873 | 2,048,186 | 160.1 | 801.82 | 799.24 | 2.5 | 5.0 | n/a | PZ | Sand | C | Quarterly | DBG |
| ELN-1003E | 470 | 2813 | 7/1/10 | 497,876 | 2,048,172 | 230.6 | 801.62 | 799.12 | 2.5 | 5.0 | 213 | PZ | Rock | E | Quarterly | DBG |
| ELN-1502A | 533 | 2813 | 10/19/15 | 499,322 | 2,046,218 | 130.3 | 902.15 | 899.20 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-1502C | 534 | 2813 | 10/14/15 | 499,317 | 2,046,221 | 203.0 | 902.36 | 899.30 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| ELN-1503A | 535 | 2813 | 10/8/15 | 499,385 | 2,047,058 | 88.7 | 862.42 | 859.26 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-1503C | 536 | 2813 | 10/7/15 | 499,377 | 2,047,057 | 162.6 | 862.29 | 859.54 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| ELN-1504B | 537 | 2813 | 9/11/15 | 497,531 | 2,048,387 | 39.8 | 780.51 | 778.34 | 2.0 | 5.0 | n/a | PZ | Sand | B | Quarterly | DBG |
| ELN-8203A | 210 | 2813 | 3/24/82 | 501,516 | 2,044,336 | 157.5 | 927.79 | 925.20 | 4.0 | 10.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-8203B | 211 | 2813 | 3/25/82 | 501,502 | 2,044,325 | 166.0 | 927.43 | 925.50 | 4.0 | 2.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| ELN-8203C | 212 | 2813 | 3/24/82 | 501,517 | 2,044,323 | 176.0 | 926.93 | 925.30 | 4.0 | 2.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| ELN-8902B | 224 | 2813 | 4/18/89 | 501,013 | 2,044,130 | 178.5 | 920.38 | 918.00 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| ELN-9107A | 227 | 2813 | 11/10/91 | 500,568 | 2,045,411 | 126.0 | 897.72 | 895.30 | 3.8 | 10.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| ELN-9107B | 228 | 2813 | 11/9/91 | 500,527 | 2,045,437 | 145.0 | 895.96 | 893.90 | 3.8 | 10.0 | n/a | OW | Sand | B | Semi-Annual | DBG |
| ELN-9402AR | 231 | 2813 | 2/15/94 | 501,014 | 2,044,060 | 145.0 | 920.92 | 919.00 | 4.0 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| S1134R | 236 | 2813 | 6/8/95 | 501,504 | 2,043,991 | 151.0 | 922.06 | 920.60 | 4.0 | 15.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| DBM-8201 | 301 | 3037 | 3/23/82 | 500,846 | 2,043,148 | 174.7 | 918.76 | 916.70 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| DBM-8202 | 302 | 3037 | 3/20/82 | 501,147 | 2,042,937 | 157.4 | 920.35 | 917.80 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| DBM-8903 | 306 | 3037 | 2/16/89 | 500,499 | 2,043,488 | 133.0 | 898.94 | 896.40 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| DBN-1001B | 472 | 3037 | 5/25/10 | 501,062 | 2,043,113 | 159.5 | 912.07 | 909.77 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| DBN-1001C | 473 | 3037 | 5/27/10 | 501,063 | 2,043,094 | 197.0 | 912.00 | 909.78 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| DBN-1001E | 474 | 3037 | 6/30/10 | 501,065 | 2,043,076 | 279.9 | 912.50 | 909.95 | 2.5 | 5.0 | 258 | PZ | Rock | E | Semi-Annual | DBG |
| DBN-1002C | 476 | 3037 | 6/17/10 | 500,487 | 2,044,488 | 210.1 | 916.12 | 913.72 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| DBN-1002E | 477 | 3037 | 7/12/10 | 500,511 | 2,044,485 | 280.6 | 916.24 | 913.84 | 2.5 | 5.0 | 265 | PZ | Rock | E | Semi-Annual | DBG |
| DBN-9501A | 314 | 3037 | 10/24/95 | 500,312 | 2,043,686 | 120.0 | 889.10 | 886.70 | 3.8 | 10.0 | n/a | OW | Sand | A | Semi-Annual | DBG |
| DBN-9501B | 315 | 3037 | 10/20/95 | 500,315 | 2,043,703 | 172.5 | 889.65 | 887.00 | 3.8 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | DBG |
| DBN-9501C | 316 | 3037 | 10/18/95 | 500,298 | 2,043,710 | 228.5 | 890.03 | 887.50 | 3.8 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | DBG |
| DBN-9501E | 317 | 3037 | 10/10/95 | 500,286 | 2,043,697 | 255.5 | 890.17 | 887.90 | 3.8 | 10.3 | 229 | PZ | Rock | E | Semi-Annual | DBG |
| S1121 | 755 | 3038 | 1/18/80 | 496,303 | 2,047,578 | 59.3 | 815.58 | 813.90 | 4.0 | 20.2 | n/a | OW | Sand | A | Semi-Annual | DBG |

**Table 3**
**Monitoring Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RIM-0703 | 440 | 3487 | 10/4/07 | 499,282 | 2,034,376 | 113.0 | 889.23 | 886.53 | 2.5 | 15.0 | n/a | OW | Sand | A | Annual | NC |
| RIM-0705 | 442 | 3487 | 10/10/07 | 497,844 | 2,035,152 | 106.0 | 884.38 | 881.30 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | NC |
| RIM-1002 | 478 | 3487 | 4/29/10 | 499,282 | 2,034,869 | 110.2 | 891.01 | 888.51 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | NC |
| RIN-1001A | 480 | 3487 | 4/28/10 | 497,066 | 2,035,221 | 106.8 | 884.38 | 882.05 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | NC |
| RIN-1001C | 481 | 3487 | 5/24/10 | 497,097 | 2,035,225 | 181.4 | 884.02 | 882.01 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | NC |
| RIN-1007C | 479 | 3487 | 6/15/10 | 497,858 | 2,035,155 | 175.3 | 883.81 | 881.41 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | NC |
| S1125 | 504 | 3487 | 12/26/79 | 496,508 | 2,036,418 | 126.5 | 895.93 | 894.90 | 4.0 | 20.3 | n/a | OW | Sand | A | Semi-Annual | NC |
| PBM-0001 | 367 | 2814 | 7/14/00 | 491,611 | 2,035,455 | 134.5 | 890.23 | 887.54 | 4.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBM-0002 | 368 | 2814 | 8/4/00 | 491,527 | 2,035,422 | 131.5 | 886.46 | 884.75 | 4.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBM-0006 | 372 | 2814 | 8/1/00 | 491,477 | 2,035,323 | 124.5 | 879.02 | 875.89 | 4.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBM-0008 | 374 | 2814 | 8/12/00 | 491,355 | 2,035,323 | 122.0 | 876.62 | 874.66 | 4.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBM-8907 | 637 | 2814 | 3/3/89 | 487,689 | 2,034,443 | 92.7 | 849.45 | 846.60 | 4.0 | 10.0 | n/a | OW | Sand | A | Annual | PBG |
| PBM-8909 | 639 | 2814 | 3/1/89 | 492,402 | 2,035,472 | 124.4 | 883.66 | 880.60 | 4.0 | 20.0 | n/a | OW | Sand | A | Biennial | PBG |
| PBM-9801 | 360 | 2814 | 10/13/98 | 491,877 | 2,035,466 | 123.5 | 890.46 | 887.85 | 4.0 | 15.0 | n/a | OW | Sand | A | Annual | PBG |
| PBN-1001C | 595 | 2814 | 6/8/10 | 485,968 | 2,035,767 | 199.7 | 840.01 | 837.71 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1003C | 592 | 2814 | 6/3/10 | 487,681 | 2,034,448 | 189.6 | 848.21 | 846.51 | 2.5 | 5.0 | n/a | PZ | Sand | C | Annual | PBG |
| PBN-1302A | 770 | 2814 | 10/16/13 | 484,705 | 2,036,460 | 84.7 | 830.23 | 828.30 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-1302B | 771 | 2814 | 10/17/13 | 484,705 | 2,036,453 | 136.2 | 829.65 | 827.60 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-1302C | 772 | 2814 | 10/22/13 | 484,705 | 2,036,448 | 187.6 | 828.98 | 827.00 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1302D | 773 | 2814 | 10/29/13 | 484,705 | 2,036,442 | 245.1 | 828.35 | 826.50 | 2.5 | 5.0 | 245 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-1303A | 774 | 2814 | 11/5/13 | 484,651 | 2,036,981 | 130.5 | 884.88 | 883.00 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-1303B | 775 | 2814 | 11/12/13 | 484,651 | 2,036,968 | 176.5 | 883.71 | 881.60 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-1303C | 776 | 2814 | 11/20/13 | 484,652 | 2,036,963 | 232.0 | 883.67 | 881.60 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1303D | 777 | 2814 | 11/22/13 | 484,652 | 2,036,958 | 287.0 | 883.42 | 881.60 | 2.5 | 5.0 | 287 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-1304A | 778 | 2814 | 12/3/13 | 484,642 | 2,037,502 | 116.0 | 871.81 | 869.40 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-1304B | 779 | 2814 | 12/10/13 | 484,642 | 2,037,496 | 163.1 | 871.49 | 869.80 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-1304C | 780 | 2814 | 12/17/13 | 484,642 | 2,037,489 | 218.0 | 872.00 | 869.70 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1304D | 781 | 2814 | 1/14/14 | 484,642 | 2,037,484 | 273.0 | 872.03 | 869.50 | 2.5 | 5.0 | 273 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-1401A | 782 | 2814 | 2/19/14 | 491,036 | 2,035,501 | 132.2 | 887.30 | 884.57 | 2.5 | 15.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-1401B | 783 | 2814 | 2/12/14 | 491,035 | 2,035,494 | 163.7 | 887.09 | 884.57 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-1401C | 784 | 2814 | 2/10/14 | 491,035 | 2,035,488 | 203.3 | 887.08 | 884.57 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1404B | 791 | 2814 | 3/11/14 | 487,745 | 2,035,891 | 179.5 | 895.08 | 892.18 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-1404C | 792 | 2814 | 3/4/14 | 487,742 | 2,035,888 | 239.3 | 895.04 | 892.18 | 2.5 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-1404D | 793 | 2814 | 2/26/14 | 487,737 | 2,035,885 | 299.8 | 894.49 | 892.18 | 2.5 | 5.0 | 300 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-1405F | 794 | 2814 | 3/25/14 | 484,824 | 2,035,411 | 319.7 | 806.29 | 803.77 | 2.5 | 5.0 | 212 | PZ | Rock | F | Biennial | PBG |
| PBN-8202A | 613 | 2814 | 5/1/82 | 491,539 | 2,035,491 | 118.5 | 886.15 | 884.09 | 4.0 | 10.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-8202B | 614 | 2814 | 3/9/82 | 491,537 | 2,035,480 | 133.0 | 885.49 | 883.48 | 4.0 | 2.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-8202C | 615 | 2814 | 3/8/82 | 491,529 | 2,035,490 | 141.2 | 885.43 | 882.47 | 4.0 | 2.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-8205A | 622 | 2814 | 3/13/82 | 490,334 | 2,035,262 | 112.5 | 878.52 | 875.80 | 4.0 | 10.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-8205B | 623 | 2814 | 3/11/82 | 490,343 | 2,035,252 | 124.3 | 877.80 | 875.88 | 4.0 | 2.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |

**Table 3**
**Monitoring Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PBN-8205C | 624 | 2814 | 3/11/82 | 490,330 | 2,035,250 | 133.5 | 878.31 | 875.80 | 4.0 | 2.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-8502A | 632 | 2814 | 10/1/85 | 489,416 | 2,035,667 | 138.1 | 898.88 | 895.80 | 5.0 | 9.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-8503A | 633 | 2814 | 10/3/85 | 489,407 | 2,034,266 | 94.8 | 851.45 | 848.10 | 5.0 | 9.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-8902BR | 795 | 2814 | 3/24/14 | 489,418 | 2,035,684 | 160.0 | 898.87 | 896.82 | 2.5 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-8902C | 645 | 2814 | 3/19/89 | 489,415 | 2,035,630 | 193.3 | 897.12 | 894.50 | 4.0 | 5.2 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-8903B | 646 | 2814 | 3/8/89 | 489,457 | 2,034,281 | 125.0 | 847.93 | 844.90 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-8903C | 647 | 2814 | 3/9/89 | 489,457 | 2,034,316 | 160.0 | 846.96 | 844.10 | 4.0 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-8912A | 654 | 2814 | 3/2/89 | 486,338 | 2,034,980 | 103.4 | 855.86 | 852.60 | 4.0 | 20.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-8912B | 655 | 2814 | 4/15/89 | 486,312 | 2,034,979 | 138.0 | 856.34 | 852.60 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-9112C | 665 | 2814 | 10/24/91 | 486,280 | 2,034,972 | 183.4 | 854.48 | 852.20 | 3.8 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-9112D | 666 | 2814 | 10/16/91 | 486,253 | 2,034,965 | 231.0 | 853.31 | 851.20 | 3.8 | 10.0 | n/a | PZ | Sand | D | Semi-Annual | PBG |
| PBN-9301B | 668 | 2814 | 3/19/93 | 489,365 | 2,036,994 | 160.5 | 875.03 | 872.20 | 3.9 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-9301C | 669 | 2814 | 3/16/93 | 489,353 | 2,037,006 | 227.5 | 874.64 | 872.22 | 3.9 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-9303B | 673 | 2814 | 3/9/93 | 486,123 | 2,036,945 | 93.5 | 816.16 | 813.49 | 3.9 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-9303C | 674 | 2814 | 3/14/93 | 486,126 | 2,036,969 | 164.5 | 815.05 | 812.45 | 3.9 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-9303D | 675 | 2814 | 3/11/93 | 486,127 | 2,036,990 | 224.5 | 813.98 | 811.41 | 3.9 | 10.0 | 223 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-9304D | 687 | 2814 | 10/19/93 | 484,890 | 2,035,315 | 210.0 | 806.09 | 804.10 | 4.0 | 10.0 | 210 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-9902D | 691 | 2814 | 7/1/99 | 484,798 | 2,035,025 | 222.5 | 811.53 | 809.50 | 4.0 | 5.0 | 217 | PZ | Sand | D | Semi-Annual | PBG |
| PBN-9903A | 692 | 2814 | 6/23/99 | 483,859 | 2,035,680 | 76.0 | 826.91 | 825.18 | 4.0 | 15.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| PBN-9903B | 693 | 2814 | 7/8/99 | 483,859 | 2,035,687 | 112.0 | 827.17 | 825.00 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| PBN-9903C | 694 | 2814 | 7/15/99 | 483,861 | 2,035,693 | 163.0 | 827.33 | 824.99 | 4.0 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-9903D | 695 | 2814 | 7/13/99 | 483,861 | 2,035,698 | 208.0 | 827.52 | 825.10 | 4.0 | 5.0 | 196 | PZ | Sand | D | Semi-Annual | PBG |
| PBM-9001D | 981 | 3485 | 8/25/90 | 477,175 | 2,038,945 | 210.5 | 831.52 | 829.00 | 4.0 | 10.0 | n/a | PZ | Sand | D | Semi-Annual | PBG |
| PBM-9002D | 982 | 3485 | 8/18/90 | 475,994 | 2,038,132 | 204.5 | 821.31 | 818.70 | 4.0 | 10.0 | n/a | PZ | Sand | D | Biennial | PBG |
| PBN-9101C | 561 | 3493 | 10/25/91 | 477,125 | 2,038,954 | 152.5 | 830.11 | 828.00 | 3.8 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| PBN-9102B | 562 | 3493 | 9/28/91 | 476,019 | 2,038,141 | 115.0 | 821.19 | 819.00 | 3.8 | 10.0 | n/a | PZ | Sand | B | Biennial | PBG |
| PBN-9102C | 563 | 3493 | 9/30/91 | 476,028 | 2,038,105 | 161.3 | 821.90 | 819.90 | 3.8 | 10.0 | n/a | PZ | Sand | C | Biennial | PBG |
| SWN-9102C | 569 | 3493 | 10/27/91 | 479,341 | 2,035,141 | 152.5 | 836.41 | 834.40 | 3.8 | 10.0 | n/a | PZ | Sand | C | Annual | PBG |
| SWN-9102D | 570 | 3493 | 10/23/91 | 479,341 | 2,035,185 | 185.0 | 836.66 | 834.50 | 4.0 | 10.0 | n/a | PZ | Sand | D | Annual | PBG |
| SWN-9103B | 571 | 3493 | 10/4/91 | 479,353 | 2,036,656 | 113.4 | 836.63 | 834.70 | 3.8 | 10.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| SWN-9103C | 572 | 3493 | 10/2/91 | 479,351 | 2,036,622 | 162.8 | 836.80 | 834.60 | 4.0 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| SWN-9103D | 573 | 3493 | 10/1/91 | 479,352 | 2,036,701 | 209.1 | 837.10 | 835.00 | 4.0 | 10.0 | 210 | PZ | Sand | D | Semi-Annual | PBG |
| SWN-9103E | 574 | 3493 | 11/10/91 | 479,352 | 2,036,753 | 237.9 | 837.38 | 835.00 | 3.8 | 10.0 | 210 | PZ | Rock | E | Semi-Annual | PBG |
| SWN-9104C | 575 | 3493 | 10/13/91 | 479,357 | 2,037,722 | 164.0 | 834.87 | 832.80 | 3.8 | 10.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| SWN-9104D | 576 | 3493 | 10/9/91 | 479,359 | 2,037,678 | 197.0 | 835.33 | 833.50 | 3.8 | 10.0 | n/a | PZ | Sand | D | Semi-Annual | PBG |
| SWN-9105B | 577 | 3493 | 10/12/91 | 478,954 | 2,038,812 | 112.5 | 832.73 | 830.50 | 3.8 | 10.0 | n/a | PZ | Sand | B | Annual | PBG |
| SWN-9105C | 578 | 3493 | 10/11/91 | 478,924 | 2,038,828 | 147.0 | 832.88 | 830.80 | 3.8 | 10.0 | n/a | PZ | Sand | C | Annual | PBG |
| SWN-9105D | 579 | 3493 | 10/10/91 | 478,885 | 2,038,855 | 200.5 | 833.35 | 831.20 | 3.8 | 10.0 | n/a | PZ | Sand | D | Annual | PBG |
| S1147 | 709 | 3499 | 10/10/83 | 484,928 | 2,034,512 | 70.8 | 817.07 | 815.70 | 5.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |
| S1148 | 710 | 3499 | 10/10/83 | 484,691 | 2,035,563 | 56.7 | 803.72 | 802.10 | 5.0 | 25.0 | n/a | OW | Sand | A | Semi-Annual | PBG |

**Table 3**
**Monitoring Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPN-8903B | 718 | 3499 | 3/22/89 | 484,935 | 2,034,532 | 93.7 | 818.14 | 815.10 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| SPN-8903C | 719 | 3499 | 4/13/89 | 484,907 | 2,034,501 | 127.7 | 818.13 | 815.30 | 4.0 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| SPN-8904B | 720 | 3499 | 3/9/89 | 484,691 | 2,035,540 | 75.0 | 804.23 | 801.60 | 4.0 | 5.0 | n/a | PZ | Sand | B | Semi-Annual | PBG |
| SPN-8904C | 721 | 3499 | 3/30/89 | 484,694 | 2,035,642 | 106.5 | 803.25 | 800.70 | 4.0 | 5.0 | n/a | PZ | Sand | C | Semi-Annual | PBG |
| SPN-9103D | 725 | 3499 | 10/8/91 | 484,909 | 2,034,440 | 200.5 | 819.29 | 816.70 | 3.8 | 10.0 | n/a | PZ | Sand | D | Semi-Annual | PBG |
| SPN-9104D | 726 | 3499 | 10/1/91 | 484,693 | 2,035,601 | 206.0 | 802.61 | 800.80 | 3.8 | 10.0 | 212 | PZ | Sand | D | Semi-Annual | PBG |

Notes

OW = Water Table Observation Well
PZ = Piezometer
DBG = Deterrent Burning Ground Plume
Central = Central Plume
NC = Nitrocellulose Production Area Plume
PBG = Propellant Burning Ground Plume
Screen Level references the typical well depth configuration

**Table 4**
**Monitoring Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1112 | 752 | 3038 | 1/4/80 | 490,050 | 2,045,210 | 91.7 | 838.03 | 836.40 | 4.0 | 20.3 | n/a | OW | Sand | A | Not Sampled | Central |
| S1113 | 753 | 3038 | 11/23/79 | 491,611 | 2,048,037 | 66.1 | 821.58 | 820.00 | 4.0 | 20.2 | n/a | OW | Sand | A | Not Sampled | Central |
| S1114 | 754 | 3038 | 11/20/79 | 491,603 | 2,048,038 | 105.4 | 821.46 | 820.10 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | Central |
| NLM-9202R | 270 | 3118 | 12/21/92 | 494,989 | 2,046,317 | 118.2 | 885.15 | 882.90 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-8201A | 252 | 3118 | 4/23/82 | 495,556 | 2,045,494 | 120.3 | 890.65 | 888.60 | 4.0 | 10.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-8201B | 253 | 3118 | 4/22/82 | 495,566 | 2,045,487 | 132.5 | 891.28 | 889.00 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | Central |
| NLN-8201C | 254 | 3118 | 4/7/82 | 495,552 | 2,045,485 | 142.0 | 890.54 | 888.60 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | Central |
| NLN-8202A | 255 | 3118 | 4/30/82 | 495,648 | 2,046,075 | 102.9 | 873.61 | 872.53 | 4.0 | 10.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-8202B | 256 | 3118 | 4/23/82 | 495,646 | 2,046,087 | 115.0 | 873.69 | 871.97 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | Central |
| NLN-8204A | 261 | 3118 | 5/8/82 | 494,911 | 2,045,873 | 125.5 | 892.72 | 891.00 | 4.0 | 10.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-8204B | 262 | 3118 | 5/8/82 | 494,899 | 2,045,877 | 137.5 | 893.44 | 891.60 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | Central |
| NLN-8204C | 263 | 3118 | 5/7/82 | 494,901 | 2,045,867 | 150.0 | 893.54 | 891.60 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | Central |
| NLN-8205B | 265 | 3118 | 5/10/82 | 494,905 | 2,046,159 | 136.5 | 899.28 | 896.90 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | Central |
| NLN-8205C | 266 | 3118 | 5/10/82 | 494,917 | 2,046,156 | 147.5 | 897.99 | 896.30 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | Central |
| NLN-9205AR | 269 | 3118 | 11/13/92 | 494,913 | 2,046,170 | 132.0 | 897.82 | 895.30 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| RPM-9101 | 509 | 3487 | 10/26/91 | 492,702 | 2,045,303 | 105.8 | 874.04 | 871.80 | 3.8 | 10.0 | n/a | OW | Sand | A | Not Sampled | Central |
| S1120 | 502 | 3487 | 1/17/80 | 493,313 | 2,044,061 | 122.8 | 880.14 | 877.40 | 4.0 | 20.2 | n/a | OW | Sand | A | Not Sampled | Central |
| S1150 | 505 | 3487 | 10/10/83 | 496,772 | 2,037,797 | 138.0 | 897.56 | 895.60 | 5.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLM-0301R | 271 | 3646 | 7/23/03 | 495,613 | 2,045,778 | 112.0 | 881.20 | 877.92 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLM-0302R | 272 | 3646 | 1/9/04 | 496,404 | 2,045,533 | 127.0 | 894.50 | 891.70 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLM-0401 | 296 | 3646 | 8/3/04 | 495,912 | 2,046,255 | 112.0 | 869.29 | 866.66 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLM-1001 | 330 | 3646 | 4/14/10 | 496,509 | 2,044,604 | 106.0 | 880.22 | 878.00 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-0701A | 297 | 3646 | 6/6/07 | 495,491 | 2,045,250 | 125.0 | 887.47 | 884.87 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | Central |
| NLN-0701C | 298 | 3646 | 6/5/07 | 495,491 | 2,045,242 | 155.0 | 887.29 | 884.79 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | Central |
| ELM-9110 | 229 | 2813 | 11/13/91 | 501,635 | 2,044,708 | 154.0 | 923.03 | 920.80 | 3.8 | 15.0 | n/a | OW | Sand | A | Not Sampled | DBG |
| ELN-8904A | 225 | 2813 | 3/30/89 | 501,790 | 2,044,600 | 162.0 | 926.34 | 924.10 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | DBG |
| ELN-8904B | 226 | 2813 | 4/2/89 | 501,721 | 2,044,645 | 199.0 | 926.61 | 924.80 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | DBG |
| LOM-8901 | 656 | 2814 | 2/17/89 | 492,014 | 2,036,131 | 157.5 | 918.08 | 915.90 | 4.0 | 20.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| LOM-9101 | 661 | 2814 | 10/10/91 | 492,618 | 2,036,184 | 151.0 | 917.76 | 915.50 | 3.8 | 10.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| LOM-9102 | 662 | 2814 | 10/25/91 | 493,326 | 2,036,375 | 148.0 | 912.46 | 910.30 | 3.8 | 10.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| LON-8902A | 657 | 2814 | 2/19/89 | 491,571 | 2,036,136 | 159.0 | 927.95 | 918.50 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| LON-8903A | 659 | 2814 | 2/20/89 | 491,581 | 2,036,311 | 158.0 | 926.36 | 919.20 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| LON-8903B | 660 | 2814 | 2/20/89 | 491,579 | 2,036,275 | 198.0 | 927.41 | 919.50 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| LON-9502BR | 683 | 2814 | 6/1/95 | 491,573 | 2,036,166 | 203.5 | 927.54 | 919.30 | 4.0 | 18.5 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBM-0003 | 369 | 2814 | 8/8/00 | 491,440 | 2,035,388 | 120.5 | 875.95 | 876.89 | 4.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-0004 | 370 | 2814 | 7/25/00 | 491,356 | 2,035,354 | 125.5 | 877.62 | 875.64 | 4.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-0005 | 371 | 2814 | 7/19/00 | 491,566 | 2,035,322 | 128.0 | 883.58 | 881.22 | 4.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-0007 | 373 | 2814 | 7/24/00 | 491,417 | 2,035,323 | 120.9 | 874.47 | 872.56 | 4.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-1201 | 764 | 2814 | 11/15/12 | 491,516 | 2,035,458 | 118.5 | 882.56 | 880.24 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-1202 | 765 | 2814 | 11/19/12 | 491,507 | 2,035,442 | 118.5 | 881.48 | 879.01 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |

**Table 4**
**Monitoring Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PBM-1203 | 766 | 2814 | 11/20/12 | 491,496 | 2,035,425 | 118.4 | 880.18 | 877.69 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8201 | 605 | 2814 | 3/18/82 | 491,409 | 2,034,559 | 100.7 | 857.36 | 855.70 | 4.0 | 20.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| PBM-8203 | 607 | 2814 | 3/16/82 | 490,778 | 2,034,771 | 108.8 | 868.42 | 862.70 | 4.0 | 20.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| PBM-8204 | 608 | 2814 | 3/17/82 | 490,553 | 2,035,006 | 115.5 | 875.72 | 869.00 | 4.0 | 20.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| PBM-8205 | 609 | 2814 | 5/3/82 | 490,547 | 2,035,178 | 123.8 | 877.11 | 874.50 | 4.0 | 20.0 | n/a | PZ | Sand | A | Not Sampled | PBG |
| PBM-8501 | 625 | 2814 | 9/22/85 | 489,712 | 2,034,851 | 121.6 | 862.73 | 859.30 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8502 | 626 | 2814 | 9/17/85 | 489,417 | 2,034,654 | 101.7 | 849.42 | 845.40 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8503 | 627 | 2814 | 9/18/85 | 489,414 | 2,035,277 | 150.5 | 886.29 | 882.90 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8504 | 628 | 2814 | 9/24/85 | 488,819 | 2,035,043 | 125.4 | 866.47 | 863.80 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8505 | 629 | 2814 | 9/28/85 | 488,223 | 2,035,056 | 111.0 | 863.97 | 861.30 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8506 | 630 | 2814 | 10/4/85 | 487,043 | 2,035,032 | 98.2 | 848.18 | 845.10 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8905 | 635 | 2814 | 3/6/89 | 489,403 | 2,033,827 | 98.1 | 855.64 | 852.30 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8906 | 636 | 2814 | 4/30/89 | 489,509 | 2,036,227 | 136.0 | 886.34 | 883.70 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8908 | 638 | 2814 | 3/14/89 | 487,520 | 2,035,745 | 125.0 | 888.68 | 885.50 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-8911 | 640 | 2814 | 3/7/89 | 493,411 | 2,035,391 | 111.0 | 884.45 | 881.60 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-9803 | 526 | 2814 | 10/7/98 | 491,595 | 2,035,352 | 121.7 | 885.16 | 882.64 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-9901 | 361 | 2814 | 6/4/99 | 491,934 | 2,035,484 | 130.0 | 891.56 | 888.90 | 4.0 | 105.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-9902 | 362 | 2814 | 6/4/99 | 491,664 | 2,035,482 | 132.0 | 890.94 | 888.35 | 4.0 | 110.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBM-9903 | 363 | 2814 | 6/4/99 | 491,628 | 2,035,319 | 126.0 | 882.42 | 880.87 | 4.0 | 105.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1001A | 593 | 2814 | 5/3/10 | 485,984 | 2,035,770 | 79.3 | 840.37 | 838.17 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1001B | 594 | 2814 | 6/2/10 | 485,976 | 2,035,768 | 139.9 | 839.93 | 838.23 | 2.5 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-1002A | 589 | 2814 | 5/20/10 | 488,451 | 2,035,897 | 130.8 | 893.90 | 891.70 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1002B | 590 | 2814 | 5/19/10 | 488,447 | 2,035,927 | 176.5 | 894.27 | 892.27 | 2.5 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-1002C | 591 | 2814 | 6/9/10 | 488,450 | 2,035,908 | 216.8 | 893.48 | 891.48 | 2.5 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-1301A | 767 | 2814 | 9/16/13 | 491,295 | 2,035,639 | 130.0 | 899.97 | 897.35 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1301B | 768 | 2814 | 9/12/13 | 491,310 | 2,035,602 | 159.5 | 897.32 | 894.58 | 2.5 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-1301C | 769 | 2814 | 9/10/13 | 491,265 | 2,035,609 | 200.0 | 897.14 | 894.54 | 2.5 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-1402A | 785 | 2814 | 2/4/14 | 490,204 | 2,035,272 | 113.6 | 878.31 | 876.47 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1402B | 786 | 2814 | 2/10/14 | 490,204 | 2,035,277 | 132.9 | 878.77 | 876.47 | 2.5 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-1402C | 787 | 2814 | 2/18/14 | 490,204 | 2,035,282 | 162.8 | 878.74 | 876.47 | 2.5 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-1403A | 788 | 2814 | 2/27/14 | 489,290 | 2,035,682 | 135.7 | 901.24 | 899.00 | 2.5 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-1403B | 789 | 2814 | 2/26/14 | 489,290 | 2,035,687 | 157.2 | 901.22 | 899.05 | 2.5 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-1403C | 790 | 2814 | 2/20/14 | 489,290 | 2,035,693 | 192.0 | 901.64 | 899.27 | 2.5 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8201A | 610 | 2814 | 3/18/82 | 492,093 | 2,035,482 | 117.8 | 884.59 | 881.50 | 4.0 | 10.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-8201B | 611 | 2814 | 3/10/82 | 492,091 | 2,035,469 | 131.5 | 883.77 | 881.50 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-8201C | 612 | 2814 | 3/10/82 | 492,101 | 2,035,476 | 141.0 | 883.98 | 881.50 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8203A | 616 | 2814 | 3/15/82 | 490,314 | 2,034,600 | 96.5 | 860.01 | 857.60 | 4.0 | 10.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-8203B | 617 | 2814 | 3/15/82 | 490,311 | 2,034,613 | 108.5 | 860.26 | 857.60 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-8203C | 618 | 2814 | 3/15/82 | 490,300 | 2,034,606 | 117.5 | 860.17 | 857.60 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8204B | 620 | 2814 | 3/13/82 | 490,027 | 2,035,049 | 120.5 | 874.74 | 873.00 | 4.0 | 2.0 | n/a | PZ | Sand | B | Not Sampled | PBG |

**Table 4**
**Monitoring Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PBN-8204C | 621 | 2814 | 3/12/82 | 490,026 | 2,035,062 | 131.5 | 875.59 | 873.00 | 4.0 | 2.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8501A | 631 | 2814 | 9/18/85 | 489,413 | 2,035,044 | 121.9 | 874.51 | 871.30 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-8504A | 634 | 2814 | 9/30/85 | 487,634 | 2,035,066 | 112.7 | 860.03 | 857.20 | 5.0 | 9.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-8901B | 641 | 2814 | 1/22/89 | 489,397 | 2,035,022 | 159.9 | 872.55 | 870.00 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-8901C | 642 | 2814 | 4/19/89 | 489,395 | 2,035,102 | 198.1 | 878.03 | 875.50 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8901D | 643 | 2814 | 1/21/89 | 489,397 | 2,035,047 | 238.2 | 874.19 | 871.50 | 4.0 | 5.0 | n/a | PZ | Sand | D | Not Sampled | PBG |
| PBN-8904B | 648 | 2814 | 3/19/89 | 487,673 | 2,035,060 | 144.0 | 859.32 | 856.70 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-8904C | 649 | 2814 | 4/16/89 | 487,651 | 2,035,092 | 180.5 | 859.87 | 857.70 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8910A | 650 | 2814 | 2/22/89 | 491,156 | 2,035,501 | 128.0 | 889.82 | 886.80 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-8910B | 651 | 2814 | 2/28/89 | 491,159 | 2,035,539 | 166.7 | 892.09 | 889.10 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-8910C | 652 | 2814 | 2/3/89 | 491,154 | 2,035,464 | 192.0 | 887.11 | 884.70 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-8910D | 653 | 2814 | 4/29/89 | 491,142 | 2,035,388 | 237.0 | 884.42 | 880.90 | 4.0 | 5.0 | n/a | PZ | Sand | D | Not Sampled | PBG |
| PBN-9106C | 663 | 2814 | 10/22/91 | 487,104 | 2,035,032 | 201.0 | 848.71 | 846.10 | 3.8 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9106D | 664 | 2814 | 10/12/91 | 487,107 | 2,035,008 | 251.0 | 847.53 | 845.80 | 3.8 | 10.0 | n/a | PZ | Sand | D | Not Sampled | PBG |
| PBN-9302B | 670 | 2814 | 3/5/93 | 487,005 | 2,036,974 | 154.5 | 873.31 | 871.26 | 3.9 | 10.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9302C | 671 | 2814 | 2/26/93 | 487,017 | 2,036,966 | 204.0 | 873.76 | 872.24 | 3.9 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9302D | 672 | 2814 | 3/7/93 | 487,001 | 2,036,953 | 289.5 | 874.93 | 870.72 | 3.9 | 10.0 | 288 | PZ | Sand | D | Not Sampled | PBG |
| PBN-9304A | 684 | 2814 | 10/12/93 | 484,886 | 2,035,343 | 50.0 | 805.93 | 804.00 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-9304B | 685 | 2814 | 10/19/93 | 484,897 | 2,035,329 | 86.0 | 805.77 | 804.00 | 4.0 | 10.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9304C | 686 | 2814 | 10/21/93 | 484,866 | 2,035,315 | 115.0 | 806.41 | 804.50 | 4.0 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9306C | 667 | 2814 | 3/22/90 | 489,507 | 2,036,238 | 227.5 | 886.51 | 884.06 | 3.9 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9401B | 677 | 2814 | 8/8/94 | 486,957 | 2,038,337 | 127.7 | 852.23 | 850.50 | 4.0 | 10.3 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9401C | 678 | 2814 | 8/9/94 | 486,981 | 2,038,338 | 167.8 | 852.96 | 851.00 | 4.0 | 10.4 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9401D | 679 | 2814 | 8/3/94 | 486,971 | 2,038,337 | 267.0 | 853.01 | 850.90 | 4.0 | 10.0 | 277 | PZ | Sand | D | Not Sampled | PBG |
| PBN-9402B | 680 | 2814 | 8/24/94 | 485,560 | 2,038,160 | 95.5 | 816.36 | 813.90 | 4.0 | 10.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9402C | 681 | 2814 | 8/22/94 | 485,560 | 2,038,150 | 135.0 | 816.35 | 813.80 | 4.0 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9402D | 682 | 2814 | 8/18/94 | 485,557 | 2,038,140 | 225.0 | 816.14 | 813.70 | 4.0 | 10.0 | n/a | PZ | Sand | D | Not Sampled | PBG |
| PBN-9404AR | 676 | 2814 | 2/18/94 | 490,017 | 2,035,038 | 118.0 | 873.63 | 871.30 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-9901A | 696 | 2814 | 6/22/99 | 484,812 | 2,034,889 | 59.0 | 810.38 | 808.39 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-9901B | 697 | 2814 | 6/29/99 | 484,808 | 2,034,889 | 107.0 | 809.93 | 808.46 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9901C | 698 | 2814 | 6/28/99 | 484,799 | 2,034,890 | 163.0 | 810.00 | 808.45 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| PBN-9901D | 699 | 2814 | 6/23/99 | 484,790 | 2,034,891 | 216.0 | 810.95 | 808.52 | 4.0 | 5.0 | 216 | PZ | Sand | D | Not Sampled | PBG |
| PBN-9902A | 688 | 2814 | 6/22/99 | 484,805 | 2,035,024 | 60.0 | 811.54 | 808.91 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| PBN-9902B | 689 | 2814 | 7/8/99 | 484,803 | 2,035,020 | 111.0 | 810.72 | 808.41 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| PBN-9902C | 690 | 2814 | 7/7/99 | 484,800 | 2,035,029 | 168.0 | 811.23 | 809.16 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| S1109 | 600 | 2814 | 2/14/80 | 488,537 | 2,032,975 | 107.3 | 856.64 | 855.10 | 4.0 | 20.4 | n/a | OW | Sand | A | Not Sampled | PBG |
| S1117 | 601 | 2814 | 2/13/80 | 490,355 | 2,034,837 | 119.1 | 867.92 | 862.30 | 4.0 | 20.2 | n/a | OW | Sand | A | Not Sampled | PBG |
| SWN-0501B | 237 | 3493 | 12/15/05 | 480,635 | 2,039,879 | 155.6 | 860.07 | 860.40 | 4.0 | 10.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| SWN-0501C | 238 | 3493 | 12/13/05 | 480,634 | 2,039,894 | 206.6 | 860.28 | 860.60 | 4.0 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| SWN-0501D | 239 | 3493 | 12/9/05 | 480,635 | 2,039,906 | 262.9 | 860.38 | 860.50 | 4.0 | 10.0 | n/a | PZ | Sand | D | Not Sampled | PBG |

**Table 4**
**Monitoring Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | NAD83 Northing (feet) | NAD83 Easting (feet) | Well Depth (feet) | Top of Casing Elevation | Ground Elevation | Well Diameter (inches) | Screen Length (feet) | Bedrock Depth (feet) | Well Type | Aquifer | Screen Level | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SWN-0501E | 240 | 3493 | 11/30/05 | 480,635 | 2,039,917 | 290.3 | 860.53 | 860.70 | 2.0 | 10.0 | 253 | PZ | Rock | E | Not Sampled | PBG |
| SWN-0502B | 241 | 3493 | 12/22/05 | 479,887 | 2,039,265 | 155.8 | 856.10 | 856.30 | 4.0 | 10.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| SWN-0502C | 242 | 3493 | 12/20/05 | 479,885 | 2,039,280 | 201.5 | 856.39 | 856.50 | 4.0 | 10.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| SWN-0502D | 243 | 3493 | 12/7/05 | 479,886 | 2,039,273 | 244.9 | 856.19 | 856.30 | 4.0 | 10.0 | n/a | PZ | Sand | D | Not Sampled | PBG |
| SWN-0502E | 244 | 3493 | 12/13/05 | 479,893 | 2,039,267 | 260.0 | 856.27 | 856.50 | 2.0 | 10.0 | 240 | PZ | Rock | E | Not Sampled | PBG |
| S1102 | 701 | 3499 | 11/5/79 | 484,693 | 2,036,063 | 64.6 | 809.25 | 807.70 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| S1103 | 702 | 3499 | 11/2/79 | 484,689 | 2,036,056 | 120.1 | 809.02 | 807.50 | 4.0 | 5.1 | n/a | PZ | Sand | C | Not Sampled | PBG |
| S1106 | 705 | 3499 | 11/14/79 | 484,794 | 2,039,567 | 135.7 | 839.91 | 838.10 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| S1133 | 708 | 3499 | 2/19/80 | 484,746 | 2,032,920 | 97.0 | 828.28 | 828.20 | 4.0 | 5.2 | n/a | PZ | Sand | B | Not Sampled | PBG |
| S1149 | 711 | 3499 | 10/10/83 | 485,128 | 2,036,476 | 60.8 | 807.75 | 806.10 | 5.0 | 25.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| S1152AR | 727 | 3499 | 4/12/95 | 484,582 | 2,036,036 | 56.0 | 812.48 | 809.80 | 4.0 | 15.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| S1152B | 713 | 3499 | 9/26/85 | 484,582 | 2,036,049 | 73.6 | 813.26 | 810.30 | 4.0 | 5.0 | n/a | OW | Sand | B | Not Sampled | PBG |
| SPN-8901C | 714 | 3499 | 3/29/89 | 484,722 | 2,032,922 | 121.0 | 830.09 | 827.80 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| SPN-8902A | 715 | 3499 | 2/22/89 | 484,748 | 2,033,808 | 71.0 | 823.67 | 820.80 | 4.0 | 20.0 | n/a | OW | Sand | A | Not Sampled | PBG |
| SPN-8902B | 716 | 3499 | 3/15/89 | 484,741 | 2,033,827 | 98.8 | 823.61 | 820.30 | 4.0 | 5.0 | n/a | PZ | Sand | B | Not Sampled | PBG |
| SPN-8902C | 717 | 3499 | 4/14/89 | 484,745 | 2,033,868 | 129.0 | 822.48 | 820.00 | 4.0 | 5.0 | n/a | PZ | Sand | C | Not Sampled | PBG |
| SPN-9102D | 724 | 3499 | 10/9/91 | 484,733 | 2,033,650 | 182.8 | 824.11 | 821.60 | 3.8 | 10.0 | n/a | PZ | Sand | D | Not Sampled | PBG |

Notes

OW = Water Table Observation Well
PZ = Piezometer
DBG = Deterrent Burning Ground Plume
Central = Central Plume
PBG = Propellant Burning Ground Plume
Screen Level references the typical well depth configuration

**Table 5**
**Residential Well Construction Information – Sampling Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer | Sample Frequency | Plume Area |
|---|---|---|---|---|---|---|---|---|---|
| USDA 1 | 828 | 3497 | 11/4/79 | 575 | 12 | 263 | Rock | Annual | Central |
| USDA 2 | 829 | 3497 | 7/18/96 | 227 | 6 | n/a | Sand | Annual | Central |
| USDA 3 | 126 | 3497 | 10/21/80 | 270 | 6 | 235 | Rock | Annual | Central |
| USDA 6 | 128 | 3497 | 3/7/06 | 140 | 8 | n/a | Sand | Annual | Central |
| WE-QN039 | 158 | 3497 | 11/15/01 | 100 | 6 | n/a | Sand | Annual | Central |
| WE-QR441 | 157 | 3497 | 1/29/02 | 118 | 5 | n/a | Sand | Annual | Central |
| WE-RD430 | 159 | 3497 | 12/10/02 | 80 | 6 | n/a | Sand | Annual | Central |
| WE-RM383 | 153 | 3497 | 6/10/03 | 81 | 6 | n/a | Sand | Annual | Central |
| WE-RR542 | 156 | 3497 | 9/20/03 | 100 | 6 | n/a | Sand | Annual | Central |
| WE-RR598 | 169 | 3497 | 3/10/04 | 106 | 6 | n/a | Sand | Annual | Central |
| WE-SQ001 | 165 | 3497 | 1/15/05 | 179 | 6 | n/a | Sand | Annual | Central |
| WE-SQ002 | 170 | 3497 | 1/20/05 | 100 | 6 | n/a | Sand | Annual | Central |
| WE-SQ017 | 164 | 3497 | 3/10/05 | 180 | 5 | n/a | Sand | Annual | Central |
| WE-TF023 | 174 | 3497 | 2/22/06 | 178 | 5 | n/a | Sand | Annual | Central |
| WE-TM599 | 129 | 3497 | 10/2/06 | 120 | 5 | n/a | Sand | Annual | Central |
| WE-UA297 | 433 | 3497 | 7/17/07 | 180 | 6 | n/a | Sand | Annual | Central |
| WE-UK125 | 431 | 3497 | 12/29/07 | 283 | 5 | 243 | Rock | Annual | Central |
| WE-XD828 | 434 | 3497 | 8/19/13 | 80 | 6 | n/a | Sand | Annual | Central |
| WE-XK342 | 435 | 3497 | 8/27/14 | 80 | 6 | n/a | Sand | Annual | Central |
| WE-YW972 | 436 | 3497 | 5/14/18 | 121 | 6 | n/a | Sand | Annual | Central |
| WE-ZE512 | 437 | 3497 | 12/22/18 | 324 | 6 | 205 | Rock | Quarterly | Central |
| Anderson-R | 411 | 3497 |  | 26 | n/a | n/a | Sand | Annual | DBG |
| Brey | 817 | 3497 |  | 85 | 6 | n/a | Sand | Annual | DBG |
| Curto | 412 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Gibbs | 839 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Grosse | 415 | 3497 |  | 110 | n/a | n/a | Sand | Annual | DBG |
| Groth | 842 | 3497 | 1/5/89 | 219 | 6 | 169 | Rock | Annual | DBG |
| Gruber-D | 417 | 3497 |  | n/a | n/a | n/a | Sand | Annual | DBG |
| Hendershot | 418 | 3497 |  | 20 | n/a | n/a | Sand | Annual | DBG |
| Howery | 419 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Kopras | 874 | 3497 | 5/28/88 | 260 | 6 | 217 | Rock | Annual | DBG |
| Lukens | 860 | 3497 | 7/25/08 | 29 | 1 | n/a | Sand | Annual | DBG |
| Melum | 423 | 3497 | 7/6/06 | 100 | 5 | n/a | Sand | Annual | DBG |
| Nowotarski | 891 | 3497 | 11/16/99 | 88 | 2 | n/a | Sand | Annual | DBG |
| Olah | 904 | 3497 |  | 30 | n/a | n/a | Sand | Annual | DBG |
| Osterland | 422 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Purcell-D | 163 | 3497 | 7/26/19 | 344 | 6 | 216 | Rock | Quarterly | DBG |
| Purcell-G | 916 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Raschein | 424 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Reif | 427 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Revers | 425 | 3497 | 5/8/89 | 80 | 6 | n/a | Sand | Annual | DBG |
| Roll | 426 | 3497 |  | n/a | n/a | n/a | unknown | Annual | DBG |
| Schumann | 428 | 3497 |  | n/a | n/a | n/a | Sand | Annual | DBG |
| Spear | 803 | 3497 | 3/1/93 | 159 | n/a | n/a | Sand | Annual | DBG |
| Wenger | 414 | 3497 |  | n/a | n/a | n/a | Sand | Annual | DBG |
| Zurbachen-A | 967 | 3497 | 8/28/78 | 176 | 6 | 173 | Rock | Annual | DBG |
| Apel | 998 | 3497 | 11/21/92 | 178 | 6 | n/a | Sand | Annual | PBG |
| Delaney | 152 | 3497 | 8/25/99 | 301 | 6 | 265 | Rock | Annual | PBG |
| Judd | 862 | 3497 |  | 180 | n/a | n/a | Sand | Annual | PBG |
| Krumenauer | 875 | 3497 | 4/8/90 | 156 | 6 | n/a | Sand | Annual | PBG |
| Mittenzwei | 800 | 3497 |  | 131 | n/a | n/a | Sand | Annual | PBG |
| PDS-3 | 911 | 3497 | 6/11/91 | 554 | 15 | 186 | Rock | Annual | PBG |
| Ramaker-J | 917 | 3497 |  | 310 | n/a | n/a | Rock | Annual | PBG |
| Schlender | 931 | 3497 |  | 280 | n/a | n/a | Rock | Annual | PBG |

Notes

DBG = Deterrent Burning Ground Plume
Central = Central Plume
PBG = Propellant Burning Ground Plume

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| Anderson | 804 | 3497 | | n/a | n/a | n/a | unknown |
| Andres | 631 | 3497 | 2016 | n/a | n/a | n/a | Sand |
| Andres | 130 | 3497 | | n/a | n/a | n/a | unknown |
| Askey-1 | 178 | 3497 | 8/6/49 | 166 | 6 | n/a | Sand |
| Askey-2 | 932 | 3497 | 3/12/77 | 256 | 6 | 200 | Rock |
| Ballweg | 131 | 3497 | | n/a | n/a | n/a | unknown |
| Bauer | 807 | 3497 | 9/18/79 | 65 | 6 | n/a | Sand |
| Behrens | 197 | 3497 | | n/a | n/a | n/a | unknown |
| Bender | 119 | 3497 | | n/a | n/a | n/a | unknown |
| Bickford-1 | 809 | 3497 | 2/13/67 | 187 | 18 | n/a | Sand |
| Bickford-2 | 810 | 3497 | 2/13/67 | 152 | 18 | n/a | Sand |
| Bickford-D | 808 | 3497 | 6/30/65 | 152 | 18 | n/a | Sand |
| Block | 117 | 3497 | 7/26/01 | 101 | 6 | n/a | Sand |
| Bluffview #1 | 813 | 3497 | 5/31/60 | 280 | 8 | 175 | Rock |
| Bluffview #2 | n/a | 3497 | 1/1/60 | n/a | 8 | n/a | Sand |
| Bluffview #3 | n/a | 3497 | 4/22/42 | 435 | 16 | 199 | Rock |
| Brabender | 171 | 3497 | | n/a | n/a | n/a | unknown |
| Bram | 168 | 3497 | 1/1/94 | n/a | n/a | n/a | unknown |
| Carlson | 124 | 3497 | | n/a | n/a | n/a | unknown |
| Checky | 132 | 3497 | | 126 | 5 | n/a | Sand |
| Christie | 820 | 3497 | | n/a | n/a | n/a | unknown |
| Clark-M | 821 | 3497 | | n/a | n/a | n/a | unknown |
| Clark-S | 822 | 3497 | | n/a | n/a | n/a | unknown |
| Co-op County Partners | 948 | 3497 | 6/20/88 | 276 | 6 | n/a | Sand |
| Coves Court | 147 | 3497 | | 372 | 8 | 196 | Rock |
| Cramer | 825 | 3497 | | n/a | n/a | n/a | unknown |
| YR846 | 628 | 3497 | 10/18/16 | 120 | 5 | n/a | Sand |
| Crow | 160 | 3497 | | n/a | n/a | n/a | unknown |
| Dahir | 827 | 3497 | | n/a | n/a | n/a | unknown |
| Danube | 830 | 3497 | | n/a | n/a | n/a | unknown |
| Delaney-L | 175 | 3497 | 10/1/74 | 263 | 6 | 225 | Rock |
| Deppe | 413 | 3497 | | n/a | n/a | n/a | Sand |
| Dischler-B | 926 | 3497 | | n/a | n/a | n/a | unknown |
| Dorman | 182 | 3497 | | n/a | n/a | n/a | unknown |
| Dybul | 133 | 3497 | | n/a | n/a | n/a | Sand |
| Dyrud-Witte | 907 | 3497 | 7/23/74 | 178 | 6 | 140 | Rock |
| E12671 | 609 | 3497 | | n/a | n/a | n/a | Sand |
| E12680 | 611 | 3497 | | n/a | n/a | n/a | Sand |
| E12690A | 613 | 3497 | | n/a | n/a | n/a | Sand |
| E12734 | 621 | 3497 | | n/a | n/a | n/a | Sand |
| E12742 | 622 | 3497 | | n/a | n/a | n/a | Sand |
| Eilertson-N | 929 | 3497 | 10/17/69 | 120 | 6 | n/a | Sand |
| Eilertson-S | 834 | 3497 | 9/14/83 | 290 | 6 | n/a | Rock |

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| Elsing | 194 | 3497 | 8/2/99 | 275 | 6 | n/a | Sand |
| Emery | 167 | 3497 | 1/1/91 | n/a | n/a | n/a | unknown |
| Engh | 184 | 3497 | 10/21/74 | 288 | 6 | 240 | Rock |
| Fehn | 121 | 3497 | | n/a | n/a | n/a | unknown |
| Fenbert | 902 | 3497 | | n/a | n/a | n/a | unknown |
| Fentress | 195 | 3497 | | n/a | n/a | n/a | unknown |
| Ferry | 836 | 3497 | 10/12/44 | 178 | 6 | n/a | Sand |
| Franks | 134 | 3497 | | n/a | n/a | n/a | unknown |
| Ganser | 187 | 3497 | 10/20/89 | 273 | 6 | 228 | Rock |
| Gasner | 113 | 3497 | | n/a | n/a | n/a | unknown |
| Gentz | 865 | 3497 | | 100 | n/a | n/a | Sand |
| Gjertson | 196 | 3497 | | n/a | n/a | n/a | unknown |
| Gleason | 135 | 3497 | 8/8/92 | 242 | 5 | n/a | Sand |
| Goelz | 173 | 3497 | | n/a | n/a | n/a | unknown |
| Goette | 845 | 3497 | 10/31/01 | 570 | 6 | n/a | Rock |
| Greimel | 841 | 3497 | | n/a | n/a | n/a | unknown |
| Grosse-garage | 416 | 3497 | | n/a | n/a | n/a | Sand |
| Gruber-North | 970 | 3497 | 8/25/75 | 240 | 6 | 170 | Rock |
| Haasl | 189 | 3497 | 11/29/73 | 270 | 6 | 245 | Rock |
| Halweg-J | 846 | 3497 | | n/a | n/a | n/a | unknown |
| Hankins | 847 | 3497 | 9/16/08 | 221 | 6 | 206 | Rock |
| Hannah | 848 | 3497 | | n/a | n/a | n/a | unknown |
| Hanson | 963 | 3497 | 4/9/90 | 307 | 6 | 278 | Rock |
| Harpold | 918 | 3497 | | 206 | 6 | 198 | Rock |
| Hasheider | 852 | 3497 | 7/8/87 | 198 | 6 | n/a | Sand |
| Heidenreich | 853 | 3497 | 3/25/82 | 235 | 6 | n/a | Rock |
| Henning | 854 | 3497 | | n/a | n/a | n/a | unknown |
| Henry | 855 | 3497 | 10/15/82 | 75 | 6 | n/a | Sand |
| Herr | 136 | 3497 | | 191 | 6 | n/a | Sand |
| Hill | 137 | 3497 | | 97 | 6 | n/a | Sand |
| Hutter-R | 857 | 3497 | | n/a | n/a | n/a | unknown |
| IA214 | n/a | 3497 | 10/31/94 | 625 | 6 | 169 | Rock |
| Jackson | 176 | 3497 | 12/7/95 | 255 | 6 | 225 | Rock |
| Jacobson | 185 | 3497 | | n/a | n/a | n/a | unknown |
| Jannenga | 188 | 3497 | 7/17/74 | 272 | 6 | 230 | Rock |
| Jewell | 859 | 3497 | | n/a | n/a | n/a | unknown |
| Johnson | 138 | 3497 | | 102 | 6 | n/a | Sand |
| Johnson-K | 139 | 3497 | | 150 | 6 | n/a | Sand |
| Jonas | 115 | 3497 | | n/a | n/a | n/a | unknown |
| Jones | 889 | 3497 | | n/a | n/a | n/a | unknown |
| Kamps | 863 | 3497 | 8/19/77 | 267 | 6 | 225 | Rock |
| Kaufman/Schmitz | 183 | 3497 | 10/3/76 | 263 | 6 | 237 | Rock |

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| Kindschi-1 | 867 | 3497 | 5/26/77 | 140 | 14 | n/a | Sand |
| Kindschi-3 | n/a | 3497 | | n/a | n/a | n/a | Sand |
| Kindschi-3 | 868 | 3497 | 2/19/82 | 181 | 14 | n/a | Sand |
| Kindschi-4 | n/a | 3497 | | n/a | n/a | n/a | Sand |
| Kindschi-A | 866 | 3497 | | n/a | n/a | n/a | unknown |
| Kindschi-J | 869 | 3497 | | n/a | n/a | n/a | unknown |
| Kindschi-V | 870 | 3497 | | n/a | n/a | n/a | unknown |
| Kirner | 843 | 3497 | 2/27/91 | 534 | 5 | 226 | Rock |
| Klepper | 140 | 3497 | | 101 | 5 | n/a | Sand |
| Kohlman | 109 | 3497 | | n/a | n/a | n/a | unknown |
| Kowalke | 181 | 3497 | | n/a | n/a | n/a | unknown |
| Kyori | 826 | 3497 | | n/a | n/a | n/a | unknown |
| Lang | 877 | 3497 | 6/12/97 | 325 | 6 | 202 | Rock |
| Lautenbach | 600 | 3497 | 8/7/18 | 80 | 6 | n/a | Sand |
| Lenerz | 193 | 3497 | 7/13/05 | 276 | 6 | 230 | Rock |
| Lins-2 | n/a | 3497 | | 162 | n/a | n/a | Sand |
| Lins-4 | n/a | 3497 | | 190 | n/a | n/a | Sand |
| Lins-K | 878 | 3497 | 3/21/96 | 288 | 6 | 248 | Rock |
| Lins-R | 879 | 3497 | | 275 | n/a | 240 | Rock |
| Lochner | 880 | 3497 | | n/a | n/a | n/a | unknown |
| Lohr | 881 | 3497 | | n/a | n/a | n/a | unknown |
| Lund | 420 | 3497 | 8/7/06 | 100 | 5 | n/a | Sand |
| Lytle | 915 | 3497 | | n/a | n/a | n/a | unknown |
| Maple Park Condos | 166 | 3497 | 9/24/64 | 270 | 8 | 165 | Rock |
| Markgraf | 885 | 3497 | 10/8/57 | 236 | 6 | 223 | Rock |
| Maschman | 120 | 3497 | 10/30/96 | 117 | 5 | n/a | Sand |
| Matz-Gary | 179 | 3497 | 8/11/77 | 248 | 6 | 210 | Rock |
| Matz-Terry | 886 | 3497 | 8/10/59 | 122 | 4 | n/a | Sand |
| McAuliffe-J | 887 | 3497 | 12/20/88 | 300 | 6 | 242 | Rock |
| McClaren | 890 | 3497 | | n/a | n/a | n/a | unknown |
| McCoy | 177 | 3497 | 6/8/81 | 249 | 6 | n/a | Sand |
| Meier | 953 | 3497 | 1/6/44 | 187 | 6 | n/a | Sand |
| Mittenzwei-2 | 141 | 3497 | | n/a | n/a | n/a | unknown |
| MK967 | n/a | 3497 | 10/19/98 | 122 | 6 | n/a | Sand |
| Moely-B | 979 | 3497 | | 100 | n/a | n/a | Sand |
| Mohrbacher | 142 | 3497 | | n/a | n/a | n/a | unknown |
| Mueller-A | 896 | 3497 | 2/6/80 | 164 | 12 | n/a | unknown |
| Mueller-C | 897 | 3497 | 12/23/67 | 240 | 6 | n/a | unknown |
| Mueller-J | 899 | 3497 | 2/20/91 | 523 | 5 | 224 | Rock |
| Mueller-S | 895 | 3497 | | n/a | n/a | n/a | unknown |
| Mueller-SM | 894 | 3497 | | n/a | n/a | n/a | unknown |
| Mullen | 900 | 3497 | | n/a | n/a | n/a | unknown |

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| Nelson | 905 | 3497 | 2/28/74 | 280 | 6 | 250 | Rock |
| Nelson-D | 901 | 3497 | | 179 | 6 | n/a | Sand |
| Nolden | n/a | 3497 | | 198 | n/a | n/a | Sand |
| Ohlsen | 903 | 3497 | | n/a | n/a | n/a | unknown |
| Orbitec | 324 | 3497 | 9/15/08 | 160 | 6 | 100 | Rock |
| Paulson | 123 | 3497 | | n/a | n/a | n/a | unknown |
| PDS Dam | 961 | 3497 | 5/15/95 | 285 | 6 | 192 | Rock |
| PDS-4 | n/a | 3497 | 3/23/12 | 580 | 30 | n/a | Rock |
| Peetz | 906 | 3497 | | n/a | n/a | n/a | unknown |
| Pierce | 143 | 3497 | | n/a | n/a | n/a | unknown |
| Powell | 833 | 3497 | 6/21/78 | 191 | 6 | n/a | Sand |
| Premo | 801 | 3497 | | 122 | n/a | n/a | Sand |
| Price | 180 | 3497 | | n/a | n/a | n/a | unknown |
| Priebe | 913 | 3497 | 4/15/57 | 76 | 9 | n/a | Sand |
| Raetzke | 940 | 3497 | 9/28/79 | 100 | 6 | n/a | Sand |
| Ramaker | 144 | 3497 | | 82 | 6 | n/a | Sand |
| Raschka | 148 | 3497 | | 120 | 5 | n/a | Sand |
| Richards | 118 | 3497 | | n/a | n/a | n/a | unknown |
| Riley | 122 | 3497 | | n/a | n/a | n/a | unknown |
| Riley-M | 145 | 3497 | | n/a | n/a | n/a | unknown |
| Robertson | 640 | 3497 | | n/a | n/a | n/a | Sand |
| Rodgers | 146 | 3497 | | 140 | 5 | n/a | Sand |
| Roth-G | 924 | 3497 | 5/26/88 | 298 | 6 | 231 | Rock |
| Roth-John | 192 | 3497 | 9/26/88 | 298 | 6 | 250 | Rock |
| Ruhland | 927 | 3497 | | n/a | n/a | n/a | unknown |
| SC375 | 637 | 3497 | 6/22/04 | 142 | 6 | n/a | Sand |
| SC388 | 610 | 3497 | 7/19/04 | 82 | 6 | n/a | Sand |
| Schwarz | 198 | 3497 | | n/a | n/a | n/a | unknown |
| Sereg | 933 | 3497 | | 175 | n/a | n/a | Sand |
| Shimniok | 934 | 3497 | | n/a | n/a | n/a | unknown |
| Sinklair-1 | 110 | 3497 | 4/10/00 | 130 | 6 | n/a | Sand |
| Sinklair-2 | 111 | 3497 | | n/a | n/a | n/a | unknown |
| Sinklair-3 | 112 | 3497 | | n/a | n/a | n/a | unknown |
| SMD | 172 | 3497 | | n/a | n/a | n/a | unknown |
| Smith | 114 | 3497 | 6/13/96 | 35 | 2 | n/a | Sand |
| Spurgeon | 190 | 3497 | 9/16/76 | 256 | 6 | 215 | Rock |
| Stensberg | 162 | 3497 | 6/16/69 | 265 | 6 | 200 | Rock |
| Stepenske | 858 | 3497 | 9/13/86 | 150 | 6 | n/a | Sand |
| Steuber | 944 | 3497 | | n/a | n/a | n/a | unknown |
| Stima | 942 | 3497 | | n/a | n/a | n/a | unknown |
| Stratton | 943 | 3497 | | n/a | n/a | n/a | unknown |
| SU393 | 641 | 3497 | 4/5/05 | 129 | 6 | n/a | Sand |

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| Summer Oaks | 945 | 3497 | 9/1/81 | 320 | 6 | 185 | Rock |
| SWS2 | n/a | 3497 | | n/a | n/a | n/a | unknown |
| Tesch | 947 | 3497 | | n/a | n/a | n/a | unknown |
| TG671 | 633 | 3497 | 1/26/06 | 141 | 6 | n/a | Sand |
| TR267 | 615 | 3497 | 4/26/04 | 97 | 5 | n/a | Sand |
| Troestler | 186 | 3497 | 6/1/77 | 279 | 6 | 255 | Rock |
| TS854 | 626 | 3497 | | 100 | 5 | n/a | Sand |
| Tschudy-Herman | 950 | 3497 | | n/a | n/a | n/a | unknown |
| Tschudy-Herman 2 | 108 | 3497 | 5/5/99 | 79 | 6 | n/a | Sand |
| TU541 | 638 | 3497 | 4/4/05 | 140 | 5 | n/a | Sand |
| TU813 | 635 | 3497 | 5/17/05 | 120 | 5 | n/a | Sand |
| TV887 | 604 | 3497 | 8/2/05 | 76 | 5 | n/a | Sand |
| Unger | 199 | 3497 | | n/a | n/a | n/a | unknown |
| Urban | 161 | 3497 | 4/29/80 | 275 | 6 | 225 | Rock |
| USDA 4 | 127 | 3497 | 3/15/94 | 273 | 6 | 238 | Rock |
| Valley of Our Lady | 954 | 3497 | | 565 | 6 | 190 | Rock |
| VM039 | 632 | 3497 | 2/22/06 | 120 | 5 | n/a | Sand |
| Volker | 952 | 3497 | 4/8/75 | 258 | 6 | 175 | Rock |
| Wells | 991 | 3497 | 5/23/89 | 108 | 6 | n/a | Sand |
| Werderits | 116 | 3497 | 10/2/90 | 67 | 6 | n/a | Sand |
| Weum | 802 | 3497 | 7/7/01 | 158 | 5 | n/a | Sand |
| Weynand | 939 | 3497 | | n/a | n/a | n/a | Sand |
| Wicklund | 957 | 3497 | | n/a | n/a | n/a | unknown |
| Wiley | 958 | 3497 | | n/a | n/a | n/a | unknown |
| Witte | 962 | 3497 | | n/a | n/a | n/a | unknown |
| Woods | 429 | 3497 | 9/12/98 | 86 | 6 | n/a | Sand |
| WW440 | n/a | 3497 | 3/12/12 | 505 | n/a | 53 | Rock |
| XE308 | 939 | 3497 | 6/14/13 | 35 | 1 | n/a | Sand |
| XG515 | 618 | 3497 | 11/25/13 | 119 | 6 | n/a | Sand |
| XG526 | 614 | 3497 | 3/6/14 | 120 | 6 | n/a | Sand |
| XG527 | 639 | 3497 | 3/7/14 | 142 | 6 | n/a | Sand |
| XI081 | 620 | 3497 | 12/3/13 | 99 | 5 | n/a | Sand |
| XL970 | 617 | 3497 | 9/9/14 | 122 | 6 | n/a | Sand |
| XP869 | 616 | 3497 | 8/5/15 | 118 | 6 | n/a | Sand |
| XR620 | 602 | 3497 | 9/1/15 | 86 | 4 | n/a | Sand |
| XT998 | 605 | 3497 | 2/23/16 | 71 | 4 | n/a | Sand |
| XU003 | 606 | 3497 | 3/30/16 | 80 | 4 | n/a | Sand |
| XW317 | 608 | 3497 | 7/20/16 | 92 | 4 | n/a | Sand |
| XW533 | 627 | 3497 | 5/4/16 | 120 | 5 | n/a | Sand |
| Yanke | 191 | 3497 | 9/13/77 | 307 | 6 | 285 | Rock |
| YF504 | 612 | 3497 | 3/31/11 | 100 | 5 | n/a | Sand |
| YJ530 | 636 | 3497 | 7/21/13 | 120 | 5 | n/a | Sand |

**Table 6**
**Residential Well Construction Information – Sampling Not Required by WDNR**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well Name | Well ID | License | Date Installed | Well Depth (feet) | Well Diameter (inches) | Bedrock Depth (feet) | Aquifer |
|---|---|---|---|---|---|---|---|
| YL970 | 645 | 3497 | 11/14/14 | 100 | 5 | n/a | Sand |
| YM397 | n/a | 3497 | 5/12/15 | 180 | 6 | n/a | Sand |
| YP340 | 623 | 3497 | 2/23/16 | 79 | 5 | n/a | Sand |
| YQ555 | 630 | 3497 | 6/9/16 | 118 | 5 | n/a | Sand |
| YR160 | 601 | 3497 | 8/17/16 | 100 | 5 | n/a | Sand |
| YR845 | 629 | 3497 | 10/18/16 | 119 | 5 | n/a | Sand |
| YR846 | 628 | 3497 | 10/18/16 | 120 | 5 | n/a | Sand |
| Zander | 849 | 3497 | 9/16/45 | 229 | 6 | n/a | Sand |
| Zeck | 964 | 3497 | 10/11/72 | 240 | 6 | n/a | unknown |
| Zick | 965 | 3497 | 8/26/97 | 141 | 6 | n/a | Sand |
| Zick-2 | 125 | 3497 | 1/23/06 | 117 | 6 | n/a | Sand |
| ZS447 | 619 | 3497 | 7/26/18 | 93 | 5 | n/a | Sand |
| Zurbachen-D | 968 | 3497 |  | n/a | n/a | n/a | unknown |

## 4.3 Well Identification and Designation

All sampled monitoring wells and residential wells are given a unique three-digit numeric well ID, i.e. 360. This well ID is used to track the well data in the on-site groundwater databases as well as the WDNR's on-line accessible Groundwater and Environmental Monitoring System (GEMS) database.

In general, groundwater monitoring wells are identified by a three-part alphanumeric code, i.e. PBN-1404B. The first two letters of the well identification are determined by the source area or waste management unit, i.e. BG, DB, EL, NL, NP, RI, PB, SE, and SP. The exception to this is the "S" series wells installed in the 1980s. The third letter determines if the well is part of a well nest "N" or a stand-alone water table monitoring well "M". The next two numbers determine what year the well was installed, i.e. 2010 = 10 or 2015 = 15. The last two numbers indicate the order that well was installed during that year, i.e. 05 is the fifth well installed that year for that source area. The last letter determines the vertical positioning of the well screen. Wells labeled "A" are screened at or near the water table surface. Wells labeled "B" are screened below the water table, approximately 1/3 of the depth between the water table and bedrock. Wells labeled "C" are screened below the water table, approximately 2/3 of the depth between the water table and bedrock. Wells labeled "D" are screened below the water table and just above the top of the bedrock. Wells labeled "E" are screened below the water table and below the top of the bedrock. Wells labeled "F" are screened below the confining layer of bedrock (shale) in a lower bedrock aquifer. The static groundwater level in an "F" well is higher than the water table and indicates an artesian condition. There are exceptions to the well depth labeling as some monitoring wells installed during the 1980s were drilled shallower than the 1/3 or 2/3 distance between the water table and bedrock.

## 4.4 Groundwater Properties

### *4.4.1 Water Level Elevation and Flow Direction*

Water level data collected from BAAP monitoring wells indicate groundwater depths ranging from 22 to 144 feet bgs or 744 to 788 feet above mean sea level (MSL). Figure 16 is a representation of the groundwater elevation surface in September 2017. The groundwater contours shown in Figure 16 are drawn at 5-foot intervals. The groundwater flow direction is generally to the south-southeast. In the southeast corner of BAAP, groundwater flow is deflected slightly to the south, due to influences from Lake Wisconsin. Due to the large number of monitoring wells, the elevation measurements for a sampling round are taken within a 30-day period. Due to the groundwater being highly conductive, the groundwater table does not radically change after precipitation and snowmelt events. The Lake Wisconsin Reservoir, located to the east and southeast of BAAP, is formed by the WP&L dam, which results in a constant lake elevation of approximately 774 feet MSL. Below the dam, the water elevation drops abruptly to 736 feet MSL as the lake reverts to the flowing Wisconsin River. The rapid change in water elevations at the dam results in a dramatic hydraulic drop in groundwater elevations around the dam. Groundwater discharges to the Reservoir in the northeastern portion of BAAP. The Reservoir discharges to the sand and gravel aquifer when adjacent groundwater levels are lower than the Reservoir level. About three miles north of the WP&L dam, the

Reservoir transitions from recharging to discharging to the underlying sand and gravel aquifer. Directly south of the WP&L dam, the Wisconsin River resumes with groundwater discharging to the river.

Figure 17 depicts the groundwater contours near the PBG during September 2017. The groundwater contours shown in Figure 17 are drawn at 0.5-foot intervals. This small contour interval was chosen to show the variability in the groundwater surface. The engineered cap (geomembrane barrier and compacted clay) of the 1949 Pit and PBG Waste Pits influences the local groundwater flow. The engineered cap restricts rainwater from percolating below the cap and into the unsaturated soil beneath the cap. The surface of the engineered cap is sloped at a 5% grade towards the west, which then directs rainwater to the west. Surface water drainage ditches surround the engineered cap on the east, north, and south sides. These ditches divert rainwater towards the west and away from the PBG source area. Depression contours 778 and 778.5 feet MSL are shown through the PBG Waste Pits. The groundwater contours shown in Figure 17 show that the cap is protecting the subsurface by reducing infiltration into the groundwater.

### *4.4.2 Hydraulic Conductivity*

Hydraulic conductivity values were calculated based on aquifer testing at two former MIRM extraction wells located near the PBG in 2005. The aquifer tests, which were comprised of a pump test followed by a step test, were conducted at former extraction wells EW-169 in February 2005 and at EW-167 in March 2005. The tests were conducted by continuously pumping the extraction wells over a period of time and measuring the drawdown in nearby observation wells. Observation wells (PBN-8504A, PBM-8505, and PBM-8904C) were monitored for the test at EW-169, which lasted two- and one-half days. The aquifer test at EW-169 yielded a hydraulic conductivity value between $1.39x10^{-02}$ to $6.27x10^{-02}$ centimeters per second (cm/sec). The aquifer test at extraction well EW-167 lasted seven days and drawdown was measured in four nearby observation wells (PBM-8503, PBN-8502A, PBN-8901C, and PBN-8902C). The results of this testing yielded a hydraulic conductivity value between $4.85x10^{-02}$ and $9.60x10^{-02}$ cm/sec. Testing methodology is presented in further detail in the *Draft Corrective Measures Implementation Report, MIRM Extraction Well Realignment Project* (Shaw Environmental, Inc., 2006).

During the RI (ABB-ES, 1993), slug tests were performed on monitoring wells across the BAAP. The 1993 RI report included hydraulic conductivity values for many monitoring wells. Table 7 summarizes the hydraulic conductivity data for each of the four groundwater plumes. The average calculated hydraulic conductivity of 25 monitoring wells in the PBG Plume was $4.2x10^{-02}$ cm/sec. The hydraulic conductivity values obtained during the MIRM pump tests correlated well with the average value obtained from the 1993 RI slug tests. The average calculated hydraulic conductivity of 17 monitoring wells in the DBG Plume was $2.5x10^{-02}$ cm/sec. There was limited slug test data from the 1993 RI report for monitoring wells in the Central Plume. Slug test data was collected during 2010 from three monitoring wells associated with Landfill 3646 (*Feasibility Report Contiguous Addition to Landfill 3646, SpecPro, Inc., October 2010*). These three monitoring wells are located in northeast corner of the Central Plume (see Figure 18). The average calculated hydraulic conductivity of three monitoring wells in the Central Plume was $3.7x10^{-02}$ cm/sec. There is no available hydraulic conductivity data for monitoring wells associated with the NC Area Plume. Due to the similarities in soil types between the PBG Plume and NC Area Plume, the PBG Plume hydraulic conductivity value of $4.2x10^{-02}$ cm/sec is being used for the NC Area Plume.

### *4.4.3 Hydraulic Gradient*

Monitoring wells are screened at various depths and assigned an alphabetical designation after the number of the well ID. Letter designation A is the shallow water table interval, and B, C, D, E, and F are piezometric intervals that increase in depth from B to F. The piezometers ending in E were constructed so that the screen was located in the bedrock. It should be noted that the unconsolidated sand and gravel aquifer is unconfined vertically.

As evident from the groundwater elevation map showing the September 2017 data (Figure 16), the area south of BAAP has a much steeper horizontal hydraulic gradient than the area to the north. Data sets from each groundwater plume were used to calculate horizontal hydraulic gradient. Groundwater elevations from the sampling periods of September 2017, April 2018, and September 2018 were used to calculate an average hydraulic gradient for each plume area shown in Table 8. The average hydraulic gradient calculated for the PBG area wells was 0.00183 feet per foot (ft/ft). The average hydraulic gradient calculated for the DBG area wells was 0.00108 ft/ft. The hydraulic gradient calculated for the Central Plume area wells was 0.00097 ft/ft. The average hydraulic gradient calculated for the NC area wells was 0.00079 ft/ft.

Vertical groundwater movement is evaluated by comparing groundwater levels from the different aquifer layers to determine vertical gradient. Monitoring well clusters, where two or more wells have screens positioned at different depths within the aquifer, are used to examine differences in the potentiometric groundwater surface between different layers of the aquifer. Vertical hydraulic gradients were evaluated for nested well pairs in the four plume areas. Table 9 summarizes the vertical groundwater gradients for the chosen well nests. Gradients were evaluated from the groundwater elevation data collected during the September 2017, April 2018, and September 2018 monitoring events. Positive vertical gradients indicate groundwater is flowing upward and negative vertical gradients indicated groundwater is flowing downward.

Four of the seven well pairs in the PBG exhibited an upward vertical groundwater gradient between deep to shallow wells; which would hinder groundwater contaminants from migrating deeper into the sand aquifer. All the DBG well pairs exhibited a downward vertical groundwater gradient between shallow to deep wells; which would allow groundwater contaminants to migrate deeper into the sand aquifer. Three of the four well pairs in the Central Plume exhibited an upward vertical groundwater gradient between deep to shallow wells; which would hinder groundwater contaminants from migrating deeper into the sand aquifer. The two well pairs in the NC Area Plume exhibited an upward vertical groundwater gradient between deep to shallow wells; which would hinder groundwater contaminants from migrating deeper into the sand aquifer.

**Table 7**
**Field Hydraulic Conductivity Test Results**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Plume Area | Well | Level Type | Hydraulic Conductivity (cm/sec) | Soil Type at Screen Interval | Reference |
|---|---|---|---|---|---|
| PBG | PBM-8911 | A | $4x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8203B | B | $1x10^{-3}$ | Sand | 1993 RI |
| PBG | PBN-8203C | C | $7x10^{-4}$ | Sand | 1993 RI |
| PBG | PBN-8901B | B | $3x10^{-2}$ | Gravel with sand | 1993 RI |
| PBG | PBN-8901C | C | $3x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8901D | D | $5x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8902B | B | $1x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8902C | C | $2x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8903B | B | $1x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8903C | C | $4x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8904C | C | $2x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8910B | B | $2x10^{-1}$ | Gravel with sand | 1993 RI |
| PBG | PBN-8910C | C | $2x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-8910D | D | $5x10^{-2}$ | Sand with gravel | 1993 RI |
| PBG | PBN-9106C | C | $2x10^{-2}$ | Sand | 1993 RI |
| PBG | PBN-9112C | C | $8x10^{-3}$ | Sand | 1993 RI |
| PBG | PBN-9112D | D | $3x10^{-2}$ | Sand | 1993 RI |
| PBG | LON-8902B | B | $4x10^{-2}$ | Gravel with cobbles | 1993 RI |
| PBG | LON-8903B | B | $1x10^{-1}$ | Sand and gravel | 1993 RI |
| PBG | SPN-8901C | C | $4x10^{-2}$ | Sand and gravel | 1993 RI |
| PBG | SPN-8902B | B | $1x10^{-2}$ | Sand | 1993 RI |
| PBG | SPN-8902C | C | $3x10^{-2}$ | Sand | 1993 RI |
| PBG | SPN-8903B | B | $4x10^{-2}$ | Sand and gravel | 1993 RI |
| PBG | SPN-8904B | B | $2x10^{-2}$ | Sand and gravel | 1993 RI |
| PBG | SPN-8904C | C | $2x10^{-2}$ | Sand | 1993 RI |
| **Average - PBG Plume** | | | **$4.2x10^{-2}$** | | |
| DBG | DBM-8901 | A | $3x10^{-2}$ | Sand | 1993 RI |
| DBG | DBN-8902A | A | $8x10^{-2}$ | Silt and clay | 1993 RI |
| DBG | DBN-8904A | A | $3x10^{-2}$ | Sand | 1993 RI |
| DBG | DBN-8904B | B | $5x10^{-2}$ | Gravel with sand | 1993 RI |
| DBG | DBM-8905 | A | $6x10^{-3}$ | Sand | 1993 RI |
| DBG | DBM-8201 | A | $7x10^{-3}$ | Silty clay | 1993 RI |
| DBG | ELN-9107A | A | $5x10^{-3}$ | Sand | 1993 RI |

**Table 7**
**Field Hydraulic Conductivity Test Results**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Plume Area | Well | Level Type | Hydraulic Conductivity (cm/sec) | Soil Type at Screen Interval | Reference |
|---|---|---|---|---|---|
| DBG | ELN-9107B | B | $2x10^{-2}$ | Sand | 1993 RI |
| DBG | ELM-9110 | A | $2x10^{-2}$ | Sand | 1993 RI |
| DBG | ELM-8901 | A | $8x10^{-3}$ | Silty sand | 1993 RI |
| DBG | ELN-8904A | A | $4x10^{-2}$ | Sand | 1993 RI |
| DBG | ELM-8905 | A | $1x10^{-2}$ | Sand with gravel | 1993 RI |
| DBG | ELM-8906B | B | $5x10^{-2}$ | Gravel and sand | 1993 RI |
| DBG | ELM-8908 | A | $4x10^{-2}$ | Sand with gravel | 1993 RI |
| DBG | ELM-8909 | A | $3x10^{-2}$ | Sand | 1993 RI |
| DBG | ELN-8203C | C | $6x10^{-3}$ | Sand | 1993 RI |
| DBG | ELN-8204A | A | $3x10^{-4}$ | Silty sand | 1993 RI |
| **Average - DBG Plume** | | | **$2.5x10^{-2}$** | | |
| Central | NLM-1001 | A | 1x10-2 | Sand | Landfill 3646 |
| Central | NLN-1001A | A | 1x10-2 | Sand | Landfill 3646 |
| Central | NLN-1001C | C | 6x10-2 | Sand | Landfill 3646 |
| **Average - Central Plume** | | | **$3.7x10^{-2}$** | | |

PBG - Propellant Burning Ground Plume
DBG - Deterrent Burning Ground Plume
Central - Central Plume
cm/sec - centimeters per second
Level Type - typical well depth configuration
1993 RI - Final Remedial Investigation Report (United States Army Environmental Center, April 1993)
Landfill 3646 - Feasibility Report Contiguous Addition to Landfill 3646 (SpecPro, Inc., October 2010)
There is no hydraulic conductivity data for the Nitrocelluose Production Area Plume wells; assume same value as PBG.

**Table 8**
**Horizontal Groundwater Gradient**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Plume Area | Well Pair | Well Distance (ft) | Sept 2017 Well Elevation (ft msl) | Sept 2017 Elevation Difference (ft) | Sept 2017 Gradient (ft/ft) | Apr 2018 Well Elevation (ft msl) | Apr 2018 Elevation Difference (ft) | Apr 2018 Gradient (ft/ft) | Sept 2018 Well Elevation (ft msl) | Sept 2018 Elevation Difference (ft) | Sept 2018 Gradient (ft/ft) | Average Gradient (ft/ft) | Average Hydraulic Conductivity (cm/sec) | Average Hydraulic Conductivity (ft/day) | Effective Porosity | Average Groundwter Flow Velocity (ft/day) | Average Groundwter Flow Velocity (ft/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PBG | PBN-1401A | 6,340 | 778.96 | 9.89 | 0.00156 | 780.05 | 9.96 | 0.00157 | 778.82 | 10.02 | 0.00158 | 0.00183 | $4.2x10^{-2}$ | 119 | 0.26 | 0.84 | 306 |
| | S1148 | | 769.07 | | | 770.09 | | | 768.80 | | | | | | | | |
| | SPN-8904B | 5,440 | 769.37 | 10.79 | 0.00198 | 770.00 | 11.81 | 0.00217 | 768.71 | 11.56 | 0.00213 | | | | | | |
| | SWN-9103B | | 758.58 | | | 758.19 | | | 757.15 | | | | | | | | |
| DBG | DBM-8202 | 6,200 | 786.35 | 6.03 | 0.00097 | 787.13 | 7.19 | 0.00116 | 786.62 | 6.88 | 0.00111 | 0.00108 | $2.5x10^{-2}$ | 72 | 0.26 | 0.30 | 109 |
| | ELN-1003A | | 780.32 | | | 779.94 | | | 779.74 | | | | | | | | |
| | DBN-1001B | 6,030 | 785.73 | 5.95 | 0.00099 | 786.29 | 6.93 | 0.00115 | 785.72 | 6.59 | 0.00109 | | | | | | |
| | ELN-1003B | | 779.78 | | | 779.36 | | | 779.13 | | | | | | | | |
| Central | NPM-8901 | 6,630 | | | | 783.04 | 5.46 | 0.00082 | | | | 0.00097 | $3.7x10^{-2}$ | 105 | 0.26 | 0.39 | 143 |
| | RIN-1002A | | | | | 777.58 | | | | | | | | | | | |
| | RIN-1002A | 8,260 | | | | 777.58 | 9.20 | 0.00111 | | | | | | | | | |
| | SEN-0503A | | | | | 768.38 | | | | | | | | | | | |
| NC | RIM-1002 | 2,210 | 787.47 | 1.87 | 0.00085 | 788.52 | 1.66 | 0.00075 | 787.13 | 1.71 | 0.00077 | 0.00079 | $4.2x10^{-2}$ | 119 | 0.26 | 0.36 | 132 |
| | RIN-1001A | | 785.60 | | | 786.86 | | | 785.42 | | | | | | | | |

ft - Feet
ft msl - Feet Mean Sea Level
ft/ft - Feet per Foot
Central Plume elevations were collected during June 2018
Groundwater flow velocity = (hydraulic conductivity)(hydraulic gradient)/effective porosity
Hydraulic conductivity conversion: 1 cm/sec = 2834 ft/day

**Table 9**
**Vertical Groundwater Gradient**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | Well Pair | Well ID | Layer | Screen Midpoint Elevation | Groundwater Elevation (ft msl) | | | Vertical Groundwater Gradient (ft/ft) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Sep-17 | Apr-18 | Sep-18 | Sep-17 | Apr-18 | Sep-18 | Average |
| Propellant Burning Ground | PBN-1401A | 782 | A | 759.90 | 778.96 | 780.05 | 778.82 | | | | |
| | PBN-1401B | 783 | B | 723.39 | 778.98 | 780.07 | 778.83 | | | | |
| | PBN-1401C | 784 | C | 683.78 | 778.94 | 780.05 | 778.82 | -0.00026 | 0.00000 | 0.00000 | -0.00009 |
| | PBN-8205A | 622 | A | 768.30 | 778.07 | 779.14 | 777.87 | | | | |
| | PBN-8205B | 623 | B | 752.63 | 778.04 | 779.13 | 777.86 | | | | |
| | PBN-8205C | 624 | C | 743.30 | 778.12 | 779.20 | 777.90 | 0.00200 | 0.00240 | 0.00120 | 0.00187 |
| | PBN-8502A | 632 | A | 762.21 | 776.65 | 777.73 | 776.49 | | | | |
| | PBN-8902BR | 795 | B | 739.37 | 776.71 | 777.77 | 776.54 | | | | |
| | PBN-8902C | 645 | C | 703.80 | 775.77 | 776.87 | 775.59 | -0.01507 | -0.01472 | -0.01541 | -0.01507 |
| | PBN-1404B | 791 | B | 715.18 | 775.20 | 776.12 | 774.79 | | | | |
| | PBN-1404C | 792 | C | 655.34 | 775.14 | 776.06 | 774.72 | | | | |
| | PBN-1404D | 793 | D | 594.89 | 774.38 | 775.29 | 773.98 | -0.00682 | -0.00690 | -0.00673 | -0.00682 |
| | S1148 | 710 | A | 757.90 | 769.07 | 770.09 | 768.80 | | | | |
| | SPN-8904B | 720 | B | 729.10 | 769.37 | 770.00 | 768.71 | | | | |
| | SPN-8904C | 721 | C | 696.70 | 769.47 | 770.09 | 768.83 | | | | |
| | SPN-9104D | 726 | D | 599.80 | 769.40 | 770.10 | 768.78 | 0.00209 | 0.00006 | -0.00013 | 0.00067 |
| | PBN-9903A | 692 | A | 756.68 | 767.56 | 768.12 | 766.84 | | | | |
| | PBN-9903B | 693 | B | 715.50 | 768.02 | 768.59 | 767.30 | | | | |
| | PBN-9903C | 694 | C | 664.49 | 768.08 | 768.65 | 767.35 | | | | |
| | PBN-9903D | 695 | D | 619.60 | 768.07 | 768.61 | 767.31 | 0.00372 | 0.00357 | 0.00343 | 0.00357 |
| | SWN-9103B | 571 | B | 726.30 | 758.58 | 758.19 | 757.15 | | | | |
| | SWN-9103C | 572 | C | 676.80 | 758.73 | 758.36 | 757.30 | | | | |
| | SWN-9103D | 573 | D | 630.90 | 758.56 | 758.18 | 757.15 | | | | |
| | SWN-9103E | 574 | E | 602.10 | 758.67 | 758.30 | 757.21 | 0.00072 | 0.00089 | 0.00048 | 0.00070 |
| | PBN-9101C | 561 | C | 680.50 | 744.75 | 744.33 | 744.40 | | | | |
| | PBM-9001D | 981 | D | 623.50 | 745.03 | 744.60 | 744.66 | 0.00491 | 0.00474 | 0.00456 | 0.00474 |
| Deterrent Burning Ground | DBM-8202 | 302 | A | 770.45 | 786.35 | 787.13 | 786.62 | | | | |
| | DBN-1001B | 472 | B | 752.77 | 785.73 | 786.29 | 785.72 | | | | |
| | DBN-1001C | 473 | C | 715.28 | 784.11 | 783.97 | 783.36 | | | | |
| | DBN-1001E | 474 | E | 632.55 | 784.54 | 784.38 | 783.71 | -0.01313 | -0.01994 | -0.02110 | -0.01806 |
| | DBN-9501A | 314 | A | 771.70 | 783.49 | 783.38 | 782.79 | | | | |
| | DBN-9501B | 315 | B | 719.50 | 783.51 | 783.38 | 782.76 | | | | |
| | DBN-9501C | 316 | C | 664.00 | 783.49 | 783.36 | 782.78 | | | | |
| | DBN-9501E | 317 | E | 637.55 | 783.38 | 783.26 | 782.66 | -0.00082 | -0.00089 | -0.00097 | -0.00089 |
| | ELN-8203A | 210 | A | 772.70 | 783.79 | 783.64 | 783.00 | | | | |
| | ELN-8203B | 211 | B | 760.50 | 783.43 | 783.12 | 782.52 | | | | |
| | ELN-8203C | 212 | C | 750.30 | 783.46 | 783.14 | 782.54 | -0.01473 | -0.02232 | -0.02054 | -0.01920 |
| | ELM-9501 | 234 | A | 779.20 | 781.23 | 780.88 | 780.36 | | | | |
| | ELN-0801B | 455 | B | 738.87 | 781.33 | 781.05 | 780.49 | | | | |
| | ELN-0801C | 456 | C | 693.42 | 781.38 | 781.04 | 780.54 | | | | |
| | ELN-0801E | 457 | E | 634.93 | 780.25 | 780.98 | 780.44 | -0.00679 | 0.00069 | 0.00055 | -0.00185 |
| | ELN-1003A | 467 | A | 776.19 | 780.32 | 779.94 | 779.74 | | | | |
| | ELN-1003B | 468 | B | 704.74 | 779.78 | 779.36 | 779.13 | | | | |
| | ELN-1003C | 469 | C | 641.64 | 779.92 | 779.50 | 779.23 | | | | |
| | ELN-1003E | 470 | E | 571.02 | 779.50 | 779.09 | 778.83 | -0.00400 | -0.00414 | -0.00444 | -0.00419 |

**Table 9**
**Vertical Groundwater Gradient**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | Well Pair | Well ID | Layer | Screen Midpoint Elevation | Groundwater Elevation (ft msl) | | | Vertical Groundwater Gradient (ft/ft) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Sep-17 | Apr-18 | Sep-18 | Sep-17 | Apr-18 | Sep-18 | Average |
| Central Plume | RIN-1002A | 492 | A | 775.76 | no data | 777.58 | no data | | | | |
| Central Plume | RIN-1002C | 493 | C | 683.56 | | 777.57 | | | | | |
| Central Plume | RIN-1501D | 540 | D | 625.56 | | 777.54 | | | -0.00027 | | -0.00027 |
| Central Plume | RIN-1005A | 496 | A | 773.74 | no data | 775.19 | no data | | | | |
| Central Plume | RIN-1005C | 497 | C | 681.99 | | 775.24 | | | 0.00054 | | 0.00054 |
| Central Plume | SEN-0501A | 580 | A | 760.14 | no data | 767.37 | no data | | | | |
| Central Plume | SEN-0501B | 581 | B | 702.87 | | 767.51 | | | | | |
| Central Plume | SEN-0501D | 582 | D | 600.22 | | 767.77 | | | 0.00250 | | 0.00250 |
| Central Plume | SEN-0503A | 585 | A | 761.63 | no data | 768.38 | no data | | | | |
| Central Plume | SEN-0503B | 586 | B | 704.39 | | 768.61 | | | | | |
| Central Plume | SEN-0503D | 587 | D | 601.31 | | 768.67 | | | 0.00181 | | 0.00181 |
| NC Plume | RIM-0705 | 442 | A | 782.80 | 786.26 | no data | 786.04 | | | | |
| NC Plume | RIN-1007C | 479 | C | 708.61 | 786.30 | | 786.06 | 0.00054 | | 0.00027 | 0.00040 |
| NC Plume | RIN-1001A | 480 | A | 782.75 | 785.60 | no data | 785.42 | | | | |
| NC Plume | RIN-1001C | 481 | C | 703.10 | 785.61 | | 785.41 | 0.00013 | | -0.00013 | 0.00000 |

Layer designation
A = shallow zone in sand and gravel aquifer
B = intermediate zone in sand and gravel aquifer
C = deep zone in sand and gravel aquifer
D = bottom zone in sand and gravel aquifer
E = top of bedrock aquifer
ft msl - Feet Mean Sea Level
ft/ft - Feet per Foot
Central Plume elevations were collected during June 2018
Gradient determined between shallow and deep well for each well cluster
Vertical Groundwater Gradient = (h2 - h1) / (z1 - z2)
h1 = shallow well groundwater elevation
h2 = deep well groundwater elevation
z1 = shallow well screen midpoint elevation
z2 = deep well screen midpoint elevation

### 4.4.4 Groundwater Flow Velocity

The advective groundwater flow velocity is derived from the hydraulic conductivity value, horizontal gradient, and effective porosity. Advective groundwater movement does not take into account dispersion, diffusion, or chemical retardation of groundwater contaminants, which can increase or decrease the rate of groundwater flow. It is a calculated value that provides an estimate of the rate of groundwater flow over time. The mathematical formula for determining advective groundwater flow velocity (v) is:

$v = Ki/n_e$ Where:

$K$ = hydraulic conductivity (feet/day)
$i$ = hydraulic gradient (feet/feet)
$n_e$ = effective porosity

The average hydraulic conductivity values found in Table 7 were used in the groundwater flow velocity calculations. The average hydraulic conductivities for the PBG, DBG, Central, and NC Area Plumes are $4.2\text{x}10^{-02}$ cm/sec or 119 ft/day, $2.5\text{x}10^{-02}$ cm/sec or 72 ft/day, $3.7\text{x}10^{-02}$ cm/sec or 105 ft/day, and $4.2\text{x}10^{-02}$ cm/sec or 119 ft/day, respectively.

The effective porosity is estimated at 0.26 or 26%. Average horizontal gradients of 0.00183 ft/ft for the PBG, 0.00108 ft/ft for the DBG, 0.00097 ft/ft for the Central Plume, and 0.00079 ft/ft for the NC Area Plume were used to calculate the groundwater flow velocities.

The calculated average groundwater flow velocities as shown in Table 8 equal 0.84 ft/day for the PBG, 0.30 ft/day for the DBG, 0.39 ft/day for the Central, and 0.36 ft/day for the NC Area. These groundwater flow velocity values equate to 306 ft/year for the PBG Plume, 109 ft/year for the DBG Plume, 143 ft/year for the Central Plume, and 132 ft/year for the NC Area Plume.

## 4.5 Nature and Extent of Groundwater Contamination

Groundwater investigation activities at BAAP began in 1980 and continue today. Site-wide groundwater-related assessment activities, agreed upon by the Army and WDNR, include the following: soil vapor surveys; monitoring well drilling, installation, and surveying; water level measurements; pump testing; and monitoring well and residential well sampling.

The groundwater sampling results were compared to the Wisconsin NR 140 PAL Groundwater Standards to identify contaminants of potential concern (COPCs) for the four groundwater plumes at BAAP. The COPCs for each groundwater plume are further discussed in the following sections.

### 4.5.1 Propellant Burning Ground Plume

Groundwater contamination in monitoring wells associated with the PBG was first detected in 1982 (Tsai, 1988). The draft final (Phase 1) RI report (January 1990) indicated that groundwater contamination had migrated beyond the southern BAAP boundary. An off-site groundwater monitoring program was initiated in January 1990. In late April 1990, sampling results from residential wells south of BAAP showed that two residential wells had been contaminated with CTET and one residential well contaminated with chloroform. The maximum concentrations of CTET and chloroform in the residential wells were 80 micrograms per liter (µg/l) and 9.9 µg/l, respectively. It was determined that a VOC plume (PBG Plume) had migrated south from the PBG Waste Pits, past the BAAP's southern boundary, and then easterly to the Wisconsin River below the WP&L dam. The Army replaced the three impacted residential wells. Prior to well replacement, bottled water had been provided to the affected residences.

The PBG Plume originates at the PBG and extends south beyond the BAAP boundary. South of BAAP, the plume turns southeast towards the Wisconsin River due to the influence of the WP&L dam, just north of Prairie du Sac. The PBG Plume shown in Figure 21 represents the area where groundwater concentrations exceed a NR 140 PAL or ES for one or more of the following compounds: CTET, ethyl ether (diethyl ether), TCE, 2,4-DNT, 2,6-DNT, or total DNT. All six DNT isomers (2,3-DNT, 2,4-DNT, 2,5-DNT, 2,6-DNT, 3,4-DNT, and 3,5-DNT) have been detected in the PBG Plume, mostly in the PBG Waste Pits. The PBG Plume boundaries shown in Figure 21 are approximate and based on total DNT and VOC groundwater data collected during 2018 from both monitoring wells and residential wells. Table 10 summarizes the groundwater analytical results from the August 2018 residential well sampling event. Table 11 summarizes the groundwater analytical results from the September 2018 monitoring well sampling event. Isoconcentration maps and cross sections were prepared for CTET, ethyl ether, TCE, and total DNT. The isoconcentration maps were prepared using all groundwater data collected during 2018. The isoconcentration cross sections were prepared mainly using groundwater data collected during August and September 2018. Supplemental groundwater data from November 2014 was used to complete the isoconcentration cross sections. These contaminants, CTET, ethyl ether, TCE, and total DNT, have shown consistent exceedances of the NR 140 ES in multiple monitoring wells to facilitate the construction of isoconcentration maps.

During 2015, 2016, 2017, and 2018, bromodichloromethane, CTET, chloroform, 2,4-DNT, 2,6-DNT, total DNT, ethyl ether, nitrate, and TCE have been COPCs in the PBG Plume. The PBG Plume groundwater results from the August and September 2018 sampling events were evaluated for COPCs that exceeded a Chapter NR 140 PAL Groundwater Standard.

Three monitoring wells had NR 140 PAL exceedances for bromodichloromethane during September 2018. Bromodichloromethane was not detected in any residential wells that were sampled during August 2018.

A total of six monitoring wells had NR 140 ES exceedances for CTET during September 2018. In addition, thirty-one monitoring wells had NR 140 PAL exceedances for CTET during September 2018. Three residential wells (Apel, Krumenauer, and Schlender) had CTET detections that were below the NR 140 PAL during August 2018. Since 2010, CTET has been detected in these three residential wells, that are located east of the PBG Plume (see Figure 20).

A total of ten monitoring wells had NR 140 PAL exceedances for chloroform during September 2018. One residential well had a chloroform detection that was below the NR 140 PAL during August 2018.

**Table 10**
**Residential Well Groundwater Analytical Results**
**August 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| August '18 Round | Level of Detection | Level of Quantitation |
|---|---|---|
| 2,3-DNT | 0.0057 | 0.029 |
| 2,4-DNT | 0.0076 | 0.029 |
| 2,5-DNT | 0.0029 | 0.029 |
| 2,6-DNT | 0.0038 | 0.029 |
| 3,4-DNT | 0.0038 | 0.029 |
| 3,5-DNT | 0.0038 | 0.029 |

*Level of detection and level of quantitation may change each round.

- (white) = Under PAL and ES
- (yellow) = Over Preventive Action Limit (PAL)
- (orange) = Over Enforcement Standard (ES)
- (gray) = No PAL or ES established
- (light blue) = Not Tested
- ND = Compound was not detected

*All results are expressed as µg/l (micrograms per liter)*

| Last Name | Well No. | Well Name | Shared With | Analyzed By | Sample Date | Toluene | Dichlorodifluoromethane | Chloromethane | Chloroform | Carbon Tetrachloride | Trichloroethene | Ethyl Ether | 1,1,1-Trichloroethane | 1,1,2-Trichloroethane | 2,6-Dinitrotoluene | 2,4-Dinitrotoluene | 2,3-Dinitrotoluene | 3,4-Dinitrotoluene | 2,5-Dinitrotoluene | 3,5-Dinitrotoluene | Dinitrotoluene, Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anderson | 411 | Anderson-R | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | 0.22 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Apel | 998 | Apel | | CT Lab | 8/20/2018 | ND | ND | ND | ND | 0.18 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Cornelius | 426 | Cornelius | | CT Lab | 8/21/2018 | ND | ND | 0.11 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Curto | 412 | Curto | *Nimmow* | CT Lab | 8/21/2018 | ND | 0.17 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Delaney | 152 | Delaney | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | 0.16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Gibbs | 839 | Gibbs | | CT Lab | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Grosse | 415 | Grosse | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Groth | 842 | Groth | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| | | | | CT Lab (D) | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Gruber | 417 | Gruber-D | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Hendershot | 418 | Hendershot | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | 2 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Howery | 419 | Howery | | | | Pump not working; well not sampled | | | | | | | | | | | | | | | |
| Judd | 862 | Judd | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Kopras | 874 | Kopras | *Miller* | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Krumenauer | 875 | Krumenauer | | CT Lab | 8/21/2018 | ND | ND | ND | ND | 0.16 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Lukens | 860 | Lukens | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Melum | 423 | Melum | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Mittenzwei | 800 | Mittenzwei | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Nowotarski | 891 | Nowotarski | | | | Not available; well not sampled | | | | | | | | | | | | | | | |
| Olah | 904 | Olah | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Osterland | 422 | Osterland | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Peckosh | 817 | Peckosh | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Prairie du Sac Utilities | 911 | PDS-3 | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Purcell | 163 | Purcell-D | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| | | | | CT Lab (D) | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Purcell | 916 | Purcell-G | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Ramaker | 917 | Ramaker-J | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Raschein | 424 | Raschein | | CT Lab | 8/21/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Reif | 427 | Reif | | CT Lab | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| | | | | CT Lab (D) | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Revers | 425 | Revers | | CT Lab | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Schlender | 931 | Schlender | *Koenig, Ballweg* | CT Lab | 8/20/2018 | ND | ND | ND | 0.13 | 0.48 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Schumann | 428 | Schumann | | CT Lab | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Spear | 803 | Spear | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | ND | ND | ND | 0.2 | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 158 | WE-QN039 | *Hilgemann, Layton* | CT Lab | 8/7/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 157 | WE-QR441 | *Hemberger, Pattarozzi, Heath* | CT Lab | 8/7/2018 | ND | ND | ND | 0.1 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 159 | WE-RD430 | *Ford, Madden, Bastien/Eddy* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 153 | WE-RM383 | *Good, Rossing* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 164 | WE-SQ017 | *Thompson* | CT Lab | 8/7/2018 | ND | ND | ND | 1.7 | 0.12 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 165 | WE-SQ001 | *Rosenau, Schwarz* | CT Lab | 8/7/2018 | ND | ND | ND | 1.4 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

# Table 10
## Residential Well Groundwater Analytical Results
## August 2018
## Remedial Investigation/Feasibility Study
## Badger Army Ammunition Plant

| August '18 Round | Level of Detection | Level of Quantitation |
|---|---|---|
| 2,3-DNT | 0.0057 | 0.029 |
| 2,4-DNT | 0.0076 | 0.029 |
| 2,5-DNT | 0.0029 | 0.029 |
| 2,6-DNT | 0.0038 | 0.029 |
| 3,4-DNT | 0.0038 | 0.029 |
| 3,5-DNT | 0.0038 | 0.029 |

*Level of detection and level of quantitation may change each round.

- (white) = Under PAL and ES
- (yellow) = Over Preventive Action Limit (PAL)
- (orange) = Over Enforcement Standard (ES)
- (grey) = No PAL or ES established
- (cyan) = Not Tested
- ND = Compound was not detected

*All results are expressed as µg/l (micrograms per liter)*

| Last Name | Well No. | Well Name | Shared With | Analyzed By | Sample Date | Toluene | Dichlorodifluoromethane | Chloromethane | Chloroform | Carbon Tetrachloride | Trichloroethene | Ethyl Ether | 1,1,1-Trichloroethane | 1,1,2-Trichloroethane | 2,6-Dinitrotoluene | 2,4-Dinitrotoluene | 2,3-Dinitrotoluene | 3,4-Dinitrotoluene | 2,5-Dinitrotoluene | 3,5-Dinitrotoluene | Dinitrotoluene, Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water's Edge Group | 156 | WE-RR542 | *Cairnes, Sherpe* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 169 | WE-RR598 | *Hall, Chow, Hartmann, Wenger* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 170 | WE-SQ002 | *Neumaier, Ramaker* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 174 | WE-TF023 | *Hilgemann* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 129 | WE-TM599 | *Riordan* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 431 | WE-UK125 | *Gust, Haag, Lochner* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 432 | WE-UK124 | *Whalen* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 433 | WE-UA297 | *Krisko* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 434 | WE-XD828 | *Riethmiller* | CT Lab | 8/7/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 435 | WE-XK342 | *Brandherm* | CT Lab | 8/7/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| | | | | CT Lab (D) | 8/7/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Water's Edge Group | 436 | WE-YW972 | *Dietzen* | CT Lab | 8/7/2018 | 0.12 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Wenger | 414 | Wenger | | CT Lab | 8/20/2018 | ND | ND | ND | ND | ND | 1.4 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Zurbachen | 967 | Zurbachen-A | | CT Lab | 8/22/2018 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Dairy Forage Res Ctr | 828 | USDA 1 | | CT Lab | 8/21/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Dairy Forage Res Ctr | 829 | USDA 2 | | CT Lab | 8/21/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Dairy Forage Res Ctr | 126 | USDA 3 | | CT Lab | 8/21/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |
| Dairy Forage Res Ctr | 128 | USDA 6 | | CT Lab | 8/22/2018 | | | | | | | | | | ND | ND | ND | ND | ND | ND | ND |

(D) = Duplicate

CT Lab = CT Laboratories, LLC

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well | Well ID | Sample Level | Sample Depth (feet) | Sample Date | Dinitrotoluene, Total | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | Nitrate, Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1,1-Dichloroethane | 1,1-Dichloroethene | 1,1,1-Trichloroethane | Bromodichloromethane | Carbon Disulfide | Carbon Tetrachloride | Chloroform | Chloromethane | Ethyl Ether | Tetrachloroethene | Trichloroethene | |
| **DBG PLUME AREA WELLS** | | | | | | | | | | | | | | | | | |
| DBM-8201 | 301 | A | 154.6-174.6 | Sep-18 | **3.005** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBM-8202 | 302 | A | 137.3-157.3 | Sep-18 | **0.608** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBM-8202 (dup) | 302 | A | 137.3-157.3 | Sep-18 | **0.562** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBM-8903 | 306 | A | 113-133 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-1001B | 472 | B | 154.5-159.5 | Sep-18 | **0.5978** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-1001C | 473 | C | 192-197 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-1001E | 474 | E | 274.9-279.9 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-1002C | 476 | C | 205.1-210.1 | Sep-18 | **0.7705** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-1002E | 477 | E | 275.5-280.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-9501A | 314 | A | 110-120 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-9501B | 315 | B | 162.5-172.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-9501C | 316 | C | 218.5-228.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| DBN-9501E | 317 | E | 245.2-255.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELM-8901 | 216 | A | 145.5-165 | Sep-18 | **1.427** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELM-8907 | 220 | A | 130.3-150.3 | Sep-18 | **0.668** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELM-8908 | 221 | A | 125-145 | Sep-18 | **0.263** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELM-8909 | 222 | A | 135-155 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELM-9501 | 234 | A | 54-69 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-0801B | 455 | B | 100-105 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-0801C | 456 | C | 145.5-150.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-0801E | 457 | E | 202.6-207.6 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-0802A | 458 | A | 92.5-107.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-0802C | 459 | C | 175.8-180.8 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1001B | 460 | B | 91.1-96.1 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1001C | 461 | C | 155.2-160.2 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well | Well ID | Sample Level | Sample Depth (feet) | Sample Date | Dinitrotoluene, Total | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1,1-Dichloroethane | 1,1-Dichloroethene | 1,1,1-Trichloroethane | Bromodichloromethane | Carbon Disulfide | Carbon Tetrachloride | Chloroform | Chloromethane | Ethyl Ether | Tetrachloroethene | Trichloroethene | Nitrate, Total |
| ELN-1001E | 462 | E | 240.5-245.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1002A | 463 | A | 55.3-70.3 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1002B | 464 | B | 111.2-116.2 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1002B (dup) | 464 | B | 111.2-116.2 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1002C | 465 | C | 159.1-164.1 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1002E | 466 | E | 231.5-236.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003A | 467 | A | 16.2-31.2 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003B | 468 | B | 91.5-96.5 | Oct-18 | **0.192** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003B (dup) | 468 | B | 91.5-96.5 | Oct-18 | **0.171** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003C | 469 | C | 155.1-160.1 | Oct-18 | **0.1327** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003E | 470 | E | 255.6-230.6 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1502A | 533 | A | 115.3-130.3 | Sep-18 | **0.627** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1502A (dup) | 533 | A | 115.3-130.3 | Sep-18 | **0.801** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1502C | 534 | C | 198-203 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1503A | 535 | A | 73.7-88.7 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1503C | 536 | C | 157.6-162.6 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1504B | 537 | B | 34.8-39.8 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-8203A | 210 | A | 147.5-157.5 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-8203B | 211 | B | 164-166 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-8203C | 212 | C | 174-176 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-8902B | 224 | B | 173.5-178.5 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-9107A | 227 | A | 116-126 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-9107B | 228 | B | 135-145 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-9402AR | 231 | A | 130-145 | Oct-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| S1121 | 755 | A | 39.11-59.3 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| S1134R | 236 | A | 136-151 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,1-Dichloroethane** | **1,1-Dichloroethene** | **1,1,1-Trichloroethane** | **Bromodichloromethane** | **Carbon Disulfide** | **Carbon Tetrachloride** | **Chloroform** | **Chloromethane** | **Ethyl Ether** | **Tetrachloroethene** | **Trichloroethene** | **Nitrate, Total** |
| **NC PRODUCTION PLUME AREA WELLS** | | | | | | | | | | | | | | | | | |
| RIM-0703 | 440 | A | 98-113 | Sep-18 | **0.029 (J)** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIM-0705 | 442 | A | 91-106 | Sep-18 | **0.089** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIM-1002 | 478 | A | 95.2-110.2 | Sep-18 | **0.21** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIM-1002 (dup) | 478 | A | 95.2-110.2 | Sep-18 | **0.22** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIN-1001A | 480 | A | 91.8-106.8 | Sep-18 | **0.073** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIN-1001C | 481 | C | 176.41-181.41 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| RIN-1007C | 479 | C | 170.3-175.3 | Sep-18 | <0.008 | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| S1125 | 504 | A | 106.25-126.5 | Sep-18 | **0.0061(J)** | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| **PBG PLUME AREA WELLS** | | | | | | | | | | | | | | | | | |
| PBM-0001 | 367 | A | 109.5-134.5 | Sep-18 | **12.98** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.14 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | **0.31** | **3.6** |
| PBM-0002 | 368 | A | 106.5-131.5 | Sep-18 | **2.33** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.29** | <0.1 | <0.1 | <0.1 | <0.1 | **0.69** | **3.4** |
| PBM-0006 | 372 | A | 99.5-124.5 | Sep-18 | **1.841** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.34** | <0.1 | <0.1 | <0.1 | <0.1 | **0.73** | **3.1** |
| PBM-0008 | 374 | A | 97-122 | Sep-18 | **1.603** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.19 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | **0.41** | NT |
| PBM-1201 | 764 | A | 103.5-118.5 | Sep-18 | **23.66** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.25** | <0.1 | <0.1 | <0.1 | <0.1 | **0.65** | NT |
| PBM-1202 | 765 | A | 103.5-118.5 | Sep-18 | **3.45** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.34** | <0.1 | <0.1 | <0.1 | <0.1 | **0.8** | NT |
| PBM-1203 | 766 | A | 103.4-118.4 | Sep-18 | **0.201** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.25** | <0.1 | <0.1 | <0.1 | <0.1 | **0.32** | NT |
| PBM-8907 | 637 | A | 82.72-92.72 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.27** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBM-8909 | 639 | A | 104.4-124.4 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.18 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBM-9001D | 981 | D | 200.5-210.5 | Oct-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **15** | **1.4** | <0.1 | <0.1 | <0.1 | **5.5** | NT |
| PBM-9801 | 360 | A | 108.5-123.5 | Sep-18 | **3.582** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.16 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | **0.35** | NT |
| PBN-1001C | 595 | C | 194.7-199.7 | Sep-18 | **0.038** | <0.1 | <0.1 | **0.49** | <0.1 | <0.2 | **0.86** | **0.65** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1003C | 592 | C | 184.6-189.6 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | **0.11 (J)** | <0.2 | <0.1 | **0.22** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1302A | 770 | A | 69.7-84.7 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.62** | <0.1 | <0.2 | **2.2** | **0.14 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1302B | 771 | B | 131.2-136.2 | Sep-18 | **0.011 (J)** | <0.1 | <0.1 | **0.55** | <0.1 | <0.2 | **2.5** | **0.14 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1302C | 772 | C | 182.6-187.6 | Sep-18 | **0.0087 (J)** | <0.1 | **0.1 (J)** | **0.68** | <0.1 | <0.2 | **3.8** | **0.69** | <0.1 | <0.1 | <0.1 | <0.1 | NT |

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,1-Dichloroethane** | **1,1-Dichloroethene** | **1,1,1-Trichloroethane** | **Bromodichloromethane** | **Carbon Disulfide** | **Carbon Tetrachloride** | **Chloroform** | **Chloromethane** | **Ethyl Ether** | **Tetrachloroethene** | **Trichloroethene** | **Nitrate, Total** |
| PBN-1302D | 773 | D | 240.1-245.1 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **1.3** | <0.1 | <0.1 | NT |
| PBN-1303A | 774 | A | 115.5-130.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.32** | <0.1 | <0.2 | **0.47** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1303B | 775 | B | 171.5-176.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.51** | <0.1 | <0.2 | **0.83** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1303B (dup) | 775 | B | 171.5-176.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.51** | <0.1 | <0.2 | **0.81** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1303C | 776 | C | 227-232 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.77** | <0.1 | <0.2 | **1.4** | **0.31** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1303D | 777 | D | 282-287 | Sep-18 | <0.008 | **0.13 (J)** | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1304A | 778 | A | 101-116 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1304B | 779 | B | 158.1-163.1 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.13 (J)** | <0.1 | <0.2 | **0.16 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1304C | 780 | C | 213-218 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1304D | 781 | D | 268-273 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.11 (J)** | **0.14 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1401A | 782 | A | 117.2-132.2 | Sep-18 | **0.742** | <0.1 | <0.1 | **0.14 (J)** | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | **0.16 (J)** | NT |
| PBN-1401B | 783 | B | 158.7-163.7 | Sep-18 | **0.552** | <0.1 | <0.1 | **0.14 (J)** | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | **0.13 (J)** | NT |
| PBN-1401B (dup) | 783 | B | 158.7-163.7 | Sep-18 | **0.47** | <0.1 | <0.1 | **0.12 (J)** | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | **0.13 (J)** | NT |
| PBN-1401C | 784 | C | 198.3-203.3 | Sep-18 | **0.058** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-1404B | 791 | B | 174.5-179.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.19 (J)** | <0.1 | <0.2 | **2.8** | **0.97** | <0.1 | <0.1 | <0.1 | **1** | NT |
| PBN-1404C | 792 | C | 234.3-239.3 | Sep-18 | **0.0044 (J)** | <0.1 | <0.1 | **0.18 (J)** | **0.16 (J)** | <0.2 | **0.73** | **0.84** | <0.1 | <0.1 | <0.1 | **0.2** | NT |
| PBN-1404D | 793 | D | 294.8-299.8 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **480** | <0.1 | <0.1 | NT |
| PBN-1405F | 794 | F | 314.7-319.7 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | **0.29 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-8202A | 613 | A | 108.5-118.5 | Sep-18 | **116.42** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.28** | <0.1 | <0.1 | <0.1 | <0.1 | **0.8** | NT |
| PBN-8202A (dup) | 613 | A | 108.5-118.5 | Sep-18 | **103.32** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.31** | <0.1 | <0.1 | <0.1 | <0.1 | **0.84** | NT |
| PBN-8202B | 614 | B | 131-133 | Sep-18 | **14.612** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.64** | <0.1 | <0.1 | <0.1 | <0.1 | **0.82** | NT |
| PBN-8202C | 615 | C | 139.2-141.2 | Sep-18 | **0.77** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | **0.14 (J)** | NT |
| PBN-8205A | 622 | A | 102.5-112.5 | Sep-18 | **0.837** | <0.1 | <0.1 | **0.29** | <0.1 | <0.2 | **2.8** | <0.1 | <0.1 | <0.1 | <0.1 | **0.71** | NT |
| PBN-8205B | 623 | B | 122.2-124.2 | Sep-18 | **0.962** | <0.1 | <0.1 | **0.29** | <0.1 | <0.2 | **3.1** | <0.1 | <0.1 | <0.1 | <0.1 | **0.76** | NT |
| PBN-8205C | 624 | C | 131.5-133.5 | Sep-18 | **1.094** | <0.1 | <0.1 | **0.42** | <0.1 | <0.2 | **3.8** | <0.1 | <0.1 | <0.1 | <0.1 | **0.91** | NT |
| PBN-8502A | 632 | A | 129-138 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.83** | <0.1 | <0.2 | **14** | **0.12 (J)** | <0.1 | <0.1 | <0.1 | **2** | NT |

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,1-Dichloroethane** | **1,1-Dichloroethene** | **1,1,1-Trichloroethane** | **Bromodichloromethane** | **Carbon Disulfide** | **Carbon Tetrachloride** | **Chloroform** | **Chloromethane** | **Ethyl Ether** | **Tetrachloroethene** | **Trichloroethene** | **Nitrate, Total** |
| PBN-8503A | 633 | A | 85.82-94.82 | Sep-18 | **0.068** | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **1.7** | <0.1 | **0.14 (J)** | <0.1 | <0.1 | <0.1 | NT |
| PBN-8902BR | 795 | B | 155-160 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **1.6** | **0.31** | **0.12 (J)** | <0.1 | <0.1 | **0.96** | NT |
| PBN-8902C | 645 | C | 188.1-193.3 | Sep-18 | **0.017 (J)** | <0.1 | <0.1 | **0.11 (J)** | <0.1 | <0.2 | **1.5** | <0.1 | <0.1 | <0.1 | <0.1 | **0.67** | NT |
| PBN-8903B | 646 | B | 120-125 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.13 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-8903C | 647 | C | 155-160 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-8912A | 654 | A | 83.4-103.4 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-8912B | 655 | B | 133-138 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.66** | <0.1 | <0.1 | <0.1 | **0.11 (J)** | **0.44** | NT |
| PBN-9101C | 561 | C | 142.5-152.5 | Oct-18 | **0.08** | <0.1 | <0.1 | **0.16 (J)** | <0.1 | <0.2 | **19** | **1.7** | <0.1 | <0.1 | <0.1 | **8.5** | NT |
| PBN-9112C | 665 | C | 173.4-183.4 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.96** | **0.13 (J)** | <0.1 | <0.1 | <0.1 | **0.33** | NT |
| PBN-9112D | 666 | D | 221-231 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-9301B | 668 | B | 150.5-160.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.31** | <0.1 | <0.2 | **3.1** | **0.37** | <0.1 | <0.1 | <0.1 | **0.13 (J)** | NT |
| PBN-9301C | 669 | C | 217.5-227.5 | Sep-18 | <0.008 | <0.1 | **0.1 (J)** | **1.1** | **0.15 (J)** | <0.2 | **1.7** | **1.1** | <0.1 | <0.1 | <0.1 | **0.34** | NT |
| PBN-9303B | 673 | B | 83.5-93.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.75** | <0.1 | <0.2 | **2.4** | **0.16 (J)** | <0.1 | <0.1 | <0.1 | **0.2** | NT |
| PBN-9303B (dup) | 673 | B | 83.5-93.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.65** | <0.1 | <0.2 | **2.1** | **0.15 (J)** | <0.1 | <0.1 | <0.1 | **0.18 (J)** | NT |
| PBN-9303C | 674 | C | 154.5-164.5 | Sep-18 | <0.008 | <0.1 | **0.37** | **1.9** | <0.1 | <0.2 | **3.5** | **1.1** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-9303D | 675 | D | 214.5-224.5 | Sep-18 | <0.008 | **0.39** | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| PBN-9304D | 687 | D | 200-210 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **560** | <0.1 | <0.1 | NT |
| PBN-9902D | 691 | D | 217.5-222.5 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **0.26** | <0.1 | <0.1 | NT |
| PBN-9903A | 692 | A | 61-76 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **1.5** | <0.1 | <0.1 | <0.1 | <0.1 | **0.12 (J)** | NT |
| PBN-9903B | 693 | B | 107-112 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.27** | <0.1 | <0.2 | **5.2** | **0.28** | <0.1 | <0.1 | <0.1 | **1.2** | NT |
| PBN-9903B (dup) | 693 | B | 107-112 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.28** | <0.1 | <0.2 | **5.2** | **0.29** | <0.1 | <0.1 | <0.1 | **1.2** | NT |
| PBN-9903C | 694 | C | 158-163 | Sep-18 | **0.078** | <0.1 | <0.1 | **0.12 (J)** | <0.1 | <0.2 | **10** | **0.23** | <0.1 | <0.1 | <0.1 | **1** | NT |
| PBN-9903D | 695 | D | 203-208 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **440** | <0.1 | <0.1 | NT |
| S1147 | 709 | A | 45.8-70.8 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| S1148 | 710 | A | 31.7-56.7 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SPN-8903B | 718 | B | 88.7-93.7 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.16 (J)** | <0.1 | <0.2 | **0.98** | **0.12 (J)** | **0.12 (J)** | <0.1 | <0.1 | **0.18 (J)** | NT |

**Table 11**
**Groundwater Analytical Results**
**September 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,1-Dichloroethane** | **1,1-Dichloroethene** | **1,1,1-Trichloroethane** | **Bromodichloromethane** | **Carbon Disulfide** | **Carbon Tetrachloride** | **Chloroform** | **Chloromethane** | **Ethyl Ether** | **Tetrachloroethene** | **Trichloroethene** | **Nitrate, Total** |
| SPN-8903C | 719 | C | 122.7-127.7 | Sep-18 | <0.008 | <0.1 | **0.19 (J)** | **1.5** | <0.1 | <0.2 | **0.54** | <0.1 | **0.11 (J)** | <0.1 | <0.1 | **0.92** | NT |
| SPN-8904B | 720 | B | 70-75 | Sep-18 | **0.061** | <0.1 | <0.1 | **0.18 (J)** | <0.1 | <0.2 | **3.3** | **0.15 (J)** | <0.1 | <0.1 | <0.1 | **1** | NT |
| SPN-8904C | 721 | C | 101.5-106.5 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.24** | <0.1 | <0.2 | **4.5** | <0.1 | <0.1 | <0.1 | <0.1 | **0.37** | NT |
| SPN-9103D | 725 | D | 190.5-200.5 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SPN-9104D | 726 | D | 196-206 | Oct-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | **2,200** | <0.1 | <0.1 | NT |
| SWN-9102C | 569 | C | 142.5-152.5 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9102D | 570 | D | 175-185 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9103B | 571 | B | 103.4-113.4 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.13 (J)** | <0.1 | <0.2 | **1.4** | **0.11 (J)** | <0.1 | <0.1 | <0.1 | **0.18 (J)** | NT |
| SWN-9103B (dup) | 571 | B | 103.4-113.4 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.14 (J)** | <0.1 | <0.2 | **1.9** | **0.13 (J)** | <0.1 | <0.1 | <0.1 | **0.2** | NT |
| SWN-9103C | 572 | C | 152.8-162.8 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.51** | **0.34** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9103D | 573 | D | 199.1-209.1 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **2.8** | **0.33** | <0.1 | <0.1 | <0.1 | **0.32** | NT |
| SWN-9103E | 574 | E | 227.9-237.9 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9104C | 575 | C | 154-164 | Sep-18 | <0.008 | <0.1 | <0.1 | **0.12 (J)** | <0.1 | <0.2 | **3.8** | **0.5** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9104D | 576 | D | 187-197 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **5.1** | **0.79** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9105B | 577 | B | 102.5-112.5 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.1 (J)** | **0.2** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9105C | 578 | C | 137-147 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.19 (J)** | **0.65** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| SWN-9105D | 579 | D | 190.5-200.5 | Sep-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.2 | **0.52** | **0.53** | <0.1 | <0.1 | <0.1 | <0.1 | NT |
| Chapter NR 140 Preventive Action Limit (PAL) | | | | | 0.005 | 85 | 0.7 | 40 | 0.06 | 200 | 0.5 | 0.6 | 3 | 100 | 0.5 | 0.5 | 2 |
| Chapter NR 140 Enforcement Standard (ES) | | | | | 0.05 | 850 | 7 | 200 | 0.6 | 1000 | 5 | 6.0 | 30 | 1000 | 5 | 5 | 10 |

Notes:
The Sample Level references the typical well depth configuration
Dinitrotoluene, Total (DNT) & VOC results are expressed in micrograms per liter (µg/l)
Nitrate, Total results are expressed in milligrams per liter (mg/l)
Bold values are detected results
Wells listed with (dup) after the name were duplicate samples
Results for Dinitrotoluene, Total were analyzed by SW8270DSIM
J = Analytical result is between the Limit of Detection (LOD) and Limit of Quantitation (LOQ)
NT = Not Tested

A total of ten monitoring wells had NR 140 ES exceedances for 2,4-DNT during September 2018. 2,4-DNT was not detected in any residential wells that were sampled during August 2018.

A total of seventeen monitoring wells had NR 140 ES exceedances for 2,6-DNT during September 2018. In addition, eight monitoring wells had NR 140 PAL exceedances for 2,6-DNT during September 2018. 2,6-DNT was not detected in any residential wells that were sampled during August 2018.

A total of twenty-one monitoring wells had NR 140 ES exceedances for total DNT during September 2018. In addition, four monitoring wells had NR 140 PAL exceedances for total DNT during September 2018. Total DNT was not detected in any residential wells that were sampled during August 2018.

One monitoring well had a NR 140 ES exceedance for ethyl ether during September 2018. In addition, three monitoring wells had NR 140 PAL exceedances for ethyl ether during September 2018. One residential well had an ethyl ether detection that was below the NR 140 PAL during August 2018.

Three monitoring wells had NR 140 PAL exceedances for nitrate during September 2018. Residential wells are no longer being sampled for nitrate due to historically low detections.

A total of two monitoring wells had NR 140 ES exceedances for TCE during September 2018. In addition, seventeen monitoring wells had NR 140 PAL exceedances for TCE during September 2018. TCE was not detected in any residential wells that were sampled during August 2018.

#### 4.5.1.1 *Carbon Tetrachloride*

The horizontal distribution of CTET is illustrated in Figure 22. The green shaded area displays where CTET was detected above the NR 140 PAL (0.5 µg/l). The blue shaded area displays where CTET was detected above the NR 140 ES (5 µg/l). These same color designations are also used in each CTET cross section. The highest concentration of CTET detected during September 2018 was 19 µg/l in PBN-9101C, which is located 2,300 feet upgradient of the Wisconsin River. The horizontal boundary of the CTET plume covers the largest area compared to ethyl ether, total DNT, and trichloroethene.

Figure 6 shows the orientation of the isoconcentration cross sections for CTET, which are illustrated in Figures 23, 24, 25, and 26. As shown in Figures 23 and 25, there is a dolomite/shale layer beneath the contamination plume that retards groundwater contamination from migrating into the lower Mt. Simon Formation (sandstone).

Figure 23 (A-A’) illustrates the estimated vertical extent of CTET, along the centerline of the PBG Plume, from the PBG (north) towards the Wisconsin River (south). The CTET concentrations are highest south of the BAAP boundary and in wells screened approximately 65 to 140 feet below the water table. The CTET plume extends north to south from the PBG to the

Wisconsin River with an average thickness of 90 feet beneath BAAP and 150 feet south of BAAP. The maximum depth of CTET is 150 feet below the water table at monitoring well PBM-9001D, which is screened in the gravel and sand just above the sandstone. Based on Figure 23, CTET has potentially entered the upper portion of the bedrock aquifer near PBM-9001D.

Based on the *Surface Waters Impact Investigation Report (BTS, LLC), November 2013*, CTET concentrations diminish as the PBG Plume migrates vertically and discharges into the Wisconsin River. CTET concentrations above the NR 140 ES were only identified in the sand aquifer; therefore, CTET does not migrate vertically into the bedrock. Isoconcentration sections for CTET (Figures 4 and 5) provided in the *Surface Waters Impact Investigation Report*, show the CTET plume boundaries in relation to the bedrock and Wisconsin River. More studies in this area would be helpful to further define the CTET concentrations above the bedrock.

CTET concentrations beneath the PBG (source area) are much lower than what is found downgradient of the PBG. The estimated boundary of the CTET plume is shown to approach the Wisconsin River. The groundwater mixes with the saturated sediment beneath the Wisconsin River. This zone is the groundwater/surface water interface. Dilution and volatilization of the CTET plume is expected to occur at the groundwater/surface water interface.

Figure 24 (B-B') illustrates the width and depth of the CTET plume approximately 2,000 feet south of the PBG. Figure 25 (C-C') illustrates the width and depth of the CTET plume approximately 6,600 feet south of the PBG and at the BAAP boundary. Figure 26 (D-D') illustrates the width and depth of the CTET plume, but off-site and approximately 12,000 feet south of the PBG. The CTET plume in Figure 24 is estimated to be approximately 3,200 feet wide and a maximum depth of 135 feet below the water table at PBN-9301C. The CTET plume in Figure 25 is estimated to be approximately 2,800 feet wide and a maximum depth of 150 feet below the water table and below PBN-1302C. The CTET plume in Figure 26 is estimated to be approximately 2,500 feet wide and a maximum depth of 120 feet below the water table at monitoring well SWN-9103D.

The following residential wells are shown on either Figure 23 (A-A') or Figure 26 (D-D'): Judd, Lins-K, Lins-R, Mueller-J, and Urban. These residential wells represent all the residential wells located near the PBG Plume. As shown in the figures, the Judd well is screened in the sand and gravel aquifer and the Lins-K, Lins-R, Mueller-J, and Urban wells are screened in the bedrock aquifer. There are several residential wells that were drilled through the CTET plume and then screened beneath the CTET plume.

#### 4.5.1.2 *Ethyl Ether*

The horizontal distribution of ethyl ether (diethyl ether) is illustrated in Figure 27. The green shaded area displays where ethyl ether was detected above the NR 140 PAL (100 µg/l). The blue shaded area displays where ethyl ether was detected above the NR 140 ES (1,000 µg/l). These same color designations are also used in each ethyl ether cross section. The highest concentration of ethyl ether detected during September 2018 was 2,200 µg/l in SPN-9104D, which is located at the BAAP Boundary. The horizontal boundary of the ethyl ether plume covers the smallest area compared to CTET, total DNT, and trichloroethene. The ethyl ether plume is shown in two small areas downgradient of the PBG.

Figure 6 shows the orientation of the isoconcentration cross sections for ethyl ether, which are illustrated in Figures 28, 29, 30, and 31. Figure 28 (A-A') illustrates the estimated vertical extent of ethyl ether, along the centerline of the PBG Plume, from the PBG (north) towards the Wisconsin River (south). The ethyl ether concentrations are highest at the BAAP boundary and in wells screened approximately 170 feet below the water table. The ethyl ether plume is approximately 60 feet thick beneath BAAP. The maximum depth of ethyl ether is 190 feet below the water table and below PBN-9304D, which is screened just above the top of the bedrock. Figure 28 shows ethyl ether to only be detected in monitoring wells near the bottom of the sand aquifer. Based on Figure 28, ethyl ether has likely entered the upper portion of the bedrock aquifer near PBN-9304D and SPN-9104D. Ethyl ether was not detected in PBN-1405F, which was constructed 110 feet beneath PBN-9304D and below the dolomite/shale layer.

Figure 29 (B-B') illustrates the width and depth of the ethyl ether plume approximately 2,000 feet south of the PBG. Figure 30 (C-C') illustrates the width and depth of the ethyl ether plume approximately 6,600 feet south of the PBG and at the BAAP boundary. Figure 31 (D-D') illustrates the width and depth of the ethyl ether plume, but off-site and approximately 12,000 feet south of the PBG. There is no ethyl ether plume shown in Figure 29 because there were no detections above 100 µg/l. The ethyl ether plume in Figure 30 is estimated to be approximately 750 feet wide and a maximum depth of 190 feet below the water table and below PBN-9304D. There is no ethyl ether plume shown in Figure 31 because there were no detections above 100 µg/l.

The following residential wells are shown on either Figure 28 (A-A') or Figure 31 (D-D'): Judd, Lins-K, Lins-R, Mueller-J, and Urban. There are also five residential wells located over 1,400 feet east of the ethyl ether plume shown in Figure 27. The highest ethyl ether concentration in these five wells was only 0.16 µg/l.

#### 4.5.1.3 *Trichloroethene*

The horizontal distribution of TCE is illustrated in Figure 32. The green shaded area displays where TCE was detected above the NR 140 PAL (0.5 µg/l). The blue shaded area displays where TCE was detected above the NR 140 ES (5 µg/l). These same color designations are also used in each TCE cross section. The highest concentration of TCE detected during September 2018 was 8.5 µg/l in PBN-9101C, which is located 2,300 feet upgradient of the Wisconsin River. The horizontal boundary of the TCE plume extends from the PBG to the Wisconsin River but is much narrower than the CTET plume.

Figure 6 shows the orientation of the isoconcentration cross sections for TCE, which are illustrated in Figures 33, 34, 35, and 36. Figure 33 (A-A') illustrates the estimated vertical extent of TCE, along the centerline of the PBG Plume, from the PBG (north) towards the Wisconsin River (south). The TCE concentrations are highest at the BAAP boundary, south of the BAAP boundary, and in wells screened approximately 65 to 140 feet below the water table. The TCE plume has an average thickness of 110 feet. The maximum depth of TCE is 145 feet below the water table and below PBM-9001D, which is screened just above the top of the bedrock. Based on Figure 33, TCE has likely entered the upper portion of the bedrock aquifer near PBM-9001D. TCE concentrations near the PBG (source area) are much lower than what is found downgradient of the PBG. The estimated boundary of the TCE plume is shown to approach the Wisconsin River.

Figure 34 (B-B') illustrates the width and depth of the TCE plume approximately 2,000 feet south of the PBG. Figure 35 (C-C') illustrates the width and depth of the TCE plume approximately 6,600 feet south of the PBG and at the BAAP boundary. Figure 36 (D-D') illustrates the width and depth of the TCE plume, but off-site and approximately 12,000 feet south of the PBG. The TCE plume in Figure 34 is estimated to be approximately 1,200 feet wide and a maximum depth of 80 feet below the water table at PBN-8902C. The TCE plume in Figure 35 is estimated to be approximately 1,400 feet wide and a maximum depth of 85 feet below the water table and below SPN-8903C. There is no TCE plume shown in Figure 36 because there were no detections above 0.5 µg/l.

The following residential wells are shown on either Figure 33 (A-A') or Figure 34 (D-D'): Judd, Lins-K, Lins-R, Mueller-J, and Urban. There are several residential wells that were drilled through the TCE plume and then screened beneath the TCE plume.

#### 4.5.1.4 *Total Dinitrotoluene*

The horizontal distribution of total DNT is illustrated in Figure 37. The total DNT concentration is the sum of all six DNT isomers (2,3-DNT, 2,4-DNT, 2,5-DNT, 2,6-DNT, 3,4-DNT, and 3,5-DNT). The green shaded area displays where total DNT was detected above the NR 140 PAL (0.005 µg/l). The blue shaded area displays where total DNT was detected above the NR 140 ES (0.05 µg/l). The red shaded area displays where total DNT was detected above 1.0 µg/l. These same color designations are also used in each total DNT cross section. The highest concentration of total DNT detected during September 2018 was 116.42 µg/l in PBN-8202A, which is immediately downgradient of the PBG. The total DNT plume is shown in three separate areas, near the PBG, near the BAAP boundary, and farther downgradient of the PBG to the Wisconsin River. The separation of the total DNT plumes maybe related to the extensive groundwater pumping conducted by the MIRM treatment system.

Figure 6 shows the orientation of the isoconcentration cross sections for total DNT, which are illustrated in Figures 38, 39, 40, 41, and 42. Figure 38 (A-A') illustrates the estimated vertical extent of total DNT, along the centerline of the PBG Plume, from the PBG (north) towards the Wisconsin River (south). The total DNT concentrations beneath the PBG (source area) are higher than what is found downgradient. The total DNT concentrations are much lower south of the BAAP boundary than what is found on BAAP. The total DNT concentrations are highest in wells screened approximately 0 to 30 feet below the water table. The total DNT plume has an average thickness of 100 feet. The maximum depth of total DNT is 100 feet below the water table at PBN-9903C, which is screened 40 feet above the top of the bedrock. Based on Figure 38, total DNT has not entered the bedrock aquifer beneath or downgradient of BAAP. The estimated boundary of the total DNT plume is shown to approach the Wisconsin River.

Figure 39 (A1-A1') illustrates the estimated vertical extent of total DNT beneath the capped PBG Waste Pits to the southeast corner of the Racetrack Area at PBN-8205A, B, C. The total DNT concentrations are highest in the shallow wells located beneath the PBG Waste Pits (source area). The highest concentrations of total DNT are shown in well nest PBN-8202A, B, C, which is downgradient of waste pit 2 (WP-2). The vertical depth of the total DNT plume beneath the PBG Waste Pits can only be estimated as there are no deeper monitoring wells.

Figure 40 (B-B') illustrates the width and depth of the total DNT plume approximately 2,000 feet south of the PBG. Figure 41 (C-C') illustrates the width and depth of the total DNT plume approximately 6,600 feet south of the PBG and at the BAAP boundary. Figure 42 (D-D') illustrates the width and depth of the total DNT plume, but off-site and approximately 12,000 feet south of the PBG. The total DNT plume in Figure 40 is estimated to be approximately 1,800 feet wide and a maximum depth of 100 feet below the water table at PBN-8902C. The total DNT plume in Figure 41 is estimated to be approximately 1,300 feet wide and a maximum depth of 130 feet below the water table and below PBN-1302C. There is no total DNT plume shown in Figure 42 because there were no detections above 0.005 µg/l.

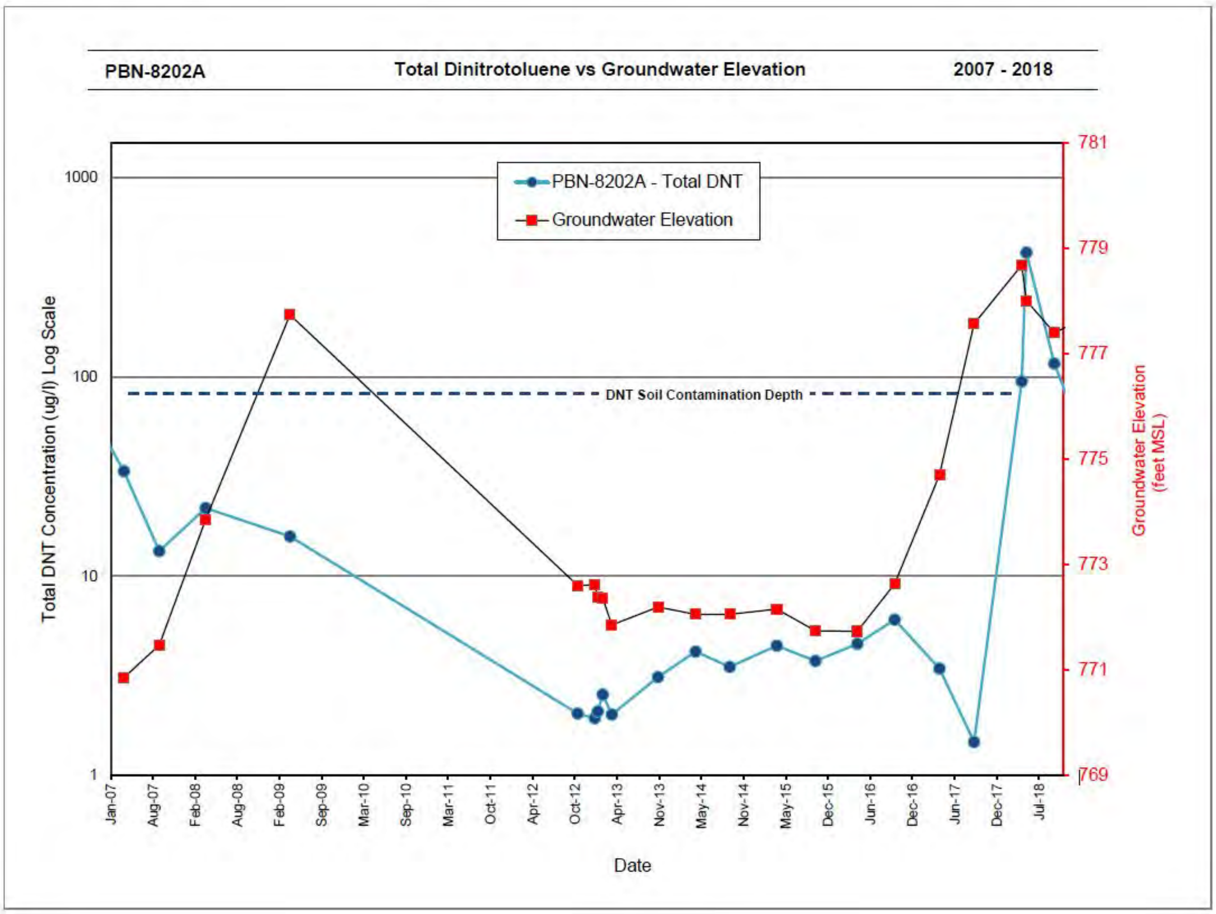
The following residential wells are shown on either Figure 38 (A-A') or Figure 42 (D-D'): Judd, Lins-K, Lins-R, Mueller-J, and Urban. There is one residential well that was drilled through the total DNT plume and then screened beneath the total DNT plume.

#### 4.5.1.5 *Concentration Graphs*

To evaluate contaminant trend data for the PBG Plume, concentration over time graphs were prepared for select monitoring wells within the plume. Graphs showing PBG Plume contaminant concentration over time are presented in Appendix E. The primary COPCs used for trend analysis were CTET, chloroform, ethyl ether, TCE, and total DNT. In the source area, data from eight monitoring wells were graphed. Graphs were prepared for 17 on-site monitoring wells located downgradient of the PBG. Graphs were prepared for 17 off-site monitoring wells located downgradient of the PBG.

The source area wells PBM-0002, PBM-0008, and PBN-8202A show a large decrease in DNT concentrations after 2002. These sharp decreases are related to the operation of the BEST system from 2001 to 2005. During December 2012, the IRM ceased groundwater pumping directly downgradient of the PBG Waste Pits and PBM-0002. Between 2012 to 2017, the total DNT concentrations in the source area wells stabilized between 1 to 5 µg/l. During April 2018, a noticeable increase in total DNT concentration was identified in PBN-8202A. PBN-8202A is located directly south and downgradient of the PBG Waste Pits (see Figure 18). The total DNT concentration in PBN-8202A increased from 1.469 µg/l during September 2017 to 94.65 µg/l during April 2018 to 420.294 µg/l during May 2018 to 116.42 µg/l during September 2018.

Between April 2016 and April 2018, the groundwater table near the PBG Waste Pits rose 6.9 feet. Provided below is a graph depicting both the total DNT concentration and groundwater elevation in PBN-8202A from 2007 to 2018. The graph shows a peak in the groundwater elevation in 2009 but not an increase of total DNT. During 2009, the IRM was still operating a groundwater pumping well approximately 125 feet southwest of PBN-8202A. The graph shows another peak in groundwater elevation in 2018 along with a sharp increase of total DNT in PBN-8202A. During 2018, the groundwater elevation in PBN-8202A ranged from 777.4 to 778.5 feet MSL. Based on the 2005 soil investigation data presented in Appendix B (Table 5), soil boring PBB-0502 (Waste Pit 2) had detectable concentrations of both 2,4-DNT and 2,6-DNT at a depth of 105 feet or 776.80 feet MSL. The following graph displays the DNT soil contamination depth in relation to the groundwater elevation. During the 2005 soil investigation, the groundwater was at an elevation of 774.5 feet MSL, below the soil contamination. Based on the above information, the groundwater beneath the PBG Waste Pits has risen above the DNT contaminated soil. The recent increase in total DNT concentrations in PBN-8202A appears to be related to the recent rise in groundwater coming into contact with the soil contamination.




The VOC compounds of CTET, chloroform, and TCE have been declining near the source area since the 1980's. The VOC compounds have declined to levels at or below the NR 140 ES.

In the on-site portion of the plume, the VOC compounds of CTET, chloroform, and TCE show decreasing trends in both the shallow and deep wells. The exception is that chloroform in PBN-8502A had a peak during 2015 but declined in 2016, 2017, and 2018. The ethyl ether concentrations in PBN-1001C and PBN-9304D have been decreasing. The DNT concentrations in the wells downgradient of the PBG show either stable or decreasing trends.

As the plume extends off-site, the VOC compounds of CTET, chloroform, and TCE show either stable or decreasing trends in both the shallow and deep wells. There are several monitoring wells that have seen peaks followed by decreases.

- The CTET concentration in SWN-9103C had a sharp peak during 2010 (90.1 µg/l) followed by a sharp decrease below 5 µg/l by 2014. The CTET concentration in PBN-9101C had a peak during 2012 (44.8 µg/l) followed by a decrease to 19 µg/l during 2018. The CTET concentration in PBM-9001D had a peak (above 25 µg/l) during 2011 followed by a slight decrease to 15 µg/l during 2017. During 2018, the CTET concentration in PBM-9001D peaked again at 25 µg/l and then dropped back to 15 µg/l. The CTET concentration in SWN-9104C has increased from 2015 to 2018, reaching 3.8 µg/l during September 2018. The CTET concentration in SWN-9104D has increased from 2015 to 2018, reaching 5.1 µg/l during September 2018.

- The chloroform concentration in SWN-9103C had a peak during 2007 (above 7 µg/l) followed by a decrease to below 0.5 µg/l during 2018. The chloroform concentration in PBN-9101C had a peak during 2011 (above 6 µg/l) followed by a decrease to 1.7 µg/l during 2018. The chloroform concentration in PBM-9001D had a peak (above 3 µg/l) during 2011 followed by a decrease to 1.4 µg/l during 2018.

- The ethyl ether concentration in PBN-9903D peaked during 2014 (above 3,500 µg/l) but decreased during 2015 and has remained stable with a concentration of 440 µg/l during 2018. Ethyl ether is not detected in the off-site monitoring wells located south (downgradient) of PBN-9903D.

- The TCE concentration in SWN-9103B had a peak during 2000 (above 7 µg/l) followed by a steady decrease to below 0.5 µg/l by 2014. The TCE concentration in SWN-9103D had a peak during 2014 (near 5 µg/l) followed by a decrease to below 0.5 µg/l by 2018. The TCE concentration in PBN-9101C had a peak during 2011 (above 14 µg/l) followed by a decrease till 2017. Between 2017 and 2018, the TCE concentration in PBN-9101C increased from 6.5 to 8.8 µg/l. PBN-9101C was not sampled between 1999 to 2010; therefore, no data was available. The TCE concentration in PBM-9001D had a peak during 2011 (above 5 µg/l) followed by a decrease till 2015. Between 2015 and 2018, the TCE concentration in PBM-9001D has increased from 3.1 to 8.6 µg/l.

- The DNT concentrations in the off-site monitoring wells have been stable or decreasing. The exception is that PBN-9101C had a peak (above 0.1 µg/l) during 2013 followed by a slight decrease to 0.08 µg/l during 2018.

#### 4.5.1.6 *Monitored Natural Attenuation*

An evaluation of existing site information and groundwater data was conducted to illustrate that monitored natural attenuation (MNA) of chlorinated solvents or VOCs has been occurring within the PBG Plume. Based on groundwater monitoring data collected between 2015 and 2018, the following VOCs have been detected above the NR 140 PAL or ES routinely in the PBG Plume: CTET, chloroform, ethyl ether, and TCE.

The *Draft Technical Report Natural Attenuation Screening Study for the Propellant Burning Ground* (Stone & Webster, August 1999) provided evidence that VOCs are naturally attenuating in the PBG Plume. The Stone & Webster report summarized that the concentrations of chlorinated solvents in the groundwater are declining over time, along the length of the plume, and decrease with separation from the source area. This indicates that, overall, the chlorinated solvents are leaving the groundwater by some natural attenuation mechanism. Stone & Webster documented that no chlorinated solvent degradation products or transformation products have been detected in the groundwater. Based on groundwater monitoring data over the past 30 years, the more toxic TCE degradation product, vinyl chloride, has not been detected.

During December 1998, Stone & Webster collected groundwater samples from 38 monitoring wells located within or near the PBG Plume. Monitoring wells were chosen upgradient of the source area, in the source area, and downgradient of the source area. The samples were laboratory analyzed for VOCs and semi-volatile organic compounds (SVOCs). The samples were also analyzed for the following geochemical parameters: chloride, dissolved oxygen, iron II, methane, nitrate, nitrite, oxidation reduction potential (ORP), pH, sulfate, sulfide, temperature, total dissolved solids, and total organic carbon. Based on this 1998 data, there is no evidence to suggest that reductive dechlorination has occurred in the PBG Plume. The PBG Plume is a well-oxygenated groundwater system (aerobic) with little or no organic matter.

Stone & Webster documented that CTET, chloroform, and TCE concentrations dropped between 1990 and 1998 in six monitoring wells that are located along the axis (centerline) of the PBG Plume (PBN-8910A, PBN-8205A, PBN-8501A, PBN-8504A, PBN-8912B, and SPN-8903B). A generalized summation of the Stone & Webster groundwater data findings is shown below.

**Summary of 1990 - 1998 VOC Groundwater Data**
**Propellant Burning Ground Plume**

| Monitoring Well | Distance from Source Area (feet) | Date Sampled | Carbon Tetrachloride | Chloroform | Trichloroethene |
|---|---|---|---|---|---|
| PBN-8910A | 700 | Mar-90 | 31.0 | 5.6 | 103.0 |
| | | Dec-98 | 11.0 | 1.6 | 48.0 |
| PBN-8205A | 1,540 | Mar-90 | 88.0 | 5.5 | 112.0 |
| | | Dec-98 | 42.0 | 2.6 | 41.0 |
| PBN-8501A | 2,520 | Mar-90 | 43.0 | 14.0 | 30.0 |
| | | Dec-98 | 17.0 | 3.3 | 20.0 |
| PBN-8504A | 3,920 | Mar-91 | 21.0 | 6.9 | 11.0 |
| | | Dec-98 | 0.8 | <0.2 | <0.2 |
| PBN-8912B | 5,600 | Mar-90 | 51.0 | 7.8 | 20.0 |
| | | Dec-98 | <0.4 | <0.2 | <0.2 |
| SPN-8903B | 7,000 | Mar-90 | 130.0 | 11.0 | <5.0 |
| | | Dec-98 | 24.0 | 2.1 | 1.3 |

Note: All results expressed in micrograms per liter (µg/l)

Shown on Figure 19 are locations of these six monitoring wells (shown above) in relation to the former IRM and MIRM extraction wells. Even though the four IRM wells (BCW-1, BCW-2, BCW-3, and SCW-1) were running from 1990 to 1998, they were only pumping a combined 350 gpm. Four of the six monitoring wells were isolated from the IRM wells and therefore not influenced by their pumping. The MIRM became operational in 1996 with six boundary extraction wells (EW-161, EW-162, EW-163, EW-164, EW-165, and EW-166) pumping a combined 3,000 gpm. Extraction wells EW-167, EW-168, EW-169, and EW-170 (EW-170R) were operational between 2006 and 2015. Five of the six monitoring wells were isolated (located far north) from the MIRM wells and therefore not influenced by their pumping. Shown in the above summary table are reductions in VOCs that clearly indicate that the PBG Plume was undergoing natural attenuation between 1990 and 1998.

Concentration over time graphs for monitoring well nests PBN-8205A, B, and C; PBN-8502A, PBN-8902BR, and PBN-8902C; and PBN-8912A, PBN-8912B, PBN-9112C, and PBN-9112D are provided in Appendix E. These 10 monitoring wells are located south of the former IRM wells and north of the original (1996) MIRM wells. These monitoring wells were not influenced by pumping operations until the MIRM was realigned in 2005. CTET, chloroform, and TCE concentrations for all 10 monitoring wells show decreasing trends. A more thorough discussion of concentration graphs for these 10 monitoring wells and 24 other monitoring wells associated with the PBG Plume is provided in Section 4.5.1.6. Ethyl ether concentrations in PBN-1001C, PBN-9304D, and PBN-9903D have been declining since 2013, graphs are provided in Appendix E.

Based on the historic groundwater data, MNA has a reasonable probability of bringing the VOCs in the PBG Plume into compliance with Chapter NR 140 groundwater quality standards within a reasonable period of time.

### *4.5.2 Deterrent Burning Ground Plume*

The DBG Plume originates at the DBG and extends southeast beyond the BAAP boundary. East of BAAP, the plume continues southeast towards Weigand's Bay which is connected to the Wisconsin River. The DBG Plume shown in Figure 21 represents the area where groundwater concentrations exceed a NR 140 PAL or ES for 2,4-DNT, 2,6-DNT, or total DNT. All six DNT isomers (2,3-DNT, 2,4-DNT, 2,5-DNT, 2,6-DNT, 3,4-DNT, and 3,5-DNT) have been detected in the DBG Plume. Because total DNT encompasses all six DNT isomers, total DNT was used to map the DBG Plume boundaries. The DBG Plume boundaries shown in Figure 21 are approximate and based on total DNT groundwater data collected during 2018 from both monitoring wells and residential wells. Table 12 summarizes the groundwater analytical results from the April 2018 sampling event for the monitoring wells associated with the DBG Plume. The April 2018 sampling round includes results for total DNT, sulfate, and VOCs. Table 10 summarizes the groundwater analytical results from the August 2018 residential well sampling event. Table 11 summarizes the groundwater analytical results from the September 2018 monitoring well sampling event. Monitoring wells associated with the DBG Plume were not sampled for VOCs during September 2018. An isoconcentration map and two cross sections were prepared for total DNT. The isoconcentration map was prepared using all groundwater

**Table 12**
**Groundwater Analytical Results**
**April 2018 (DBG Plume)**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,2-Dichloroethane** | **1,2-Dichloropropane** | **1,1,1-Trichloroethane** | **1,1,2-Trichloroethane** | **Dichlorodifluoromethane** | **Ethyl Ether** | **Tetrahydrofuran** | **Trichloroethene** | **Sulfate, Total** |
| **DBG PLUME AREA WELLS** | | | | | | | | | | | | | | |
| DBM-8201 | 301 | A | 154.6-174.6 | Apr-18 | **2.216** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **18** |
| DBM-8202 | 302 | A | 137.3-157.3 | Apr-18 | **0.578** | <0.1 | <0.1 | **0.97** | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **31** |
| DBM-8903 | 306 | A | 113-133 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-1001B | 472 | B | 154.5-159.5 | Apr-18 | **0.48** | <0.1 | <0.1 | **1.5** | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-1001C | 473 | C | 192-197 | Apr-18 | **0.024 (J)** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-1001E | 474 | E | 274.9-279.9 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-1002C | 476 | C | 205.1-210.1 | Apr-18 | **0.772** | <0.1 | <0.1 | **0.23** | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **19** |
| DBN-1002E | 477 | E | 275.5-280.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **18** |
| DBN-9501A | 314 | A | 110-120 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-9501B | 315 | B | 162.5-172.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-9501C | 316 | C | 218.5-228.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| DBN-9501E | 317 | E | 245.2-255.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELM-8901 | 216 | A | 145.5-165 | Apr-18 | **1.409** | <0.1 | <0.1 | **1.2** | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **76** |
| ELM-8907 | 220 | A | 130.3-150.3 | Apr-18 | **0.57** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **17** |
| ELM-8908 | 221 | A | 125-145 | Apr-18 | **0.345** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **15** |
| ELM-8909 | 222 | A | 135-155 | Apr-18 | <0.008 | <0.1 | <0.1 | **0.76** | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **13** |
| ELM-9501 | 234 | A | 54-69 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-0801B | 455 | B | 100-105 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-0801B (dup) | 455 | B | 100-105 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-0801C | 456 | C | 145.5-150.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-0801E | 457 | E | 202.6-207.6 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |

**Table 12**
**Groundwater Analytical Results**
**April 2018 (DBG Plume)**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,2-Dichloroethane** | **1,2-Dichloropropane** | **1,1,1-Trichloroethane** | **1,1,2-Trichloroethane** | **Dichlorodifluoromethane** | **Ethyl Ether** | **Tetrahydrofuran** | **Trichloroethene** | **Sulfate, Total** |
| ELN-1001B | 460 | B | 91.1-96.1 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1001C | 461 | C | 155.2-160.2 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1001E | 462 | E | 240.5-245.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1002A | 463 | A | 55.3-70.3 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1002B | 464 | B | 111.2-116.2 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1002B (dup) | 464 | B | 111.2-116.2 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1002C | 465 | C | 159.1-164.1 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1002E | 466 | E | 231.5-236.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1003A | 467 | A | 16.2-31.2 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1003B | 468 | B | 91.5-96.5 | Apr-18 | **0.232** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1003B (dup) | 468 | B | 91.5-96.5 | Apr-18 | **0.225** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1003B | 468 | B | 91.5-96.5 | May-18 | **0.186** | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003C | 469 | C | 155.1-160.1 | Apr-18 | **0.074** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1003C | 469 | C | 155.1-160.1 | May-18 | **0.108** | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1003E | 470 | E | 255.6-230.6 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1502A | 533 | A | 115.3-130.3 | Apr-18 | **0.594** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1502A (dup) | 533 | A | 115.3-130.3 | Apr-18 | **0.537** | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1502A | 533 | A | 115.3-130.3 | May-18 | **0.69** | NT | NT | NT | NT | NT | NT | NT | NT | NT |
| ELN-1502C | 534 | C | 198-203 | Apr-18 | **0.022 (J)** | <0.1 | <0.1 | **0.71** | <0.1 | **0.14 (J)** | <0.1 | <1 | <0.1 | NT |
| ELN-1503A | 535 | A | 73.7-88.7 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1503C | 536 | C | 157.6-162.6 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| ELN-1504B | 537 | B | 34.8-39.8 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |

**Table 12**
**Groundwater Analytical Results**
**April 2018 (DBG Plume)**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| | | | | | | Volatile Organic Compounds (VOC) - SW8260C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Well ID** | **Sample Level** | **Sample Depth (feet)** | **Sample Date** | **Dinitrotoluene, Total** | **1,2-Dichloroethane** | **1,2-Dichloropropane** | **1,1,1-Trichloroethane** | **1,1,2-Trichloroethane** | **Dichlorodifluoromethane** | **Ethyl Ether** | **Tetrahydrofuran** | **Trichloroethene** | **Sulfate, Total** |
| ELN-8203A | 210 | A | 147.5-157.5 | Apr-18 | <0.008 | <0.1 | **0.28** | <0.1 | **0.3** | **0.15 (J)** | **0.49** | <1 | <0.1 | **1100** |
| ELN-8203B | 211 | B | 164-166 | Apr-18 | <0.008 | <0.1 | **0.36** | <0.1 | **0.98** | **0.36** | **0.27** | <1 | <0.1 | **990** |
| ELN-8203B (dup) | 211 | B | 164-166 | Apr-18 | <0.008 | <0.1 | **0.35** | **0.11 (J)** | **0.87** | **0.38** | **0.31** | <1 | <0.1 | **1000** |
| ELN-8203C | 212 | C | 174-176 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | **0.38** | <0.1 | <0.1 | <1 | <0.1 | **55** |
| ELN-8902B | 224 | B | 173.5-178.5 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **18** |
| ELN-9107A | 227 | A | 116-126 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **21** |
| ELN-9107B | 228 | B | 135-145 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | **0.25** | <0.1 | <0.1 | <1 | <0.1 | **34** |
| ELN-9402AR | 231 | A | 130-145 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | **11** |
| S1121 | 755 | A | 39.11-59.3 | Apr-18 | <0.008 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1 | <0.1 | NT |
| S1134R | 236 | A | 136-151 | Apr-18 | <0.008 | <0.1 | **0.11 (J)** | <0.1 | **0.42** | <0.1 | <0.1 | <1 | <0.1 | **750** |
| Chapter NR 140 Preventive Action Limit (PAL) | | | | | 0.005 | 0.5 | 0.5 | 40 | 0.5 | 200 | 100 | 10 | 0.5 | 125 |
| Chapter NR 140 Enforcement Standard (ES) | | | | | 0.05 | 5 | 5 | 200 | 5 | 1000 | 1000 | 50 | 5 | 250 |

Notes:
- The Sample Level references the typical well depth configuration
- Dinitrotoluene, Total (DNT) & VOC results are expressed in micrograms per liter (µg/l)
- Sulfate, Total results are expressed in milligrams per liter (mg/l)
- Bold values are detected results
- Wells listed with (dup) after the name were duplicate samples
- Results for Dinitrotoluene, Total were analyzed by SW8270DSIM
- J = Analytical result is between the Limit of Detection (LOD) and Limit of Quantitation (LOQ)
- NT = Not Tested

data collected during 2018. The isoconcentration cross sections were prepared using groundwater data collected during August and September 2018.

During 2015, 2016, 2017, and 2018, 2,4-DNT, 2,6-DNT, total DNT, sulfate, and 1,1,2-trichloroethane (1,1,2-TCA) have been COPCs in the DBG Plume. The DBG Plume groundwater results from the April, August, and September 2018 sampling events were evaluated for COPCs that exceeded a Chapter NR 140 PAL Groundwater Standard.

A total of three monitoring wells had NR 140 PAL exceedances for 2,4-DNT during April 2018. 2,4-DNT was not detected in any residential wells that were sampled during August 2018.

A total of two monitoring wells had NR 140 ES exceedances for 2,6-DNT during April 2018. In addition, eight monitoring wells had NR 140 PAL exceedances for 2,6-DNT during April 2018. One monitoring well had a NR 140 ES exceedance for 2,6-DNT during September 2018. In addition, eight monitoring wells had NR 140 PAL exceedances for 2,6-DNT during September 2018. 2,6-DNT was not detected in any residential wells that were sampled during August 2018.

A total of ten monitoring wells had NR 140 ES exceedances for total DNT during April 2018. In addition, two monitoring wells had NR 140 PAL exceedances for total DNT during April 2018. A total of eleven monitoring wells had NR 140 ES exceedances for total DNT during September 2018. Total DNT was not detected in any residential wells that were sampled during August 2018.

Three monitoring wells had an NR 140 ES exceedance for sulfate during April 2018. Residential wells are no longer being sampled for sulfate due to historically low detections.

Two residential wells had NR 140 PAL exceedances for TCE during August 2018. No monitoring wells had a TCE detection during 2018. Historically, TCE has not been detected in monitoring wells associated with the DBG Plume. Because TCE can be a residential contaminant and the contamination related to past Army operations has not been present in this area, these residential wells are assumed to not be contaminated by the DBG Plume. Based on Army investigations, some residential wells pumps have been found to contain TCE.

One monitoring well had a NR 140 PAL exceedance for 1,1,2-TCA during April 2018. One residential well had a 1,1,2-TCA detection but below the NR 140 PAL during August 2018.

#### 4.5.2.1 *Total Dinitrotoluene*

The horizontal distribution of total DNT is illustrated in Figure 43. The green shaded area displays where total DNT was detected above the NR 140 PAL (0.005 µg/l). The blue shaded area displays where total DNT was detected above the NR 140 ES (0.05 µg/l). The red shaded area displays where total DNT was detected above 1.0 µg/l. These same color designations are also used in each total DNT cross section. The highest concentration of total DNT detected during 2018 was 3.005 µg/l in DBM-8201, which is immediately downgradient of the DBG. The horizontal boundary of the DBG Plume extends from the DBG towards Weigand's Bay but does not reach it. There are two wells shown in Figure 43 that are between the DBG Plume and

Weigand's Bay. Total DNT was not detected in these two wells (ELN-1504B and Purcell-D) during 2018. During April 2019, there was a detection of 3,4-DNT and total DNT in residential well Purcell-D that was above the NR 140 ES.

Figure 6 shows the orientation of the contaminant plume isoconcentration cross sections for total DNT, which are illustrated in Figures 44 and 45. Figure 44 (E-E') illustrates the estimated vertical extent of total DNT, along the centerline of the DBG Plume, from the DBG (northwest) towards Weigand's Bay (southeast). The total DNT concentrations adjacent to the DBG (source area) are higher than what is found downgradient. The highest total DNT concentrations are found in wells screened approximately 0 to 30 feet below the water table. The total DNT plume extends northwest to southeast approximately 6,700 feet with an average thickness of 80 feet. Figure 44 shows that the DNT plume is only present in the sand and gravel aquifer and has not migrated downward into the bedrock.

Figure 45 (F-F') illustrates the width and depth of the total DNT plume between 200 to 1,200 feet south of the DBG. The total DNT plume is estimated to be approximately 1,000 feet wide and a maximum depth of 55 feet below the water table in Figure 45 (F-F'), which is close to the source area.

The Purcell-D residential well is shown on Figure 44 (E-E') at the leading edge of the DBG Plume. The Purcell-D residential well was chosen based on its location along the cross section. The Purcell-D residential well is 112 feet deep and screened in the sand and gravel aquifer. Most of the residential wells in the Weigand's Bay area (downgradient of the DBG Plume) are screened in the sand and gravel aquifer along with a few bedrock wells. Based on the depth and location in relation to the DBG Plume and the historic groundwater monitoring data results, the DBG Plume containing total DNT is migrating toward the residential wells. Results from the August 2018 sampling of 23 residential wells located east and southeast of the DBG Plume did not detect total DNT (see Table 10). However, during April 2019 there was a detection of 3,4-DNT and total DNT in residential well Purcell-D that was above the NR 140 ES.

#### 4.5.2.2 *Sulfate*

The horizontal distribution of sulfate is illustrated in Figure 46. The sulfate isoconcentrations are interpreted from the April 2018 groundwater data. Annually during April, 16 monitoring wells are sampled for sulfate. Table 12 summarizes the sulfate groundwater analytical results from the April 2018 sampling event. Since 2013, residential wells are no longer sampled for sulfate due to the historically low detections and the stability of the sulfate near Landfill #5. The green shaded area displays where sulfate was detected above the NR 140 PAL [125 milligrams per liter (mg/l)]. The blue shaded area displays where sulfate was detected above the NR 140 ES (250 mg/l). The highest concentration of sulfate detected during April 2018 was 1,100 mg/l in ELN-8203A, which is immediately downgradient of Landfill #5. The limits of the sulfate isoconcentrations are approximately 500 by 850 feet. Due to the limited extent of sulfate detections, cross sections were not prepared. Wisconsin has a "secondary" NR 140 Public Welfare Groundwater Quality Standard for sulfate. The sulfate Chapter NR 140 Groundwater Standard is based on a taste threshold and not based on risk to human health.

#### 4.5.2.3 *1,1,2-Trichloroethane*

Concentrations of 1,1,2-trichloroethane (1,1,2-TCA) exceeded the NR 140 PAL in monitoring well ELN-8203B, which is downgradient of Landfill #5 (see Figure 21). Table 12 summarizes the 1,1,2-TCA groundwater analytical results from the April 2018 sampling event. The April 2018 concentration of 1,1,2-TCA in ELN-8203B was 0.98 µg/l. 1,1,2-TCA is detected in several other monitoring wells but below the NR 140 PAL (0.5 µg/l). 1,1,2-TCA is routinely detected (below the PAL) in the Spear residential well, which is located 2,600 feet southeast of ELN-8203B. Due to the limited extent of 1,1,2-TCA detections, an isoconcentration map or cross section were not prepared.

#### 4.5.2.4 *Trichloroethene*

The groundwater results from the August 2018 sampling event show that TCE was detected in three residential wells (Anderson-R, Hendershot, and Wenger). Two of those residential wells had TCE detections above the NR 140 PAL (0.5 µg/l). All three residential wells are located in the Weigand's Bay area (downgradient of the DBG Plume), see Figure 20. All three residential wells are screened in the sand aquifer, see Table 5. TCE has routinely been detected in the Anderson-R and Hendershot residential wells since 2007 and the Wenger residential well since 2010. The maximum concentration of TCE (4.7 µg/l) was detected in the Hendershot residential well during August 2016. This TCE concentration is below the federal MCL and the NR 140 ES of 5 µg/l for drinking water. The TCE concentration in the Hendershot residential well during August 2018 was 2.0 µg/l.

Table 12 summarizes the TCE groundwater analytical results from the April 2018 monitoring well sampling event. No monitoring wells had a TCE detection during April 2018. Historically, TCE has not been detected in monitoring wells associated with the DBG Plume. There has been no source of TCE identified at BAAP that is upgradient of the Weigand's Bay area. A potential source of TCE is the shallow well jet pump at each residence. During 2012, the Army investigated TCE contamination in the Goelz residential well adjacent to Gruber's Grove Bay. The investigation determined that the well jet pump was the source of TCE contamination in the shallow residential well. Due to the absence of TCE in monitoring wells, TCE is not a COPC in the DBG Plume; therefore, an isoconcentration map or cross section was not prepared.

#### 4.5.2.5 *Concentration Graphs*

To evaluate contaminant trend data for the DBG Plume, concentration over time graphs were prepared for select monitoring wells within the plume. Graphs showing DBG Plume contaminant concentration over time are presented in Appendix E. The primary COPC in the DBG Plume is total DNT; therefore, concentrations of total DNT were evaluated for trends. In the source area, data from wells DBM-8201, DBM-8202, and DBN-1001B, C, E were graphed. DBM-8201 shows a generally stable trend with some periods of elevated concentrations. DBM-8202 shows a spike in 2003 followed by a stable to decreasing trend. DBN-1001B shows a decreasing trend from 2014 till 2017. Between 2017 and 2018, the total DNT concentration in DBN-1001B has increased from 0.162 to 0.5978 µg/l. At the center of the DBG Plume, data from wells ELM-8901, ELM-8907, ELM-8908, and ELN-1502A, C were graphed. ELM-8901 shows a steep decreasing trend since 2009. ELM-8907 showed a generally stable trend followed by an increase between 2008 and 2011 then a steadily decreasing trend. ELM-8908 showed some variability then noticeable increases in 2008 and 2013 followed by a decreasing trend since 2014. Data from four wells (ELM-9501 and ELN-0801B, C, E) were used to evaluate the downgradient portion of the plume. All four wells have shown either stable or decreasing trends since 2009. During 2018, total DNT was not detected in ELM-9501 and ELN-0801B, C, E.

ELN-1502A and ELN-1502C were installed in 2015 to provide additional definition of the center of the DBG Plume near the BAAP boundary (see Figure 21). The total DNT concentration in ELN-1502A has been steadily increasing from 0.0087 µg/l during December 2015 to 0.801 µg/l during September 2018. Data from a nest of wells (ELN-1003A, B, C, E) located at the leading edge of the plume indicates a steady increase of total DNT in ELN-1003B and ELN-1003C. The total DNT concentration in ELN-1003B increased from 0.051 µg/l during April 2017 to 0.32 µg/l during November 2018. The total DNT concentration in ELN-1003C increased from 0.0085 µg/l during April 2017 to 0.278 µg/l during November 2018.

### *4.5.3 Central Plume*

The source of the Central Plume is suspected to be related to production waste water, which was discharged to open ditches in the rocket paste and rocket propellant areas. The soil in this area has been thoroughly investigated and remediated. No groundwater contamination source was clearly identified. The Central Plume shown in Figure 21 represents the area where groundwater concentrations exceed a NR 140 PAL for 2,6-DNT or total DNT. 2,6-DNT has been routinely detected in either monitoring wells or residential wells in the Central Plume. Because total DNT encompasses all six DNT isomers, total DNT was used to map the Central Plume boundary. The Central Plume boundary shown in Figure 21 is approximate and based on total DNT groundwater data collected during 2018 from both monitoring wells and residential wells. Total DNT has been detected at shallow depths in the sand and gravel aquifer. Table 13 summarizes the groundwater analytical results from the June 2018 monitoring well sampling event. Table 10 summarizes the groundwater analytical results from the August 2018 residential well sampling event. An isoconcentration map and cross section were prepared for total DNT. The isoconcentration map was prepared using all groundwater data collected during 2018. The isoconcentration cross section was prepared using groundwater data collected only during June and August 2018. Since there has been no historical NR 140 ES exceedances for chloroform, an isoconcentration map or cross section were not prepared.

During 2015, 2016, 2017, and 2018, 2,6-DNT, total DNT, and chloroform have been COPCs in the Central Plume. The Central Plume groundwater results from the June and August 2018 sampling events were evaluated for COPCs that exceeded a Chapter NR 140 PAL Groundwater Standard. Six monitoring wells and one residential well had NR 140 ES exceedances for both 2,6-DNT and total DNT during 2018. Three monitoring wells and two residential wells had NR 140 PAL exceedances for chloroform during 2018.

**Table 13**
**Groundwater Analytical Results - June 2018**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Well | Well ID | Sample Level | Sample Depth (feet) | Sample Date | Dinitrotoluene, Total | Chloroform |
|---|---|---|---|---|---|---|
| **DBG PLUME AREA WELLS** | | | | | | |
| ELN-1003B | 468 | B | 91.5-96.5 | Jun-18 | **0.179** | NT |
| ELN-1003C | 469 | C | 155.1-160.1 | Jun-18 | <0.008 | NT |
| ELN-1003C (dup) | 469 | C | 155.1-160.1 | Jun-18 | <0.008 | NT |
| ELN-1504B | 537 | B | 34.8-39.8 | Jun-18 | <0.008 | NT |
| **CENTRAL PLUME AREA WELLS** | | | | | | |
| NLN-1001A | 331 | A | 96-111.5 | Jun-18 | **0.209** | NT |
| NLN-1001C | 332 | C | 149-154.5 | Jun-18 | **0.203** | NT |
| NLN-8203A | 258 | A | 105.5-115.5 | Jun-18 | <0.008 | NT |
| NLN-8203B | 259 | B | 125.5-127.5 | Jun-18 | <0.008 | NT |
| NLN-8203B (dup) | 259 | B | 125.5-127.5 | Jun-18 | <0.008 | NT |
| NLN-8203C | 260 | C | 136.5-138.5 | Jun-18 | <0.008 | NT |
| NPM-8901 | 506 | A | 80-100 | Jun-18 | <0.008 | NT |
| RIM-1003 | 491 | A | 99.3-114.3 | Jun-18 | <0.008 | NT |
| RIM-1004 | 494 | A | 55.5-70.5 | Jun-18 | <0.008 | NT |
| RIN-0701C | 443 | C | 175-180 | Jun-18 | <0.008 | NT |
| RIN-0702C | 444 | C | 196-201 | Jun-18 | <0.008 | NT |
| RIN-0703C | 445 | C | 202-207 | Jun-18 | <0.008 | NT |
| RIN-1002A | 492 | A | 77.2-92.2 | Jun-18 | <0.008 | NT |
| RIN-1002C | 493 | C | 174.8-179.8 | Jun-18 | **0.062** | NT |
| RIN-1003A | 495 | A | 75.5-90.5 | Jun-18 | <0.008 | NT |
| RIN-1004B | 498 | B | 141.7-146.7 | Jun-18 | **0.066** | NT |
| RIN-1004B (dup) | 498 | B | 141.7-146.7 | Jun-18 | **0.066** | NT |
| RIN-1005A | 496 | A | 45.5-60.5 | Jun-18 | <0.008 | NT |
| RIN-1005C | 497 | C | 142-147 | Jun-18 | **0.063** | NT |
| RIN-1501B | 538 | B | 113.5-123.5 | Jun-18 | <0.008 | NT |
| RIN-1501C | 539 | C | 160.2-165.2 | Jun-18 | <0.008 | NT |
| RIN-1501D | 540 | D | 232.8-237.8 | Jun-18 | <0.008 | NT |
| RIN-1502B | 541 | B | 98.4-103.4 | Jun-18 | <0.008 | NT |
| RIN-1502C | 542 | C | 138.1-143.1 | Jun-18 | <0.008 | NT |
| RIN-1502D | 543 | D | 208.3-213.3 | Jun-18 | <0.008 | NT |
| RPM-8901 | 507 | A | 104.8-124.3 | Jun-18 | <0.008 | NT |
| S1111 | 751 | A | 78.75-99 | Jun-18 | <0.008 | NT |
| SEN-0501A | 580 | A | 17-32 | Jun-18 | <0.008 | **0.17 (J)** |
| SEN-0501B | 581 | B | 77-87 | Jun-18 | <0.008 | **0.46** |
| SEN-0501D | 582 | D | 180-190 | Jun-18 | <0.008 | **0.91** |
| SEN-0502A | 583 | A | 18-33 | Jun-18 | <0.008 | <0.1 |
| SEN-0502D | 584 | D | 177-187 | Jun-18 | <0.008 | **0.63** |
| SEN-0503A | 585 | A | 40.5-55.5 | Jun-18 | <0.008 | <0.1 |
| SEN-0503B | 586 | B | 100-110 | Jun-18 | **0.065** | <0.1 |
| SEN-0503B (dup) | 586 | B | 100-110 | Jun-18 | **0.064** | <0.1 |
| SEN-0503D | 587 | D | 203-213 | Jun-18 | <0.008 | **1.2** |
| Chapter NR 140 Preventive Action Limit (PAL) | | | | | 0.005 | 0.6 |
| Chapter NR 140 Enforcement Standard (ES) | | | | | 0.05 | 6 |

Notes:
The Sample Level references the typical well depth configuration
All results are expressed in micrograms per liter (µg/l)
Bold values are detected results
Wells listed with (dup) after the name were duplicate samples
Results for Dinitrotoluene, Total were analyzed by SW8270DSIM
J = Analytical result is between the Limit of Detection (LOD) and Limit of Quantitation (LOQ)

NE = Not Established
NT = Not Tested

#### 4.5.3.1 *Total Dinitrotoluene*

The horizontal distribution of total DNT is illustrated in Figure 47. The green shaded area displays where total DNT was detected above the NR 140 PAL (0.005 µg/l). The blue shaded area displays where total DNT was detected above the NR 140 ES (0.05 µg/l). These same color designations are used in the total DNT cross section. The highest concentration of total DNT detected during June or August 2018 was 0.209 µg/l in NLN-1001A, which is located in northeast corner of the Central Plume (see Figure 21). Figure 47 shows that total DNT in the northern section of the Central Plume, near the source area, has been depleted. Prior to 2017, the Central Plume encompassed a larger area that stretched up to the source area (NPM-8901) and further west towards RIM-1003 and RPM-8901.

Figure 6 shows the orientation of the contaminant plume isoconcentration cross section for total DNT, which is illustrated in Figure 48. Figure 48 (G-G') illustrates the estimated vertical extent of total DNT, along the centerline of the Central Plume, as it migrates towards Gruber's Grove Bay. The total DNT concentrations are highest in the northern portion of the Central Plume and in wells screened within 60 feet below the water table. The total DNT plume extends from the north to the south with an average thickness of 100 feet in the northern and southern sections. The total DNT plume is thinner, 60 feet, within the middle section. Figure 48 indicates that the DNT plume is only present in the sand and gravel aquifer and has not migrated downward into the bedrock.

The WE-UK125 residential well is shown on Figure 48 (G-G'). The WE-UK125 residential well was chosen based on its location along the cross section. The WE-UK125 residential well is screened in the bedrock aquifer, but the majority of the residential wells in the Water's Edge Subdivision are screened in the sand and gravel aquifer. Many of the residential wells located in the Water's Edge Subdivision are screened at the same depth (60 feet below the water table) that the DNT plume occurs. The DNT plume encompasses a portion of the residential wells located in the Water's Edge Subdivision.

#### 4.5.3.2 *Benzene*

The groundwater results from the June 2017 sampling event indicated that benzene was detected in SEN-0503B at a concentration of 10 µg/l, which is above the NR 140 ES of 5 µg/l. SEN-0503B is located in the Water's Edge Subdivision (see Figure 21). None of the other seven monitoring wells or 16 residential wells in the Water's Edge Subdivision had detections of benzene during 2017. Between 2005 and 2016, benzene had not been detected in SEN-0503B. Since June 2017, SEN-0503B has been sampled twice during 2017 and twice during 2018 with no benzene detections. Benzene was also not detected in any monitoring wells or residential wells that were sampled during 2018. The source of the benzene is unknown. However, there is no evidence to suggest that these past benzene detections are attributable to the Army. Therefore, benzene is not considered to be a COPC.

#### 4.5.3.3 *Concentration Graphs*

To evaluate contaminant trend data for the Central Plume, concentration over time graphs were prepared for select monitoring wells within the plume. Concentration over time graphs are provided in Appendix E. The primary COPC in the Central Plume is total DNT; therefore, concentrations of total DNT were evaluated. Seventeen of the 23 wells selected showed stable to decreasing trends throughout the plume. The other six wells (NLN-1001A, NLN-1001C, RIN-1002C, RIN-1005C, RIN-1004B, and SEN-0503B) have shown increasing total DNT concentrations. The total DNT concentrations in these six wells increased from below the NR 140 ES during June 2017 to above the NR 140 ES during June 2018.

### *4.5.4 Nitrocellulose Production Area Plume*

The source of the NC Area Plume is believed to be from various nitrocellulose production buildings in the northwest section of BAAP. The NC Area Plume shown in Figure 21 represents the area where groundwater concentrations exceed a NR 140 PAL or ES for 2,6-DNT or total DNT. 2,6-DNT has been routinely detected in monitoring wells in the NC Area Plume. Because total DNT encompasses all six DNT isomers, total DNT was used to map the NC Area Plume boundary. The NC Area Plume boundary shown in Figure 21 is approximate and based on total DNT groundwater data collected during 2018 from only monitoring wells. There are no residential wells located near the NC Area Plume. Total DNT has only been detected at shallow depths in the sand and gravel aquifer. Table 11 summarizes the groundwater analytical results from the September 2018 monitoring well sampling event. An isoconcentration map and cross section were prepared for total DNT. The isoconcentration map was prepared using all groundwater data collected during 2018. The isoconcentration cross section was prepared using groundwater data collected during September 2018.

During 2015, 2016, 2017, and 2018, 2,6-DNT and total DNT have been COPCs in the NC Area Plume. The NC Area Plume groundwater results from the September 2018 sampling event were evaluated for COPCs that exceeded a Chapter NR 140 PAL Groundwater Standard. Three monitoring wells had an NR 140 ES exceedance for both 2,6-DNT and total DNT. In addition, two monitoring wells had a NR 140 PAL exceedance for both 2,6-DNT and total DNT.

#### 4.5.4.1 *Total Dinitrotoluene*

The horizontal distribution of total DNT is illustrated in Figure 49. The green shaded area displays where total DNT was detected above the NR 140 PAL (0.005 μg/l). The blue shaded area displays where total DNT was detected above the NR 140 ES (0.05 μg/l). This same color designation is used in the total DNT cross section. The highest concentration of total DNT detected during September 2018 was 0.22 μg/l in RIM-1002, which is located in the northern section of the NC Area Plume.

Figure 6 shows the orientation of the contaminant plume isoconcentration cross section for total DNT, which is illustrated in Figure 50. Figure 50 (H-H’) illustrates the estimated vertical extent of total DNT, along the centerline of the NC Area Plume, as it migrates south. The total DNT concentrations are highest in wells screened at the water table. The total DNT plume extends from the north to the south with an average thickness of 30 feet. Figure 50 indicates that DNT has not migrated vertically into the monitoring wells screened 80 feet below the water table.

#### 4.5.4.2 *Concentration Graphs*

To evaluate contaminant trend data for the NC Area Plume, concentration over time graphs were prepared for select monitoring wells within the plume. Concentration over time graphs are provided in Appendix E. The primary COPC in the NC Area Plume is total DNT; therefore, concentrations of total DNT were evaluated. The total DNT concentration in RIM-1002 has increased from 0.045 µg/l during September 2016 to 0.22 µg/l during September 2018. Four of the five wells selected showed stable to decreasing trends throughout the plume. These four wells are located downgradient of RIM-1002. There are no residential wells located near the NC Area Plume.

## 4.6 Residential Well Replacement

### *4.6.1 Propellant Burning Ground Plume*

The Army has replaced three residential wells due to impacts from chlorinated solvents. All three residential wells were located in the southern portion of the PBG Plume (see Figure 20). CTET was detected above the NR 140 ES in the Kirner (former Gruber-South) residential well during April 1990. The Kirner (former Gruber-South) replacement residential well, located on Hwy 78, was installed by the Army in 1990. CTET was detected above the NR 140 ES in the Mueller-J residential well during April 1990. The Mueller-J replacement residential well, located on Hwy 78, was installed by the Army in 1990. CTET and chloroform were detected above the NR 140 ES in the Lins-K residential well during April 1990. The Lins-K replacement residential well, located on County Road Z, was installed by the Army in 1996. Prior to well replacement, bottled water had been provided to the affected residences.

### *4.6.2 Deterrent Burning Ground Plume*

The Army has replaced one residential well due to impacts from total DNT. The Purcell-D residential well is located at the southeastern extent of the DBG Plume (shown in Inset A on Figure 20). The Purcell-D residential well, located on Hwy 78, was replaced by the Army in July 2019. During April 2019, 3,4-DNT and total DNT were detected at 0.056 µg/l in the Purcell-D residential well. This total DNT concentration was above the NR 140 ES. The contaminated residential well was screened in the sand aquifer down to 112 feet deep. The replacement well was drilled into the lower bedrock aquifer, sealing off the upper sand aquifer with a grouted steel casing. Prior to well replacement, bottled water was being provided to the affected residence.

### *4.6.3 Central Plume*

The Army has replaced three residential wells due to impacts from 2,6-DNT. All three residential wells were located in the southern portion of the Central Plume and in the Water's Edge Subdivision (see Inset B on Figure 20). During 2004, the 2,6-DNT and total DNT concentrations in two residential wells exceeded the NR 140 ES. In 2005, the Army replaced the WE-RM385 and WE-RR541 residential wells with WE-SQ017 and WE-SQ001, respectively. The original residential wells were screened in the sand and gravel aquifer down to 100 feet deep. The replacement residential wells were also screened in the sand and gravel aquifer but at 180 feet deep. During June 2018, the 2,6-DNT and total DNT concentrations in the WE-UK124 residential well exceeded the NR 140 ES. In 2018, the Army replaced the WE-UK124 residential well with WE-ZE512. The original residential well (WE-UK124) was screened in the sand and gravel aquifer down to 100 feet deep. The replacement well (WE-ZE512) was drilled into the lower bedrock aquifer, sealing off the upper sand aquifer with a grouted steel casing. Prior to well replacement, bottled water had been provided to the affected residences.

# 5.0 GROUNDWATER HUMAN HEALTH RISK ASSESSMENT

A groundwater human health risk assessment (HHRA) was performed to determine and document whether groundwater contamination originating from BAAP posed a potential current or hypothetical future risk to human health. Because the RI only pertains to groundwater contamination, the focus of the HHRA was only groundwater. Soil remedial actions conducted by the Army and property restrictions have minimized the potential exposure of soil contamination to human health based on the anticipated future land use at the former BAAP.

Source areas and associated contaminant plumes for BAAP are shown on Figure 1. This HHRA provides risk managers information for determining whether unacceptable human health risks (cancer and non-cancer health hazards) might be caused by exposure to contaminants in the groundwater such that additional evaluation or action is necessary. The HHRA addresses human exposure pathways related to groundwater including the potential for vapor intrusion and for potable use or other domestic purposes. The Army will use the HHRA results in determining the scope of any response action(s) undertaken to address contaminants in the groundwater caused by past Army activities at BAAP.

## 5.1 Risk Assessment Overview

A HHRA is required to be completed as part of a remedial investigation/feasibility study under CERCLA to evaluate the potential human health risks associated with chemical exposure to environmental media (e.g., groundwater). This HHRA was conducted using standard USEPA risk assessment guidance, exposure assumptions, and toxicity factors. The USEPA HHRA process uses conservative assumptions about exposure to chemicals and their toxicity so that risks reported within this HHRA will not be underestimated. In all circumstances, priority is given to evaluating the potential human health risk regardless of the impact.

Risk assessments generally make risk estimates for defined groups or populations. The term receptor is often used to designate people who may be exposed to an environmental hazard and to whom the HHRA would be directed. Identification of receptor location and pathways by which they might be exposed is an integral part of any HHRA.

The focus of this HHRA is related to groundwater and the risk it may pose to humans. The HHRA does not address any potential risks associated with the direct exposure to contaminated soil or ecological receptors. For some media such as soil, the potential for exposure does not currently exist.

A screening level groundwater risk evaluation was conducted for each of the four plumes using USEPA human health risk assessment methods (USEPA 1989, 1991). The screening risk evaluation was conducted in two steps. First, site chemical concentrations were compared to health-based screening levels to identify chemicals of potential concern (COPCs). Second, risk estimates were calculated for COPCs that exceeded screening levels. The risk estimates were then compared to risk management criteria to put the magnitude of the risks into perspective.

The following four sections provide plume-specific screening level groundwater risk evaluations for each of the four plume areas. The risks for all four plume areas are assessed for the on-site portion of the plume and the off-site portion of the plume.

## 5.2 Identification of Exposure Pathways

As defined in the Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A (USEPA 1989), an exposure pathway is composed of the following elements:

- A source and mechanism of chemical release to the environment
- An environment transportation medium (e.g. groundwater) for the released chemical and/or mechanism to transfer the chemical from one medium to another
- A point of potential contact by humans with contaminated medium
- A route of exposure (i.e., ingestion, inhalation or dermal)

The exposure routes associated with domestic use of water include ingestion, inhalation, and dermal exposure.

- **Ingestion** – Potential chemical exposure because of groundwater use for potable purposes for drinking water and preparing food.
- **Inhalation** – Potential exposure due to groundwater use for domestic purposes resulting in inhalation of the contaminants during activities such as bathing, food preparation, and dishwashing.
- **Dermal** – Potential use of groundwater resulting in chemical absorption through skin during activities such as washing hands and bathing.

## 5.3 Screening Level Groundwater Risk Evaluation

A Screening Level Groundwater Risk Evaluation was conducted by Exponent, see Appendix F. The objectives of the risk evaluation were to estimate current and hypothetical future risks using groundwater quality data from existing residential and off-site monitoring wells (current risk) and on-site groundwater monitoring wells (hypothetical future risk). Exponent's screening level groundwater risk evaluation was conducted using standard USEPA risk assessment methods. The conservative calculations for this risk screening overestimate the actual risk. The maximum concentrations of analytes associated with each plume for current (residential wells and off-site monitoring wells) and hypothetical future (on-site monitoring wells) scenarios were used to estimate the risks.

### *5.3.1 Data Collection and Evaluation*

Groundwater quality data for residential wells and off-site monitoring wells monitored by the Army from the past four years (2015, 2016, 2017, and 2018) were used to evaluate current groundwater exposure and risk. To evaluate hypothetical future groundwater exposure and risk, on-site monitoring well data collected over the past four years (same period) were used. The past four years of groundwater quality data was selected to best represent current groundwater quality conditions.

The maximum concentrations of contaminants in the wells associated with each plume were used to estimate the risks. In other words, the highest concentrations of each chemical in each plume (i.e., many wells) were evaluated as if they had occurred in any one well. Consequently, the risks represented should be viewed as upper bound estimates of potential groundwater risks within a specific plume area.

### *5.3.2 Chemicals of Potential Concern Selection Process*

The first step in the screening level groundwater risk evaluation is to select those chemicals that exceed screening levels for groundwater. Both USEPA's tapwater RSLs and Wisconsin NR 140 Groundwater Standards (ES and PAL) were used to screen chemicals. A comprehensive summary of the groundwater screening levels is provided in the Screening Level Groundwater Risk Evaluation included in Appendix F. The determination of which groundwater standard was used to screen each chemical is further defined in Table 1 of Appendix F. A Total Hazard Quotient (THQ) Table THQ = 0.1 was used for screening as it is recommended by the USEPA for sites with multiple chemicals. Chemicals or analytes that exceeded the lowest available groundwater screening value are referred to as the COPCs. The maximum concentration of the chemicals detected in each plume were compared to the lowest of the groundwater screening values. These COPCs were retained for further risk evaluation and calculations.

### *5.3.3 Exposure Assessment and Assumption*

USEPA's tapwater RSLs are risk-based concentrations developed using specific generic exposure assumptions that represent reasonable maximum exposure (RME) to groundwater. Exposure to chemicals in groundwater are incorporated into the tapwater RSLs for both ingestion and dermal contact with the water, as well as inhalation of the portion of the chemicals in groundwater that are volatilized from the water as it is used (e.g., for bathing). Tapwater RSLs based on non-cancer effects are also developed separately for adults and children, and then the lower of the two RSLs is selected for evaluating risks to people. RSLs based on cancer incorporate exposure during both childhood and adulthood. For this reason, the tapwater RSLs are considered a conservative risk-based benchmark on which to estimate risk associated with groundwater chemical exposure.

The groundwater risk evaluation was performed using tapwater RSLs that incorporate RME factors that characterize how adults and children are assumed to be exposed to groundwater. Some of the key exposure assumptions used to develop the tapwater RSLs are listed below.

**USEPA Tapwater Regional Screening Levels (RSLs) Exposure Assumptions**

| Assumption | Adult | Child |
|---|---|---|
| Exposure Duration (cancer effects) | 20 years | 6 years |
| Exposure Duration (non-cancer effects) | 26 years | 6 years |
| Exposure Frequency | 350 days/year | 350 days/year |
| Water Ingestion Rate | 2.5 liters/day | 0.78 liter/day |
| Hours/day Air Inhaled | 24 hours/day | 24 hours/day |
| Body Weight | 80 kilograms | 15 kilograms |
| Averaging Time (cancer effects) [averaging of exposure is integrated over a person's lifetime] | 25,550 days (i.e., 365 days/year x 70 years) | |
| Averaging Time (non-cancer effects) [averaging occurs over the adult or child's exposure duration] | 9,490 days (i.e., 365 days/year x 26 years) | 2,190 days (i.e., 365 days/year x 6 years) |

#### 5.3.3.1 *Cancer Risk Characterization*

Cancer risks were estimated for each COPC related to each plume. The cancer risk is the probability that an individual will develop cancer due to chemical exposure in the groundwater over their lifetime. This probability of contracting cancer due to chemical exposure represents the incremental increase in the probability of developing cancer during one's lifetime above and beyond the background probability of developing cancer. For example, $1x10^{-6}$ represents a one in a million chance of contracting cancer. This cancer risk is in addition to the general background level risk of contracting cancer of any kind during one's lifetime unrelated to groundwater chemical exposure. Based on the USEPA's National Contingency Plan, cumulative carcinogenic risk below $1x10^{-6}$ are generally considered to represent a negligible risk, cumulative risks between $1x10^{-6}$ and $1x10^{-4}$ are within a range considered acceptable under most conditions and cumulative cancer risk above $1x10^{-4}$ indicate unacceptable levels of risk where potential action or further evaluation needs to be considered.

In off-site areas, where the Army does not have control over the use of the groundwater as a drinking water source, a cumulative cancer risk greater than $1x10^{-6}$ is cause for potential action or additional evaluation. For areas within the BAAP property, where the Army has control over the use of groundwater as a drinking source, a cumulative cancer risk greater than $1x10^{-4}$ is cause for potential action or additional evaluation.

#### 5.3.3.2 *Non-Cancer Risk Characterization*

Non-cancer risks were estimated for each COPC related to each plume. For non-cancer effects, the likelihood that a receptor will develop an adverse effect other than cancer (e.g., kidney disease) is estimated by comparing the predicted level of exposure for a chemical with the highest level of exposure that is considered protective. The chemical-specific non-cancer risk is represented by a hazard quotient (HQ) value, which is derived by comparing the groundwater chemical concentrations to the chemical-specific tapwater RSLs. If an HQ value is less than or equal to one, then adverse health effects associated with exposure to that chemical in the groundwater are unlikely to occur even among sensitive individuals (e.g., children). An HQ greater than one indicates that there is the potential for a health effect and that additional analysis is necessary. The sum of all non-cancer risks (i.e., each HQ for each COPC) within an area or plume is referred to as the hazard index (HI). An HI greater than one indicates a level of exposure that needs to be evaluated further to determine if a health concern exists.

#### 5.3.3.3 *Risk Calculations*

The default tapwater RSL values provided in the USEPA's RSL Resident Tapwater Generic Table (November 2018) were used to calculate the risks. Groundwater risk estimates were calculated for each plume using a simple scaling method developed by the USEPA. For each COPC, the calculations described below were used to estimate potential cancer and non-cancer risks.

Cancer Risk: (Groundwater Concentration x Target Cancer Risk)/RSL for Tapwater
Non-cancer HQ: (Groundwater Concentration x Target Hazard Quotient)/RSL for Tapwater

The target cancer risk that the RSL is based upon is $1x10^{-6}$ and the target hazard quotient is 0.1 as recommended by USEPA since multiple contaminants are present at the site.

#### 5.3.3.4 *Risk Evaluation Results*

A comprehensive summary of the groundwater risk calculations is provided in the Screening Level Groundwater Risk Evaluation included in Appendix F. The total DNT concentration represents the sum of all isomers of DNT detected in the water sample. The risk associated with DNT was evaluated for both total DNT and individual isomers. The higher of the two risk estimates (i.e., based on total or the sum of the individual isomers) were used in calculating the total risk for each plume area.

## 5.4 Propellant Burning Ground Plume

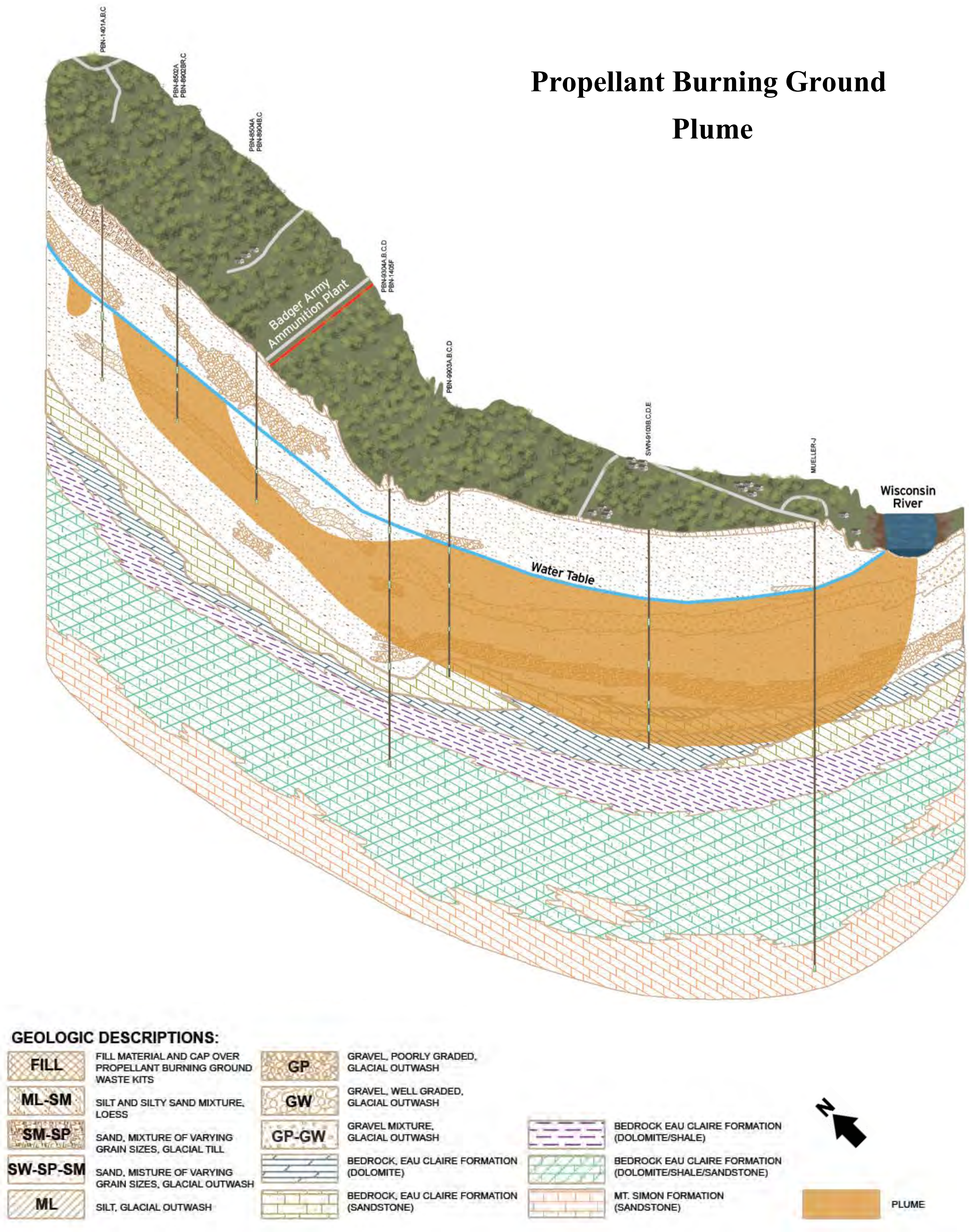
### *5.4.1 Characterization of Exposure Settings*

The sources of the PBG Plume are in the southwestern portion of BAAP, see Figure 1. The PBG sources are comprised of the PBG Waste Pits, 1949 Pit, Racetrack Area, and Landfill #1. The Army has covered each of the PBG source areas with either an engineered cap or soil cover to inhibit the movement of contaminants in the soil to the groundwater. The PBG Waste Pits and 1949 Pit became active sometime between 1942 and 1949 and were last used in 1983. A clay and geomembrane barrier cap was installed over the 1949 Pit in 1998 and the PBG Waste Pits in 2008. The Racetrack Area consisted of a series of burning pads, plates and pits that were used from 1949 to 1994. In 1995, three-fourths of the Racetrack Area was covered with soil to prevent contact with residual lead in the soil. Contaminated soil was removed from the remaining portion of the Racetrack Area in 1997. Landfill #1 is a closed demolition debris disposal facility located east of the PBG Waste Pits that was used between 1942 and 1959. A composite cap (two feet of clay and geomembrane barrier) was installed over Landfill #1 in 1997. Section 3.1 provides additional details on remediation activities of the source areas.

DNT and volatile organic solvents (e.g. carbon tetrachloride, chloroform, and trichloroethene) are known to have been disposed of at the PBG through open burning and burial during production periods. Contamination from these disposal and open burning activities migrated through the soil and into the groundwater. Groundwater beneath the PBG source areas is approximately 105 feet deep. The contaminated groundwater in the PBG Plume has migrated south to southeast (off-site) and then discharges into the Wisconsin River, see Figure 1. As the PBG Plume migrates away from the source area, it sinks lower into the sand aquifer. The off-site portion of the PBG Plume sinks deeper into the sand aquifer. Groundwater in the PBG Plume travels approximately 306 feet per year. Contaminants in the PBG Plume are expected to travel at the same speed as groundwater. Groundwater beneath the off-site residential areas is approximately 80 feet deep. Contaminated groundwater (above the NR 140 ES) in the off-site portion of the PBG Plume has been identified within the sand aquifer at depths between 80 and 210 feet. The sand aquifer extends down to 210 feet. The three residential wells located within the areal extent of the PBG Plume range in depth from 240 to 534 feet and are screened in the bedrock. These bedrock residential wells draw their groundwater from beneath the contaminated portion of the PBG Plume. The residential wells located outside the areal extent of the PBG Plume range in depth from 122 to 310 feet and average 250 feet deep. Over half the residential wells located outside of the PBG Plume are screened in the bedrock. Both DNT and VOCs have been detected in monitoring wells located in the PBG Plume. Sections 4.4 and 4.5 provide additional details on groundwater properties and groundwater contaminants.

The Army has performed various soil remediation activities at the PBG source areas (bioremediation, soil excavation, and soil vapor extraction). The Army performed groundwater remediation using a groundwater pump and treat system from 1990 to 2015 at the source areas and downgradient of the source areas. The pump and treat system influenced the groundwater flow in the PBG Plume by drawing groundwater downward within the area of pumping influence. The pump and treat system also reduced the off-site migration of the PBG Plume when it was operational. Since pumping was stopped in 2015, the portion of the PBG Plume near the BAAP boundary has shifted eastward toward residential wells. Over the past 24 months, the groundwater table beneath the PBG source areas has risen six feet. This rise in groundwater has resulted in an increase of DNT concentrations directly downgradient (south) of the source areas. Sections 4.4 and 4.5 provide additional details on groundwater properties and groundwater contaminants.

A graphical depiction of the PBG Plume in relationship to the local geology, monitoring wells, residential wells, site features, and groundwater plume boundaries is shown on the subsequent page. The groundwater flow direction is from the upper left (north) towards the right (southeast). The groundwater contaminant plume is shown below the water table and migrates into the Wisconsin River. The groundwater contaminant plume is shown to have traveled past the BAAP property and beneath a residential area.


Propellant Burning Ground
Plume
PBN-1401A,B,C
PBN-8502A
PBN-8902BR,C
PBN-8504A
PBN-8904B,C
PBN-9304A,B,C,D
PBN-1405F
PBN-9903A,B,C,D
SWN-9103B,C,D,E
MUELLER-J
Badger Army Ammunition Plant
Wisconsin River
Water Table
GEOLOGIC DESCRIPTIONS:
FILL
FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE KITS
ML-SM
SILT AND SILTY SAND MIXTURE, LOESS
SM-SP
SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
SW-SP-SM
SAND, MISTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
ML
SILT, GLACIAL OUTWASH
GP
GRAVEL, POORLY GRADED, GLACIAL OUTWASH
GW
GRAVEL, WELL GRADED, GLACIAL OUTWASH
GP-GW
GRAVEL MIXTURE, GLACIAL OUTWASH
BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE)
MT. SIMON FORMATION (SANDSTONE)
PLUME
N

A groundwater conceptual site model (CSM) for the PBG Plume is provided in Appendix G. The CSM shows the relationship between the sources of contamination, how the contamination is transported, type of media exposure, the route of exposure, and who may be exposed. The contaminants infiltrated through the soil (leaching) below the waste disposal areas until they reached the groundwater. The contaminants within the groundwater have been transported with the directional flow of groundwater into the Wisconsin River to the south-southeast. Contaminated groundwater has the potential to reach residential wells which may be used for domestic or potable purposes. Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during bathing or dishwashing, and dermal contact while bathing.

The exposure routes associated with domestic use of water, as shown on the CSM (Appendix G), include ingestion, inhalation, and dermal exposure. The off-site residential use pathways are potentially complete under current land use conditions and warrant further evaluation. The on-site hypothetical future residential use pathways are incomplete or considered insignificant under current land use conditions but potentially complete under hypothetical future on-site groundwater usage.

The exposure route associated with vapor intrusion, as shown on the CSM, includes only inhalation of indoor vapors. Both the off-site and on-site residential use vapor intrusion exposure pathways are incomplete or considered insignificant based on past vapor intrusion investigations and so no further evaluation is warranted. Section 5.4.2 discusses the potential vapor intrusion exposure into buildings.

### *5.4.2 Exposure Quantification – Vapor Intrusion Pathway Analysis*

An evaluation was conducted to determine whether vapors from PBG Plume of groundwater contamination pose a current or hypothetical future risk to human health. Vapor intrusion occurs when there is a migration of vapor-forming chemicals from a subsurface source (i.e., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air.

The subsurface contaminants that have the greatest potential to pose a health concern via vapor intrusion, based upon their volatility, and potential hazards is provided in the USEPA's Office of Solid Waste and Emergency Response (OSWER) Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air [OSWER Publication 9200.2-154, June 2015]. The USEPA's OSWER Technical Guide specifies that a chemical generally is "volatile" if: 1) vapor pressure is greater than 1 millimeter of mercury (mm Hg), or 2) Henry's law constant (ratio of a chemical's vapor pressure in air to its solubility in water) is greater than $10^{-5}$ atmosphere-meter cubed per mole (atm $m^3$ $mol^{-1}$). Common vapor-forming chemicals are VOCs, such as carbon tetrachloride, gasoline compounds, and trichloroethene. Other compounds such as the six DNT isomers (2,3-, 2,4-, 2,5-, 2,6-, 3,4-, and 3,5-) are not as volatile and are semi-volatile organic compounds (SVOCs).

The USEPA's OSWER specifications were compared to the chemical properties of the six DNT isomers. The vapor pressures for all six DNT isomers are well below 1 mm Hg. Also, Henry's law constants for all DNT isomers are well below $10^{-5}$ atm $m^3$ $mol^{-1}$. Therefore DNT is not likely to volatilize from the groundwater into soil and therefore does not pose a vapor pathway risk. Based on this information, DNT does not contribute to vapor intrusion risk related to human health. In addition to DNT, the PBG Plume contains VOCs that could be considered a vapor intrusion risk; therefore, further evaluation of VOC vapor intrusion was conducted.

During 2012, the Army conducted two vapor intrusion pathway analysis investigations associated with the PBG Plume. Copies of these investigation reports are enclosed in Appendix H. The goal of the vapor intrusion pathway analysis was to evaluate if VOCs in the groundwater could vertically migrate through the subsurface and into buildings. Vapor sampling was conducted at eight locations south of BAAP, within/near the PBG Plume. The off-site locations were also positioned near current residential properties. Vapor samples were collected using the post-run tubing vapor sampling technique in accordance with WDNR vapor intrusion guidance, Addressing Vapor Intrusion at Remediation & Redevelopment Sites in Wisconsin, PUB-RR-800, December 2010. The vapor samples were collected through soil borings drilled approximately 40 feet below ground surface. The groundwater depth for the sampling locations was approximately 80 feet below ground surface. The vapor samples were laboratory analyzed for chloroform, carbon tetrachloride, and trichloroethene by the Wisconsin State Laboratory of Hygiene. Based on groundwater samples collected from monitoring wells located within the off-site portion of the PBG Plume, only chloroform, carbon tetrachloride, and trichloroethene were detected. Evaluation or laboratory analysis of other VOCs was not warranted during the 2012 vapor intrusion pathway analysis investigations.

Analytical results of soil gas samples collected off-site did not exceed the 2011 WDNR Vapor Regional Screening Levels (RSLs) for Deep Soil Gas. The 2012 vapor intrusion pathway analysis reports concluded that the PBG Plume does not present a risk to human health via vapor intrusion off-site of BAAP. Because the vapor sample analysis results for chloroform, carbon tetrachloride, and trichloroethene did not exceed the RSLs, additional investigation (e.g., sub-slab, indoor air) of the vapor pathway was not warranted.

Based on the vapor intrusion pathway analysis investigations conducted during 2012, inhalation exposure due to soil gas vapor intrusion from the PBG Plume does not pose a current or potential future risk to area residents.

### *5.4.3 Exposure Quantification – Groundwater Pathway Analysis*

#### 5.4.3.1 *Current and Potential Future Uses of Groundwater*

Groundwater located in the PBG Plume within the boundary of BAAP is not used for human consumption. The land that was transferred from the Army to other property owners includes a deed restriction on the use of groundwater and so restricts the potential exposure to groundwater within the boundary of BAAP. These groundwater access restrictions state that the property owner "shall not access or use groundwater underlying the property for any purpose without the prior written approval of the Army and the WDNR".

Residential wells located outside of BAAP use groundwater for potable water and domestic purposes. The potential future use of groundwater adjacent to and downgradient of BAAP is expected to be for potable water and domestic purposes.

Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during showering or dishwashing, and dermal contact while bathing. Groundwater contaminants from BAAP impacted three residential wells located in the PBG Plume. The Army replaced these three residential wells due to impacts from VOCs (carbon tetrachloride and/or chloroform). Section 4.6 provides additional details on the residential well replacements conducted by the Army.

### *5.4.4 Risk Evaluation Summary*

#### 5.4.4.1 *Hypothetical Future On-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to hypothetical future on-site risks associated with the PBG Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-4}$ or HI > 1).

**Summary of Hypothetical Future Risk – Propellant Burning Ground Plume (On-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| On-Site (Hypothetical Future Risk) | **$6x10^{-3}$** | **53** | 2,6-DNT<br>Ethyl Ether<br>Trichloroethene |

Risks calculated using the simple scaling method for a hypothetical future residential scenario, along with the maximum observed concentration of each COPC, yielded cumulative cancer risk estimates above the risk management criterion for the on-site portion of the PBG Plume. The cumulative cancer risk ($6x10^{-3}$) for the PBG Plume was above the risk management criterion ($1x10^{-4}$). The contaminant of concern that contributed to the cumulative cancer risk for the PBG Plume was 2,6-DNT.

The calculated non-cancer HI of 53 was above the risk management criterion (HI > 1) in the on-site portion of the PBG Plume. The contaminants of concern that contributed to the HI > 1 in the PBG Plume were 2,6-DNT, ethyl ether and trichloroethene.

Based on the maximum risk scenario, the on-site portion of the PBG Plume represents an area that, if groundwater migrated off-site would be associated with cumulative groundwater risks above the risk management criteria (cumulative cancer risk above $1x10^{-4}$ and non-cancer HI above 1). The on-site portion of the PBG Plume has the potential to migrate off-site, thus impacting downgradient residential wells. Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

#### 5.4.4.2 *Current Off-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to current off-site groundwater risks associated with the PBG Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-6}$ or HI > 1).

**Summary of Current Risk – Propellant Burning Ground Plume**
**(Residential Well and Off-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| Off-Site (Current Risk) | **$1x10^{-4}$** | **5** | 2,6-DNT<br>Carbon Tetrachloride<br>Chloroform<br>Trichloroethene |

Risks calculated using the simple scaling method for a current residential scenario, along with the maximum observed concentration of COPC, yielded cumulative cancer risk estimates above the risk management criterion for the off-site portion of the PBG Plume. The cumulative cancer risk ($1x10^{-4}$) for the PBG Plume was above the risk management criterion ($1x10^{-6}$). The contaminants of concern that contributed to the cumulative cancer risk for the PBG Plume were 2,6-DNT, carbon tetrachloride, chloroform, and trichloroethene.

The calculated non-cancer HI of 5 was above the risk management criterion (HI > 1) in the off-site portion of the PBG Plume. The contaminant of concern that contributed to the HI > 1 in the PBG Plume was trichloroethene.

Based on the maximum risk scenario, the off-site portion of the PBG Plume is associated with cumulative groundwater risks above the risk management criteria (cumulative cancer risk above $1x10^{-6}$ and non-cancer HI above 1). Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

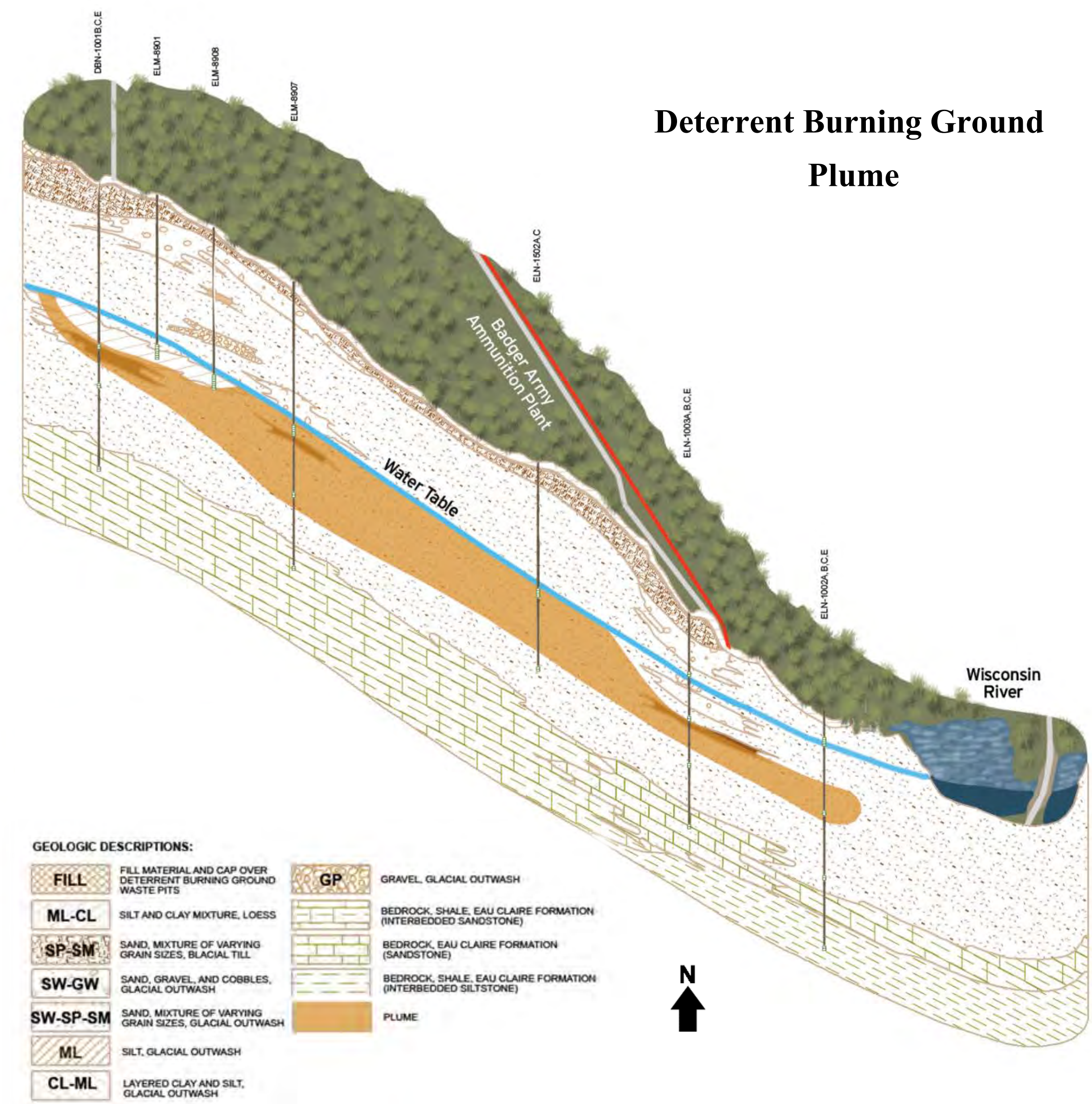
## 5.5 Deterrent Burning Ground Plume

### *5.5.1 Characterization of Exposure Settings*

The sources of the DBG Plume are in the northeastern portion of BAAP, see Figure 1. The DBG sources are comprised of the DBG (waste pits), Landfill #3, and Landfill #5. From the 1940s to the 1970s, liquid deterrent, comprised mostly of DNT, is known to have been burned and disposed of at the DBG. During the same period, coal ash from the power plant, construction debris, trash, and burned garbage were disposed of in Landfill #3. In 2003, a geosynthetic clay and geomembrane barrier were installed above the DBG and Landfill #3 as one contiguous cap. In addition, an enhanced biodegradation system was operated at this site from 2003 to 2008. From 1979 to 1988, solid waste including office and laboratory waste, demolition debris, and coal ash were disposed of in Landfill #5. In 1988, Landfill #5 was closed with a clay barrier cap. The Army has covered each of the DBG source areas with an engineered cap to inhibit the movement of contaminants in the soil to the groundwater. The Army has performed various soil remediation activities at the DBG (bioremediation and soil excavation). The Army has not performed any groundwater remediation in the DBG Plume. Section 3.2 provides additional details on remediation activities of the source areas.

Contamination from these disposal and open burning activities migrated through the soil and into the groundwater. Groundwater beneath the DBG source areas is approximately 130 feet deep. The contaminated groundwater in the DBG Plume has migrated southeast (off-site) towards the Wisconsin River (Weigand's Bay), see Figure 1. As the DBG Plume migrates away from the source area, it sinks lower into the sand aquifer. The off-site portion of the DBG Plume sinks below the groundwater surface and deeper into the sand aquifer. Groundwater in the DBG Plume travels approximately 109 feet per year. Contaminants in the DBG Plume are expected to travel at the same speed as groundwater. Groundwater beneath the off-site residential areas is approximately 25 feet deep. Contaminated groundwater (above the NR 140 ES) in the off-site portion of the DBG Plume has been identified within the sand aquifer at depths between 50 and 180 feet. The sand aquifer extends down to 216 feet. The residential wells located outside the areal extent of the DBG Plume range in depth from 20 to 260 feet and average 100 feet deep. Most of the residential wells located outside the areal extent of the DBG Plume are screened in the sand. Total DNT has been detected in monitoring wells located both on-site and off-site in the DBG Plume. Over the past three years, the total DNT concentrations in off-site monitoring wells (ELN-1003B and ELN-1003C) have been increasing. These increases indicate that the DBG Plume is migrating off-site (southeast) towards residential wells located near Weigand's Bay. During April 2019, total DNT was detected in a residential well above the NR 140 ES. During July 2019, the Army replaced one residential well associated with the DBG Plume that was impacted by total DNT. Sections 4.4 and 4.5 provide additional details on groundwater properties and groundwater contaminants. Section 4.6 provides additional details on the residential well replacement conducted by the Army.

A graphical depiction of the DBG Plume in relationship to the local geology, monitoring wells, site features, and groundwater plume boundaries is shown on the subsequent page. The groundwater contaminant plume is shown below the water table and migrating towards the Wisconsin River. The groundwater contaminant plume is shown to have traveled past the BAAP property.




A groundwater CSM for the DBG Plume is provided in Appendix G. The CSM shows the relationship between the sources of contamination, how the contamination is transported, type of media exposure, the route of exposure, and who may be exposed. The contaminants infiltrated through the soil (leaching) below the waste disposal areas until they reached the groundwater. The contaminants within the groundwater have been transported with the directional flow of groundwater towards the Wisconsin River (Weigand's Bay) to the southeast. Contaminated groundwater has the potential to reach residential wells which may be used for domestic or potable purposes. Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during bathing or dishwashing, and dermal contact while bathing.

The exposure routes associated with domestic use of water, as shown on the CSM (Appendix G), include ingestion, inhalation, and dermal exposure. The off-site residential use pathways are potentially complete under current land use conditions and warrant further evaluation. The on-site hypothetical future residential use pathways are incomplete or considered insignificant under current land use conditions but potentially complete under hypothetical future on-site groundwater usage.

The exposure route associated with vapor intrusion, as shown on the CSM, includes only inhalation of indoor vapors. Both the off-site and on-site residential use vapor intrusion exposure pathways are incomplete or considered insignificant based on past vapor intrusion investigations and so no further evaluation is warranted. Section 5.5.2 discusses the potential vapor intrusion exposure into buildings.

### *5.5.2 Exposure Quantification – Vapor Intrusion Pathway Analysis*

An evaluation was conducted to determine whether vapors from the DBG Plume of groundwater contamination pose a current or hypothetical future risk to human health. Vapor intrusion occurs when there is a migration of vapor-forming chemicals from a subsurface source (i.e., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air.

The Army did not conduct a vapor intrusion pathway analysis investigation specifically in the DBG Plume. Section 5.4.2 discussed the 2012 vapor intrusion pathway analysis investigations conducted by the Army in the PBG Plume. The PBG Plume represents the worst-case scenario for volatile-forming chemicals present in the groundwater and thus provides a conservative representation of vapor conditions associated with the DBG Plume. The 2012 vapor intrusion pathway analysis reports concluded that VOCs in the PBG Plume do not present a risk to human health via vapor intrusion.

Based on the information in Section 5.4.2, inhalation exposure due to soil gas vapor intrusion from the DBG Plume does not pose a current or potential future risk to area residents.

### *5.5.3 Exposure Quantification - Groundwater Pathway Analysis*

#### 5.5.3.1 *Current and Potential Future Uses of Groundwater*

Groundwater located in the DBG Plume within the boundary of BAAP is not used for human consumption. The land that was transferred from the Army to other property owners includes a deed restriction on the use of groundwater and so restricts the potential exposure to groundwater within the boundary of BAAP. These groundwater access restrictions state that the property owner "shall not access or use groundwater underlying the property for any purpose without the prior written approval of the Army and the WDNR".

Currently, residential wells located outside of BAAP use groundwater for potable water and domestic purposes. The potential future use of groundwater adjacent to and downgradient of BAAP is expected to be for potable water and domestic purposes.

Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during showering or dishwashing, and dermal contact while bathing. Groundwater contaminants from BAAP have resulted in groundwater impacts in one residential well located in the DBG Plume. The Army replaced one residential well associated with the DBG Plume that has been impacted by total DNT. Section 4.6 provides additional details on the residential well replacement conducted by the Army.

### *5.5.4 Risk Assessment Summary*

#### 5.5.4.1 *Hypothetical Future On-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to hypothetical future on-site risks associated with the DBG Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-4}$ or HI > 1).

**Summary of Hypothetical Future Risks – Deterrent Burning Ground Plume (On-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| On-Site (Hypothetical Future Risk) | $9x10^{-5}$ | **3** | 1,1,2-Trichloroethane |

Risks calculated using the simple scaling method for a hypothetical future residential scenario, along with the maximum observed concentration of each COPC, yielded cumulative cancer risk estimates below the risk management criterion ($1x10^{-4}$) for the on-site portion of the DBG Plume.

The calculated non-cancer HI of 3 was above the risk management criterion (HI > 1) in the on-site portion of the DBG Plume. The contaminant of concern that contributed to the HI > 1 in the DBG Plume was 1,1,2-trichloroethane.

Based on the maximum risk scenario, the on-site portion of the DBG Plume represents an area that, if future residential development occurred, would be associated with cumulative non-cancer risk above the risk management criterion (HI above 1). The on-site portion of the DBG Plume has the potential to migrate off-site, thus impacting downgradient residential wells. Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

#### 5.5.4.2 *Current Off-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to current off-site groundwater risks associated with the DBG Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-6}$ or HI > 1).

**Summary of Current Risk – Deterrent Burning Ground Plume**
**(Residential Well and Off-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| Off-Site (Current Risk) | **$2x10^{-5}$** | **2** | Chloroform<br>Total DNT<br>Trichloroethene |

Risks calculated using the simple scaling method for a current residential scenario, along with the maximum observed concentration of COPC, yielded cumulative cancer risk estimates above the risk management criterion for the off-site portion of the DBG Plume. The cumulative cancer risk ($2x10^{-5}$) for the DBG Plume area was above the risk management criterion ($1x10^{-6}$). The contaminants of concern that contributed to the cumulative cancer risk for the DBG Plume were chloroform, total DNT, and trichloroethene.

The calculated non-cancer HI of 2 was above the risk management criterion (HI > 1) in the off-site portion of the DBG Plume. The contaminant of concern that contributed to the HI > 1 in the DBG Plume was trichloroethene.

Based on the maximum risk scenario, the off-site portion of the DBG Plume represents an area that would be associated with cumulative groundwater risks above the risk management criteria (cumulative cancer risk above $1x10^{-6}$ and non-cancer HI above 1). Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

## 5.6 Central Plume

### *5.6.1 Characterization of Exposure Settings*

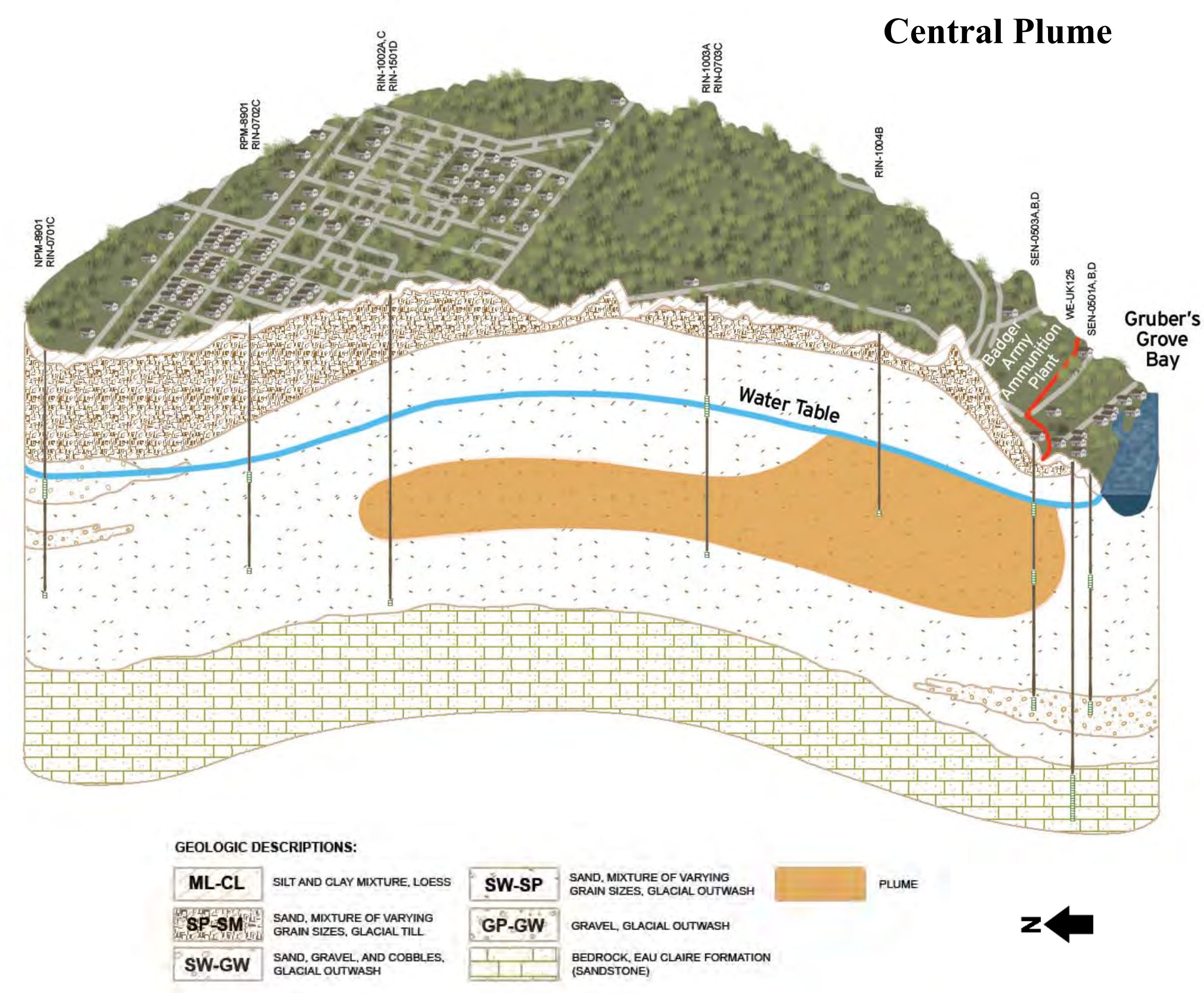
The source of the Central Plume is in the north-central portion of BAAP where nitroglycerin, rocket paste, and rocket propellant were produced, see Figure 1. Within the production area, containers of production chemicals, which contained DNT, were transported by rail to each Pre-Mix House from the Bag Loading House. Nitrocellulose and nitroglycerin were added to the chemical mixture in each Pre-Mix House. The resulting slurry was then pumped to the Final Mix Houses. The Rocket Paste production area was not connected to the main industrial sewer network, so production related wash waters were discharged to open ditches. It is believed that the broad production area may have caused the DNT impacted groundwater. The primary source of contaminated soil originated in former production areas. The Army has performed numerous soil excavations in ditches and ponds, sewer pipe removals, and building demolition throughout the Central Plume source area. The Army has not performed any groundwater remediation in the Central Plume.

The contaminated groundwater in the Central Plume has migrated south and off-site towards the Wisconsin River (Gruber's Grove Bay), see Figure 1. Based on current groundwater monitoring data, there is no evidence to suggest that the Central Plume is discharging into the Wisconsin River. As the Central Plume migrates south, it vertically sinks into the sand aquifer. The thickness of Central Plume narrows as it moves off-site and towards the Wisconsin River. Groundwater in the Central Plume travels approximately 143 feet per year. Contaminants in the Central Plume are expected to travel at the same speed as groundwater. Groundwater beneath the Central Plume source area is approximately 105 feet deep. Contaminated groundwater (above the NR 140 ES) in the Central Plume has only been identified within the sand aquifer at depths between 85 and 130 feet. Groundwater beneath the off-site residential areas is approximately 20 feet deep. Section 3.3 provides additional details on source investigation and remediation. Sections 4.4 and 4.5 provide additional details on groundwater properties and groundwater contaminants.

The seven residential wells located within the areal extent of the Central Plume range in depth from 80 to 324 feet. Two of those seven residential wells are screened in the bedrock and draw their groundwater from beneath the contaminated portion of the Central Plume. Three of those seven residential wells are screened in the sand but draw their groundwater from beneath the contaminated portion of the Central Plume. Two of those seven residential wells are screened in the sand and at the same depth as the contaminated portion of the Central Plume. DNT has been detected in these two residential wells below the NR 140 ES.

The residential wells located outside the areal extent of the Central Plume range in depth from 80 to 575 feet. Most of the residential wells located outside of the Central Plume are screened in the sand and average 120 feet deep. DNT has been detected in monitoring wells located both on-site and off-site in the Central Plume. The Army has replaced three residential wells, screened in the sand, located in the southern extent of the Central Plume. Section 4.6 provides additional details on the residential well replacements conducted by the Army.

A graphical depiction of the Central Plume in relationship to the local geology, monitoring wells, residential wells, site features, and groundwater plume boundaries is shown below. The groundwater flow direction is from the left (north) towards the right (south). The groundwater contaminant plume is shown below the water table and migrating towards Gruber's Grove Bay. The groundwater contaminant plume is shown to have traveled past the BAAP property and beneath a residential area.




A groundwater CSM for the Central Plume is provided in Appendix G. The CSM shows the relationship between the sources of contamination, how the contamination is transported, type of media exposure, the route of exposure, and who may be exposed. The contaminants infiltrated through the soil (leaching) beneath production areas (i.e., buildings, ditches, ponds or sewers) until they reached the groundwater. The contaminants within the groundwater have been transported with the directional flow of groundwater towards the Wisconsin River (Gruber's Grove Bay) to the south. Contaminated groundwater has the potential to reach residential wells which may be used for domestic or potable purposes. Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during bathing or dishwashing, and dermal contact while bathing.

The exposure routes associated with domestic use of water, as shown on the CSM (Appendix G), include ingestion, inhalation, and dermal exposure. The off-site residential use pathways are potentially complete under current land use conditions and warrant further evaluation. The on-site hypothetical future residential use pathways are incomplete or considered insignificant under current land use conditions but potentially complete under hypothetical future on-site groundwater usage.

The exposure route associated with vapor intrusion, as shown on the CSM, includes only inhalation of indoor vapors. Both the off-site and on-site residential use vapor intrusion exposure pathways are incomplete or considered insignificant based on past vapor intrusion investigations and so no further evaluation is warranted. Section 5.6.2 discusses the potential vapor intrusion exposure into buildings.

### *5.6.2 Exposure Quantification – Vapor Intrusion Pathway Analysis*

An evaluation was conducted to determine whether vapors from the Central Plume of groundwater contamination pose a current or hypothetical future risk to human health. Vapor intrusion occurs when there is a migration of vapor-forming chemicals from a subsurface source (i.e., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air.

The Army did not conduct a vapor intrusion pathway analysis investigation specifically in the Central Plume. Section 5.2.3 discussed the 2012 vapor intrusion pathway analysis investigations conducted by the Army in the PBG Plume. The PBG Plume represents the worst-case scenario for volatile-forming chemicals present in the groundwater and thus provides a conservative representation of vapor conditions associated with the Central Plume. The 2012 vapor intrusion pathway analysis reports concluded that VOCs in the PBG Plume do not present a risk to human health via vapor intrusion.

Based on the above information in Section 5.2.3, inhalation exposure due to soil gas vapor intrusion from the Central Plume does not pose a current or potential future risk to area residents.

### *5.6.3 Exposure Quantification - Groundwater Pathway Analysis*

#### 5.6.3.1 *Current and Potential Future Uses of Groundwater*

Groundwater located in the Central Plume found within the boundary of BAAP is not used for human consumption. The land that was transferred from the Army to other property owners includes a deed restriction on the use of groundwater and so restricts the potential exposure to groundwater within the boundary of BAAP. These groundwater access restrictions state that the property owner “shall not access or use groundwater underlying the property for any purpose without the prior written approval of the Army and the WDNR”.

Currently, residential wells located outside of BAAP use groundwater for potable water and domestic purposes. The potential future use of groundwater adjacent to and downgradient of BAAP is expected to be for potable water and domestic purposes.

Residential well users can be exposed to contaminated groundwater through ingestion or drinking of water, inhalation of vapor during showering or dishwashing, and dermal contact while bathing. Groundwater contaminants from BAAP have resulted in groundwater impacts in three residential wells located in the Central Plume. The Army has replaced three residential wells due to impacts from DNT. Section 4.6 provides additional details on the residential well replacements conducted by the Army.

### 5.6.4 Risk Assessment Summary

#### 5.6.4.1 *Hypothetical Future On-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to hypothetical future on-site risks associated with the Central Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-4}$ or HI > 1).

**Summary of Hypothetical Future Risks – Central Plume (Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| On-Site (Hypothetical Future Risk) | $3x10^{-6}$ | 0.02 | None |

Risks calculated using the simple scaling method for a hypothetical future residential scenario, along with the maximum observed concentration of each COPC, yielded cumulative cancer risk estimates below the risk management criterion ($1x10^{-4}$) for the on-site portion of the Central Plume.

The non-cancer HI risk calculations were below the risk management criterion (HI ≤ 1) in the on-site portion of the Central Plume.

Based on the maximum risk scenario, the on-site portion of the Central Plume represents an area where cumulative risk estimates are below the risk management criteria, and so no contaminants of concern were identified. Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

#### 5.6.4.2 *Current Off-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to current off-site groundwater risks associated with the Central Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-6}$ or HI > 1).

**Summary of Current Risk – Central Plume**
**(Residential Well and Off-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| Off-Site (Current Risk) | **$4x10^{-5}$** | 0.4 | 1,2-Dichloroethane<br>2,6-DNT<br>Benzene<br>Chloroform |

Risks calculated using the simple scaling method for a current residential scenario, along with the maximum observed concentration of COPC, yielded cumulative cancer risk estimates above the risk management criterion for the off-site portion of the Central Plume. The cumulative cancer risk ($4x10^{-5}$) for the Central Plume was above the risk management criterion ($1x10^{-6}$). The contaminants of concern that contributed to the cumulative cancer risk for the Central Plume were 1,2-dichloroethane, 2,6-DNT, benzene, and chloroform.

The non-cancer HI risk calculations were below the risk management criterion (HI $\leq$ 1) in the off-site portion of the Central Plume.

Based on the maximum risk scenario, the off-site portion of the Central Plume represents an area that would be associated with a cumulative cancer risk above the risk management criterion (above $1x10^{-6}$). Further evaluation of the risks is provided in Section 8.0 Remedial Alternative Development Process.

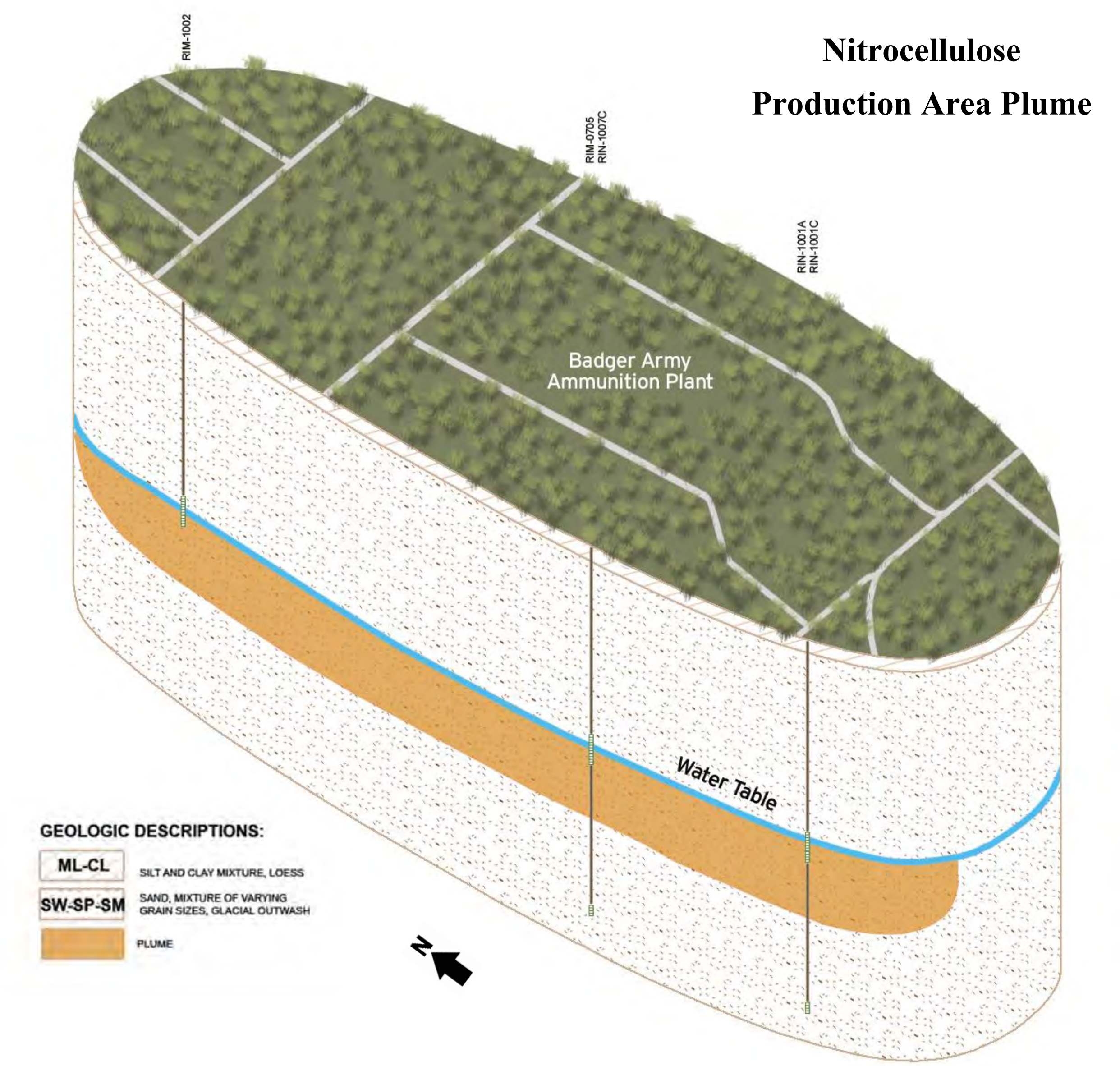
## 5.7 Nitrocellulose Production Area Plume

### *5.7.1 Characterization of Exposure Settings*

The source of the NC Area Plume is in the northwestern portion of BAAP where nitrocellulose was produced (see Figure 1). Completed nitrocellulose was used to manufacture single-base propellants such as smokeless powder or double-base propellants such as rocket grains or Ball Powder. DNT was added to the manufacturing process in various production buildings. The broad production area contained numerous production buildings and process water disposal sewer piping that caused the DNT impacted groundwater. The sources of the DNT contamination have been removed. The Army has performed numerous soil excavations, sewer pipe removals, and building demolition throughout the NC Area Plume.

As the NC Area Plume migrates south, it remains near the groundwater surface and doesn’t sink vertically. Groundwater in the NC Area travels approximately 132 feet per year. Contaminants in the NC Area Plume are expected to travel at the same speed as groundwater. Groundwater beneath the NC Area Plume is approximately 100 feet deep. Contaminated groundwater (above the NR 140 ES) in the NC Area Plume has only been identified within the sand aquifer at depths between 100 and 120 feet. The contaminated groundwater in the NC Area Plume has migrated south but remains on-site, see Figure 1. The Army has not performed any groundwater remediation in the NC Area Plume. Based on the direction of groundwater flow, the NC Area Plume is migrating towards the PBG Plume. In the future, the NC Area Plume could comingle with the PBG Plume while on BAAP property. There are no residential wells located within 2 miles downgradient (south) of the NC Area Plume. Sections 4.4 and 4.5 provide additional details on groundwater properties and groundwater contaminants.

A graphical depiction of the NC Area Plume in relationship to the local geology, monitoring wells, site features, and groundwater plume boundaries is shown below. The groundwater flow direction is from the upper left (north) towards the lower right (south). The groundwater contaminant plume is shown below the water table. The groundwater contaminant plume is contained on the BAAP property.



A groundwater CSM for the NC Area Plume is provided in Appendix G. The CSM shows the relationship between the sources of contamination, how the contamination is transported, type of media exposure, the route of exposure, and who may be exposed. The contaminants infiltrated through the soil (leaching) beneath production areas (i.e., buildings or sewers) until they reached the groundwater. The contaminants within the groundwater have been transported with the directional flow of groundwater but have remained on-site.

The exposure routes associated with domestic use of water, as shown on the CSM (Appendix G), include ingestion, inhalation, and dermal exposure. The off-site residential use pathways are considered incomplete since the NC Area Plume has not migrated off-site. The on-site hypothetical future residential use pathways are incomplete or considered insignificant under current land use conditions but potentially complete under hypothetical future on-site groundwater usage.

The exposure route associated with vapor intrusion, as shown on the CSM, includes only inhalation of indoor vapors. Both the off-site and on-site residential use vapor intrusion exposure pathways are incomplete or considered insignificant based on past vapor intrusion investigations and so no further evaluation is warranted. Section 5.7.2 discusses the potential vapor intrusion exposure into buildings.

### *5.7.2 Exposure Quantification - Vapor Intrusion Pathway Analysis*

Contaminated groundwater from the NC Area Plume has not migrated off-site. There are no on-site buildings located over the NC Area Plume. Based on these factors, there is no vapor intrusion exposure pathway from groundwater associated with the NC Area Plume and there is no current or potential future risk to area residents.

### *5.7.3 Exposure Quantification - Groundwater Pathway Analysis*

#### 5.7.3.1 *Current and Potential Future Uses of Groundwater*

Groundwater located in the NC Area Plume is only found within the boundary of BAAP and is not used for human consumption. The land that was transferred from the Army to other property owners includes a deed restriction on the use of groundwater and so restricts the potential exposure to groundwater within the boundary of BAAP. These groundwater access restrictions state that the property owner “shall not access or use groundwater underlying the property for any purpose without the prior written approval of the Army and the WDNR”. It should be noted that there are no residential wells located within 2 miles downgradient (south) of the NC Area Plume. In addition, there are no off-site monitoring wells associated with the NC Area Plume.

### 5.7.4 Risk Assessment Summary

#### 5.7.4.1 *Hypothetical Future On-Site Groundwater Risks*

The cumulative cancer risk, non-cancer HI and contaminants of concern related to hypothetical future on-site groundwater risks associated with the NC Area Plume are summarized below. Contaminants of concern are analytes found to significantly contribute to the cumulative risk in an area where risk was estimated to be above the risk management criteria (cumulative cancer risk > $1x10^{-4}$ or HI > 1).

**Summary of Hypothetical Future Well Risks – NC Area Plume**
**(On-Site Monitoring Well Data)**

| Location | Cumulative Cancer Risk | Non-cancer Hazard Index (HI) | Contaminants of Concern |
|---|---|---|---|
| On-Site (Hypothetical Future Risk) | $4x10^{-6}$ | 0.04 | None |

Risks calculated using the simple scaling method for a hypothetical future residential scenario, along with the maximum observed concentration of each COPC, yielded cumulative cancer risk estimates below the risk management criterion ($1x10^{-4}$) for the NC Area Plume.

The non-cancer HI risk calculations were below the risk management criterion (HI ≤ 1) in the NC Area Plume.

Based on the maximum risk scenario, the NC Area Plume represents an area where cumulative risk estimates are below the risk management criteria, and so no contaminants of concern were identified.

#### 5.7.4.2 *Current Off-Site Groundwater Risks*

There are no off-site monitoring wells associated with the NC Area Plume. In addition, there are no residential wells located within 2 miles downgradient (south) of the NC Area Plume; therefore, current groundwater risks were not evaluated.

# 6.0 REGULATORY REQUIREMENTS

CERCLA requires that on-site remedial actions attain or waive federal environmental applicable and relevant and appropriate requirements (ARARs), or more stringent state environmental ARARs, upon completion of the remedial action. The USEPAs 1994 National Oil and Hazardous Substances Pollution Contingency Plan (NCP) also requires compliance with ARARs during removal and remedial actions to the extent practicable. These ARARs, in conjunction with the overall protection to human health and the environment criterion, help form the criteria to evaluate remedial alternatives. Under CERCLA, remedial actions must be protective of human health and the environment. Additionally, CERCLA remedial actions must meet a level and standard of control that attains standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. Information that is "to be considered" (TBC) federal and state criteria, advisories, and guidance may also be considered/evaluated along with ARARs as a part of a risk assessment conducted at a CERCLA site to help set clean-up level targets.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site. In other words, an applicable requirement is one with which a private party would have to comply by law if the same action was being undertaken apart from CERCLA authority.

If a requirement is not applicable, it still may be relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

"Applicability" is a legal and jurisdictional determination, while the determination of "relevant and appropriate" relies on professional judgment, considering environmental and technical factors at the site.

USEPA identifies three basic types of ARARs:

- Chemical-specific ARARs are generally health- or risk-based values which, when applied to site-specific conditions, result in numerical values. These values establish the acceptable concentration of a chemical that may be found in, or discharged to, the ambient environment.

- Location-specific ARARs are restrictions placed upon removal activities of hazardous substances solely because they are occurring in a particular place.

- Action-specific ARARs are general technology or activity-based requirements on actions taken with respect to hazardous substances. These requirements are triggered by the particular activities that are selected to accomplish a remedy. Thus, action-specific requirements do not in themselves determine the removal alternative; rather, they indicate how the selected alternative must be achieved.

TBCs are non-promulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of potential ARARs; however, TBCs may be considered along with ARARs as part of the site risk assessment and may be used in determining the necessary level of clean-up for protection of health and the environment.

Potential State and Federal ARARs and TBCs to be used in the groundwater remedial alternatives evaluation are presented in Table 14.

**Table 14**
**Potential State and Federal Applicable or Relevant and Appropriate Requirements**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Standard, Requirement, Criteria, or Limitation | Citation | Description | Applicable or Relevant and Appropriate Requirement (ARAR) |
|---|---|---|---|
| **Chemical-Specific ARARs and TBCs** | | | |
| Groundwater Quality | Wisconsin Administrative Code, Chapter NR 140.26 | Chemical-specific groundwater Enforcement Standard (ES). | ARAR – Establishes applicable groundwater quality standards. |
| National Primary Drinking Water Regulations: Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels | 40 CFR Part 141 Subpart G | Chemical-specific drinking water quality standards. | ARAR – Establishes relevant and appropriate groundwater quality standards. |
| National Secondary Drinking Water Regulations | 40 CFR Part 143 | Chemical-specific drinking water quality standards related to aesthetics. | TBC – Recommended drinking water quality guidelines. |
| Regional Screening Level (RSL) Resident Tapwater Table | USEPA – November 2017 | Screening level guidance for human health risk from exposure to groundwater. | TBC – Recommended groundwater quality screening levels. |
| **Location-Specific ARARs** | | | |
| No Location-Specific ARARs were identified. | | | |
| **Action-Specific ARARs** | | | |
| Well Construction and Pump Installation | Wisconsin Administrative Code, Chapter NR 812 excluding subsections 812.05, 25, 38, 39, 40, 42, 43, 44 and 45. | Establishes requirements for installing water supply wells and extracting groundwater. | ARAR – Applicable to alternatives that would replace a contaminated residential well or active remediation activities that pump groundwater. |

Note: Table 16 lists the groundwater cleanup level & regulatory concentration for each contaminant of concern.

# 7.0 CONTAMINANTS OF CONCERN

This section presents the contaminants of concern (COC) for the groundwater contamination associated with four groundwater contamination plumes at BAAP. The COCs are based on the results of the HHRA detailed in Section 5.0. Table 15 summarizes the groundwater COCs for the BAAP. Table 15 provides a breakdown of which risk-based COCs were identified as having a cancer risk and/or non-cancer risk. Table 15 also shows which risk-based COC was identified as an on-site or off-site risk above the risk management criteria.

Table 16 provides the groundwater cleanup levels for each risk-based COC related to the PBG Plume, DBG Plume, Central Plume, and NC Area Plume. The groundwater cleanup level for each risk-based COC is based on the lower of either the MCLs (National Primary Drinking Water Regulations per 40 CFR Part 141) or the Wisconsin NR 140 ES.

## 7.1 Propellant Burning Ground Plume

The risk-based COCs identified in the PBG Plume were chloroform, CTET, ethyl ether, TCE, and 2,6-DNT.

- Chloroform was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, chloroform concentrations were not identified above the groundwater cleanup level listed in Table 16. Therefore, remedial alternatives are not being considered for chloroform.
- CTET was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, CTET concentrations were identified above the groundwater cleanup level listed in Table 16.
- Ethyl ether was identified as having an on-site non-cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, ethyl ether concentrations were identified above the groundwater cleanup level listed in Table 16.
- TCE was identified as having both an off-site cancer risk and an on-site and off-site non-cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, TCE concentrations were identified above the groundwater cleanup level listed in Table 16.
- 2,6-DNT was identified as having an on-site and off-site cancer risk plus an on-site non-cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, 2,6-DNT concentrations were identified above the groundwater cleanup level listed in Table 16.

Based on the above information, CTET, ethyl ether, TCE, and 2,6-DNT will be the COCs considered in the FS for the development of remedial alternatives in the PBG Plume. However, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

**Table 15**
**Groundwater Contaminants of Concern**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Groundwater Plume | Contaminant of Concern (COC) - HHRA | | | | | |
|---|---|---|---|---|---|---|
| | Cancer Risk (1) | | | Non-Cancer Risk (2) | | |
| | COC | On-Site | Off-Site | COC | On-Site | Off-Site |
| Propellant Burning Ground | Carbon Tetrachloride | | X | | | |
| | Chloroform | | X | | | |
| | | | | Ethyl Ether | X | |
| | Trichloroethene | | X | Trichloroethene | X | X |
| | 2,6-Dinitrotoluene | X | X | 2,6-Dinitrotoluene | X | |
| Deterrent Burning Ground | Chloroform | | X | | | |
| | | | | 1,1,2-Trichloroethane | X | |
| | Trichloroethene (3) | | X | Trichloroethene (3) | | X |
| | Dinitrotoluene, Total * | | X | | | |
| Central | Benzene (4) | | X | none | | |
| | Chloroform | | X | | | |
| | 1,2-Dichloroethane | | X | | | |
| | 2,6-Dinitrotoluene | | X | | | |
| Nitrocellulose Production Area | none | | | none | | |

Notes:

Based on analytical lab results from residential and groundwater monitoring well samples for 2015, 2016, 2017, and 2018.

HHRA - Human Health Risk Assessment

(1) Contaminants found to contribute to a cumulative human cancer risk above the risk management criteria.

(2) Contaminants found to contribute to a cumulative human non-cancer risk above the risk management criteria.

(3) Trichloroethene (TCE) is not considered a COC in the Detererent Burning Ground Plume.
The source of TCE is not attributable to the Army and has been found in residential well jet pumps.

(4) Benzene is not considered a COC in the Central Plume. The source of benzene is not attributable to the Army.

* Total Dinitrotoluene (DNT) Isomers (2,3-DNT; 2,4-DNT; 2,5-DNT ; 2,6-DNT; 3,4-DNT; 3,5-DNT) - NR 140.10

Table 16 lists the groundwater cleanup level & regulatory concentration for each contaminant of concern.

**Table 16**
**Groundwater Cleanup Levels**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| Groundwater Plume | Contaminants of Concern (COC) | State | Federal | Groundwater Cleanup Level [1] |
|---|---|---|---|---|
| | | NR 140 ES | 40 CFR Part 141 MCLs | |
| Propellant Burning Ground | Carbon Tetrachloride | 5 | 5 | 5 |
| | Chloroform | 6 | 80 [2] | 6 |
| | 2,6-Dinitrotoluene | 0.05 | none | 0.05 |
| | Ethyl Ether | 1000 | none | 1000 |
| | Trichloroethene | 5 | 5 | 5 |
| Deterrent Burning Ground | Chloroform | 6 | 80 [2] | 6 |
| | Total Dinitrotoluene | 0.05 | none | 0.05 |
| | 1,1,2-Trichlorethane | 5 | 5 | 5 |
| | Trichloroethene [3] | 5 | 5 | 5 |
| Central | Benzene [4] | 5 | 5 | 5 |
| | Chloroform | 6 | 80 [2] | 6 |
| | 1,2-Dichloroethane | 5 | 5 | 5 |
| | 2,6-Dinitrotoluene | 0.05 | none | 0.05 |
| Nitrocellulose Production Area | none | none | none | none |

Notes:

[1] Cleanup Level is the lowest value of either the NR 140 ES or Federal MCL.

[2] The Chloroform MCL is for Total Trihalomethanes (sum of bromodichloromethane, bromoform, dibromochloromethane, & chloroform)

[3] Trichloroethene is not considered a COC in the Detererent Burning Ground Plume. The source of trichloroethene is not attributable to the Army. Trichloroethene has been found in residential well jet pumps.

[4] Benzene is not considered a COC in the Central Plume. The source of benzene is not attributable to the Army.

All concentration values are expresed in micrograms-per-liter (µg/l)

ES = Enforcement Standard

40 CFR Part 141 - National Primary Drinking Water Regulations: Maximum Contaminant Levels (MCLs)

Total Dinitrotoluene (DNT) consists of isomers (2,3-DNT; 2,4-DNT; 2,5-DNT ; 2,6-DNT; 3,4-DNT; 3,5-DNT)

### 7.2 Deterrent Burning Ground Plume

The risk-based COCs identified in the DBG Plume were chloroform, 1,1,2-TCA, TCE, and total DNT.

- Chloroform was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, chloroform concentrations were not identified above the groundwater cleanup level listed in Table 16. Therefore, remedial alternatives are not being considered for chloroform.
- 1,1,2-TCA was identified as having an on-site non-cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, 1,1,2-TCA concentrations were not identified above the groundwater cleanup level listed in Table 16. Therefore, remedial alternatives are not being considered for 1,1,2-TCA.
- TCE was identified as having both an off-site cancer and non-cancer risk above the risk management criteria. TCE has not been detected in monitoring wells nor is there a known source associated with the DBG Plume. The source of TCE is not attributable to the Army and has been found in residential well jet pumps. Therefore, remedial alternatives are not being considered for TCE.
- Total DNT was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, total DNT concentrations were identified above the groundwater cleanup level listed in Table 16.

Based on the above information, total DNT will be the only COC considered in the FS for the development of remedial alternatives in the DBG Plume.

### 7.3 Central Plume

The risk-based COCs identified in the Central Plume were benzene, chloroform, 1,2-dichloroethane, and 2,6-DNT.

- Benzene was identified as having an off-site cancer risk above the risk management criteria. Benzene has not been detected in monitoring wells located on-site (upgradient) nor is there a known source associated with the Central Plume. The source of benzene is not attributable to the Army. Benzene was also not detected in any monitoring wells or residential wells that were sampled during 2018. Therefore, remedial alternatives are not being considered for benzene.
- Chloroform was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, chloroform concentrations were not identified above the groundwater cleanup level listed in Table 16. Therefore, remedial alternatives are not being considered for chloroform.
- 1,2-Dichloroethane was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, 1,2-dichloroethane concentrations were not identified above the groundwater cleanup level

listed in Table 16. Therefore, remedial alternatives are not being considered for 1,2-dichloroethane.

- 2,6-DNT was identified as having an off-site cancer risk above the risk management criteria. Based on the groundwater monitoring data from 2015 to 2018, 2,6-DNT concentrations were identified above the groundwater cleanup level listed in Table 16.

Based on the above information, 2,6-DNT will be the only COC considered in the FS for the development of remedial alternatives in the Central Plume. However, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

## 7.4 Nitrocellulose Production Area Plume

The HHRA did not identify any human health risk related COCs for the NC Area Plume; therefore, no remedial alternatives will be developed for the NC Area Plume in the FS.

# 8.0 REMEDIAL ALTERNATIVE DEVELOPMENT PROCESS

As described in Section 5.0, a HHRA was completed as it relates to current and hypothetical future risks for the groundwater contaminant plumes as appropriate. Based on groundwater monitoring results for 2015, 2016, 2017 and 2018, the HHRA found unacceptable risk related to groundwater from BAAP and identified a completed exposure pathway for the PBG, DBG, and Central Plumes. Based on these factors (cleanup level exceedances, risk identified above the risk management criteria and completed exposure pathway identification), the Army is evaluating the feasibility of groundwater remedial actions to reduce, control, or mitigate exposure to be protective of human health and the environment for the PBG, DBG, and Central Plumes. Section 7.0 identifies the COCs for each plume and the groundwater cleanup levels for each COC.

The HHRA did not identify risk above the risk management criteria for the NC Area Plume. Therefore, groundwater remedial alternatives are not being considered by the Army for the NC Area Plume and groundwater sampling of the monitoring wells is not part of the CERCLA remedy for the NC Area Plume.

For ease of review, clarity and appropriateness, the remedial alternative development process was completed for each individual plume. As each contaminant plume has a specific set of circumstances including but not limited to size, location, geology, hydrogeology and contaminants of concern, plume-specific alternatives were developed. This process allows plume-specific alternatives to be tailored to the circumstances associated with each individual plume.

## 8.1 Previous Soil Remedial Activities

Soil remedial activities have been conducted at the source areas of the four groundwater contaminant plumes, PBG Plume, DBG Plume, Central Plume, and NC Area Plume. These soil remedial activities are summarized in Sections 3.1, 3.2, 3.3, and 3.4. Source areas with contaminated soil have been addressed at BAAP either with removal, in-situ treatment, vapor extraction, soil covers, or engineered barriers. These remedial activities have minimized the potential exposure to contaminated soil at BAAP. The Army has received site closure from the WDNR on all soil related investigations and remedial actions at BAAP.

## 8.2 Previous Groundwater Remedial Activities

Groundwater remedial activities were first conducted at the PBG Plume starting in 1990 with the construction and operation of the IRM. The IRM ultimately consisted of two source control wells, three boundary control wells, a treatment process building and a discharge pipeline to the Wisconsin River. These wells extracted and treated approximately 310 gpm of groundwater until the IRM's operational termination in 2012. The IRM was augmented by the construction of the MIRM in 1996. This system ultimately consisted of five extraction wells, a treatment process building and discharge pipeline to the Wisconsin River. These wells extracted and treated approximately 2,400 gpm of groundwater until the MIRM's operational termination in 2015. Biochemical treatment of groundwater at the PBG Waste Pits began in 2001 and was operational until 2005. These groundwater remedial activities are summarized in Section 3.1.

Groundwater remedial activities have not been conducted at the Central Plume, DBG Plume, or NC Area Plume.

## 8.3 Groundwater Remedial Action Objectives

Groundwater remedial action objectives (RAOs) provide a general description of what the cleanup will accomplish, serve as the basis for evaluating each remedial alternative, and provide an understanding of how the unacceptable risks will be addressed by each remedial alternative. Groundwater RAOs require the remedy to protect human health by preventing exposure to contaminated groundwater, to restore groundwater to the extent practicable, and minimize the impact of the contaminant plumes on the environment. Specifically, the RAOs for any individual plume are achieved when the risk-based groundwater COCs listed in Table 15 are below the groundwater cleanup levels provided in Table 16. The groundwater cleanup levels shown in Table 16 are based on either the NR 140 ES or federal MCL.

## 8.4 General Response Actions

The General Response Actions (GRAs) are general actions that would satisfy the RAOs. The potential applicability of GRAs and associated technologies were evaluated based on site specific constraints. The applicable GRAs and a brief description for the BAAP groundwater are listed below.

- **Land Use Controls** – Administrative actions such as land use restrictions to protect public health and the environment.
- **Development of New Water Resources** – Provision of bottled water well replacement and alternate water supply systems.
- **Groundwater Treatment** – Removal, treatment and disposal of contaminated groundwater.
- **Groundwater Containment** – Isolation of groundwater using subsurface barriers.

## 8.5 Identification and Screening of Potentially Applicable Technologies

This section identifies the appropriate plume specific remedial technologies and process options for each GRA for groundwater at BAAP. Process options refer to a specific process within each technology type. For example, the vertical barrier technology category could include process options such as a slurry wall, sheet pile wall or deep soil mixing. For each GRA, several broad technology types may be identified and within each remedial technology, several process options may be applicable.

During this screening step, process options and entire technology types are eliminated from further consideration based on technical implementability. This is completed by using readily available information from site conditions, contaminant types and concentrations and site-specific circumstances. Based on this evaluation, some remedial technologies and process options were eliminated from further consideration. The technology screening process and subsequent process option evaluation for each plume meeting the qualifying criteria (cleanup level exceedances, risk identified above the risk management criteria and completed exposure pathway identification) is shown in Table 17.

## 8.6 Process Option Screening Criteria

This section contains the description of process options screening criteria for each technology which provides the basis for developing remedial alternatives. For technologies with more than one process option, each option was evaluated. Each process option is evaluated according to the following criteria:

- **Effectiveness** – which includes evaluating the following:
  - Potential effectiveness in handling the estimated area or volumes of media.
  - Potential in meeting the RAOs.
  - Potential impacts to human health and the environment during the construction and implementation phase.
  - Demonstrated reliability of the process with respect to the contaminants and site conditions.

- **Implementability** – which includes technical and administrative feasibility of implementing a process option:
  - Technologies passing the initial screen of applicability are screened based on technical feasibility. This criterion means feasibility under site specific conditions. This evaluation may indicate that although a technology may be generally applicable for the COCs, the specific technology may be limited due to site-specific conditions.
  - Institutional feasibility emphasizing the institutional aspects of implementability such as the ability to obtain necessary permits for off-site actions.

- **Cost** – Plays a limited role in the screening process and is used only when two alternatives are found to be equally protective. Cost analyses are based on engineering judgement and evaluated as to whether costs are high, moderate or low in relation to other process options.

Following the selection of the most appropriate process options for each technology type, the process options are combined to form remedial alternatives. Remedial alternatives are discussed in Sections 9.0 for the PBG Plume, 10.0 for the DBG Plume, and 11.0 for the Central Plume.

## 8.7 Evaluation and Selection of Representative Process Options

This section evaluates the process options using the criteria listed in Section 8.6: effectiveness, implementability and cost. Only the most applicable process options, as identified in Table 17, were carried forward and are included in the development of remedial alternatives.

**Table 17**
**Technology Screening**
**Remedial Investigation/Feasibility Study**
**Badger Army Ammunition Plant**

| General Response Action | Remedial Technology | Process Option | Description/Comments | Retained for Further Consideration |
|---|---|---|---|---|
| Land Use Controls | Access Restrictions | Deed Restrictions - On-site | Deed would restrict on-site water use only. | Yes |
| Development of New Water Resources | Alternate Water Supply | Provision of Bottled Water | Provide bottled water to residential well owners with impacts above the Enforcement Standards. | Yes |
| | | Impacted Well Replacement | Replacement of residential wells impacted above the Enforcement Standards. | Yes |
| | | Well Replacement - Plume Areas | Replacement of residential wells within plume boundaries. | Yes |
| | | Municipal Water Supply - New System | Construct new municipal water system for residential well owners south and east of BAAP. Army does not have authority. | No |
| Groundwater Treatment | Groundwater Removal | Extraction Wells | Series of wells to extract contaminated groundwater. | Yes |
| | | Subsurface Drains | Perforated pipe in trenches backfilled with porous media to collect contaminated groundwater. Not feasible due to depth of necessary trenches. | No |
| | In-Situ Treatment | Biochemical Injection | Injection of treatment agent into groundwater. | Yes |
| | | Permeable Reactive Barrier | Reactive barrier allows contaminated groundwater to pass through with passive treatment. Not feasible due to depth of contamination. | No |
| | | Monitored Natural Attenuation | Allowing natural processes (dilution, dispersion and sorption) to slowly degradation contamination. | Yes |
| | Ex-Situ - On-site Treatment | Mobile Treatment Facility | Utilize mobile treatment units to treat contaminated water. | Yes |
| | | On-site Treatment Facility | Construct on-site facility to treat contaminated water. Army no longer owns property. | No |
| | | Bluffview Sanitary District (BSD) | Utilize BSD wastewater treatment plant. Not feasible due to flow limitations. | No |
| | Ex-Situ - Off-site | Publicly Owned Treatment Works (POTW) | Haul extracted groundwater to POTW. Not feasible due to anticipated volume. | No |
| | Groundwater Disposal | On-site Discharge - Injection | Treated water discharged to deep well injection system. Not feasible due to anticipated volume. | No |
| | | On-site Discharge - Infiltration Gallery | Treated water discharged to an on-site infiltration gallery. Not feasible due to anticipate volume. | No |
| | | Pipeline to Wisconsin River | Treated water discharged into the Wisconsin River. | Yes |
| Groundwater Containment | Vertical Barriers | Slurry Wall | Trench around impacted area is filled with a soil/cement/bentonite mix. Not feasible due to depth of contamination. | No |
| | | Sheet Pile Wall | Sheet pile wall around impacted areas. Not feasible due to depth of contamination. | No |
| | | Deep Soil Mixing | Mixing of bentonite in soil through augers. Not feasible due to depth of contamination. | No |

### *8.7.1 Land Use Controls*

***Access Restrictions - On-site Deed Restrictions*** - Groundwater access restrictions for the BAAP property are already in place and restricts property owners from accessing groundwater as part of the property transfer agreement. Specifically, the Groundwater Restrictions state, "The Grantee, its successors and assigns, shall not access or use groundwater underlying the Property for any purpose without the prior written approval of the Army and the WDNR. For the purpose of this restriction, "groundwater" shall have the same meaning as Section 101(12) of CERCLA."

- **Effectiveness** – Access restrictions are effective in controlling human activities such as potable well construction on the BAAP property.
- **Implementability** – These deed restrictions are currently implemented as a result of parcel transfer agreements.
- **Cost** – Low

Land Use Controls are carried forward as a process option which can be combined with other process options to meet the RAO.

### *8.7.2 Development of New Water Resources*

***Alternate Water Supply - Provision of Bottled Water and Well Replacement*** - For areas impacted by groundwater contamination off the BAAP property, the Army currently has an environmental monitoring and health protection program in place that is protective of the residential water well users. If a Chapter NR 140 ES is exceeded in a residential well once, bottled water is made available to the occupant. If the exceedance occurs a second, consecutive time, well replacement is offered to the owner. Bottled water would be made available to the occupant until the well is replaced, operational and water quality verified (typically 3 months and based on driller availability). If the NR 140 ES exceedance is not detected for two consecutive rounds after the first NR 140 ES exceedance detection, bottled water would be discontinued. To date, the Army has replaced seven shallow residential wells with deeper aquifer residential wells.

- **Effectiveness** – The alternate water supply has been effective in conjunction with groundwater monitoring to replace residential wells.
- **Implementability** – These options can be readily implemented.
- **Cost** – Low

Alternate Water Supply – Provision of Bottled Water and Well Replacement is carried forward as a process option which can be combined with other process options to meet the RAO.

***Alternate Water Supply – Well Replacement within the Plume Areas*** - This process option would involve replacing individual residential shallow wells with a deeper aquifer well for existing residents. If sampling results indicate an increasing trend for a plume's COC in three consecutive rounds and that the plume is migrating toward a residential well, the Army will evaluate if well replacement is necessary. This process option would provide a safe, clean and reliable water source for potentially affected residential well owners downgradient of BAAP. The Army currently monitors 54 residential wells.

- **Effectiveness** – This process option would eliminate receptors from potential exposure to groundwater contamination within the plume areas by proactively providing a deeper aquifer well. This process option would rely on natural processes such as dilution, dispersion and sorption to degrade the contaminant plume over time.
- **Implementability** – This process option could be implemented by replacing individual shallow wells, meeting the criteria, with an individual deeper aquifer well.
- **Cost** – Low to Moderate depending upon replacement frequency.

Alternate Water Supply – Well Replacement within the Plume Area is carried forward as a process option which can be combined with other process options to meet the RAO.

***Alternate Water Supply – Municipal Water System*** - This process option would involve construction of a new municipal water system servicing residents located east and south of the BAAP with the potential of being impacted by the contaminant plumes. In 2011, the Army submitted a Revised Alternative Feasibility Study, Groundwater Remedial Strategy report to the WDNR. The selected groundwater remedy was Monitored Natural Attenuation (MNA). Due to the relatively long remedial timeframe for the MNA remedy to achieve the proposed cleanup levels, the proposed remedy included construction and operation of a municipal drinking water system that would provide residents in the communities surrounding the BAAP with drinking water while groundwater contamination continued to diminish over time. During an evaluation by the Army's Office of General Counsel it was determined the Army did not have the legal or funding authority to procure and operate a municipal water system as identified in the 2011 Revised Alternative Feasibility Study, so this option was not carried forward in the Feasibility Study.

While a draft Decision Document (DD) for Site-Wide Groundwater was being prepared in 2012, the Army identified several areas where the draft DD did not meet both legal and policy requirements. Specifically, a human health risk assessment was not prepared, incorrect legal standards were identified for the selected groundwater remedy and key components of the proposed response action were outside the Army's authority. For these reasons, this process option was not carried forward.

### *8.7.3 Groundwater Treatment*

**Groundwater Removal - Extraction Wells** - Vertical extraction wells are installed to collect and extract contaminated groundwater to reduce concentrations and/or contain a contaminant plume.

- **Effectiveness** – This process option is commonly used as an effective groundwater removal technology. Proper well location is necessary for effective source reduction and plume control. This process has been used at BAAP and based on previous experience, additional study and design may be needed to maximize source reduction and plume control.
- **Implementability** – This process option has been used at BAAP and is commonly used in the industry to remove groundwater. This process option would require utilities to be

extended to the site of the extraction well network. Groundwater extraction wells are relatively easy to install. This process option would also require coordination from existing property owners on- and off-site as the land in which the extraction wells would be located is owned and/or managed by other entities.
- **Cost** – Moderate cost due to site infrastructure improvements necessary for site specific conditions.

Groundwater Removal – Extraction Wells is carried forward as a process option which can be combined with other process options to meet the RAO.

**Groundwater Removal – Subsurface Drains** - This process option utilizes horizontal interceptor trenches filled with porous media to convey impacted water to extraction points. This application is typically used in shallow applications. Based on the depth of the contaminant plumes, this process option was not carried forward.

**Groundwater Treatment - In-situ Biochemical Injection** - Vertical injection points are installed within the contaminant plume, in areas where COCs exceed groundwater cleanup levels, and injected with a biochemical selected for the ability to degrade specific chemicals into harmless by-products through anaerobic biodegradation.

- **Effectiveness** – The procedures and applications of biochemical injection are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.
- **Implementability** – Equipment and expertise would be readily available; however, a field-scale pilot test would be necessary. This process option would also require coordination from existing property owners on- and off-site as the land in which the injection points would be located is owned and/or managed by other entities.
- **Cost** – Moderate to high cost depending upon the amount and corresponding cost of biochemical necessary to treat the plume.

Groundwater Treatment - In-situ Biochemical Injection is carried forward as a process option which can be combined with other process options to meet the RAO.

**Groundwater Treatment - Permeable Reactive Barrier** - This process option utilizes reactive media constructed across the path of a contaminant plume to treat groundwater. A permeable reactive barrier is generally limited to shallow applications and its effectiveness is a concern based on the longevity of the reactive media. Due to the depth of the contaminant plumes and concerns about the lifespan of the reactive media, this process option was not carried forward.

**Groundwater Treatment - Monitored Natural Attenuation** - MNA is a passive remedial process that utilizes groundwater sampling results to monitor the reduction in groundwater contaminants. Natural processes such as dilution, dispersion and sorption would be monitored over time to confirm contaminant reduction.

These natural attenuation processes include a variety of physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways: (1) transformation of contaminant(s) to a less toxic form through destructive processes such as biodegradation or abiotic transformations; (2) reduction of contaminant concentrations whereby potential exposure levels may be reduced; and (3) reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

Under CERCLA, MNA is considered to be a remedy like any other remedy. According to the USEPA (OSWER Directive 9200.4-17P), MNA can be an alternative means of achieving the RAO that may be appropriate for specific site circumstances where its use meets the applicable statutory and regulatory requirements. MNA can be used in conjunction with other remedies as a follow-up measure that will be monitored and compared with expectations. The USEPA expects that MNA will be most appropriate when used in conjunction with other remedial methods (e.g., source control, groundwater extraction), or as a follow-up to active remedial methods that have already been implemented. Both the USEPA and WDNR recognize MNA may be an appropriate remedial method for contaminated groundwater under certain circumstances.

- **Effectiveness** – This process option is an effective long-term solution as groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process.
- **Implementability** – This process option is easily implemented as monitoring well and residential well sampling and analytical testing are currently being conducted in accordance with the most recent regulatory approval.
- **Cost** – Low

Groundwater Treatment - Monitored Natural Attenuation is carried forward as a process option which can be combined with other process options to meet the RAO.

**Groundwater Treatment – Mobile Treatment** - Pressurized, mobile, tractor-trailer mounted treatment tanks utilizing activated carbon to treat extracted groundwater water in areas where COCs exceed groundwater cleanup levels.

- **Effectiveness** – Activated carbon has been previously used at BAAP to successfully treat DNT.
- **Implementability** – These units are capable of supporting treatment at flow rates up to 500 gpm. A separate mobile treatment unit would be required to support each well. This process option would require utilities to be extended to the site of the mobile treatment facility. This process option would also require coordination from existing property owners on- and off-site as the land on which the treatment units would be located is owned and/or managed by other entities. These mobile treatment units could be used in cold weather months with appropriate heating and insulation provisions.
- **Cost** – Moderate

Groundwater Treatment – Mobile Treatment is carried forward as a process option which can be combined with other process options to meet the RAO.

**Groundwater Treatment - On-site Treatment Facility** - A treatment facility for the extracted groundwater in areas where COCs exceed groundwater cleanup levels would be located on the BAAP property. The treatment system would require a structure (treatment facility) equipped with supporting utilities including gas, electric, water, sewer and communication. Utilities would need to be extended to the site in addition to other site improvements. At the treatment facility, activated carbon is the treatment media expected to be utilized to treat the impacted groundwater. This process option has been utilized at the BAAP previously. The Army no longer owns the land in or around the contaminant plumes, for which they would require, for facility construction. For this reason, this process option was not carried forward.

**Groundwater Treatment – Bluffview Sanitary District** - This process option would involve pumping extracted groundwater to the Bluffview Sanitary District's WWTP. The maximum daily capacity of this facility is 45,000 gallons per day which will not accommodate the flow rates anticipated for a pump and treat system. Each extraction well is expected to pump 720,000 gallons per day. For this reason, this process option was not carried forward.

**Groundwater Treatment at Publicly Owned Treatment Works** - This process option would involve pumping extracted groundwater in areas where COCs exceed groundwater cleanup levels to a holding tank and utilizing tanker trucks to transport the extracted groundwater to a publicly owned treatment works. Based on the anticipated flow rates needed for source removal and plume control (720,000 gallons per day per extraction well), the number of tanker trucks necessary to transport the impacted water would be not practicable. For this reason, this process option was not carried forward.

**Groundwater Disposal - On-site Discharge** - This process option would discharge treated groundwater on-site to either groundwater injection points or to an infiltration gallery. The areas near the contaminant plumes are on property owned and/or managed by other entities. Based on the anticipated flow rates needed for source removal and plume control, the size of the area necessary to facilitate injection or infiltration would be not practicable. Base on the anticipated discharge rates (720,000 gallons per day per extraction well) and subsequent size of the injection or infiltration area necessary for disposal, on-site discharge was not carried forward as a process option or remediation technology.

**Off-site Discharge Pipeline to the Wisconsin River** - This process option would discharge treated groundwater into the Wisconsin River. This would require pumping and a piping network to convey treated groundwater to the surface water discharge point.

- **Effectiveness** – This process option is an effective method for discharge water disposal provided that permit requirements could be met. This process option has been previously utilized at the BAAP.
- **Implementability** – This process option can be implemented as equipment and materials required for construction are readily available. This process option would require additional studies to design the discharge system to meet site specific requirements and constraints. This process option would also require coordination from existing property owners as the land in which the discharge piping would be located is owned and/or managed by other entities.

- **Cost** – Moderate cost depending upon discharge system design.

Off-site Discharge Disposal to the Wisconsin River is carried forward as a process option which can be combined with other process options to meet the RAO.

### *8.7.4 Groundwater Containment*

**Vertical Barriers** - Vertical barriers including slurry and sheet pile walls and deep soil mixing would be installed around the contaminant plumes to provide horizontal containment. These walls are typically "keyed" into a relatively impervious formation, providing horizontal and vertical containment. However, there are some of these walls that are constructed to "hang" when the contaminant plume is at shallow elevations effectively stagnating the plume. Based on site geology and depth of the contaminant plumes, vertical barriers were not carried forward as a process option or remediation technology.

### *8.7.5 Summary of Process Options for Groundwater*

The following process options remain after screening:

- Land Use Controls including on-site groundwater access restrictions
- Development of New Water Resources including provision of bottled water and residential well replacement within the plume areas
- Groundwater Treatment including removal through extraction wells, treatment through biochemical injection, monitored natural attenuation, and mobile treatment units and discharge through pipeline to the Wisconsin River

## 8.8 Alternatives Analysis Process

The NCP (40 CFR 300.430) states that the primary objective of the FS is to "ensure that appropriate remedial alternatives are developed and evaluated," and that "the number and type of alternatives to be analyzed shall be determined at each site, considering the scope characteristics and complexity of the site problem that is being addressed."

Nine evaluation criteria have been developed to serve as the basis for conducting a detailed analysis of the remedial alternatives. The evaluation criteria with the associated statutory considerations are:

1. Overall Protection of Human Health and the Environment
2. Compliance with the ARARs
3. Long-Term Effectiveness and Permanence
4. Reduction in Toxicity, Mobility and Volume through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

A process to evaluate remedial alternatives has been developed based on statutory requirements. The nine criteria are categorized into three groups and include threshold criteria, primary balancing criteria and modifying criteria.

Evaluation against two criteria relate directly to statutory findings that must ultimately be made in the remedy. Therefore, these are categorized as threshold criteria in that each alternative must meet them. These two criteria are briefly described below:

- **Overall Protection of Human Health and the Environment** – The assessment against this criterion describes how the alternative achieves and maintains protection of human health and the environment.

- **Compliance with ARARs** – The assessment against this criterion describes how the alternative complies with ARARs. The assessment also addresses other information from advisories, criteria and guidance.

The five criteria listed below represent the primary balancing criteria upon which the analysis is based.

- **Long-Term Effectiveness and Permanence** – The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met.

- **Reduction of Toxicity Mobility and Volume through Treatment** – The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternate may employ.

- **Short-Term Effectiveness –** The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.

- **Implementability –** This assessment evaluates the technical and administrative feasibility of alternatives and the availability of require goods and services.

- **Cost –** This assessment evaluates the capital and operation and maintenance (O&M) cost of each alternative. For environmental cleanup decision-making, the Army must follow both CERCLA guidance and the DoD Manual 4715.2. This relates primarily to budgeting purposes for the Army. The DoD Manual outlines the procedures the Army must follow when conducting environmental restoration under the DERP. DERP guidance (13.(a)(6)) states, "For long-term maintenance phases that are expected to continue indefinitely, cost-to-complete estimates should include a finite period of 30 years." Consequently, remedial alternatives for which the O&M term is expected to exceed 30 years, the Army must limit the O&M term to 30 years per DERP guidance.

The final two modifying criteria are briefly described below.

- **State Acceptance –** This assessment reflects that State's apparent preferences among or concerns about the remedy. State acceptance of an alternative will be evaluated in the Proposed Plan issued for public comment. Therefore, this criterion is not considered in this FS.

- **Community Acceptance –** This assessment reflects the community's apparent preferences among or concerns about alternatives. Community acceptance of each alternative will be evaluated after a Proposed Plan is issued for public comment. Therefore, this criterion is not considered in this FS.

The sections below present the detailed analysis of alternatives based on criteria 1 through 7 from the NCP (40 CFR 300.4309(e)(9)), as listed above.

# 9.0 REMEDIAL ALTERNATIVES – PBG PLUME

As identified in Section 7.1, CTET, ethyl ether, TCE, and 2,6-DNT were the only risk-related COCs considered for the development of remedial alternatives in the PBG Plume. However, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The RAO for the PBG Plume requires the remedy to protect human health by preventing exposure to contaminated groundwater, to minimize the impact of the contaminants on the environment, and to restore groundwater to the extent practicable. The RAO for the PBG Plume will be achieved when groundwater concentrations of CTET, ethyl ether, TCE, and 2,6-DNT are below the groundwater cleanup level listed in Table 16. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

Based on site conditions and the screening of process options, six remedial alternatives were developed to address the presence of groundwater COCs in the PBG Plume. Monitored Natural Attenuation (MNA) is expected to reduce the concentrations of the following VOCs by natural processes: CTET, chloroform, ethyl ether, and TCE. Active remedial alternatives were developed specifically for elevated concentrations of 2,6-DNT for the PBG Plume; however, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Alternative 1 - No Action, provides a baseline to evaluate the other alternatives.

**Alternative 1: No Action**

The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. This alternative would have no impact on the contaminant plume and would not require groundwater monitoring of residential wells or monitoring wells. This alternative would include on-site groundwater access restrictions.

**Alternative 2: Monitored Natural Attenuation and Alternate Water Supply**

The Monitored Natural Attenuation and Alternate Water Supply Alternative would continue the current remedial action approach and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement

**Alternative 3: Active Groundwater Remediation – Pump and Treat**

The Active Groundwater Remediation – Pump and Treat Alternative would target removing and treating impacted groundwater with elevated 2,6-DNT concentrations and include the below listed components. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater removal through the installation of four groundwater extraction wells
- Groundwater treatment through the use of four mobile treatment units

- Groundwater disposal through the construction of piping leading to the Wisconsin River

**Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation**

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target treating impacted groundwater with elevated 2,6-DNT concentrations and include the below listed components. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater treatment through in-situ biochemical injection at nine permanent injection well locations directly downgradient of the source area
- Groundwater treatment through in-situ biochemical injection at 150 temporary locations (on-site and off-site)

**Alternative 5: Well Replacement – Plume Area**

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer wells (meeting qualifying criteria) within the PBG Plume area with deeper aquifer wells and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Replacement of as many as 47 existing residential wells

**Alternative 6: Source Area Treatment**

The Source Area Treatment Alternative would target treating impacted groundwater with elevated 2,6-DNT concentrations directly downgradient of the source area and include the below listed components. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater treatment through in-situ biochemical injection at nine permanent injection well locations directly downgradient of the source area

## 9.1 Alternative 1 – No Action

The No Action Alternative would have no impact on any of the contaminant plumes and would not require groundwater monitoring of residential wells or monitoring wells. There would be no contaminant removal, treatment, containment or monitoring related to this alternative. As a condition of the Army's property transfer, groundwater access restrictions would continue for areas within the BAAP boundary.

**Overall Protection of Human Health and the Environment**

Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary; however, there are no groundwater access restrictions outside the BAAP boundary. This alternative would not provide any protection of human health or the environment beyond the groundwater access restrictions within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program.

**Compliance with ARARs**

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would result in the Army terminating the residential and monitoring well sampling program. This alternative would not comply with ARARs.

**Long-Term Effectiveness and Permanence**

This alternative would not provide an effective or permanent long-term solution. In this alternative, groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). This alternative would result in the Army terminating the residential and monitoring well sampling program. Consequently, the degradation process would not be evaluated under this alternative.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

Limited reductions in toxicity, mobility, and volume would occur through natural degradation processes only. This alternative would discontinue the residential and monitoring well sampling program. Consequently, the degradation process would not be evaluated.

**Short-Term Effectiveness**

There would be no action taken for this alternative. Since groundwater monitoring would be discontinued, any groundwater exceedances would go unidentified. Therefore, this alternative has no short-term effects.

**Implementability**

This alternative is inherently implementable as no remedial action would be taken.

**Cost**

There is no cost associated with the No Action Alternative.

## 9.2 Alternative 2 – Monitored Natural Attenuation and Alternate Water Supply

The Monitored Natural Attenuation and Alternate Water Supply Alternative would include MNA for the PBG Plume, on-site groundwater access restrictions and a provision for an alternate water supply condition for residential wells. This alternative would also continue residential and monitoring well sampling of the PBG Plume as previously specified in Section 4.2 and Appendix D.

MNA relies on natural attenuation processes to achieve the RAO within a time frame that is reasonable compared to that offered by other more active remedial methods. MNA is expected to reduce the concentrations of the COCs identified in Section 7.1 and carried forward in the development of remedial alternatives. These natural attenuation processes include a variety of physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

The Army currently has an environmental monitoring and health protection program in place that is protective of the residential water well users, “alternate water supply”. If a Chapter NR 140 ES is exceeded in a residential well once, bottled water is made available to the occupant. If the exceedance occurs a second, consecutive time, well replacement is offered to the owner. Bottled water would be made available to the occupant until the well is replaced, operational and water quality verified (typically 3 months and based on driller availability). If the NR 140 ES exceedance is not detected for two consecutive rounds after the first NR 140 ES exceedance detection, bottled water would be discontinued. To date, the Army has replaced three shallow residential wells within the PBG Plume.

**Overall Protection of Human Health and the Environment**

This alternative would provide protection of human health and the environment due to groundwater access restrictions within the BAAP boundary and the provision of an alternate water supply condition for residential wells. The groundwater sampling program would monitor the groundwater concentrations for compliance and contaminant reduction.

**Compliance with ARARs**

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would continue the residential and groundwater monitoring program and comply with ARARs over time though natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative offers a long-term solution as groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential well impacts. Groundwater impacts are expected to remain and the groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

Limited reductions in toxicity, mobility, and volume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

This alternative offers a short-term solution as it is currently being applied and no additional work associated with implementation would be required. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential wells. If the alternate water supply provision is necessary, state licensed well drillers would be utilized for well replacement. The well drillers would be appropriately trained and would maintain applicable certifications to install any replacement well necessary.

**Implementability**

This alternative would be easily implementable as this action is currently being applied to the site. No remedial activities other than sampling under the MNA program would be performed. Groundwater access restrictions are already in place within BAAP.

**Cost**

The estimated total cumulative costs for Alternative 2 are shown below. See Appendix I for a summary of the costs for Alternative 2.

**Alternative 2 – Monitored Natural Attenuation and Alternate Water Supply**

| | | |
|---|---|---|
| Direct Capital Cost: | $ | 0 |
| Indirect Capital Cost: | $ | 0 |
| 30 Years of Annual O&M: | $ | 4,913,113 |
| **Total Present Worth:** | **$** | **4,913,113** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 9.3 Alternative 3 – Active Groundwater Remediation – Pump and Treat

The Active Groundwater Remediation – Pump and Treat Alternative would include groundwater extraction and treatment with mobile treatment units and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 9.0, active remedial alternatives are only being developed for 2,6-DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the extraction wells would be strategically located to target elevated 2,6-DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for 2,6-DNT. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

It is anticipated that four extraction wells and four mobile treatment units (one treatment unit per extraction well) would be necessary for source area reduction and plume migration control. Four extraction wells were selected based on previous performance (capture zone) of extraction wells in this area. Generally, three of the extraction wells would be located on-site, south of the source area. The northern-most well would be located directly downgradient of the source area for source area reduction. The other two on-site extraction wells would be located in the southern portion of the on-site plume for migration control. One additional well would be located off-site, just south of the BAAP southern boundary, for migration control. Proposed pumping well locations and target pumping capture zones are shown on Drawing PBG-ALT 3 in Appendix J. The remainder of the PBG Plume located by Highway 78 would be allowed to degrade through natural processes, as no at-risk residential wells have been identified in this area.

Each extraction well is expected to pump at approximately 500 gpm. Similarly, each mobile treatment unit would be designed to treat 500 gpm. Based on previous experience with pump and treat systems in this area, groundwater flow velocities of 306 ft/yr (see Table 8) and assuming no additional source area contribution, the individual extraction wells and mobile treatment units are expected to operate continuously for various durations. The two extraction wells located in the southern on-site portion of the plume are expected to operate for at least 8 years. The extraction well located off-site is expected to operate for at least 6 years. The extraction well located closest to the source area is expected to operate for at least 2 years. The mobile treatment units are expected to use activated carbon as the primary treatment media as activated carbon has successfully treated DNT at BAAP. Site improvements including mobile treatment trailer staging area construction, electrical utility provision and site security would be necessary at each one of the extraction well/mobile treatment trailer areas.

A network of piping and appurtenances would be necessary to route extracted water from the extraction wells to the mobile treatment units and treated water from the mobile treatment units to a discharge location. Treated groundwater would ultimately discharge to the Wisconsin River. It is anticipated that the pump and treat system would require the services of an environmental technician to monitor and maintain the extraction wells and mobile treatment units.

**Overall Protection of Human Health and the Environment**

This alternative would be designed to control and limit the migration of and treat the groundwater with elevated 2,6-DNT concentrations. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Compliance with ARARs**

This alternative would be designed to comply with ARARs. The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce contaminant concentrations to comply with regulatory standards in groundwater through recovery and treatment of the portion of the PBG Plume with elevated 2,6-DNT concentrations. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. The previous pump and treat effort (MIRM) at the PBG showed effective DNT concentration reduction.

Based on previous experience, the groundwater pump and treat system's individual extraction wells and mobile treatment units are expected to operate continuously for various durations for up to eight years. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative is expected to result in reductions in toxicity, mobility, and volume through treatment of the PBG Plume with elevated 2,6-DNT concentrations. It is assumed that there would be no additional contribution of 2,6-DNT from the source areas into the groundwater. Based on performance of this technology at the BAAP (MIRM), the pump and treat system showed effective DNT concentration reduction. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The groundwater contamination would also continue to decrease due to natural attenuation processes.

**Short-Term Effectiveness**

For this alternative, there would be some short-term effects to workers, residents and the environment during implementation. As described above, this alternative would require three on-site and one off-site extraction wells coupled with a mobile treatment unit for each extraction well. These locations would require construction of a staging area for the well and mobile treatment unit, security and electricity for the site for operations and lighting.

It is anticipated that from each extraction well to the mobile treatment unit and from the mobile treatment unit to a discharge location, a discharge pipe would be constructed. Treated water is expected to be discharged to the Wisconsin River.

There is some risk associated with the operation of heavy equipment for site preparation, well drilling, excavation, piping installation and backfilling; however, proper training and equipment would be required to mitigate these risks. Utility crossing, near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction and plume migration control, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately one year. Construction and implementation of this alternative including well installation, piping construction, treatment area preparation and utility extension is expected to be completed in approximately one year.

**Implementability**

Equipment and materials required for construction of this alternative are readily available. However, extraction well and mobile treatment unit locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the PBG Plume. In addition, utilities to support the extraction wells and mobile treatment facility would need to be extended to the site, since none currently exist. The discharge line location would need to be determined and appropriate piping and appurtenance construction competed. The previous pump and treat discharge location to the Wisconsin River was identified during winter months with a high-visibility buoy system. This identified open water as a safety precaution to those who utilize the Wisconsin River in the winter for recreational activities such as ice fishing and snowmobiling. It is expected that a similar buoy system would be installed during the winter months and subsequently removed in the spring. This process of installation and decommissioning the buoy system would need to be repeated each winter and spring, respectively, as long as the system continued operation.

**Cost**

The estimated total cumulative costs for Alternative 3 are shown below. See Appendix I for a summary of the costs for Alternative 3.

**<u>Alternative 3 – Active Groundwater Remediation – Pump and Treat</u>**

| | |
|---|---|
| Direct Capital Cost: | $ 3,633,573 |
| Indirect Capital Cost: | $ 1,635,108 |
| 30 Years of Annual O&M: | $ 7,433,131 |
| **Total Cost:** | **$ 12,701,812** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 9.4 Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would include in-situ anaerobic biodegradation of groundwater contaminants and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 9.0, active remedial alternatives are only being developed for 2,6-DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the in-situ biochemical injection locations would be strategically located to target elevated 2,6-DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for 2,6-DNT. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

For this alternative, a nutrient-enriched emulsified vegetable oil (EVO) is being proposed as the injection product. EVO has been used to stimulate in-situ anaerobic biodegradation of groundwater contaminants at commercial, industrial, and military sites. The procedures and applications of EVO are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.

The primary objective of injecting EVO into the groundwater is to stimulate the anaerobic biodegradation of the target contaminants. Groundwater aquifers are complex ecosystems populated by a broad and diverse array of microbial communities. The composition and activity of these microbial communities' changes continuously as their environment changes. Alterations in aquifer geochemistry and the availability of substrates and nutrients that can be used to generate energy and support growth and reproduction significantly affect microbial activity.

EVO would be distributed in the aquifer as an oil-in-water emulsion (mixture). In this approach, an oil-in-water emulsion would be first prepared using a food-grade oil, food-grade surfactants, and water. The emulsion would have small uniform droplets to allow transport in the aquifer. The emulsion would be injected into the aquifer (through injection wells or DPT) with additional water to distribute the oil droplets. The oil droplets would be distributed through the aquifer pore spaces and adhere to soil particles. The soil particle surfaces would gradually become coated with a thin layer of oil droplets that provide a carbon source for long-term anaerobic biodegradation. The oil droplets remain in the aquifer as a viable carbon source for approximately two years. Soluble substrates and nutrients (e.g., lactate, yeast extract, vitamins) can be added to the mixture prior to injection to stimulate rapid growth of desired bacteria. When the contaminated groundwater naturally flows toward and through the distributed EVO, the groundwater contaminants interact with the carbon source and break-down into less harmful byproducts.

It is anticipated that 159 injection points (both on-site and off-site and at varying stratigraphic depths) would be required to treat the plume. These injection points would be arranged in a series of eight treatment lines and consist of both permanent injection wells (nine) and temporary injection points (150). The nine permanent wells would be arranged in one treatment line located just downgradient of the source area. It is assumed that the source area would no longer contribute to the groundwater contamination. However, should this occur, the permanent wells could be utilized for additional injections. The other seven treatment lines consisting of temporary injection points would be located both on-site and off-site within the plume. Anticipated treatment line locations are shown on Drawing PBG-ALT 4 in Appendix J.

The spacing of the treatment lines is based on a groundwater flow velocity of 306 ft/yr (see Table 8) and the viability of the carbon source remaining in the aquifer for approximately two years. The distance between each treatment line is based on two years of treatment. Based on the geology and hydrogeology associated with the plume, a 25-foot radius of influence is anticipated to provide sufficient distribution of the EVO within the aquifer. The radius of influence is measured from the injection well or point location radially, out to the maximum extent of EVO product distribution. Each treatment line would be designed to fully capture contaminated groundwater migrating downgradient.

Though EVO is a proven technology to effectively treat chlorinated solvents and energetics, a field-scale pilot test would be necessary to determine the site specific constraints and a design to be developed to target 2,6-DNT within the plume at BAAP. Upon successful completion of a field-scale pilot test, the remedial design could be finalized. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

**Overall Protection of Human Health and the Environment**

This alternative would be designed to meet the requirements of the RAO as it would effectively degrade the contaminants in the PBG Plume. The provision of the alternate water supply condition would address concerns associated with residential well impacts. Groundwater access restrictions would continue for areas within the BAAP.

**Compliance with ARARs**

Concentrations of contaminants in the treated area are expected to comply with ARARs relatively quickly (approximately two years). The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce the concentration in groundwater to comply with regulatory standards for 2,6-DNT. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. It is anticipated that a single round of injections of the biochemical product would be sufficient to treat the plume. Based on a groundwater flow velocity and the viability of the carbon source, treatment is expected to take approximately two years. However, depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications. The proposed biochemical product for use with this technology has shown successful contaminant reduction with explosives and chlorinated solvents; however, it has not been applied at full scale for DNT treatment. Lastly, potential increases in groundwater table elevation may have the ability to mobilize residual contamination remaining in the vadose zone. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

### Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative is expected to reduce the toxicity, mobility, and volume of 2,6-DNT and chlorinated solvents in the treated areas more quickly than natural processes alone. It is assumed that there would be no additional contribution of 2,6-DNT from the source areas into the groundwater. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The groundwater contamination would also continue to decrease due to natural attenuation processes.

### Short-Term Effectiveness

There would be some short-term effects to workers, residents and the environment during implementation. As described above, this alternative would require both on-site and off-site injection points.

There is some risk associated with heavy equipment necessary for permanent injection well installation, temporary injection point installation and injection. Proper training and equipment would be required to mitigate these risks. The bioremediation is expected to occur over the course of two years and no additional worker safety issues have been identified. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately two years. Construction and implementation of this alternative including permanent well installation, temporary injection point installation, biochemical injection and injection point abandonment is expected to be completed in approximately one year.

### Implementability

The installation of permanent injection wells and temporary injection points may be challenging at certain locations based on the stratigraphy. The area has been studied extensively and previous investigations have identified glacial outwash that may contain larger boulders. The potential stratigraphic obstructions may result in the need to change the location of permanent injection wells or temporary injection points.

Equipment and materials required for construction are readily available. However, permanent injection wells and temporary injection point locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the PBG Plume.

The biochemical product has been demonstrated to be effective in treating explosives and chlorinated solvents. Depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications.

**Cost**

The estimated total cumulative costs for Alternative 4 are shown below. See Appendix I for a summary of the costs for Alternative 4.

**Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation**

| | |
|---|---|
| Direct Capital Cost: | $ 3,254,729 |
| Indirect Capital Cost: | $ 1,464,628 |
| 30 Years of Annual O&M: | $ 4,913,113 |
| **Total Cost:** | **$ 9,632,470** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 9.5 Alternative 5 – Well Replacement – Plume Area

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer wells, meeting replacement criteria, within the PBG Plume area with deeper aquifer wells. This alternative would also include continued groundwater monitoring of residential and monitoring wells and on-site groundwater access restrictions.

A reasonable worst-case scenario was developed considering potential plume migration which resulted in the potential for 47 existing wells being impacted. If sampling results indicate an increasing trend for a plume's COC in three consecutive rounds and that the plume is migrating toward a residential well, the Army will evaluate if well replacement is necessary.

Based on deeper aquifer well information in the area, replacement wells would be drilled to approximately 500 feet below the existing ground surface and into the Mt. Simon Sandstone Formation. This formation is isolated from the shallow impacted groundwater by a confining shale layer. The 500-foot depth is necessary to satisfy water quality and production criteria. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. Connections from the well to the dwelling would be completed. Well replacement would be completed with abandonment of the shallow well and restoration of disturbed areas.

**Overall Protection of Human Health and the Environment**

This alternative would be protective of human health as potential receptors would be provided potable water from a deeper aquifer. Effectively, there would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary.

**Compliance with ARARs**

Groundwater monitoring would continue in monitoring and residential wells to monitor groundwater quality. Since the deep aquifer has been unimpacted by BAAP production or disposal activities, compliance with ARARs is expected. The contaminants within the plume are expected to comply with ARARs over time though natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative would be an effective long-term and permanent solution. These wells are expected to provide receptors with long-term access to potable water that has been unimpacted by BAAP production or disposal activities. This alternative would also continue to restrict groundwater access within the BAAP property. Groundwater contamination within the plume is expected to decrease over time due to natural degradation processes only. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

The well replacement alternative would eliminate the groundwater exposure pathway by providing potential receptors access to potable water from a deep aquifer. Limited reductions in toxicity, mobility, and volume of contaminants within the plume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

For this alternative, there would be some short-term effects to workers, residents and the environment during implementation. The alternative would require off-site well installation on private property. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. There is some risk associated with heavy equipment necessary for well installation. Proper training and equipment would be required to mitigate these risks. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

Implementation and construction of this alternative is expected to be completed in approximately three months once qualifying criteria have been established for a residential well. Additional well replacements would be addressed as necessary upon establishment of qualifying criteria.

**Implementability**

Implementation of this alternative would involve well installation and residential connections on private property. Equipment and materials required for construction are readily available and wells would be installed by a state licensed well driller. However, well replacement would have to be coordinated with private land owners.

**Cost**

The estimated total cumulative costs for Alternative 5 are shown below. See Appendix I for a summary of the costs for Alternative 5.

**Alternative 5 – Well Replacement – Plume Area**

| | |
|---|---|
| Direct Capital Cost: | $ 2,350,000 |
| Indirect Capital Cost: | $ 1,057,500 |
| 30 Years of Annual O&M: | $ 4,511,746 |
| **Total Cost:** | **$ 7,919,246** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 9.6 Alternative 6 – Source Area Treatment

The Source Area Treatment Alternative would involve in-situ anaerobic biodegradation of groundwater contaminants directly downgradient of the source area. This alternative would also include continued groundwater monitoring of residential and monitoring wells, on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 9.0, active remedial alternatives are only being developed for 2,6-DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the in-situ biochemical injection locations would be strategically located to target elevated 2,6-DNT concentrations directly downgradient of the source area. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for 2,6-DNT. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

For this alternative, a nutrient-enriched emulsified vegetable oil (EVO) is being proposed as the injection product. EVO has been used to stimulate in-situ anaerobic biodegradation of groundwater contaminants at commercial, industrial, and military sites. The procedures and applications of EVO are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.

The primary objective of injecting EVO into the groundwater is to stimulate the anaerobic biodegradation of the target contaminants. Groundwater aquifers are complex ecosystems populated by a broad and diverse array of microbial communities. The composition and activity of these microbial communities' changes continuously as their environment changes. Alterations in aquifer geochemistry and the availability of substrates and nutrients that can be used to generate energy and support growth and reproduction significantly affect microbial activity.

EVO would be distributed in the aquifer as an oil-in-water emulsion (mixture). In this approach, an oil-in-water emulsion would be first prepared using a food-grade oil, food-grade surfactants, and water. The emulsion would have small uniform droplets to allow transport in the aquifer.

The emulsion would be injected into the aquifer (through injection wells or direct-push-technology) with additional water to distribute the oil droplets. The oil droplets would be distributed through the aquifer pore spaces and adhere to soil particles. The soil particle surfaces would gradually become coated with a thin layer of oil droplets that provide a carbon source for long-term anaerobic biodegradation. The oil droplets remain in the aquifer as a viable carbon source for approximately two years. Soluble substrates and nutrients (e.g., lactate, yeast extract, vitamins) can be added to the mixture prior to injection to stimulate rapid growth of desired bacteria. When the contaminated groundwater naturally flows toward and through the distributed EVO, the groundwater contaminants interact with the carbon source and break-down into less harmful byproducts.

It is anticipated that nine permanent injection wells would be installed and arranged in one treatment line located just downgradient of the source area. It is assumed that the source area would no longer contribute to the groundwater contamination. However, should this occur, the permanent wells could be utilized for additional injections. Anticipated treatment line locations are shown on Drawing PBG-ALT 6 in Appendix J.

The spacing of the treatment lines is based on a groundwater flow velocity of 306 ft/yr (see Table 8) and the viability of the carbon source remaining in the aquifer for approximately two years. Based on the geology and hydrogeology associated with the plume, a 25-foot radius of influence is anticipated to provide sufficient distribution of the EVO within the aquifer. The radius of influence is measured from the injection well or point location radially, out to the maximum extent of EVO product distribution. Each treatment line would be designed to fully capture contaminated groundwater migrating downgradient.

Though EVO is a proven technology to effectively treat chlorinated solvents and energetics, a field-scale pilot test would be necessary to determine the site specific constraints and a design to be developed to target 2,6-DNT within the PBG Plume. Upon successful completion of a field-scale pilot test, the remedial design could be finalized. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

**Overall Protection of Human Health and the Environment**

This alternative would be protective of human health and the environment. This alternative would be designed to treat the highest concentrations of 2,6-DNT in the PBG Plume directly downgradient of the source area. The remainder of the plume would degrade over time through natural processes only; however, the provision of the alternate water supply condition would address concerns associated with residential well impacts. Groundwater access restrictions would continue for areas within the BAAP.

**Compliance with ARARs**

Concentrations of contaminants in the treated area are expected to comply with ARARs relatively quickly (approximately two years). The remainder of the plume would degrade over time through natural processes only; however, the provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

It is anticipated that this alternative would be effective in the long term as the highest concentrations of 2,6-DNT would be treated directly downgradient of the source area. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). It is anticipated that a single round of injections of the biochemical product would be sufficient to treat the highest concentrations in the plume directly downgradient of the source. Based on a groundwater flow velocity and the viability of the carbon source, treatment is expected to take at approximately two years. However, depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications. The proposed biochemical product for use with this technology has shown successful contaminant reduction with explosives and chlorinated solvents; however, it has not been applied at full scale for DNT treatment. Lastly, potential increases in groundwater table elevation may have the ability to mobilize residual contamination remaining in the vadose zone. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. The groundwater monitoring program is expected to continue at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative would reduce toxicity, mobility and volume of 2,6-DNT and chlorinated solvents in the treated areas more quickly than natural processes alone. It is assumed that there would be no additional contribution of 2,6-DNT from the source areas into the groundwater. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Parts of the plume untreated are expected to decrease in concentration due to natural degradation processes. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

There would be minimal short-term effects to workers, residents and the environment during implementation as most of the work would be completed on-site. Generally, there is some risk associated with heavy equipment necessary for well installation and injection. Proper training and equipment would be required to mitigate these risks.

To maximize contaminant reduction, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately two years. Construction and implementation of this alternative including permanent injection well installation, temporary injection point installation, biochemical injection and injection point abandonment is expected to be complete in approximately one year.

**Implementability**

The installation of the permanent injection wells may be challenging at certain locations based on the stratigraphy. The area has been studied extensively and previous investigations have identified glacial outwash that may contain larger boulders. The potential stratigraphic obstructions may result in the need to change the location of the permanent injection wells.

Equipment and materials required for construction are readily available. However, permanent injection well locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the PBG Plume.

The biochemical product has been demonstrated to be effective in treating explosives and chlorinated solvents. Depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications.

**Cost**

The estimated total cumulative costs for Alternative 6 are shown below. See Appendix I for a summary of the costs for Alternative 6.

**<u>Alternative 6 – Source Area Treatment</u>**

| | |
|---|---|
| Direct Capital Cost: | $ 201,433 |
| Indirect Capital Cost: | $ 90,645 |
| 30 Years of Annual O&M: | $ 4,913,113 |
| **Total Cost:** | **$ 5,205,190** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 9.7 PBG Plume Remedial Alternative Summary

A summary of the cleanup timeframe, treatment duration, groundwater monitoring duration, and cost for each of the six proposed remedial alternatives for the PBG Plume is presented below.

**Propellant Burning Ground Plume**
**Remedial Alternative Summary**

| Alternative | Time to Achieve Cleanup | Active Treatment Duration | Groundwater Monitoring Duration | Total Cost |
|---|---|---|---|---|
| Alternative 1 – No Action | NA | NA | NA | $0 |
| Alternative 2 – MNA and Alternate Water Supply | 30 Years | NA | 30 Years | $4.9 |
| Alternative 3 – Pump and Treat | 30 Years | 8 Years | 30 Years | $12.7 |
| Alternative 4 – Anaerobic Bioremediation | 30 Years | 2 Years | 30 Years | $9.6 |
| Alternative 5 – Well Replacement | 30 Years | NA | 30 Years | $7.9 |
| Alternative 6 – Source Area Treatment | 30 Years | 2 Years | 30 Years | $5.2 |

Notes: Total cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
Total cost is based on current rates and does not include inflation.
See Section 8.8 for an explanation of why the time to achieve cleanup and the O&M term are limited to 30 years.

An evaluation criteria summary of the proposed remedial alternatives for the PBG Plume is presented below. Each of the six proposed alternatives are listed in the left column. As described in Section 8.8, nine evaluation criteria have been developed to serve as the basis for conducting a detailed analysis of the remedial alternatives. The nine criteria include threshold, primary balancing and modifying criteria are listed below in the top row. The two modifying criteria (State Acceptance and Community Acceptance) are incorporated during the remedy selection stage and presented in the Proposed Plan.

An objective and qualitative evaluation was completed to compare the six proposed remedial alternatives. A designation of "H" represents a high confidence of the alternative meeting the criteria. Similarly, a designation of "L" represents a low and "M" represents a moderate confidence of the alternative meeting the criteria. A designation of "N" represents no confidence of the alternative meeting the criteria and a designation of "TBD" represents to be determined. The designations are supported by their respective preceding text section for each remedial alternative and were made in relation to other alternatives. Approximate total costs for each remedial alternative are shown in the right column.

## Propellant Burning Ground Plume
## Evaluation Criteria Summary

| Alternative | Evaluation Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Protection to Human Health & Environment | Compliance with ARARs | Long-Term Effectiveness & Permanence | Reduction in Toxicity, Mobility & Volume Through Treatment | Short-Term Effectiveness | Implementability | State Acceptance | Community Acceptance | Total Cost (1)(2) |
| Alternative 1 – No Action<br>• Groundwater access restrictions | L | N | N | N | N | H | TBD | TBD | $0 |
| Alternative 2 – MNA and Alternate Water Supply<br>• Groundwater access restrictions<br>• Groundwater monitoring<br>• Alternate water supply | M | L | M | L | M | H | TBD | TBD | $4.9 |
| Alternative 3 – Pump and Treat (3)<br>• Extraction wells (four)<br>• Mobile treatment units (four) | H | H | H | H | M | M | TBD | TBD | $12.7 |
| Alternative 4 – Anaerobic Bioremediation (3)<br>• Permanent injection wells (nine)<br>• Temporary injection points (150) | H | H | M | H | M | M | TBD | TBD | $9.6 |
| Alternative 5 – Well Replacement (4)<br>• Replacement of residential wells (47) | M | M | H | L | M | M | TBD | TBD | $7.9 |
| Alternative 6 – Source Area Treatment (3)<br>• Permanent injection wells (nine) | M | M | M | M | H | M | TBD | TBD | $5.2 |

Notes: H – High, L – Low, M – Moderate, N – None, TBD – To Be Determined.
(1) Cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
(2) Based on current rates and does not include inflation.
(3) Alternative includes groundwater access restrictions, groundwater monitoring and alternate water supply.
(4) Alternative includes groundwater access restrictions and groundwater monitoring.

# 10.0 REMEDIAL ALTERNATIVES – DBG PLUME

As identified in Section 7.2, total DNT was the only risk-related COC considered for the development of remedial alternatives in the DBG Plume. The RAO for the DBG Plume requires the remedy to protect human health by preventing exposure to contaminated groundwater, to minimize the impact of the contaminants on the environment, and to restore groundwater to the extent practicable. The RAO for the DBG Plume will be achieved when groundwater concentrations of total DNT are below the groundwater cleanup level listed in Table 16.

Based on site conditions and the screening of process options, six remedial alternatives were developed to address the presence of total DNT in the DBG Plume. Alternative 1 - No Action, provides a baseline to evaluate the other alternatives.

**Alternative 1: No Action**

The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. This alternative would have no impact on the contaminant plume and would not require groundwater monitoring of residential wells or monitoring wells. This alternative would include on-site groundwater access restrictions.

**Alternative 2: Monitored Natural Attenuation and Alternate Water Supply**

The Monitored Natural Attenuation and Alternate Water Supply Alternative would continue the current remedial action approach and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement

**Alternative 3: Active Groundwater Remediation – Pump and Treat**

The Active Groundwater Remediation – Pump and Treat Alternative would target removing and treating impacted groundwater with elevated total DNT concentrations and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater removal through the installation of three groundwater extraction wells
- Groundwater treatment through the use of three mobile treatment units
- Groundwater disposal through the construction of piping leading to the Wisconsin River

**Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation**

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target treating impacted groundwater with elevated total DNT concentrations and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater treatment through in-situ biochemical injection at 406 temporary locations (on-site and off-site)

**Alternative 5: Well Replacement – Plume Area**

The Well Replacement – Plume Area Alternative would involve replacing all shallow aquifer wells (meeting qualifying criteria) within the DBG Plume area with deeper aquifer wells and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Replacement of as many as 57 existing residential wells

**Alternative 6: Source Area Treatment**

The Source Area Treatment Alternative would target treating impacted groundwater with elevated total DNT concentrations directly downgradient of the source area and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater treatment through in-situ biochemical injection at 56 temporary on-site locations

## 10.1 Alternative 1 – No Action

The No Action Alternative would have no impact on any of the contaminant plumes and would not require groundwater monitoring of residential wells or monitoring wells. There would be no contaminant removal, treatment, containment or monitoring related to this alternative. As a condition of the Army's property transfer, groundwater access restrictions would continue for areas within the BAAP boundary.

### Overall Protection of Human Health and the Environment

Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary; however, there are no groundwater access restrictions outside the BAAP boundary. This alternative would not provide any protection of human health or the environment beyond the groundwater access restrictions within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program.

**Compliance with ARARs**

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would result in the Army terminating the residential and monitoring well sampling program. This alternative would not comply with ARARs.

**Long-Term Effectiveness and Permanence**

This alternative would not provide an effective or permanent long-term solution. In this alternative, groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). This alternative would result in the Army terminating the residential and monitoring well sampling program. Consequently, the degradation process would not be evaluated under this alternative.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

Limited reductions in toxicity, mobility, and volume would occur through natural degradation processes only. This alternative would discontinue the sampling of residential and groundwater monitoring wells. Consequently, the degradation process would not be evaluated.

**Short-Term Effectiveness**

There would be no action taken for this alternative. Since groundwater monitoring would be discontinued, any groundwater exceedances would go unidentified. Therefore, this alternative has no short-term effects.

**Implementability**

This alternative is inherently implementable as no remedial action would be taken.

**Cost**

There is no cost associated with the No Action Alternative.

## 10.2 Alternative 2 – Monitored Natural Attenuation and Alternate Water Supply

The Monitored Natural Attenuation and Alternate Water Supply Alternative would include MNA for the DBG Plume, on-site groundwater access restrictions and a provision for an alternate water supply condition for residential wells. This alternative would also continue residential and monitoring well sampling of the DBG Plume as previously specified in Section 4.2 and Appendix D.

MNA relies on natural attenuation processes to achieve the RAO within a time frame that is reasonable compared to that offered by other more active remedial methods. MNA is expected to reduce the concentrations of the COCs that were carried forward in the development of remedial alternatives (see Section 7.2), which includes only total DNT. These natural attenuation processes include a variety of physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

The Army currently has an environmental monitoring and health protection program in place that is protective of the residential water well users, “alternate water supply”. If a Chapter NR 140 ES is exceeded in a residential well once, bottled water is made available to the occupant. If the exceedance occurs a second, consecutive time, well replacement is offered to the owner. Bottled water would be made available to the occupant until the well is replaced, operational and water quality verified (typically 3 months and based on driller availability). If the NR 140 ES exceedance is not detected for two consecutive rounds after the first NR 140 ES exceedance detection, bottled water would be discontinued. The Army has replaced one residential well associated with the DBG Plume that has been impacted by total DNT.

**Overall Protection of Human Health and the Environment**

This alternative would provide protection of human health and the environment due to groundwater access restrictions within the BAAP boundary and the provision of an alternate water supply condition for residential wells. The groundwater sampling program would monitor the groundwater concentrations for compliance and contaminant reduction.

**Compliance with ARARs**

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would continue the residential and groundwater monitoring program and comply with ARARs over time through natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative offers a long-term solution as groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). The alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential well impacts. Groundwater impacts are expected to remain and the groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

Limited reductions in toxicity, mobility, and volume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

This alternative offers a short-term solution as it is currently being applied and no additional work associated with implementation would be required. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential wells. If the alternate water supply provision is necessary, state licensed well drillers would be utilized for well replacement. The well drillers would be appropriately trained and would maintain applicable certifications to install any replacement well necessary.

**Implementability**

This alternative would be easily implementable as this action is currently being applied to the site. No remedial activities other than sampling under the MNA program would be performed. Groundwater access restrictions are already in place within BAAP.

**Cost**

The estimated total cumulative costs for Alternative 2 are shown below. See Appendix I for a summary of the costs for Alternative 2.

**Alternative 2 – Monitored Natural Attenuation**

| | | |
|---|---|---|
| Direct Capital Cost: | $ | 0 |
| Indirect Capital Cost: | $ | 0 |
| 30 Years of Annual O&M: | $ | 4,240,490 |
| **Total Present Worth:** | **$** | **4,240,490** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 10.3 Alternative 3 – Active Groundwater Remediation – Pump and Treat

The Active Groundwater Remediation – Pump and Treat Alternative would include groundwater extraction and treatment with mobile treatment units and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 10.0, active remedial alternatives are only being developed for total DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the extraction wells would be strategically located to target elevated total DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for total DNT.

It is anticipated that three extraction wells and three mobile treatment units (one treatment unit per extraction well) would be necessary to provide source control and minimize off site migration of the plume. Three extraction wells were selected based on previous performance (capture zone) of extraction wells located in the PBG Plume area. One extraction well would be located directly downgradient of the source area (on-site), along the long axis of the plume, and within the highest total DNT concentration for source control. The other on-site extraction well would be located at the BAAP boundary to minimize off-site plume migration. One additional extraction well would be located off-site toward the southeastern end of the DBG Plume. Proposed pumping well locations and target pumping capture zones are shown on Drawing DBG-ALT 3 in Appendix J.

Each extraction well is expected to pump at approximately 500 gpm. Similarly, each mobile treatment unit would be designed to treat 500 gpm. Based on previous experience with pump and treat systems at BAAP (MIRM), groundwater flow velocities of 109 ft/yr (see Table 8) and assuming no additional source area contribution, the individual extraction wells and mobile treatment units are expected to operate continuously for various durations. The extraction well located closest to the source area is expected to operate for at least 10 years. The two other extraction wells are expected to operate for at least 22 years. The mobile treatment units are expected to use activated carbon as the primary treatment media as activated carbon has successfully treated DNT at BAAP. Site improvements including mobile treatment trailer staging area construction, electrical utility provision and site security would be necessary at each one of the extraction well/mobile treatment trailer areas.

A network of piping and appurtenances would be necessary to route extracted water from the extraction wells to the mobile treatment units and treated water from the mobile treatment units to a discharge pipeline leading to the Wisconsin River. It is anticipated that the pump and treat system would require the services of an environmental technician to monitor and maintain the extraction wells and mobile treatment units.

**Overall Protection of Human Health and the Environment**

This alternative would be designed to control and limit the migration of and treat the groundwater with elevated total DNT concentrations. The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Compliance with ARARs**

This alternative would be designed to comply with ARARs. The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce contaminant concentrations to comply with regulatory standards in groundwater through recovery and treatment of the portion of the DBG Plume with elevated total DNT concentrations. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. A similar pump and treat system was operated at BAAP (MIRM) and showed effective DNT concentration reduction.

Based on previous experience, the groundwater pump and treat system's individual extraction wells and mobile treatment units are expected to operate continuously for various durations for up to 22 years. The groundwater monitoring program is expected to continue for at least 24 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative is expected to result in reductions in toxicity, mobility, and volume through treatment of the DBG Plume with elevated total DNT concentrations. It is assumed that there would be no additional contribution of total DNT from the source areas into the groundwater. Based on performance of this technology at the BAAP (MIRM), the pump and treat system showed effective DNT concentration reduction. The groundwater contamination would also continue to decrease due to natural attenuation processes.

**Short-Term Effectiveness**

For this alternative there would be some short-term effects to workers, residents and the environment during implementation. As described above, the technology would require two on-site and one off-site extraction wells coupled with a mobile treatment units for each extraction well. These locations would require construction of a staging area for the well and mobile treatment trailer, security and electricity for the site for operations and lighting.

It is anticipated that a new discharge pipeline would need to be constructed for the mobile treatment unit's discharge. From each extraction well and mobile treatment unit staging areas a discharge pipe would be constructed to transport treated water to the discharge piping leading to the Wisconsin River.

There is some risk associated with the operation of heavy equipment for site preparation, well drilling, excavation, piping installation and backfilling; however, proper training and equipment would be required to mitigate these risks. Utility crossing, near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction and plume migration control, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately one year. Construction and implementation of this alternative including well installation, piping construction, treatment area preparation and utility extension is expected to be completed in approximately one year.

**Implementability**

Equipment and materials required for construction of this alternative are readily available. However, extraction well and mobile treatment unit locations would have to be coordinated carefully and with input from the existing land owners as they are responsible for the ownership and/or management of the area around the DBG Plume. In addition, utilities to support the extraction wells and mobile treatment facility would need to be extended to the site, since none currently exist. The discharge line location would need to be determined and appropriate piping and appurtenance construction competed. The discharge location to the Wisconsin River would need to be identified during winter months with a high-visibility buoy system. This would identify open water as a safety precaution to those who utilize the Wisconsin River in the winter for recreational activities such as ice fishing and snowmobiling. It is expected that this buoy system would be installed during the winter months and subsequently removed in the spring. This process of installation and decommissioning the buoy system would need to be repeated each winter and spring, respectively, as long as the system continued operation.

**Cost**

The estimated total cumulative costs for Alternative 3 are shown below. See Appendix I for a summary of the costs for Alternative 3.

**<u>Alternative 3 – Active Groundwater Remediation – Pump and Treat</u>**

| | |
|---|---|
| Direct Capital Cost: | $ 2,776,030 |
| Indirect Capital Cost: | $ 1,249,214 |
| 24 Years of Annual O&M: | $ 8,522,395 |
| **Total Cost:** | **$ 12,547,639** |

* Total costs use current rates and do not include inflation

## 10.4 Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would include in-situ anaerobic biodegradation of groundwater contaminants and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 10.0, active remedial alternatives are only being developed for total DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the in-situ biochemical injection locations would be strategically located to target elevated total DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for total DNT.

For this alternative, a nutrient-enriched emulsified vegetable oil (EVO) is being proposed as the injection product. EVO has been used to stimulate in-situ anaerobic biodegradation of groundwater contaminants at commercial, industrial, and military sites. The procedures and applications of EVO are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.

The primary objective of injecting EVO into the groundwater is to stimulate the anaerobic biodegradation of the target contaminants. Groundwater aquifers are complex ecosystems populated by a broad and diverse array of microbial communities. The composition and activity of these microbial communities' changes continuously as their environment changes. Alterations in aquifer geochemistry and the availability of substrates and nutrients that can be used to generate energy and support growth and reproduction significantly affect microbial activity.

EVO would be distributed in the aquifer as an oil-in-water emulsion (mixture). In this approach, an oil-in-water emulsion would be first prepared using a food-grade oil, food-grade surfactants, and water. The emulsion would have small uniform droplets to allow transport in the aquifer. The emulsion would be injected into the aquifer (through injection wells or DPT) with additional water to distribute the oil droplets. The oil droplets would be distributed through the aquifer pore spaces and adhere to soil particles. The soil particle surfaces would gradually become coated with a thin layer of oil droplets that provide a carbon source for long-term anaerobic biodegradation. The oil droplets remain in the aquifer as a viable carbon source for approximately two years. Soluble substrates and nutrients (e.g., lactate, yeast extract, vitamins) can be added to the mixture prior to injection to stimulate rapid growth of desired bacteria. When the contaminated groundwater naturally flows toward and through the distributed EVO, the groundwater contaminants interact with the carbon source and break-down into less harmful byproducts.

It is anticipated that 406 injection points (both on-site and off-site and at varying stratigraphic depths) would be required to treat the plume. These injection points would be arranged in a series of 29 treatment lines and consist of temporary injection points. It is assumed that the source area would no longer contribute to the groundwater contamination. Anticipated treatment line locations are shown on Drawing DBG-ALT 4 in Appendix J.

The spacing of the treatment lines is based on a groundwater flow velocity of 109 ft/yr (see Table 8) and the viability of the carbon source remaining in the aquifer for approximately two years. The distance between each treatment line is based on two years of treatment. Based on the geology and hydrogeology associated with the plume, a 25-foot radius of influence is anticipated to provide sufficient distribution of the EVO within the aquifer. The radius of influence is measured from the injection well or point location radially, out to the maximum extent of EVO product distribution. Each treatment line would be designed to fully capture contaminated groundwater migrating downgradient.

Though EVO is a proven technology to effectively treat chlorinated solvents and energetics, a field-scale pilot test would be necessary to determine the site specific constraints and a design to be developed to target total DNT within the plume at BAAP. Upon successful completion of a field-scale pilot test, the remedial design could be finalized.

**Overall Protection of Human Health and the Environment**

This alternative would be designed to meet the requirements of the RAO as it would effectively degrade the contaminants in the DBG Plume. The provision of the alternate water supply condition would address concerns associated with residential well impacts. Groundwater access restrictions would continue for areas within the BAAP.

**Compliance with ARARs**

Concentrations of contaminants in the treated area are expected to comply with ARARs relatively quickly (approximately two years). The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce the concentration in groundwater to comply with regulatory standards for total DNT. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. Several issues have been identified regarding the alternative's long-term effectiveness and permanence. It is anticipated that a single round of injections of the biochemical product would be sufficient to treat the plume. Based on a groundwater flow velocity and the viability of the carbon source, treatment is expected to take approximately two years. However, depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications. The proposed biochemical product for use with this technology has shown successful contaminant reduction with chlorinated solvents; however, it has not been applied at full scale for total DNT treatment. The groundwater monitoring program is expected to continue for at least four years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative is expected to reduce the toxicity, mobility, and volume of total DNT and chlorinated solvents in the treated areas more quickly than natural processes alone. It is assumed that there would be no additional contribution of total DNT from the source areas into the groundwater. The groundwater contamination would also continue to decrease due to natural attenuation processes.

**Short-Term Effectiveness**

There would be some short-term effects to workers, residents and the environment during implementation. As described above, this alternative would require both on-site and off-site injection points.

There is some risk associated with heavy equipment necessary for temporary injection point installation and injection. Proper training and equipment would be required to mitigate these risks. The bioremediation is expected to occur over the course of two years and no additional worker safety issues have been identified. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately two years. Construction and implementation of this alternative including temporary injection point installation, biochemical injection and injection point abandonment is expected to be completed in approximately one year.

**Implementability**

The installation of temporary injection points may be challenging at certain locations based on the stratigraphy. The area has been studied extensively and previous investigations have identified glacial outwash that may contain larger boulders. The potential stratigraphic obstructions may result in the need to change locations of temporary injection points.

Equipment and materials required for construction are readily available. However, temporary injection point locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the DBG Plume.

The biochemical product has been demonstrated to be effective in treating explosives and chlorinated solvents. Depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications.

**Cost**

The estimated total cumulative costs for Alternative 4 are shown below. See Appendix I for a summary of the costs for Alternative 4.

**Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation**

| | |
|---|---|
| Direct Capital Cost: | $ 8,107,868 |
| Indirect Capital Cost: | $ 3,648,540 |
| 4 Years of Annual O&M: | $ 706,748 |
| **Total Cost:** | **$ 12,463,156** |

* Total costs use current rates and do not include inflation

## 10.5 Alternative 5 – Well Replacement – Plume Area

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer wells, meeting replacement criteria, within the DBG Plume area with deeper aquifer wells. This alternative would also include continued groundwater monitoring of residential and monitoring wells and on-site groundwater access restrictions.

A reasonable worst-case scenario was developed considering potential plume migration which resulted in the potential for 57 existing wells being impacted. If sampling results indicate an increasing trend for a plume's COC in three consecutive rounds and that the plume is migrating toward a residential well, the Army will evaluate if well replacement is necessary.

Based on deeper aquifer well information in the area, replacement wells would be drilled to approximately 400 feet below the existing ground surface and into the Mt. Simon Sandstone

Formation. This sandstone formation is isolated from the shallow impacted groundwater by a confining layer of dolomite, shale, and siltstone. The 400-foot depth is necessary to satisfy water quality and production criteria. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. Connections from the well to the dwelling would be completed. Well replacement would be completed with abandonment of the shallow well and restoration of disturbed areas.

**Overall Protection of Human Health and the Environment**

This alternative would be protective of human health as potential receptors would be provided potable water from a deeper aquifer. Effectively, there would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary.

**Compliance with ARARs**

Groundwater monitoring would continue in monitoring and residential wells to monitor groundwater quality. Since the deep aquifer has been unimpacted by BAAP production or disposal activities, compliance with ARARs is expected. The contaminants within the plume are expected to comply with ARARs over time through natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative would be an effective long-term and permanent solution. These wells are expected to provide receptors with long-term access to potable water that has been unimpacted by BAAP production or disposal activities. This alternative would also continue to restrict groundwater access within the BAAP property. Groundwater contamination within the plume is expected to decrease over time due to natural degradation processes only. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative would eliminate the groundwater exposure pathway by providing potential receptors access to potable water from a deep aquifer. Limited reductions in toxicity, mobility, and volume of contaminants within the plume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

For this alternative, there would be some short-term effects to workers, residents and the environment during implementation. The alternative would require off-site well installation on private property. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. There is some risk associated with heavy equipment necessary for well installation. Proper training and equipment would be required to mitigate these risks. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

Implementation and construction of this alternative is expected to be completed in approximately three months once qualifying criteria have been established for a residential well. Additional well replacements would be addressed as necessary upon establishment of qualifying criteria.

**Implementability**

Implementation of this alternative would involve well installation and residential connections on private property. Equipment and materials required for construction are readily available and wells would be installed by a state licensed well driller. However, well replacement would have to be coordinated with private land owners.

**Cost**

The estimated total cumulative costs for Alternative 5 are shown below. See Appendix I for a summary of the costs for Alternative 5.

**<u>Alternative 5 – Well Replacement – Plume Area</u>**

| | | |
|---|---|---|
| Direct Capital Cost: | $ | 2,280,000 |
| Indirect Capital Cost: | $ | 1,026,000 |
| 30 Years of Annual O&M: | $ | 3,839,123 |
| **Total Cost:** | **$** | **7,145,123** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 10.6 Alternative 6 – Source Area Treatment

The Source Area Treatment Alternative would involve in-situ anaerobic biodegradation of groundwater contaminants directly downgradient of the source area. This alternative would also include continued groundwater monitoring of residential and monitoring wells, on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 10.0, active remedial alternatives are only being developed for total DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the in-situ biochemical injection locations would be strategically located to target elevated total DNT concentrations directly downgradient of the source area. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for total DNT.

For this alternative, a nutrient-enriched emulsified vegetable oil (EVO) is being proposed as the injection product. EVO has been used to stimulate in-situ anaerobic biodegradation of groundwater contaminants at commercial, industrial, and military sites. The procedures and applications of EVO are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.

The primary objective of injecting EVO into the groundwater is to stimulate the anaerobic biodegradation of the target contaminants. Groundwater aquifers are complex ecosystems populated by a broad and diverse array of microbial communities. The composition and activity of these microbial communities' changes continuously as their environment changes. Alterations in aquifer geochemistry and the availability of substrates and nutrients that can be used to generate energy and support growth and reproduction significantly affect microbial activity.

EVO would be distributed in the aquifer as an oil-in-water emulsion (mixture). In this approach, an oil-in-water emulsion would be first prepared using a food-grade oil, food-grade surfactants, and water. The emulsion would have small uniform droplets to allow transport in the aquifer. The emulsion would be injected into the aquifer (through injection wells or direct-push-technology) with additional water to distribute the oil droplets. The oil droplets would be distributed through the aquifer pore spaces and adhere to soil particles. The soil particle surfaces would gradually become coated with a thin layer of oil droplets that provide a carbon source for long-term anaerobic biodegradation. The oil droplets remain in the aquifer as a viable carbon source for approximately two years. Soluble substrates and nutrients (e.g., lactate, yeast extract, vitamins) can be added to the mixture prior to injection to stimulate rapid growth of desired bacteria. When the contaminated groundwater naturally flows toward and through the distributed EVO, the groundwater contaminants interact with the carbon source and break-down into less harmful byproducts.

It is anticipated that 56 temporary injection points would be installed on-site. These injection points would be arranged in a series of four treatment lines located just downgradient of the source area. It is assumed that the source area would no longer contribute to the groundwater contamination. Anticipated treatment line locations are shown on Drawing DBG-ALT 6 in Appendix J.

The spacing of the treatment lines is based on a groundwater flow velocity of 109 ft/yr (see Table 8) and the viability of the carbon source remaining in the aquifer for approximately two years. Based on the geology and hydrogeology associated with the plume, a 25-foot radius of influence is anticipated to provide sufficient distribution of the EVO within the aquifer. The radius of influence is measured from the injection well or point location radially, out to the maximum extent of EVO product distribution. Each treatment line would be designed to fully capture contaminated groundwater migrating downgradient.

Though EVO is a proven technology to effectively treat chlorinated solvents and energetics, a field-scale pilot test would be necessary to determine the site specific constraints and a design to be developed to target total DNT within the DBG Plume. Upon successful completion of a field-scale pilot test, the remedial design could be finalized.

**Overall Protection of Human Health and the Environment**

This alternative would be protective of human health and the environment. This alternative would be designed to treat the highest concentrations of total DNT in the DBG Plume. The provision of the alternate water supply condition would address concerns associated with residential well impacts. Groundwater access restrictions would continue for areas within the BAAP.

**Compliance with ARARs**

Concentrations of contaminants in the treated area are expected to comply with ARARs relatively quickly (approximately two years). The remainder of the plume's contamination would decrease over time through natural processes only; however, the provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

It is anticipated that this alternative would be effective in the long term as the highest concentrations of total DNT would be treated directly downgradient of the source area. It is anticipated that a single round of injections of the biochemical product would be sufficient to treat the highest concentrations in the plume directly downgradient of the source area. Based on a groundwater flow velocity and the viability of the carbon source, treatment is expected to take at approximately two years. However, depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications. The proposed biochemical product for use with this technology has shown successful contaminant reduction with explosives and chlorinated solvents; however, it has not been applied at full scale for total DNT treatment. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative would reduce toxicity, mobility and volume of total DNT and chlorinated solvents in the treated areas more quickly than natural processes alone. It is assumed that there would be no additional contribution of total DNT from the source areas into the groundwater. Portions of the plume untreated are expected to decrease in concentration due to natural attenuation processes. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

There would be minimal short-term effects to workers, residents and the environment during implementation as most of the work would be completed on-site. Generally, there is some risk associated with heavy equipment necessary for temporary injection point installation, and injection. Proper training and equipment would be required to mitigate these risks.

To maximize contaminant reduction, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately two years. Construction and implementation of this alternative including temporary injection point installation, biochemical injection and injection point abandonment is expected to be complete in approximately one year.

**Implementability**

The installation of temporary injection points may be challenging at certain locations based on the stratigraphy. The area has been studied extensively and previous investigations have identified glacial outwash that may contain larger boulders. The potential stratigraphic obstructions may result in the need to change locations of temporary injection points.

Equipment and materials required for construction are readily available. However, temporary injection point locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the DBG Plume.

The biochemical product has been demonstrated to be effective in treating explosives and chlorinated solvents. Depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications.

**Cost**

The estimated total cumulative costs for Alternative 6 are shown below. See Appendix I for a summary of the costs for Alternative 6.

**Alternative 6 – Source Area Treatment**

| | |
|---|---|
| Direct Capital Cost: | $ 645,631 |
| Indirect Capital Cost: | $ 290,534 |
| 30 Years of Annual O&M: | $ 4,240,490 |
| **Total Cost:** | **$ 5,176,654** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 10.7 DBG Plume Remedial Alternative Summary

A summary of the cleanup timeframe, treatment duration, groundwater monitoring duration, and cost for each of the six proposed remedial alternatives for the DBG Plume is presented below.

**Deterrent Burning Ground Plume**
**Remedial Alternative Summary**

| Alternative | Time to Achieve Cleanup | Active Treatment Duration | Groundwater Monitoring Duration | Total Cost |
|---|---|---|---|---|
| Alternative 1 – No Action | NA | NA | NA | $0 |
| Alternative 2 – MNA and Alternate Water Supply | 30 Years | NA | 30 Years | $4.2 |
| Alternative 3 – Pump and Treat | 24 Years | 22 Years | 24 Years | $12.5 |
| Alternative 4 – Anaerobic Bioremediation | 4 Years | 2 Years | 4 Years | $12.5 |
| Alternative 5 – Well Replacement | 30 Years | NA | 30 Years | $7.1 |
| Alternative 6 – Source Area Treatment | 30 Years | 2 Years | 30 Years | $5.2 |

Notes: Total cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
Total cost is based on current rates and does not include inflation.
See Section 8.8 for an explanation of why the time to achieve cleanup and the O&M term are limited to 30 years.

An evaluation criteria summary of the proposed remedial alternatives for the DBG Plume is presented below. Each of the six proposed alternatives are listed in the left column. As described in Section 8.8, nine evaluation criteria have been developed to serve as the basis for conducting a detailed analysis of the remedial alternatives. The nine criteria include threshold, primary balancing and modifying criteria are listed below in the top row. The two modifying criteria (State Acceptance and Community Acceptance) are incorporated during the remedy selection stage and presented in the Proposed Plan.

An objective and qualitative evaluation was completed to compare the six proposed remedial alternatives. A designation of “H” represents a high confidence of the alternative meeting the criteria. Similarly, a designation of “L” represents a low and “M” represents a moderate confidence of the alternative meeting the criteria. A designation of “N” represents no confidence of the alternative meeting the criteria and a designation of “TBD” represents to be determined. The designations are supported by their respective preceding text section for each remedial alternative and were made in relation to other alternatives. Approximate total costs for each remedial alternative are shown in the right column.

## Deterrent Burning Ground Plume
## Evaluation Criteria Summary

| Alternative | Evaluation Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Protection to Human Health & Environment | Compliance with ARARs | Long-Term Effectiveness & Permanence | Reduction in Toxicity, Mobility & Volume Through Treatment | Short-Term Effectiveness | Implementability | State Acceptance | Community Acceptance | Total Cost (1)(2) |
| Alternative 1 – No Action<br>• Groundwater access restrictions | L | N | N | N | N | H | TBD | TBD | $0 |
| Alternative 2 – MNA and Alternate Water Supply<br>• Groundwater access restrictions<br>• Groundwater monitoring<br>• Alternate water supply | M | L | M | L | M | H | TBD | TBD | $4.2 |
| Alternative 3 – Pump and Treat (3)<br>• Extraction wells (three)<br>• Mobile treatment units (three) | H | H | H | H | M | M | TBD | TBD | $12.5 |
| Alternative 4 – Anaerobic Bioremediation (3)<br>• Biochemical injection points (406) | H | H | M | H | M | M | TBD | TBD | $12.5 |
| Alternative 5 – Well Replacement (4)<br>• Replacement of residential wells (57) | M | M | H | L | M | M | TBD | TBD | $7.1 |
| Alternative 6 – Source Area Treatment (3)<br>• Temporary injection points (56) | M | M | M | M | H | M | TBD | TBD | $5.2 |

Notes: H – High, L – Low, M – Moderate, N – None, TBD – To Be Determined.
(1) Cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
(2) Based on current rates and does not include inflation.
(3) Alternative includes groundwater access restrictions, groundwater monitoring and alternate water supply.
(4) Alternative includes groundwater access restrictions and groundwater monitoring.

# 11.0 REMEDIAL ALTERNATIVES – CENTRAL PLUME

As identified in Section 7.3, 2,6-DNT was the only risk-related COC considered for the development of remedial alternatives in the Central Plume. However, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The RAO for the Central Plume requires the remedy to protect human health by preventing exposure to contaminated groundwater, to minimize the impact of the contaminants on the environment, and to restore groundwater to the extent practicable. The RAO for the Central Plume will be achieved when groundwater concentrations of 2,6-DNT are below the groundwater cleanup level listed in Table 16. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

Based on site conditions and the screening of process options, five remedial alternatives were developed to address the presence of groundwater COCs in the Central Plume. A source area alternative was not developed for the Central Plume due to no known source areas remaining. Alternative 1 - No Action, provides a baseline to evaluate the other alternatives.

**Alternative 1: No Action**

The No Action Alternative is a mandatory evaluation that provides a baseline to evaluate the other alternatives. This alternative would have no impact on the contaminant plume and would not require groundwater monitoring of residential wells or monitoring wells. This alternative would include on-site groundwater access restrictions.

**Alternative 2: Monitored Natural Attenuation and Alternate Water Supply**

The Monitored Natural Attenuation and Alternate Water Supply Alternative would continue the current remedial action approach and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement

**Alternative 3: Active Groundwater Remediation – Pump and Treat**

The Active Groundwater Remediation – Pump and Treat Alternative would target removing and treating impacted groundwater with elevated 2,6-DNT concentrations and include the below listed components. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater removal through the installation of eight groundwater extraction wells
- Groundwater treatment through the use of eight mobile treatment units
- Groundwater disposal through the construction of piping leading to the Wisconsin River

**Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation**

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would target treating impacted groundwater with elevated 2,6-DNT concentrations and include the below listed components. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Provision for an alternate water supply condition including bottled water and well replacement
- Groundwater treatment through in-situ biochemical injection at 988 temporary locations (on-site and off-site)

**Alternative 5: Well Replacement – Plume Area**

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer wells (meeting qualifying criteria) within the Central Plume area with deeper aquifer wells and include the below listed components.

- Continued groundwater monitoring of residential and monitoring wells
- On-site groundwater access restrictions
- Replacement of as many as 23 existing residential wells

## 11.1 Alternative 1 – No Action

The No Action Alternative would have no impact on any of the contaminant plumes and would not require groundwater monitoring of residential wells or monitoring wells. There would be no contaminant removal, treatment, containment or monitoring related to this alternative. As a condition of the Army's property transfer, groundwater access restrictions would continue for areas within the BAAP boundary.

### Overall Protection of Human Health and the Environment

Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary; however, there are no groundwater access restrictions outside the BAAP boundary. This alternative would not provide any protection of human health or the environment beyond the groundwater access restrictions within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program.

### Compliance with ARARs

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would result in the Army terminating the residential and monitoring well sampling program. This alternative would not comply with ARARs.

### Long-Term Effectiveness and Permanence

This alternative would not provide an effective or permanent long-term solution. In this alternative, groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). This alternative would result in the Army terminating the residential and monitoring well sampling program. Consequently, the degradation process would not be evaluated under this alternative.

### Reduction of Toxicity, Mobility, and Volume through Treatment

Limited reductions in toxicity, mobility, and volume would occur through natural degradation processes only. This alternative would discontinue the sampling of residential and groundwater monitoring wells. Consequently, the degradation process would not be evaluated.

### Short-Term Effectiveness

There would be no action taken for this alternative. Since groundwater monitoring would be discontinued, any groundwater exceedances would go unidentified. Therefore, this alternative has no short-term effects.

### Implementability

This alternative is inherently implementable as no remedial action would be taken.

### Cost

There is no cost associated with the No Action Alternative.

## 11.2 Alternative 2 – Monitored Natural Attenuation and Alternate Water Supply

The Monitored Natural Attenuation and Alternate Water Supply Alternative would include MNA for the Central Plume, on-site groundwater access restrictions and a provision for an alternate water supply condition for residential wells. This alternative would also continue residential and monitoring well sampling of the Central Plume as previously specified in Section 4.2 and Appendix D.

MNA relies on natural attenuation processes to achieve the RAO within a time frame that is reasonable compared to that offered by other more active remedial methods. MNA is expected to reduce the concentrations of the COCs identified in Section 7.3 and carried forward in the development of remedial alternatives. These natural attenuation processes include a variety of physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

The Army currently has an environmental monitoring and health protection program in place that is protective of the residential water well users, "alternate water supply". If a Chapter NR 140 ES is exceeded in a residential well once, bottled water is made available to the occupant. If the exceedance occurs a second, consecutive time, well replacement is offered to the owner. Bottled water would be made available to the occupant until the well is replaced, operational and water quality verified (typically 3 months and based on driller availability). If the NR 140 ES exceedance is not detected for two consecutive rounds after the first NR 140 ES exceedance detection, bottled water would be discontinued. To date, the Army has replaced three shallow residential wells within the Central Plume.

**Overall Protection of Human Health and the Environment**

This alternative would provide protection of human health and the environment due to groundwater access restrictions within the BAAP boundary and the provision of an alternate water supply condition for residential wells. The MNA program would monitor the groundwater concentrations for compliance and contaminant reduction.

**Compliance with ARARs**

The residential and monitoring well sampling program is being conducted in accordance with the most recent regulatory approval. This alternative would continue the residential and groundwater monitoring program and comply with ARARs over time through natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative offers long-term solution as groundwater concentrations are expected to decrease as the chemicals would continue to undergo a slow degradation process (dilution, dispersion, and sorption). The alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential well impacts. Groundwater impacts are expected to remain and the groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

Limited reductions in toxicity, mobility, and volume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

This alternative offers a short-term solution as it is currently being applied and no additional work associated with implementation would be required. This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition would address concerns associated with residential wells. If the alternate water supply provision is necessary, state licensed well drillers would be utilized for well replacement. The well drillers would be appropriately trained and would maintain applicable certifications to install any replacement well necessary.

**Implementability**

This alternative would be easily implementable as this action is currently being applied to the site. No remedial activities other than sampling under the MNA program would be performed. Groundwater access restrictions are already in place within BAAP.

**Cost**

The estimated total cumulative costs for Alternative 2 are shown below. See Appendix I for a summary of the costs for Alternative 2.

**<u>Alternative 2 – Monitored Natural Attenuation and Alternate Water Supply</u>**

| | | |
|---|---|---|
| Direct Capital Cost: | $ | 0 |
| Indirect Capital Cost: | $ | 0 |
| 30 Years of Annual O&M: | $ | 2,398,538 |
| **Total Cost:** | **$** | **2,398,538** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 11.3 Alternative 3 - Active Groundwater Remediation – Pump and Treat

The Active Groundwater Remediation – Pump and Treat Alternative would include groundwater extraction and treatment with mobile treatment units and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 11.0, active remedial alternatives are only being developed for 2,6-DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the extraction wells would be strategically located to target elevated 2,6-DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for 2,6-DNT. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

It is anticipated that eight extraction wells and eight mobile treatment units (one treatment unit per extraction well) would be necessary for source are reduction and plume migration control. Eight extraction wells were selected based on previous performance (capture zone) of extraction wells at the BAAP. Spatially, the wells would be located along the long axis of the plume and equidistant from one another and the plume's upgradient and downgradient extents. Proposed pumping well locations and target pumping capture zones are shown on Drawing Central-ALT 3 in Appendix J.

Each extraction well is expected to pump at approximately 500 gpm. Similarly, each mobile treatment unit would be designed to treat 500 gpm. Based on previous experience with pump and treat systems at BAAP, groundwater flow velocities of 143 ft/yr (see Table 8) and assuming no additional source area contribution, the individual extraction wells and mobile treatment units are expected to operate continuously for at least 10 years. The mobile treatment units are expected to use activated carbon as the primary treatment media as activated carbon has successfully treated DNT at BAAP. Site improvements including mobile treatment trailer staging area construction, electrical utility provision and site security would be necessary at each one of the extraction well/mobile treatment trailer areas.

A network of piping and appurtenances would be necessary to route extracted water from the extraction wells to the mobile treatment units and treated water from the mobile treatment units to a discharge location. Treated groundwater would ultimately discharge to the Wisconsin River. It is anticipated that the pump and treat system would require the services of an environmental technician to monitor and maintain the extraction wells and mobile treatment units.

**Overall Protection of Human Health and the Environment**

This alternative would be designed to control and limit the migration of and treat the groundwater with elevated 2,6-DNT concentrations. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Compliance with ARARs**

This alternative would be designed to comply with ARARs. The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce contaminant concentrations to comply with regulatory standards in groundwater through recovery and treatment of the portion of the Central Plume with total elevated 2,6-DNT concentrations. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. A similar pump and treat system (MIRM) showed effective DNT concentration reduction.

Based on previous experience, the groundwater pump and treat system is expected to operate continuously for 10 years. The groundwater monitoring program is expected to continue for at least 12 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative is expected to result in reductions in toxicity, mobility, and volume through treatment of the Central Plume with elevated 2,6-DNT concentrations. It is assumed that there would be no additional contribution of 2,6-DNT from the source areas into the groundwater. Based on performance of this technology at the BAAP (MIRM), the pump and treat system showed effective DNT concentration reduction. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The groundwater contamination would also continue to decrease due to natural attenuation processes.

**Short-Term Effectiveness**

For this alternative there would be some short-term effects to workers, residents and the environment during implementation. As described above, the alternative would require eight extraction wells coupled with a mobile treatment units for each extraction well. These locations would require construction of a staging area for the well and mobile treatment unit, security and electricity for the site for operations and lighting.

It is anticipated that from each extraction well to the and mobile treatment and from the mobile treatment unit to a discharge location, a discharge pipe would be constructed. Treated water is expected to be  discharged to the Wisconsin River.

There is some risk associated with the operation of heavy equipment for site preparation, well drilling, excavation, piping installation and backfilling; however, proper training and equipment would be required to mitigate these risks. Utility crossing, near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction and plume migration control, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately one year. Construction and implementation of this alternative including well installation, piping construction, treatment area preparation and utility extension is expected to be completed in approximately one year.

**Implementability**

Equipment and materials required for construction of this alternative are readily available. However, extraction well, mobile treatment unit locations and piping alignment would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the Central Plume. In addition, utilities to support the extraction wells and mobile treatment facility would need to be extended to the site, since none currently exist. The discharge line location  would need to be determined and appropriate  piping and appurtenance construction competed. The discharge location to the Wisconsin River would need to be identified during winter months with a high-visibility buoy system. This would identify open water as a safety precaution to those who utilize the Wisconsin River in the winter for recreational activities such as ice fishing and snowmobiling. It is expected that this buoy system would be installed during the winter months and subsequently removed in the spring. This process of installation and decommissioning the buoy system would need to be repeated each winter and spring, respectively, as long as the system continued operation.

**Cost**

The estimated total cumulative costs for Alternative 3 are shown below. See Appendix I for a summary of the costs for Alternative 3.

**Alternative 3 – Active Groundwater Remediation – Pump and Treat**

| | |
|---|---|
| Direct Capital Cost: | $ 6,939,247 |
| Indirect Capital Cost: | $ 3,122,661 |
| 12 Years of Annual O&M: | $ 7,953,709 |
| **Total Cost:** | **$ 18,015,617** |

* Total costs use current rates and do not include inflation

## 11.4 Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation

The Active Groundwater Remediation – Anaerobic Bioremediation Alternative would include in-situ anaerobic biodegradation of groundwater contaminants and continued groundwater monitoring of residential and monitoring wells. This alternative would also include on-site groundwater access restrictions and a provision for an alternate water supply condition.

As identified in Section 11.0, active remedial alternatives are only being developed for 2,6-DNT concentrations above the groundwater cleanup level listed in Table 16. Consequently, the in-situ biochemical injection locations would be strategically located to target elevated 2,6-DNT concentrations. This technology is expected to also reduce the concentrations of chlorinated solvents that coexist within the targeted treatment areas for 2,6-DNT. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

For this alternative, a nutrient-enriched emulsified vegetable oil (EVO) is being proposed as the injection product. EVO has been used to stimulate in-situ anaerobic biodegradation of groundwater contaminants at commercial, industrial, and military sites. The procedures and applications of EVO are applicable to numerous anaerobically biodegradable contaminants including but not limited to chlorinated solvents, energetics, and nitrates.

The primary objective of injecting EVO into the groundwater is to stimulate the anaerobic biodegradation of the target contaminants. Groundwater aquifers are complex ecosystems populated by a broad and diverse array of microbial communities. The composition and activity of these microbial communities' changes continuously as their environment changes. Alterations in aquifer geochemistry and the availability of substrates and nutrients that can be used to generate energy and support growth and reproduction significantly affect microbial activity.

EVO would be distributed in the aquifer as an oil-in-water emulsion (mixture). In this approach, an oil-in-water emulsion would be first prepared using a food-grade oil, food-grade surfactants, and water. The emulsion would have small uniform droplets to allow transport in the aquifer. The emulsion would be injected into the aquifer (through injection wells or DPT) with additional water to distribute the oil droplets. The oil droplets would be distributed through the aquifer pore spaces and adhere to soil particles. The soil particle surfaces would gradually become coated with a thin layer of oil droplets that provide a carbon source for long-term anaerobic biodegradation. The oil droplets remain in the aquifer as a viable carbon source for approximately two years. Soluble substrates and nutrients (e.g., lactate, yeast extract, vitamins) can be added to the mixture prior to injection to stimulate rapid growth of desired bacteria. When the contaminated groundwater naturally flows toward and through the distributed EVO, the groundwater contaminants interact with the carbon source and break-down into less harmful byproducts.

It is anticipated that 988 injection points (both on-site and off-site and at varying stratigraphic depths) would be required to treat the plume. These injection points would be arranged in a series of 38 treatment lines and consist of temporary injection points. It is assumed that the source area would no longer contribute to the groundwater contamination. Anticipated treatment line locations are shown on Drawing Central-ALT 4 in Appendix J.

The spacing of the treatment lines is based on a groundwater flow velocity of 143 ft/yr (see Table 8) and the viability of the carbon source remaining in the aquifer for approximately two years. The distance between each treatment line is based on two years of treatment. Based on the geology and hydrogeology associated with the plume, a 25-foot radius of influence is anticipated to provide sufficient distribution of the EVO within the aquifer. The radius of influence is measured from the injection well or point location radially, out to the maximum extent of EVO product distribution. Each treatment line would be designed to fully capture contaminated groundwater migrating downgradient.

Though EVO is a proven technology to effectively treat chlorinated solvents and energetics, a field-scale pilot test would be necessary to determine the site specific constraints and a design to be developed to target 2,6-DNT within the plume at BAAP. Upon successful completion of a field-scale pilot test, the remedial design could be finalized. The Army’s groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

**Overall Protection of Human Health and the Environment**

This alternative would be designed to meet the requirements of the RAO as it would effectively degrade the contaminants in the Central Plume. The provision of the alternate water supply condition would address concerns associated with residential well impacts. Groundwater access restrictions would continue for areas within the BAAP.

**Compliance with ARARs**

Concentrations of contaminants in the treated area are expected to comply with ARARs relatively quickly (approximately two years). The provision of the alternate water supply condition would address concerns associated with residential well impacts.

**Long-Term Effectiveness and Permanence**

This alternative would be designed to reduce the concentration in groundwater to comply with regulatory standards for 2,6-DNT. Furthermore, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). This alternative would continue to restrict groundwater access within the BAAP and the provision of an alternate water supply condition for residential wells. It is anticipated that a single round of injections of the biochemical product would be sufficient to treat the plume. Based on a groundwater flow velocity and the viability of the carbon source, treatment is expected to take approximately two years. However, depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications. The proposed biochemical product for use with this technology has shown successful contaminant reduction with explosives and chlorinated solvents; however, it has not been applied at full scale for 2,6-DNT treatment. The groundwater monitoring program is expected to continue for at least 4 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative is expected to reduce the toxicity, mobility, and volume of 2,6-DNT and chlorinated solvents in the treated areas more quickly than natural processes alone. It is assumed that there would be no additional contribution of 2,6-DNT from the source areas into the groundwater. Regarding DNT, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The groundwater contamination would also continue to decrease due to natural attenuation processes.

**Short-Term Effectiveness**

There would be some short-term effects to workers, residents and the environment during implementation. As described above, this alternative would require both on-site and off-site injection points.

There is some risk associated with heavy equipment necessary for temporary injection point installation and injection. Proper training and equipment would be required to mitigate these risks. The bioremediation is expected to occur over the course of two years and no additional worker safety issues have been identified. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

To maximize contaminant reduction, it is anticipated that additional investigation, sampling and testing would need to be completed. This effort is expected to take approximately two years. Construction and implementation of this alternative including temporary injection point installation, biochemical injection and injection point abandonment is expected to be completed in approximately one year.

**Implementability**

The installation of temporary injection points may be challenging at certain locations based on the stratigraphy. The area has been studied extensively and previous investigations have identified glacial outwash that may contain larger boulders. The potential stratigraphic obstructions may result in the need to change the location of temporary injection points.

Equipment and materials required for construction are readily available. However, temporary injection point locations would have to be coordinated carefully and with input from existing land owners as they are responsible for the ownership and/or management of the area around the Central Plume.

The biochemical product has been demonstrated to be effective in treating explosives and chlorinated solvents. Depending upon groundwater monitoring results, it is possible that this technology may require supplemental post-treatment applications.

**Cost**

The estimated total cumulative costs for Alternative 4 are shown below. See Appendix I for a summary of the costs for Alternative 4.

**Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation**

| | |
|---|---|
| Direct Capital Cost: | $ 16,082,742 |
| Indirect Capital Cost: | $ 7,237,234 |
| 4 Years of Annual O&M: | $ 399,756 |
| **Total Cost:** | **$ 23,719,733** |

* Total costs use current rates and do not include inflation

## 11.5 Alternative 5 – Well Replacement – Plume Area

The Well Replacement – Plume Area Alternative would involve replacing shallow aquifer wells, meeting replacement criteria, within the Central Plume area with deeper aquifer wells. This alternative would also include continued groundwater monitoring of residential and monitoring wells and on-site groundwater access restrictions.

A reasonable worst-case scenario was developed considering potential plume migration which resulted in the potential for 23 existing wells being impacted. If sampling results indicate an increasing trend for a plume's COC in three consecutive rounds and that the plume is migrating toward a residential well, the Army will evaluate if well replacement is necessary.

Based on deeper aquifer well information in the area, replacement wells would be drilled to approximately 400 feet below the existing ground surface and into the Mt. Simon Sandstone Formation. This formation is isolated from the shallow impacted groundwater by a confining shale layer. The 400-foot depth is necessary to satisfy water quality and production criteria. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. Connections from the well to the dwelling would be completed. Well replacement would be completed with abandonment of the shallow well and restoration of disturbed areas.

**Overall Protection of Human Health and the Environment**

This alternative would be protective of human health as potential receptors would be provided potable water from a deeper aquifer. Effectively, there would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. Groundwater access is restricted within the BAAP boundary based on conditions of property transfer documentation. The groundwater access restrictions would require Army and WDNR authorization prior to well installation within the BAAP boundary.

**Compliance with ARARs**

Groundwater monitoring would continue in monitoring and residential wells to monitor groundwater quality. Since the deep aquifer has been unimpacted by BAAP production or disposal activities, compliance with ARARs is expected. The contaminants within the plume are expected to comply with ARARs over time through natural degradation processes only.

**Long-Term Effectiveness and Permanence**

This alternative would be an effective long-term and permanent solution. These wells are expected to provide receptors with long-term access to potable water that has been unimpacted by BAAP production or disposal activities. This alternative would also continue to restrict groundwater access within the BAAP property. Groundwater contamination within the plume is expected to decrease over time due to natural degradation processes only. The groundwater monitoring program is expected to continue for at least 30 years. See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

**Reduction of Toxicity, Mobility, and Volume through Treatment**

This alternative would eliminate the groundwater exposure pathway by providing potential receptors access to potable water from a deep aquifer. Limited reductions in toxicity, mobility, and volume of contaminants within the plume is expected to occur through natural degradation processes only. This reduction would be verified through the monitoring program.

**Short-Term Effectiveness**

For this alternative, there would be some short-term effects to workers, residents and the environment during implementation. The alternative would require off-site well installation on private property. Wells would be installed by a state licensed well driller and would be cased to isolate the shallow aquifer from the deeper bedrock aquifer. There is some risk associated with heavy equipment necessary for well installation. Proper training and equipment would be required to mitigate these risks. Near public road working conditions and work on private land would also be items that would need planning, coordination, and health and safety training.

Implementation and construction of this alternative is expected to be completed in approximately three months once qualifying criteria have been established for a residential well. Additional well replacements would be addressed as necessary upon establishment of qualifying criteria.

**Implementability**

Equipment and materials required for construction of this alternative are readily available and wells would be installed by a state licensed well driller. However, well replacement would have to be coordinated with private land owners.

**Cost**

The estimated total cumulative costs for Alternative 5 are shown below. See Appendix I for a summary of the costs for Alternative 5.

**Alternative 5 – Well Replacement – Plume Area**

| | | |
|---|---|---|
| Direct Capital Cost: | $ | 920,000 |
| Indirect Capital Cost: | $ | 414,000 |
| 30 Years of Annual O&M: | $ | 1,997,172 |
| **Total Cost:** | **$** | **3,331,172** |

* Total costs use current rates and do not include inflation
** See Section 8.8 for an explanation of why the O&M term is limited to 30 years.

## 11.6 Central Plume Remedial Alternative Summary

A summary of the cleanup timeframe, treatment duration, groundwater monitoring duration, and cost for each of the five proposed remedial alternatives for the Central Plume is presented below.

**Central Plume**
**Remedial Alternative Summary**

| Alternative | Time to Achieve Cleanup | Active Treatment Duration | Groundwater Monitoring Duration | Total Cost |
|---|---|---|---|---|
| Alternative 1 – No Action | NA | NA | NA | $0 |
| Alternative 2 – MNA and Alternate Water Supply | 30 Years | NA | 30 Years | $2.4 |
| Alternative 3 – Pump and Treat | 12 Years | 10 Years | 12 Years | $18.0 |
| Alternative 4 – Anaerobic Bioremediation | 4 Years | 2 Years | 4 Years | $23.7 |
| Alternative 5 – Well Replacement | 30 Years | NA | 30 Years | $3.3 |

Notes: Total cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
Total cost is based on current rates and does not include inflation.
See Section 8.8 for an explanation of why the time to achieve cleanup and the O&M term are limited to 30 years.

An evaluation criteria summary of the proposed remedial alternatives related to the Central Plume is presented below. Each of the five proposed alternatives are listed in the left column. As described in Section 8.8, nine evaluation criteria have been developed to serve as the basis for conducting a detailed analysis of the remedial alternatives. The nine criteria include threshold, primary balancing and modifying criteria are listed below in the top row. The two modifying criteria (State Acceptance and Community Acceptance) are incorporated during the remedy selection stage and presented in the Proposed Plan.

An objective and qualitative evaluation was completed to compare the six proposed remedial alternatives. A designation of "H" represents a high confidence of the alternative meeting the criteria. Similarly, a designation of "L" represents a low and "M" represents a moderate confidence of the alternative meeting the criteria. A designation of "N" represents no confidence of the alternative meeting the criteria and a designation of "TBD" represents to be determined. The designations are supported by their respective preceding text section for each remedial alternative and were made in relation to other alternatives. Approximate total costs for each remedial alternative are shown in the right column.

**Central Plume**
**Evaluation Criteria Summary**

| Alternative | Evaluation Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Protection to Human Health & Environment | Compliance with ARARs | Long-Term Effectiveness & Permanence | Reduction in Toxicity, Mobility & Volume Through Treatment | Short-Term Effectiveness | Implementability | State Acceptance | Community Acceptance | Total Cost (1)(2) |
| Alternative 1 – No Action<br>• Groundwater access restrictions | L | N | N | N | N | H | TBD | TBD | $0 |
| Alternative 2 – MNA and Alternate Water Supply<br>• Groundwater access restrictions<br>• Groundwater monitoring<br>• Alternate water supply | M | L | M | L | M | H | TBD | TBD | $2.4 |
| Alternative 3 – Pump and Treat (3)<br>• Extraction wells (eight)<br>• Mobile treatment units (eight) | H | H | H | H | M | M | TBD | TBD | $18.0 |
| Alternative 4 – Anaerobic Bioremediation (3)<br>• Biochemical injection points (988) | H | H | M | H | M | M | TBD | TBD | $23.7 |
| Alternative 5 – Well Replacement (4)<br>• Replacement of residential wells (23) | M | M | H | L | M | M | TBD | TBD | $3.3 |

Notes: H – High, L – Low, M – Moderate, N – None, TBD – To Be Determined.

(1) Cost in millions of dollars & includes direct capital, indirect capital and annual operation and maintenance costs.
(2) Based on current rates and does not include inflation.
(3) Alternative includes groundwater access restrictions, groundwater monitoring and alternate water supply.
(4) Alternative includes groundwater access restrictions and groundwater monitoring.

# 12.0 REMEDY SELECTION

The Army's preferred alternative or remedy will be presented in the Proposed Plan; the remedy will be based on the results of this RI/FS. The Proposed Plan will briefly summarize the remedial investigation and the remedial alternatives evaluated in this RI/FS, highlighting the key factors that led to identifying the preferred alternative. The Army will submit the Proposed Plan to the regulatory agencies and then the public for review. After this review, the Army will release a Decision Document that documents the selected remedy, certifies that the remedy selection process was carried out in accordance with CERCLA, and addresses public comments on the Proposed Plan.

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# Figures

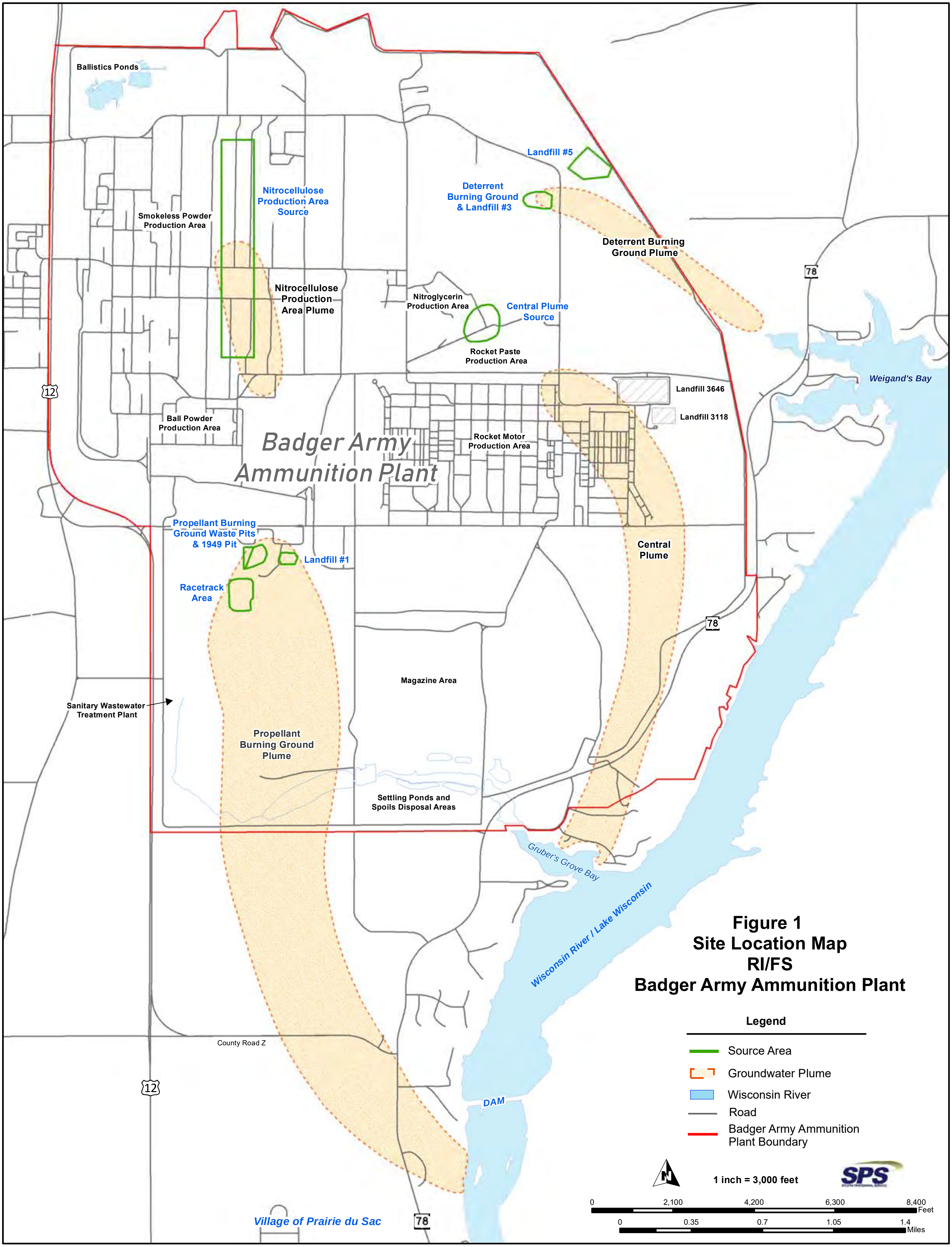
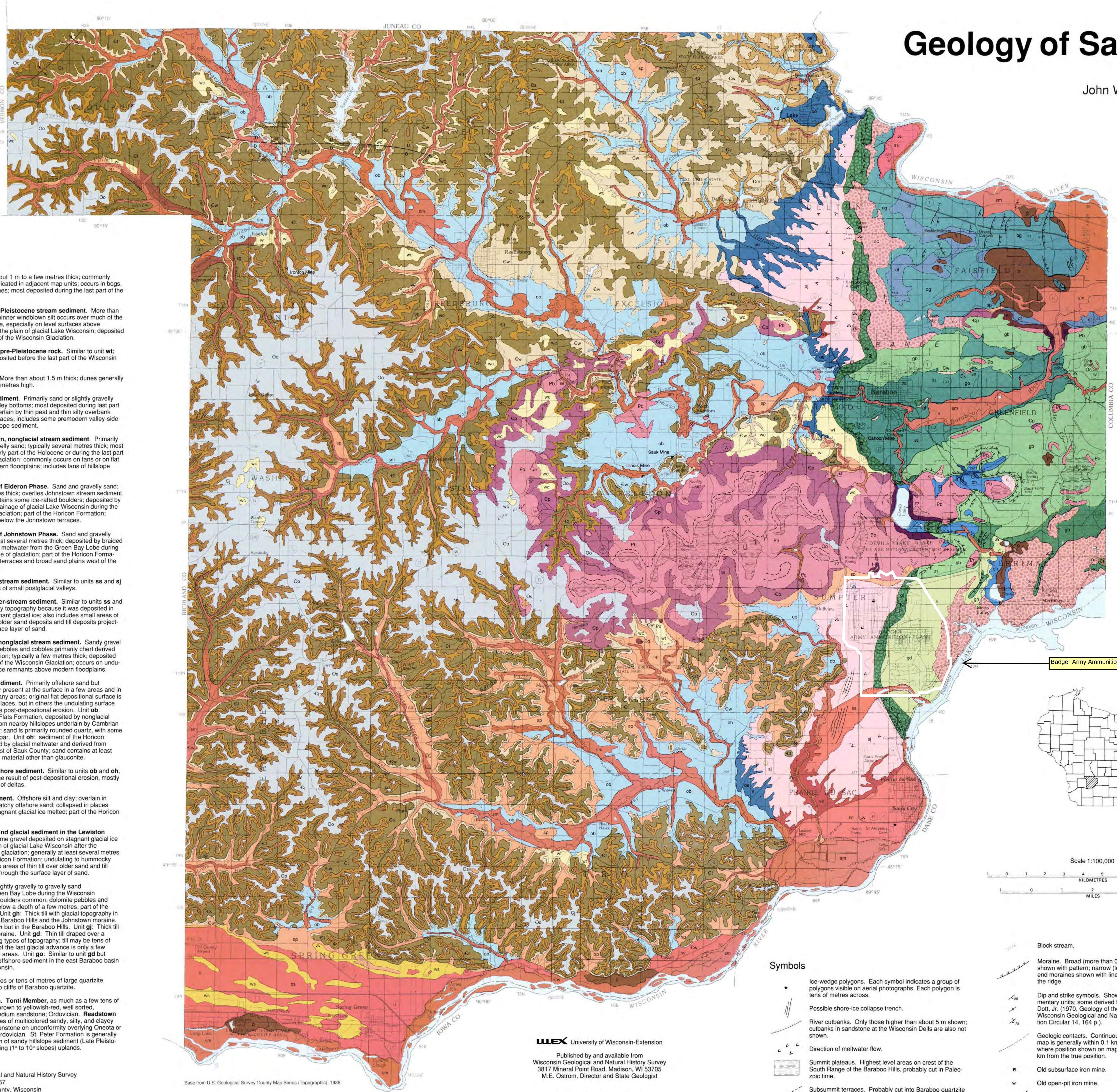


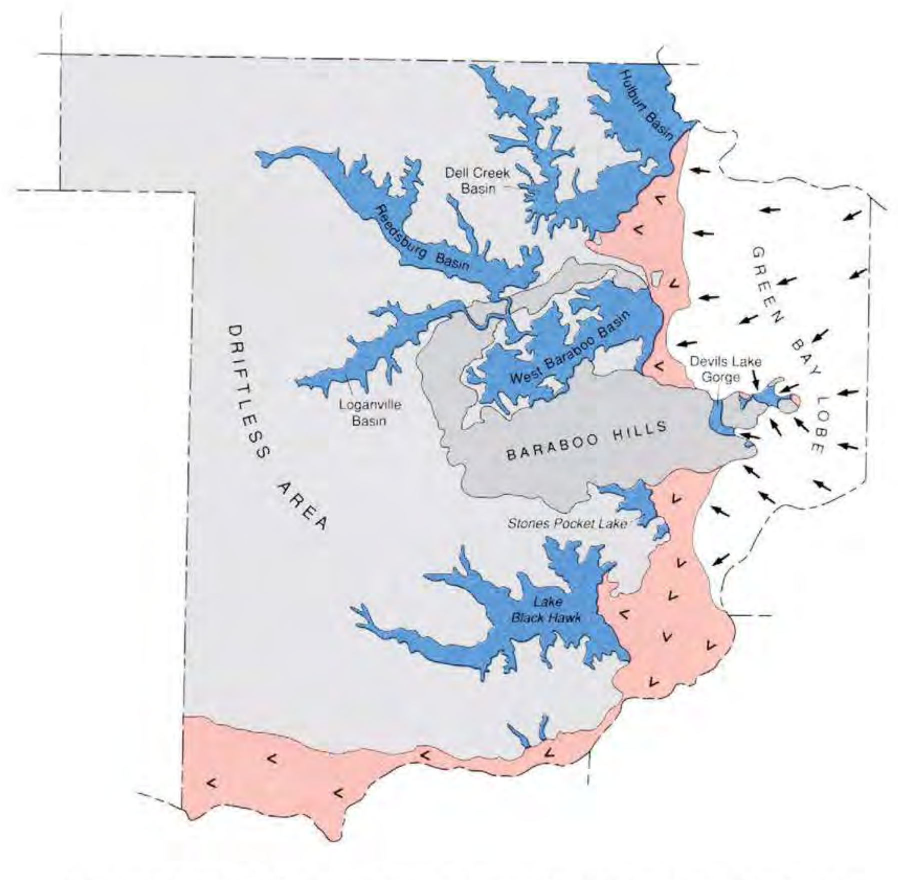

**Figure 1**
**Site Location Map**
**RI/FS**
**Badger Army Ammunition Plant**

# Geology of Sauk County, Wisconsin

John W. Attig and Lee Clayton, 1990

**Figure 2**




*Major geologic features of Sauk County during the maximum late Wisconsin extent of the Green Bay Lobe. The map shows the location of the western edge of the Green Bay Lobe (arrows show direction of ice flow), outwash plains (red), and lakes (blue). The Baraboo Hills and the remainder of the Driftless Area in Sauk County are shown in shades of gray.*

## Explanation

p — **Peat**. Generally about 1 m to a few metres thick; commonly overlies material indicated in adjacent map units; occurs in bogs, swamps, and marshes; most deposited during the last part of the Holocene.

wt — **Windblown silt on Pleistocene stream sediment**. More than about 1.5 m thick; thinner windblown silt occurs over much of the rest of the landscape, especially on level surfaces above outwash plains and the plain of glacial Lake Wisconsin; deposited during the last part of the Wisconsin Glaciation.

wc — **Windblown silt on pre-Pleistocene rock.** Similar to unit **wt**; may include silt deposited before the last part of the Wisconsin Glaciation.

ws — **Windblown sand**. More than about 1.5 m thick; dunes generally no more than a few metres high.

sm — **Modern stream sediment**. Primarily sand or slightly gravelly sand on modern valley bottoms; most deposited during last part of the Holocene; overlain by thin peat and thin silty overbank sediment in many places; includes some premodern valley-side fans of fluvial and slope sediment.

sp — **Younger premodern, nonglacial stream sediment**. Primarily sand or slightly gravelly sand; typically several metres thick; most deposited during early part of the Holocene or during the last part of the Wisconsin Glaciation; commonly occurs on fans or on flat terraces above modern floodplains; includes fans of hillslope sediment.

ss — **Stream sediment of Elderon Phase.** Sand and gravelly sand; typically a few metres thick; overlies Johnstown stream sediment in many places; contains some ice-rafted boulders; deposited by floodwater during drainage of glacial Lake Wisconsin during the Elderon Phase of glaciation; part of the Horicon Formation; occurs on terraces below the Johnstown terraces.

sj — **Stream sediment of Johnstown Phase.** Sand and gravelly sand; typically at least several metres thick; deposited by braided streams that carried meltwater from the Green Bay Lobe during the Johnstown Phase of glaciation; part of the Horicon Formation; occurs as high terraces and broad sand plains west of the Johnstown moraine.

se — **Eroded meltwater-stream sediment.** Similar to units **ss** and **sj** but exposed in sides of small postglacial valleys.

sc — **Collapsed meltwater-stream sediment.** Similar to units **ss** and **sj** but has hummocky topography because it was deposited in some areas on stagnant glacial ice; also includes small areas of thin till draped over older sand deposits and till deposits projecting through the surface layer of sand.

sg — **Older premodern, nonglacial stream sediment.** Sandy gravel and gravelly sand; pebbles and cobbles primarily chert derived from Oneota Formation; typically a few metres thick; deposited before the last part of the Wisconsin Glaciation; occurs on undulating to rolling terrace remnants above modern floodplains.

ob, oh — **Coarse offshore sediment.** Primarily offshore sand but offshore silt and clay present at the surface in a few areas and in the subsurface in many areas; original flat depositional surface is preserved in many places, but in others the undulating surface has undergone some post-depositional erosion. Unit **ob**: sediment of the Big Flats Formation, deposited by nonglacial water and derived from nearby hillslopes underlain by Cambrian sand and sandstone; sand is primarily rounded quartz, with some glauconite and feldspar. Unit **oh**: sediment of the Horicon Formation, deposited by glacial meltwater and derived from areas to the northeast of Sauk County; sand contains at least several percent dark material other than glauconite.

oe — **Eroded coarse offshore sediment.** Similar to units **ob** and **oh**, but much hillier as the result of post-depositional erosion, mostly on the foreset faces of deltas.

of — **Fine offshore sediment.** Offshore silt and clay; overlain in places by thin and patchy offshore sand; collapsed in places where underlying stagnant glacial ice melted; part of the Horicon Formation.

og — **Offshore, stream, and glacial sediment in the Lewiston basin.** Sand and some gravel deposited on stagnant glacial ice in the Lewiston basin of glacial Lake Wisconsin after the Johnstown Phase of glaciation; generally at least several metres thick; part of the Horicon Formation; undulating to hummocky topography; includes areas of thin till over older sand and till deposits projecting through the surface layer of sand.

gh, gb, gj, gd, go — **Till.** Clayey, silty, slightly gravelly to gravelly sand deposited by the Green Bay Lobe during the Wisconsin Glaciation; surface boulders common; dolomite pebbles and cobbles abundant below a depth of a few metres; part of the Horicon Formation. Unit **gh**: Thick till with glacial topography in areas other than the Baraboo Hills and the Johnstown moraine. Unit **gb**: Same as **gh** but in the Baraboo Hills. Unit **gj**: Thick till of the Johnstown moraine. Unit **gd**: Thin till draped over a variety of pre-existing types of topography; till may be tens of metres thick, but till of the last glacial advance is only a few metres thick in many areas. Unit **go**: Similar to unit **gd** but includes patches of offshore sediment in the east Baraboo basin of glacial Lake Wisconsin.

t — **Talus.** Several metres or tens of metres of large quartzite boulders below steep cliffs of Baraboo quartzite.

Os — **St. Peter Formation. Tonti Member**, as much as a few tens of metres of very pale brown to yellowish-red, well sorted, quartzose, fine to medium sandstone; Ordovician. **Readstown Member**, a few metres of multicolored sandy, silty, and clayey breccia with some ironstone on unconformity overlying Oneota or Jordan Formation; Ordovician. St. Peter Formation is generally overlain by about 1 m of sandy hillslope sediment (Late Pleistocene); flat to undulating (1° to 10° slopes) uplands.

Oo — **Oneota and Rountree Formations. Oneota Formation**–up to 20 m of very pale brown to light brownish-gray dolomite, commonly algal, with chert nodules; some sandstone near base of formation; some caverns and cavities, mostly filled with red clay; Ordovician; flat to undulating (1° to 10° slopes) upland plateaus; unit includes some unmappable small areas of St. Peter Formation; scattered residual boulders of St. Peter sandstone are present in many places on the Oneota plateau. **Rountree Formation**–several metres of clay, sandy clay, and clayey sand, typically with red hues, with cobbles and pebbles of chert; includes hillslope sediment derived from residuum from the underlying Oneota dolomite; late Cenozoic.

Ꞓj — **Jordan Formation.** About 20 m of white to brown, quartzose, fine to coarse sandstone, coarsening upward; silicified zone at top; Cambrian; generally overlain by about 1 m of sandy hillslope sediment (Late Pleistocene); outcrops at edge of Oneota plateaus; upper slope is a sandstone cliff in many places, especially in the northwestern part of county; below the cliff is a tree-covered slope of about 15° to 30°.

Ꞓs — **St. Lawrence Formation. Lodi Member**, about 10 to 20 m of pale yellow, thin-bedded, siltstone, and very fine to fine sandstone with some gray shale; Cambrian. **Black Earth Member**, as much as a few metres of dolomite at base of the formation; Cambrian. St. Lawrence Formation is generally overlain by less than 1 m of sandy hillslope sediment (Late Pleistocene); upper part of the St. Lawrence slope is a continuation of the Jordan escarpment (10° to 25°), which flattens into an undulating (5° to 10°) bench near the base of the unit.

Ꞓt — **Tunnel City Formation.** 30 to 45 m thick. **Lone Rock Member**, thin-bedded, quartzose, glauconitic, fine sand and sandstone; shaley near base; Cambrian. **Mazomanie Member**, slightly glauconitic sandstone near middle of the formation; thickens eastward; Cambrian. Tunnel City Formation is generally overlain by less than 1 m of hillslope sediment (Late Pleistocene); commonly a series of billowy hills or a rounded bench (2° to 10°, with slopes of 10° to 15° above and below) occurs near the middle of the formation; flat bench (1° to 7°) occurs near the base of formation in the northwestern part of the county.

Ꞓw — **Wonewoc and Eau Claire Formations. Ironton Member**, at the top of the Wonewoc Formation, a few metres of brown, burrowed, quartzose, fine to medium sandstone; Cambrian; forms a low cliff in most places, especially in the northwestern part of the county. **Galesville Member**, at the bottom of the Wonewoc Formation, 15 to more than 20 m of white, quartzose, medium sandstone; Cambrian; generally a steep (10° to 30°) tree-covered slope, but in some places steeper or flatter; commonly overlain by about 1 m of sandy hillslope sediment (Late Pleistocene). **Eau Claire Formation**--a few metres of poorly sorted, variably colored, quartzose sandstone; commonly silty and bioturbated; Cambrian; forms a low undulating (1° to 5°) bench; overlain by thin (generally less than 1 m) sandy hillslope or shoreline sediment (Late Pleistocene).

Ꞓm — **Mount Simon Formation**. More than 30 m of white, quartzose, fine to medium sand and sandstone; Cambrian; commonly overlain by a few metres of hillslope, shoreline, offshore, or windblown sand (Late Pleistocene); flat to undulating (1° to 3°) in most areas but steeper in some places, with vertical cliffs in the Wisconsin Dells.

Ꞓp — **Parfreys Glen Formation**. Mostly quartz sandstone; parts conglomeratic; locally contains angular talus blocks several metres across, adjacent to the Baraboo Formation; some zones glauconitic; commonly very hard (silica cement); generally unfossiliferous; generally occurs within several hundred metres of the Baraboo Hills; bedding generally slopes a few degrees away from the Baraboo Hills; chronologic equivalent of the Mount Simon, Eau Claire, Wonewoc, Tunnel City, St. Lawrence, and Jordan Formations, and perhaps also of the Oneota, St. Peter, and younger formations; contact with the Baraboo Formation is imprecisely located in most areas.

Ꞓk — **"Dake formation"?** Similar to the Baraboo quartzite; Early Proterozoic.

Pb — **Baraboo Formation.** About 1.5 km of gray to pink quartzite; very well cemented in most places; Early Proterozoic; generally overlain by hillslope debris consisting of quartzose sand and gravel on steep slopes and finer material on gentle slopes (Late Pleistocene).

**Granite in Baxter Hollow**. Pink to red granite and quartz diorite beneath the Baraboo Formation; Early Proterozoic.

**Diorite near Denzer**. Gray to red diorite or granodiorite; Early Proterozoic.

**Rhyolite near the Lower Narrows, Denzer, and Devils Nose**. Metamorphosed red to black tuffaceous rock and lava flows; Early Proterozoic.

## Symbols

Ice-wedge polygons. Each symbol indicates a group of polygons visible on aerial photographs. Each polygon is tens of metres across.

Possible shore-ice collapse trench.

River cutbanks. Only those higher than about 5 m shown; cutbanks in sandstone at the Wisconsin Dells are also not shown.

Direction of meltwater flow.

Summit plateaus. Highest level areas on crest of the South Range of the Baraboo Hills, probably cut in Paleozoic time.

Subsummit terraces. Probably cut into Baraboo quartzite by wave erosion during the Ordovician.

Block stream.

Moraine. Broad (more than 0.2 km wide) end moraines shown with pattern; narrow (less than 0.2 km wide) end moraines shown with line symbol marking the crest of the ridge.

Dip and strike symbols. Shown on Precambrian metasedimentary units; some derived from I.W. Dalziel and R.H. Dott, Jr. (1970, Geology of the Baraboo District, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 14, 164 p.).

Geologic contacts. Continuous where position shown on map is generally within 0.1 km of the true position; dashed where position shown on map is commonly more than 0.1 km from the true position.

Old subsurface iron mine.

Gravel pit.

Old open-pit iron mine.

Rock quarry.

Fault (or narrow monocline).

Anticline.

University of Wisconsin-Extension

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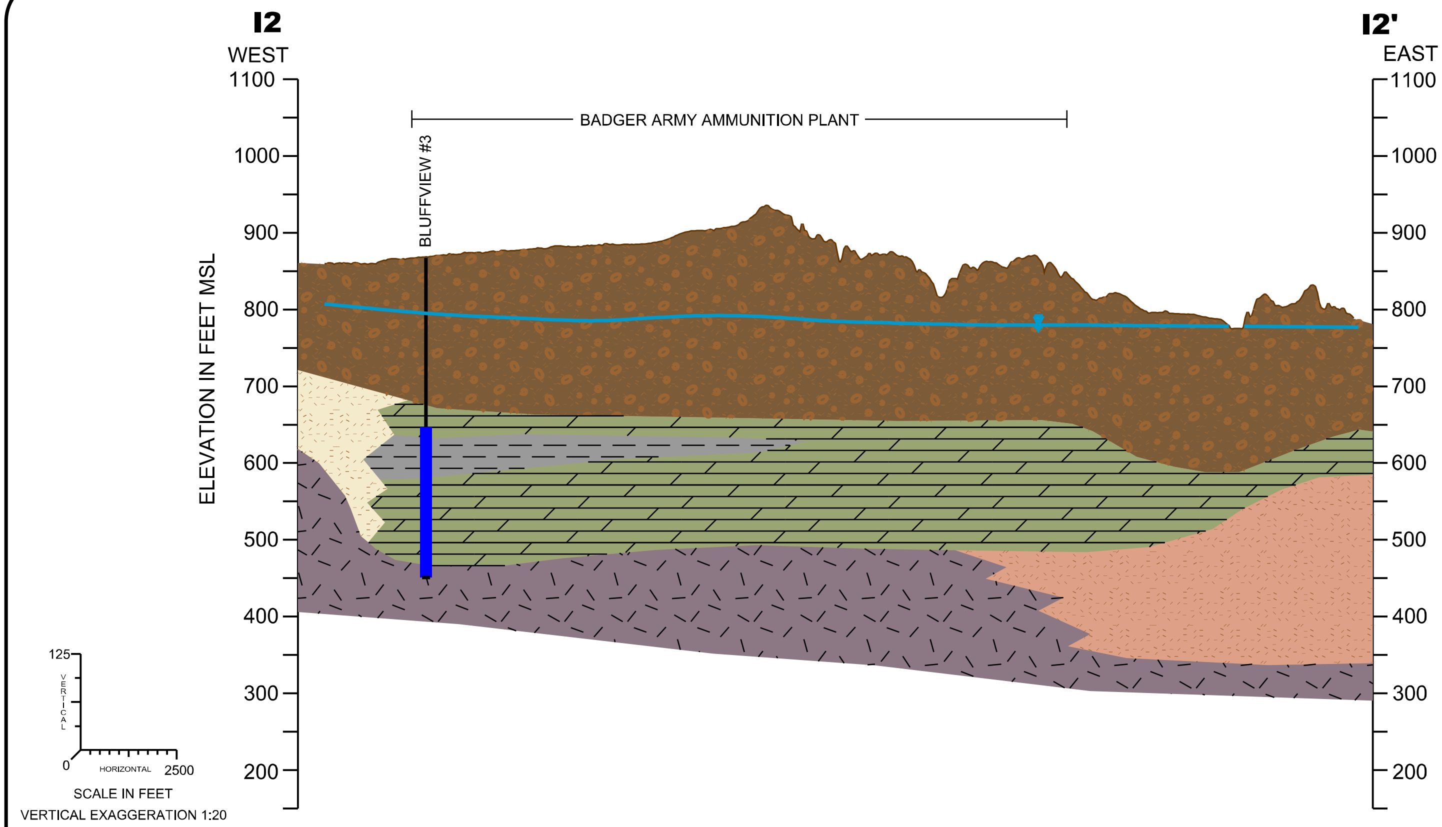
M.E. Ostrom, Director and State Geologist

Cartography by D.L. Patterson

Wisconsin Geological and Natural History Survey
Information Circular 67
Geology of Sauk County, Wisconsin
Plate 1 (Map 90-1a): Geologic map




LEGEND

WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E & F)

WELL

GROUND SURFACE

WATER TABLE ELEVATION

WELL SCREEN

BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

SAND AND GRAVEL, AQUIFER

WONEWOC FORMATION, AQUIFER (SANDSTONE)

EAU CLAIRE FORMATION, AQUITARD/AQUIFER (SHALE, DOLOMITE, SILTSTONE, SANDSTONE)

EAU CLAIRE FORMATION, AQUITARD (SHALE)

MT. SIMON FORMATION, AQUIFER (SANDSTONE)

BARABOO FORMATION, AQUITARD (QUARTZITE)

NOTES:
ADAPTED FROM GOTKOWITZ AND OTHERS (2005), HYDROGEOLOGY AND SIMULATION OF GROUNDWATER FLOW IN SAUK COUNTY, WISCONSIN

CROSS SECTION LOCATION

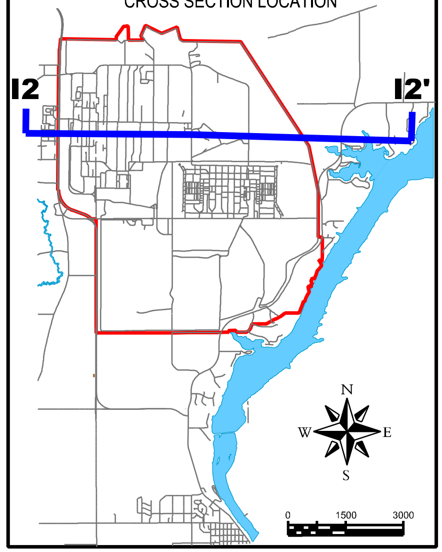


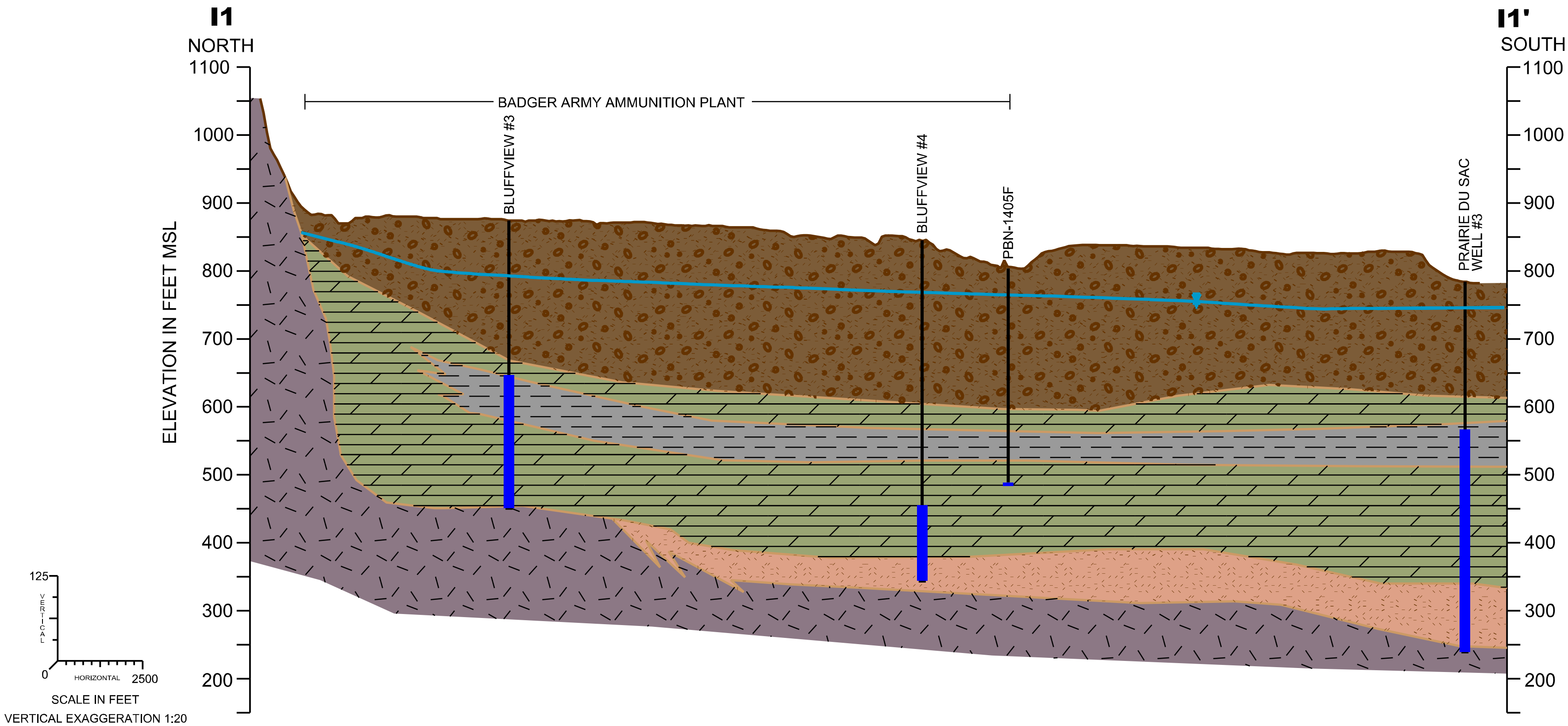

FIGURE 3

GENERALIZED GEOLOGIC CROSS SECTION WEST-EAST

RI/FS

BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




## LEGEND

WELL

WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E & F)

GROUND SURFACE

WATER TABLE ELEVATION

WELL SCREEN

BOTTOM OF EXPLORATION

## GEOLOGIC DESCRIPTIONS:

SAND AND GRAVEL, AQUIFER

EAU CLAIRE FORMATION, AQUITARD/AQUIFER (SHALE, DOLOMITE, SILTSTONE, SANDSTONE)

EAU CLAIRE FORMATION, AQUITARD (SHALE)

MT. SIMON FORMATION, AQUIFER (SANDSTONE)

BARABOO FORMATION, AQUITARD (QUARTZITE)

NOTES:
ADAPTED FROM GOTKOWITZ AND OTHERS (2005), HYDROGEOLOGY AND SIMULATION OF GROUNDWATER FLOW IN SAUK COUNTY, WISCONSIN

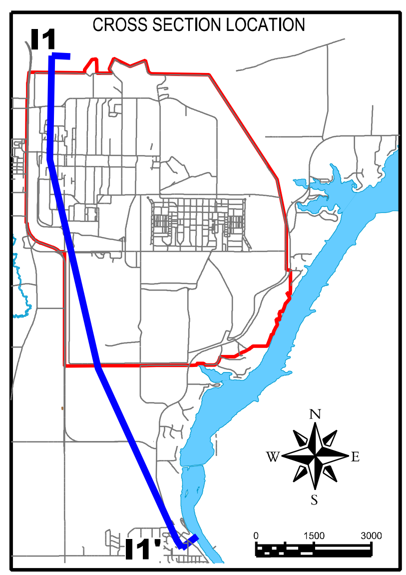
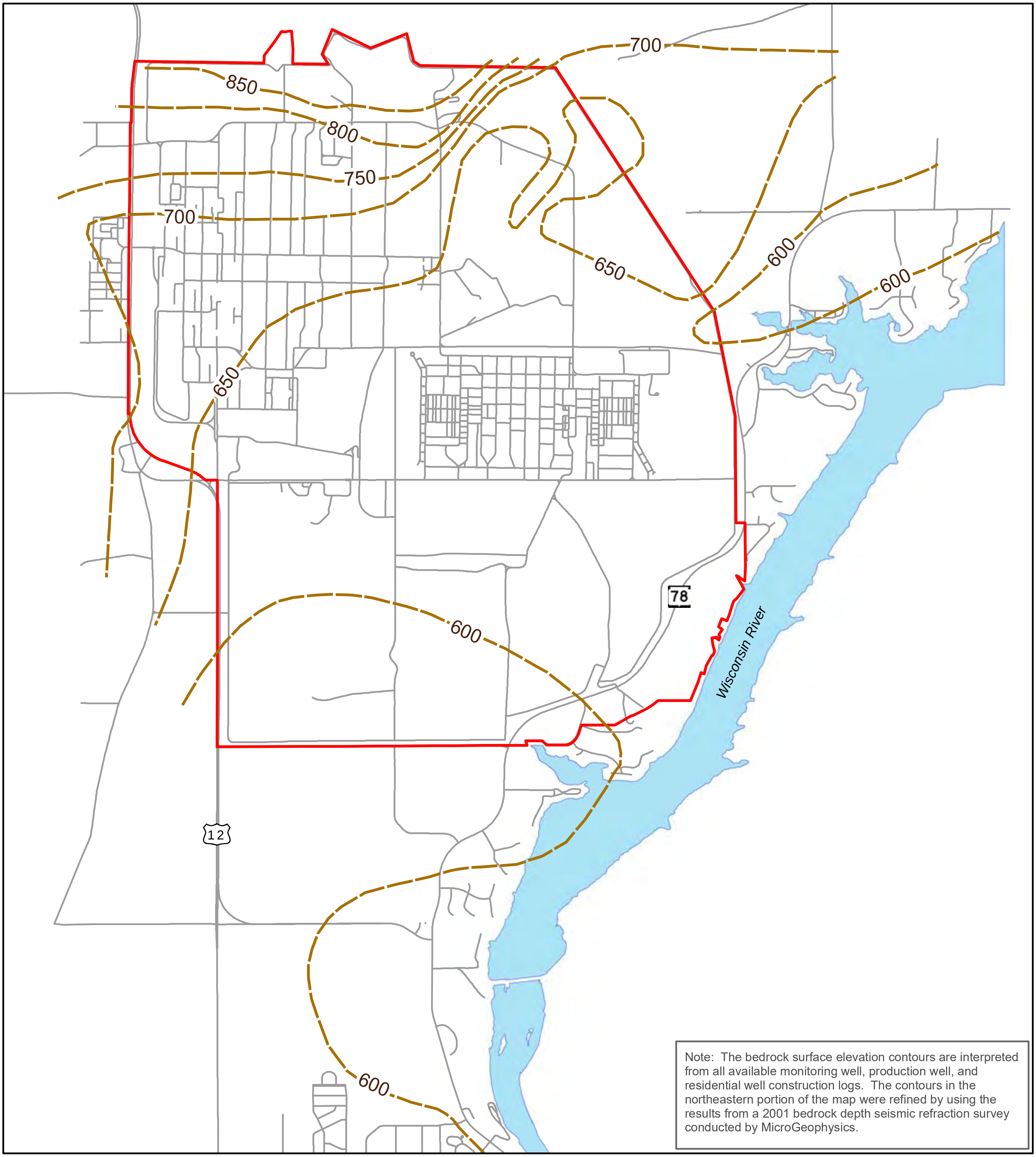



FIGURE 4

GENERALIZED GEOLOGIC CROSS SECTION NORTH-SOUTH
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




Note: The bedrock surface elevation contours are interpreted from all available monitoring well, production well, and residential well construction logs. The contours in the northeastern portion of the map were refined by using the results from a 2001 bedrock depth seismic refraction survey conducted by MicroGeophysics.

**Legend**

- Badger Army Ammunition Plant Boundary
- Bedrock Surface Elevation Contour
  Contour Interval = 50 feet
- Wisconsin River
- Road

# Figure 5

## Bedrock Surface Map
## RI/FS
## Badger Army Ammunition Plant

1 inch = 3,750 feet

0 | 6,250 | 12,500 Feet

SPS
SPECPRO PROFESSIONAL SERVICES

N

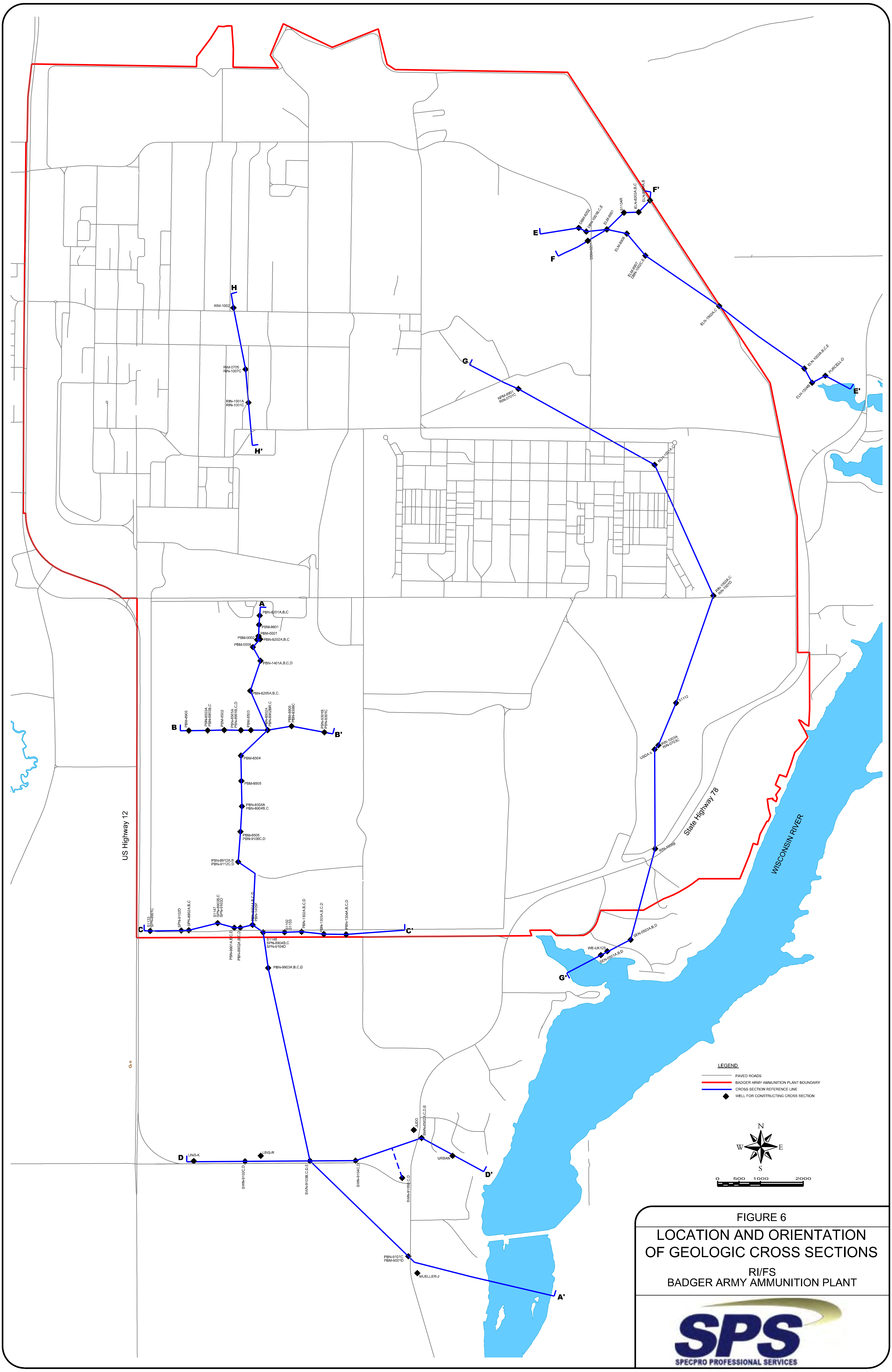


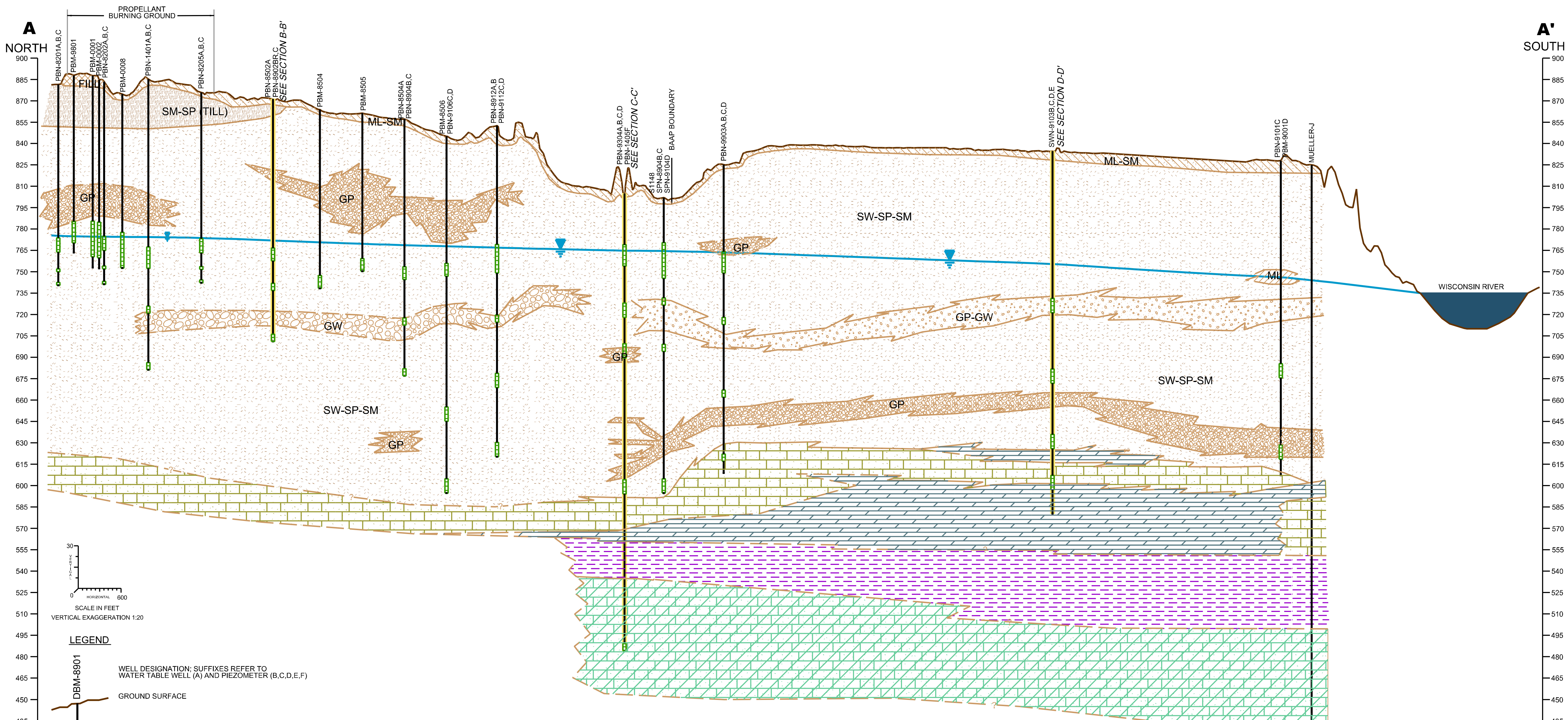

FIGURE 6

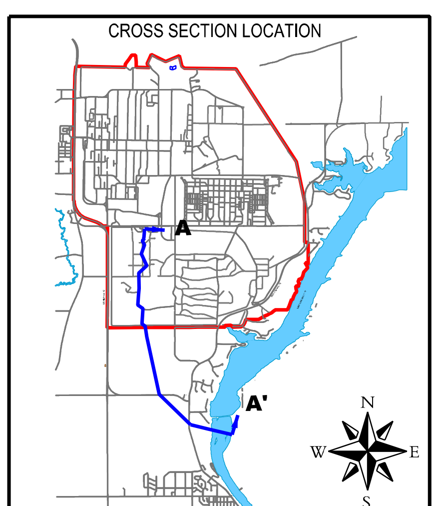
LOCATION AND ORIENTATION OF GEOLOGIC CROSS SECTIONS

RI/FS

BADGER ARMY AMMUNITION PLANT

SPS SPECPRO PROFESSIONAL SERVICES




GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| | MT. SIMON FORMATION (SANDSTONE) |

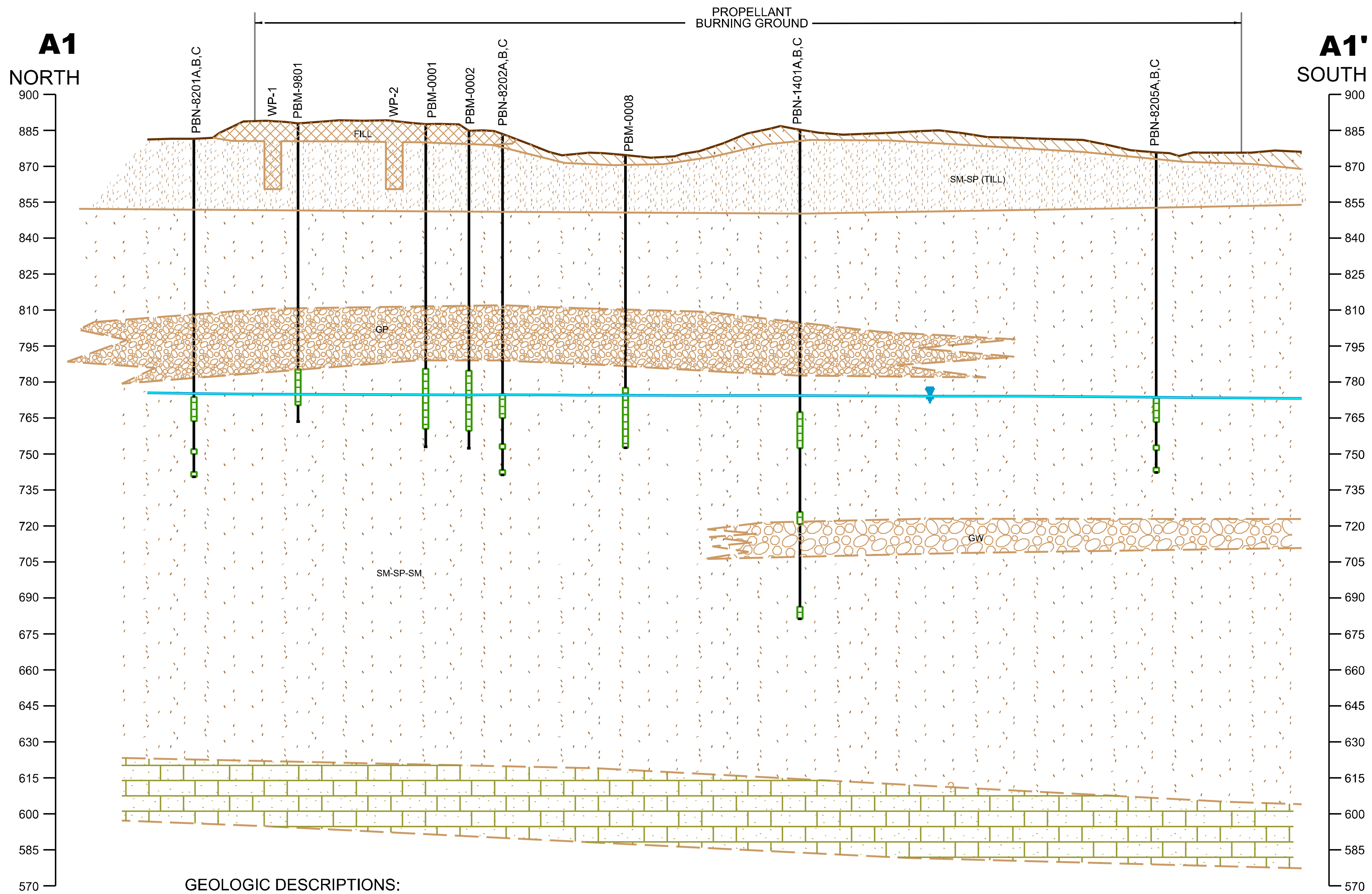
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 7

# GEOLOGIC CROSS SECTION A-A'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

BOTTOM OF EXPLORATION

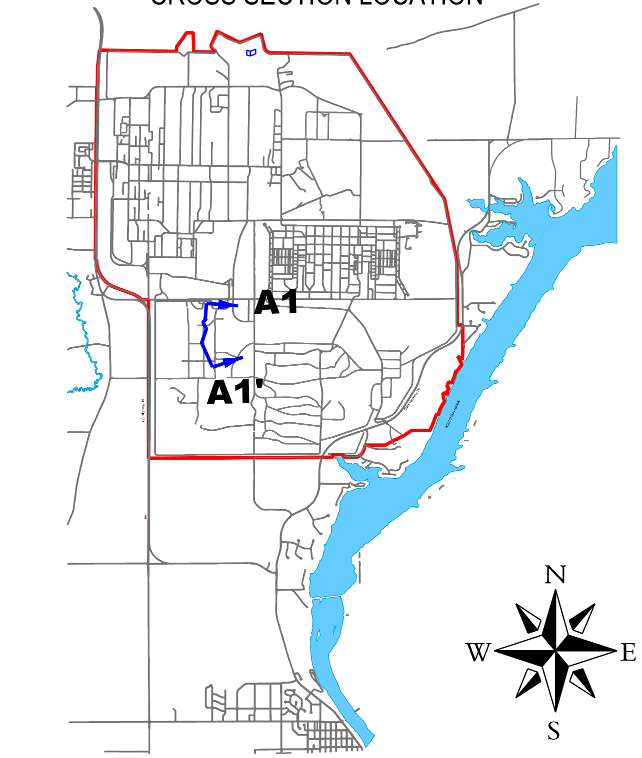
30 / 0 / HORIZONTAL / 150

SCALE IN FEET
VERTICAL EXAGGERATION 1:5

## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| | MT. SIMON FORMATION (SANDSTONE) |

## CROSS SECTION LOCATION



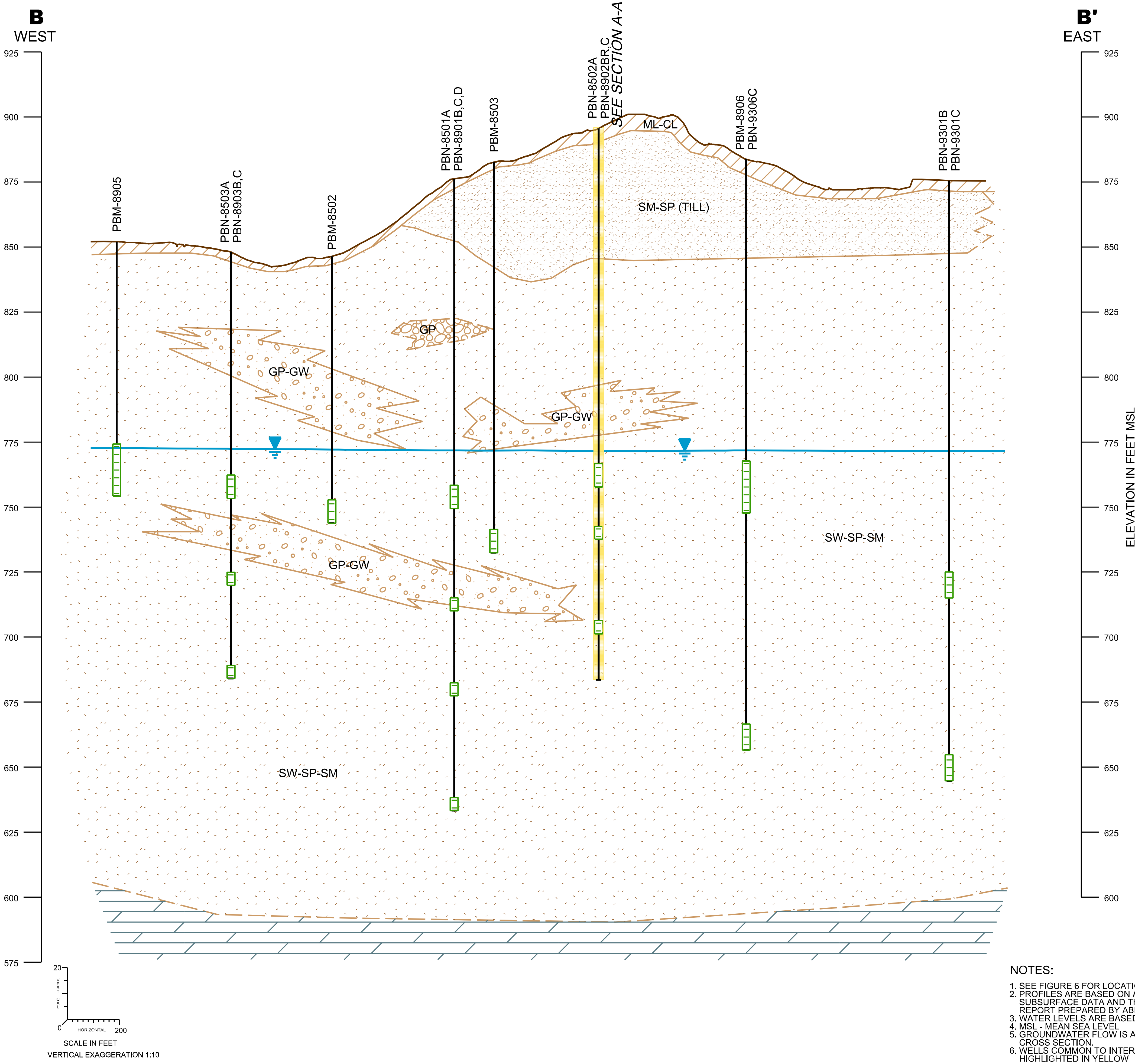

NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 8

# GEOLOGIC CROSS SECTION A1-A1'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

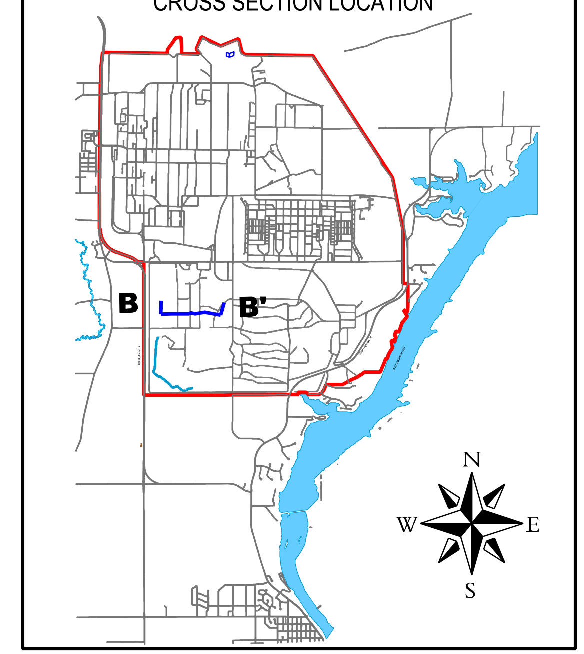
SCREENED INTERVAL

BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
- GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)

CROSS SECTION LOCATION



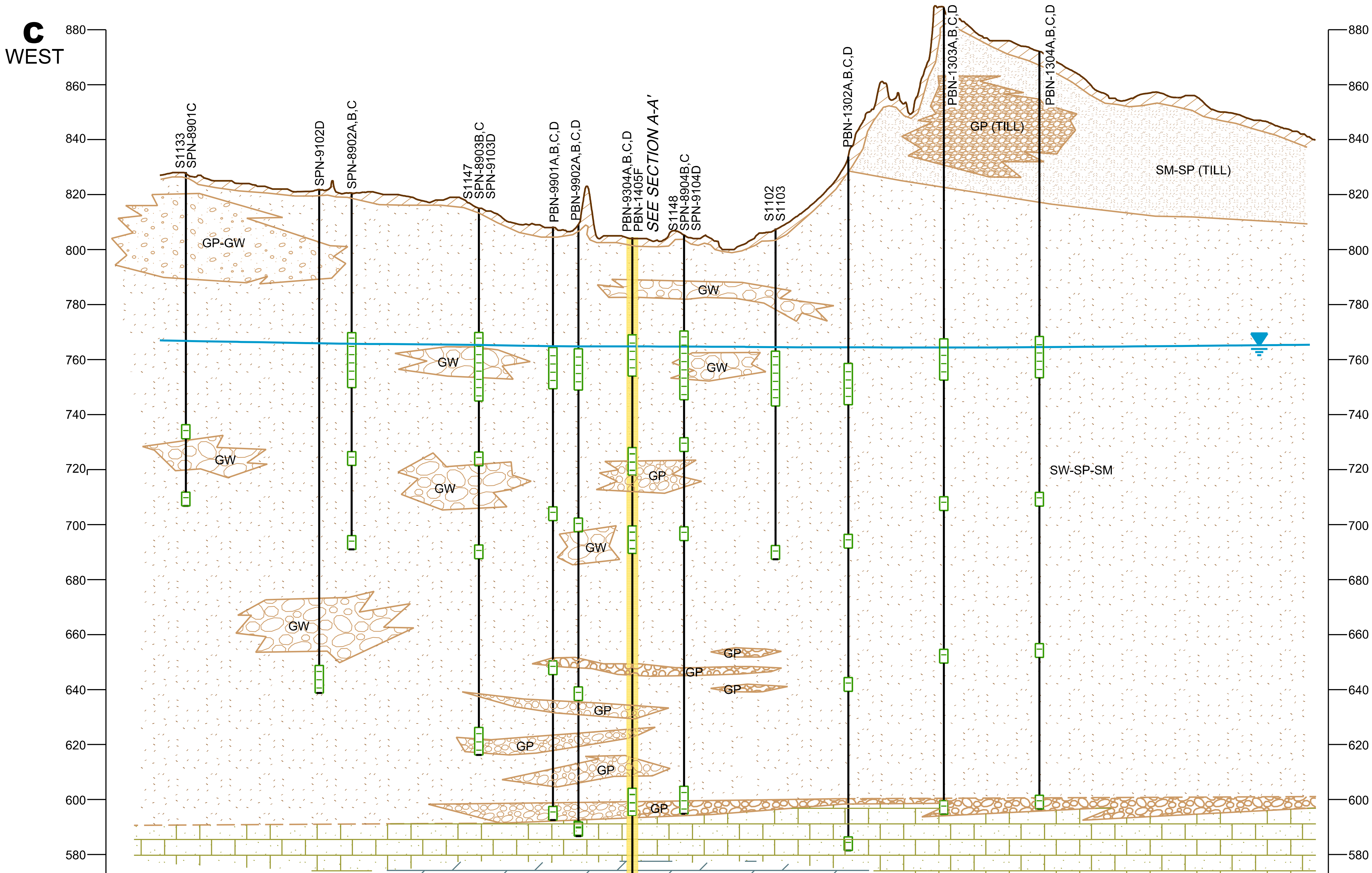

NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 9

GEOLOGIC CROSS SECTION B-B'
PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

LEGEND

- DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)
- GROUND SURFACE
- WATER TABLE ELEVATION
- SCREENED INTERVAL
- BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

- FILL — FILL MATERIAL
- ML-CL — SILT AND CL AY MIXTURE, LOESS
- SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP — GRAVEL, POORLY GRADED, GLACIAL TILL
- GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
- GW — GRAVEL, WELL GRADED, GLACIAL OUTWASH
- GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)
- BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
- BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE)
- BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE)

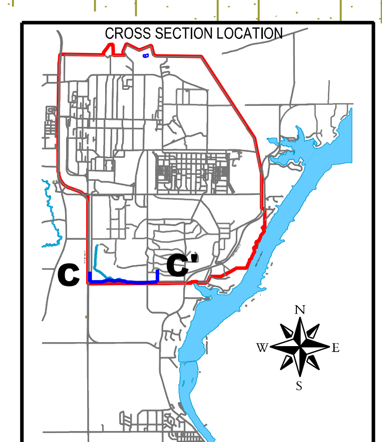
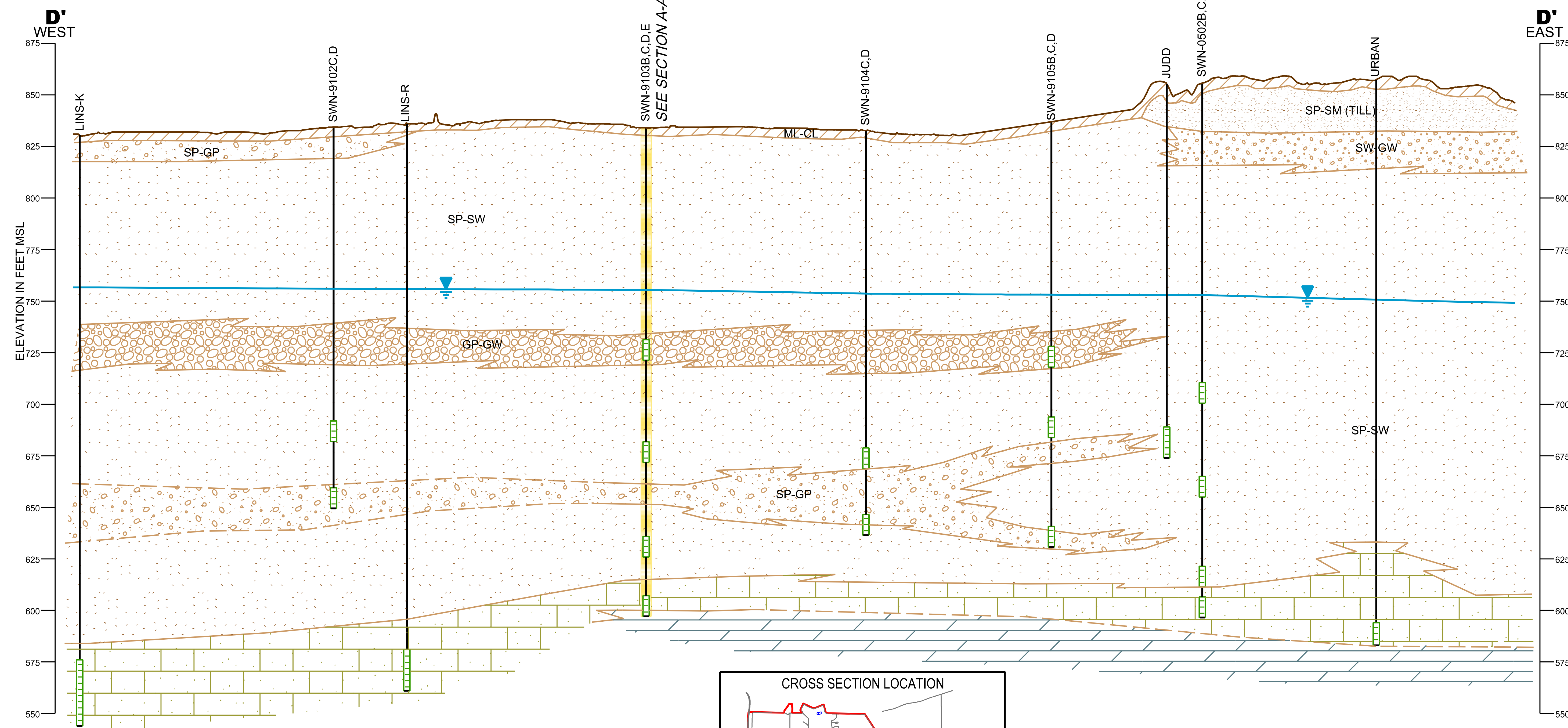


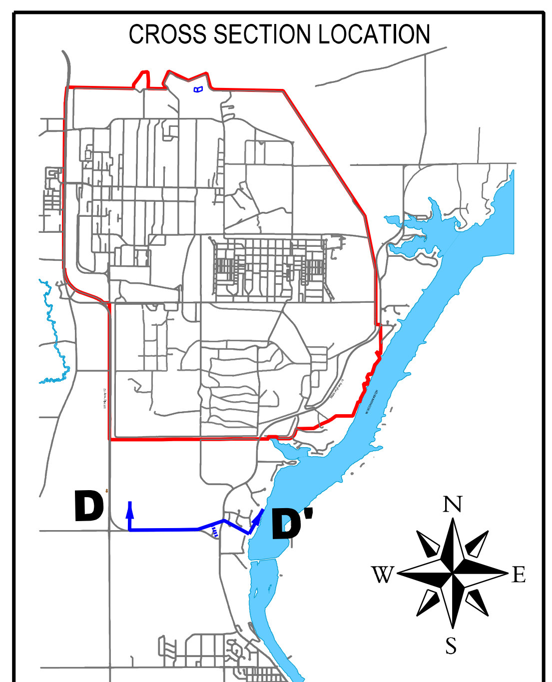

FIGURE 10

# GEOLOGIC CROSS SECTION C-C'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




## LEGEND

| | |
|---|---|
| DBM-8901 | WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E) |
| | GROUND SURFACE |
| | WATER TABLE ELEVATION |
| | SCREENED INTERVAL |
| | BOTTOM OF EXPLORATION |

## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SP-GP | SAND AND GRAVEL, GLACIAL OUTWASH |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SP-SW | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| GP-GW | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |

## NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. SWN-9105 B,C,D ARE OFFSET 750 FEET SOUTH OF THE SECTION LINE.
6. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

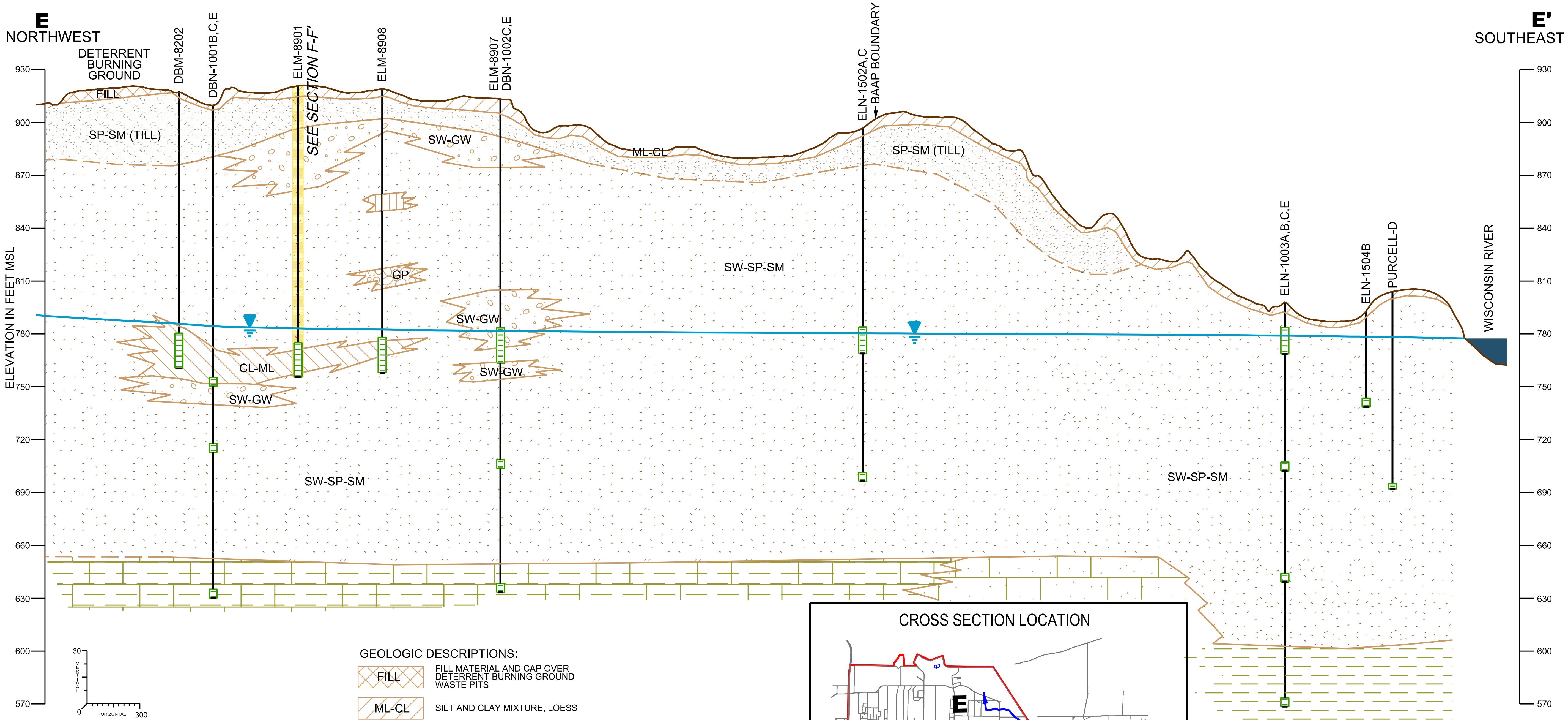
25 VERTICAL 0 HORIZONTAL 250
SCALE IN FEET
VERTICAL EXAGGERATION 1:10

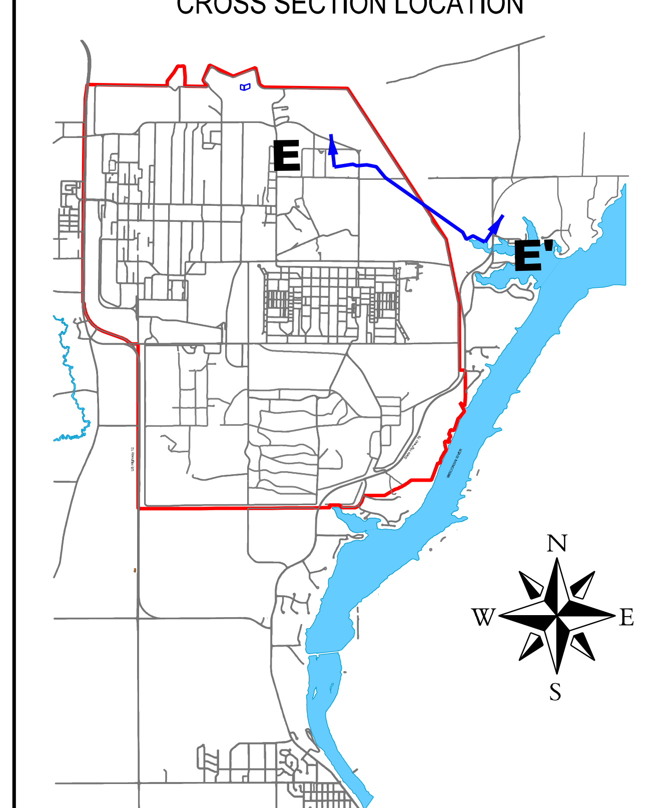
FIGURE 11

# GEOLOGIC CROSS SECTION D-D'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

BOTTOM OF EXPLORATION

## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER DETERRENT BURNING GROUND WASTE PITS |
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| CL-ML | LAYERED CLAY AND SILT, GLACIAL OUTWASH |
| GP | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, SHALE, EAU CLAIRE FORMATION (INTERBEDDED SANDSTONE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK, SHALE, EAU CLAIRE FORMATION (INTERBEDDED SILTSTONE) |

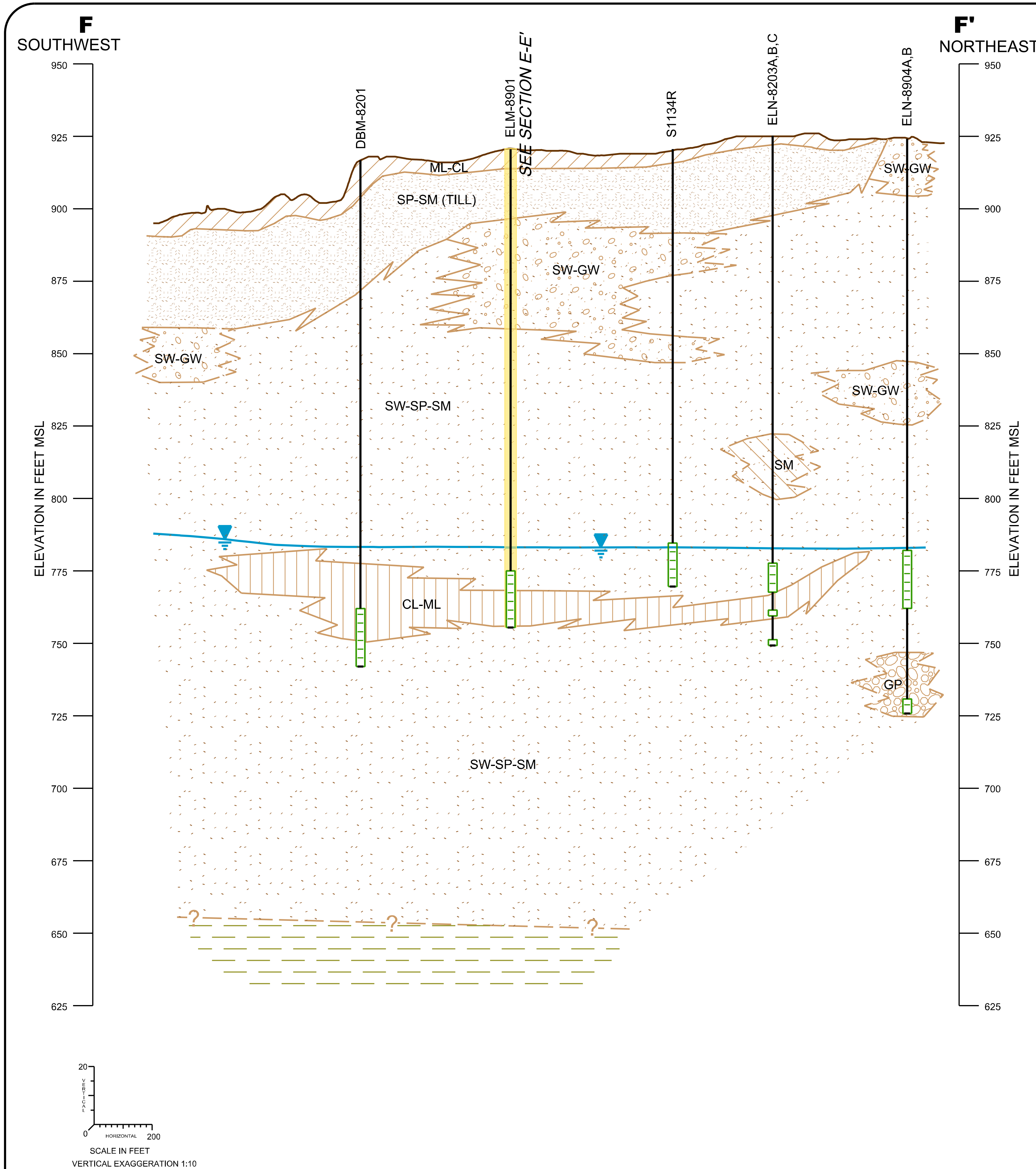
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 12

# GEOLOGIC CROSS SECTION E-E'

DETERRENT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES



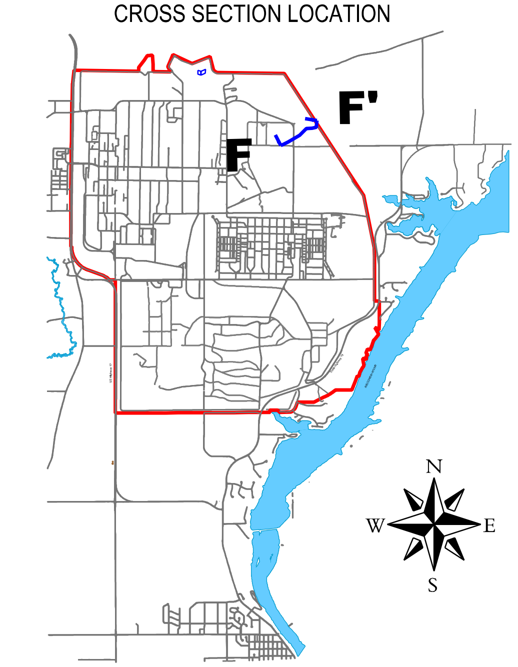

LEGEND

- DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)
- GROUND SURFACE
- WATER TABLE ELEVATION
- SCREENED INTERVAL
- BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-GW — SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- SM — SILTY SAND, GLACIAL OUTWASH
- CL-ML — LAYERED CLAY AND SILT, GLACIAL OUTWASH
- GP — GRAVEL, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (SHALE, INTERBEDDED SANDSTONE)

CROSS SECTION LOCATION




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 13

GEOLOGIC CROSS SECTION F-F'

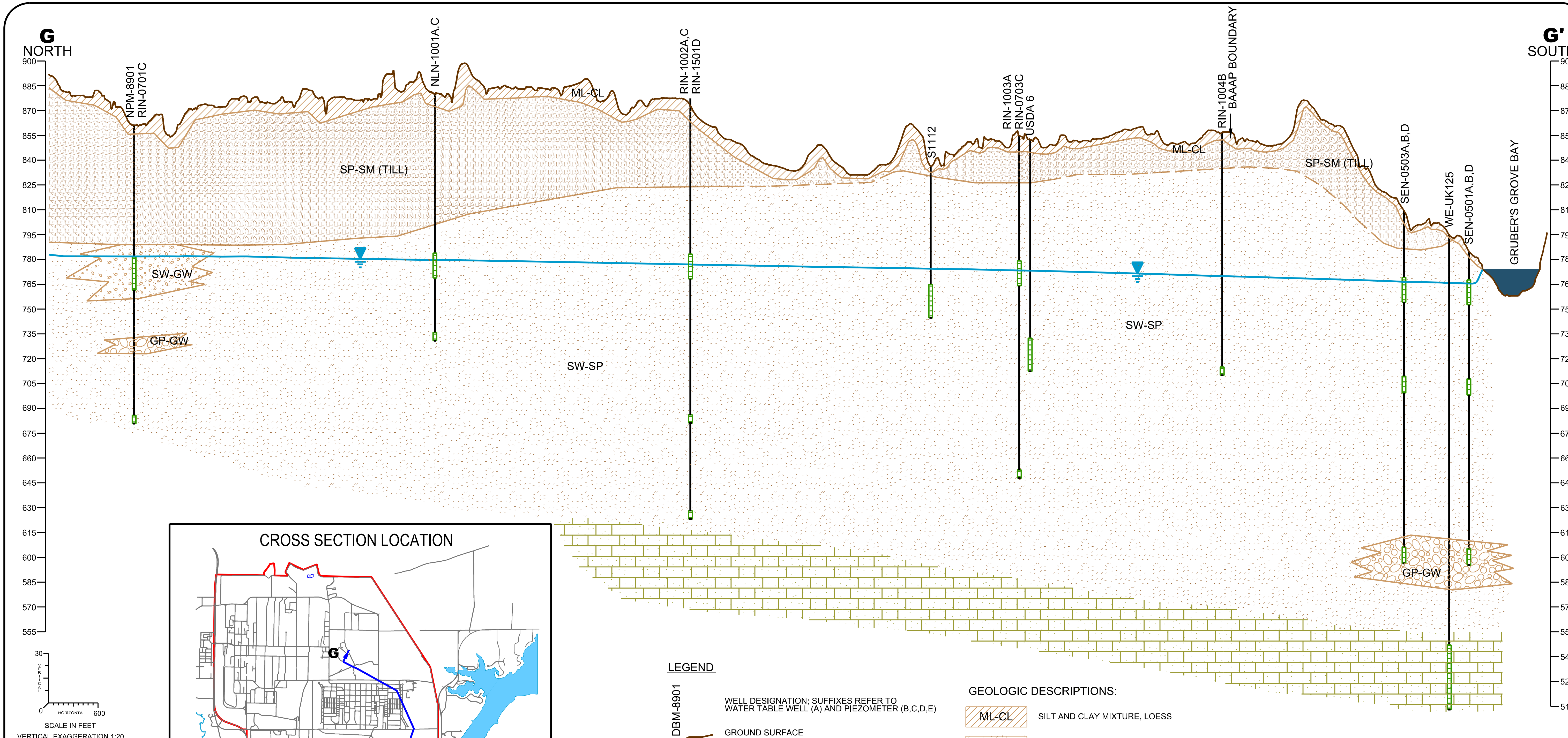
DETERRENT BURNING GROUND

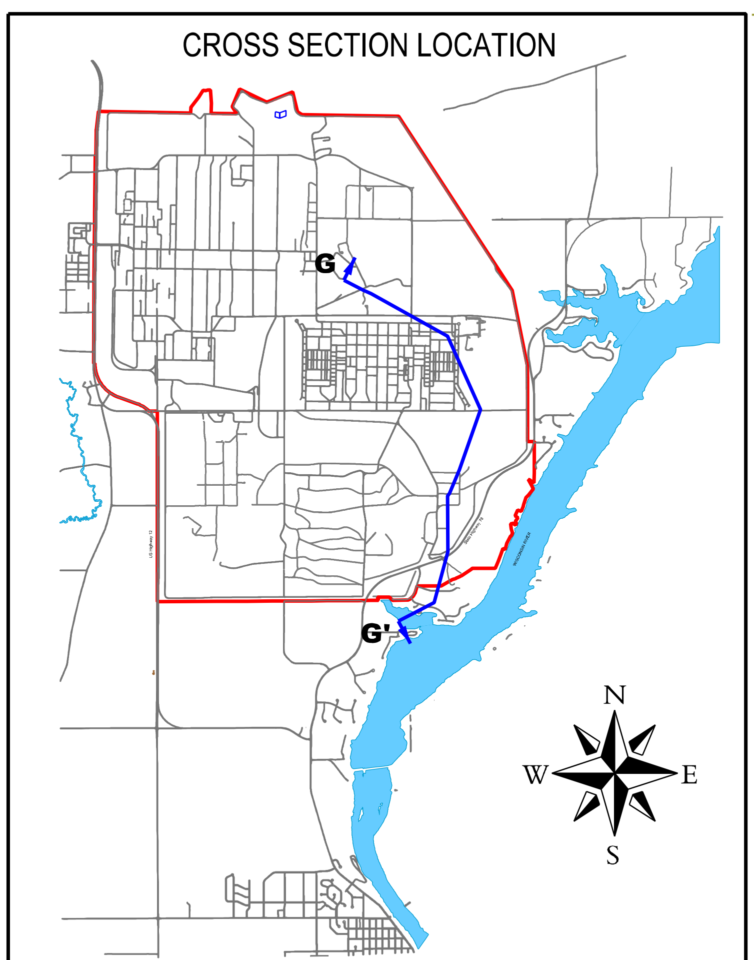
RI/FS

BADGER ARMY AMMUNITION PLANT

SPS

SPECPRO PROFESSIONAL SERVICES




LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

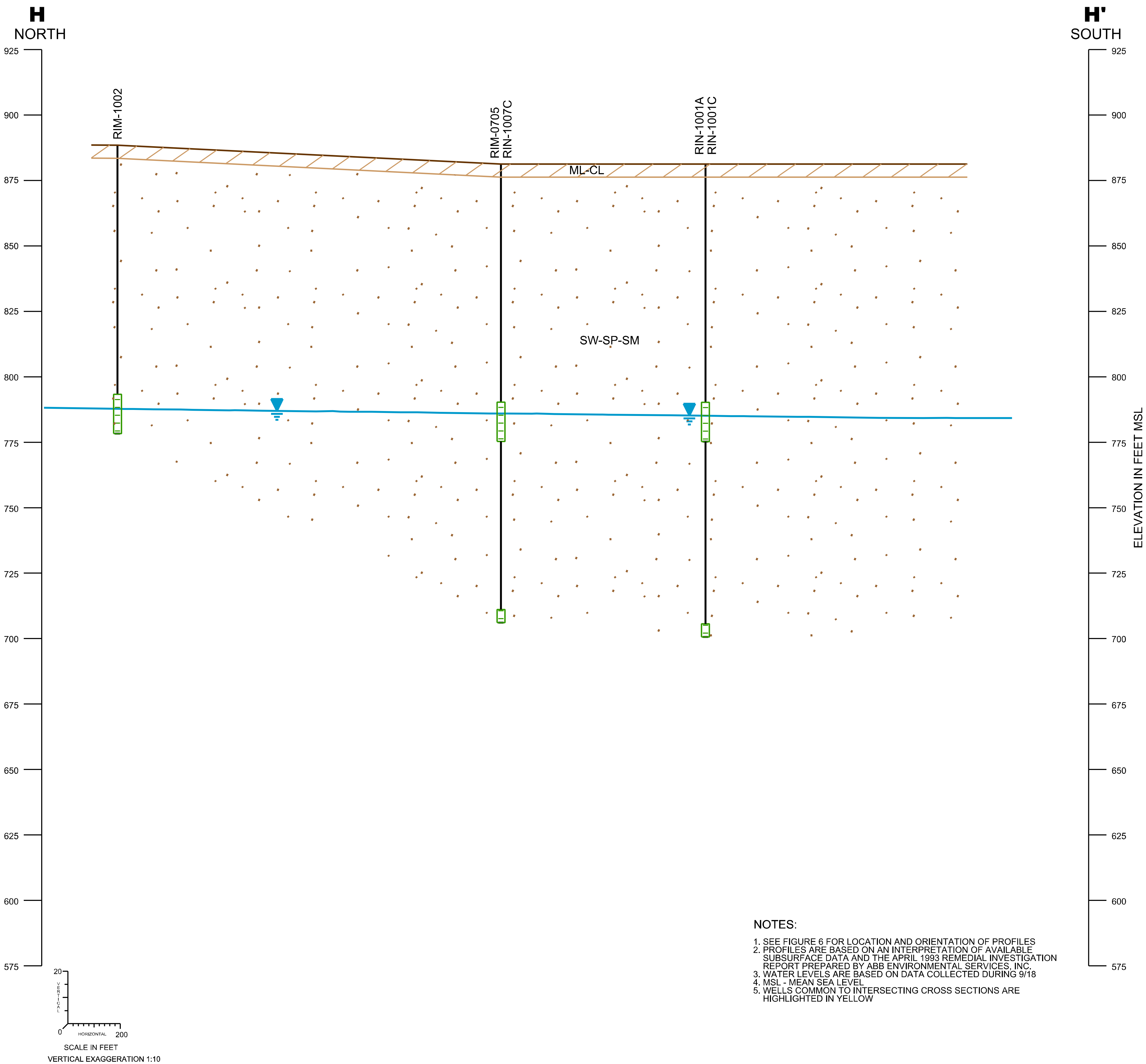
| | |
|---|---|
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SW-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| GP-GW | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |

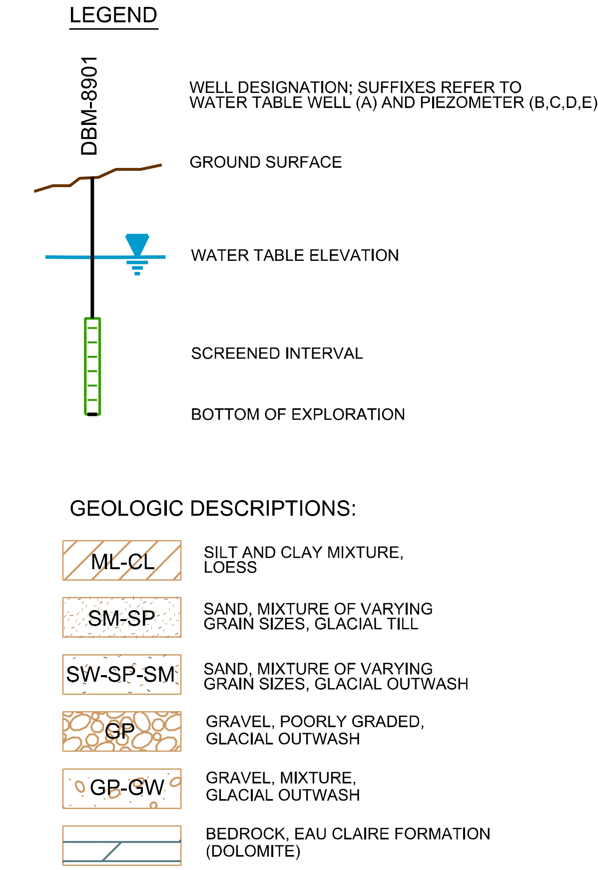
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 6/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

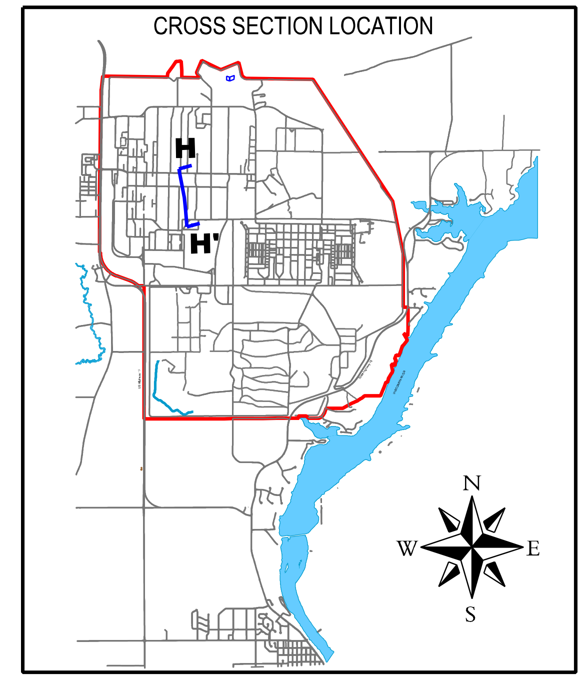
FIGURE 14

GEOLOGIC CROSS SECTION G-G'
CENTRAL PLUME
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 9/18
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 15

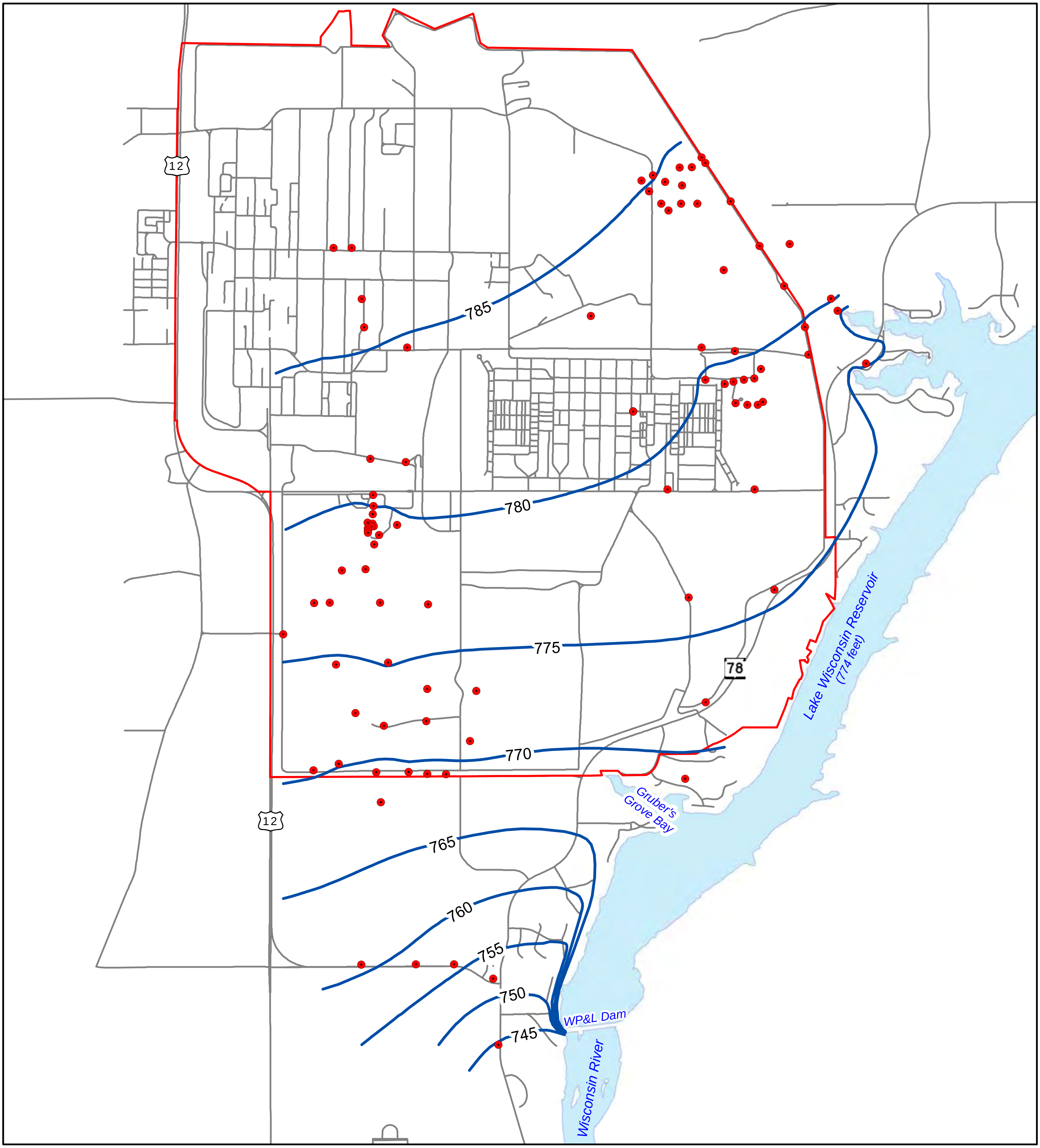
# GEOLOGIC CROSS SECTION H-H'

NITROCELLULOSE PRODUCTION AREA

RI/FS

BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




**Legend**

- Badger Army Ammunition Plant Boundary
- Monitoring Well (used to draw contours)
- Wisconsin River
- Road
- Groundwater Contour

Contour Interval = 5 feet

# Figure 16

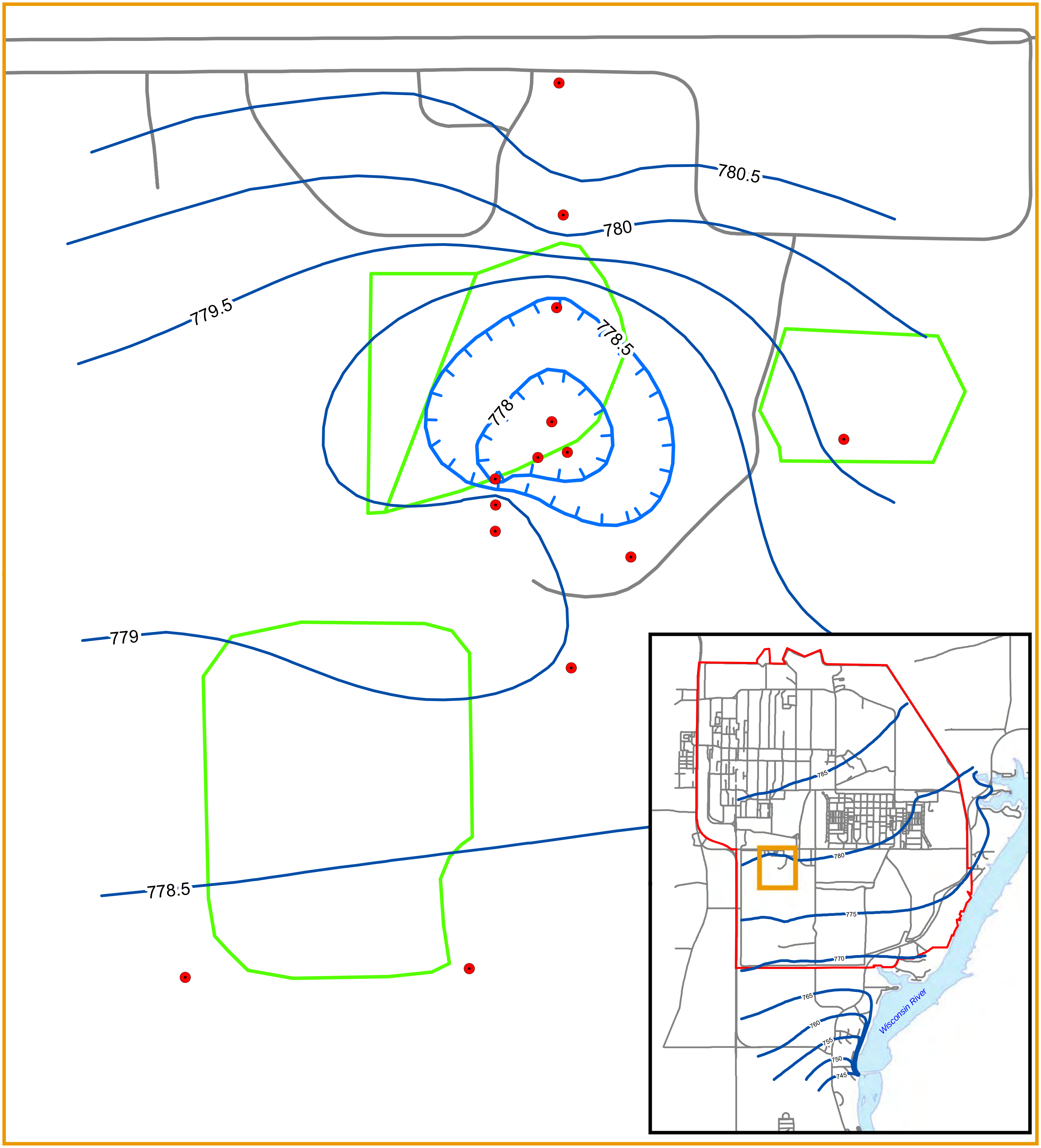
September 2017 Groundwater Contours
RI/FS
Badger Army Ammunition Plant

1 inch = 3,475 feet

Feet
0 5,300 10,600

SPS
SPECPRO PROFESSIONAL SERVICES

N




**Legend**

- Badger Army Ammunition Plant Boundary
- Monitoring Well (used to draw contours)
- Source Area
- Road
- 0.5 feet Groundwater Contour
- 0.5 feet Depression Groundwater Contour

# Figure 17

September 2017 Groundwater Contours
Propellant Burning Ground
RI/FS
Badger Army Ammunition Plant

1 inch = 291 feet

Feet
0 300 600

SPS
SPECPRO PROFESSIONAL SERVICES

N

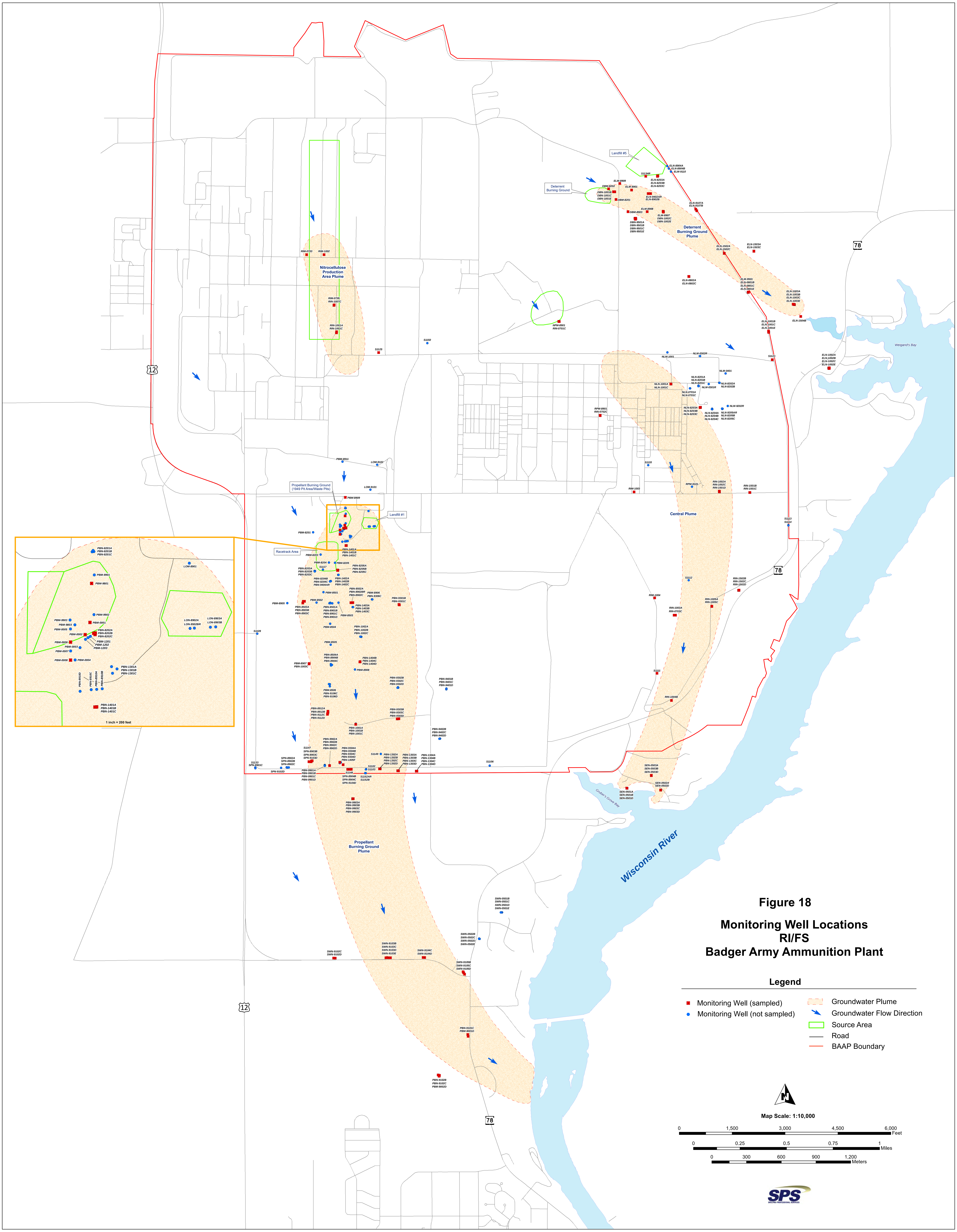



**Figure 18**

**Monitoring Well Locations**
**RI/FS**
**Badger Army Ammunition Plant**

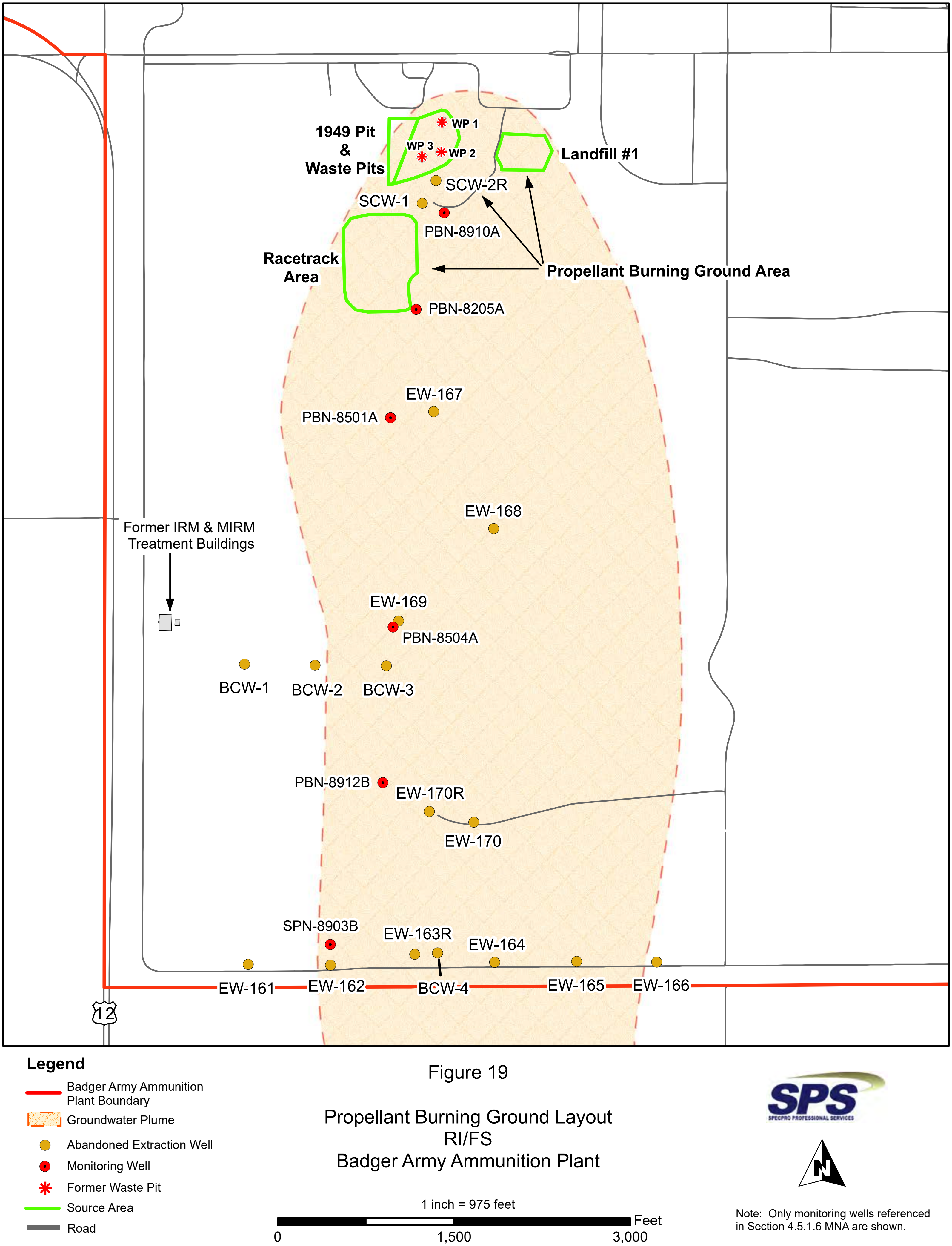



Figure 19

Propellant Burning Ground Layout
RI/FS
Badger Army Ammunition Plant

Note: Only monitoring wells referenced in Section 4.5.1.6 MNA are shown.

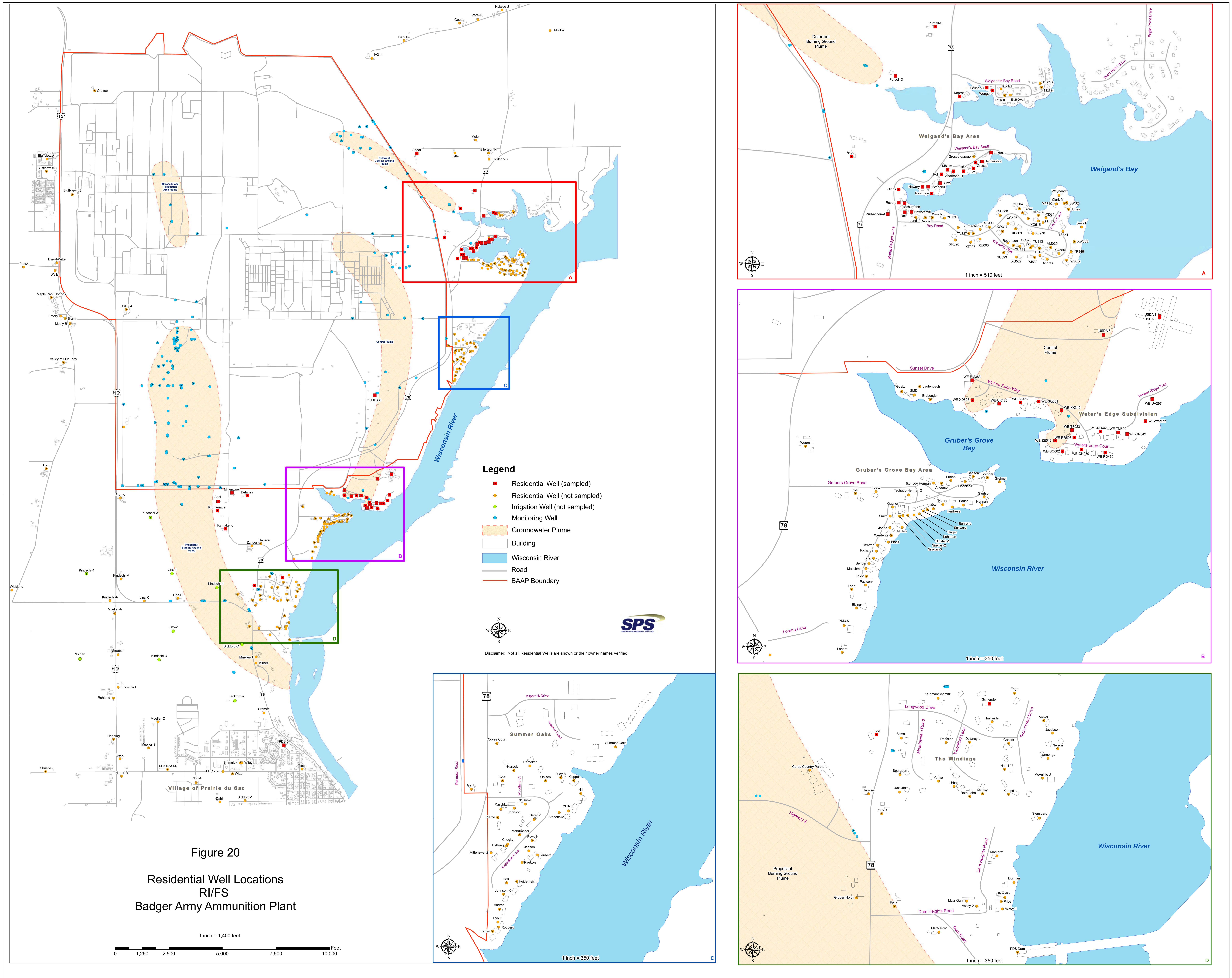
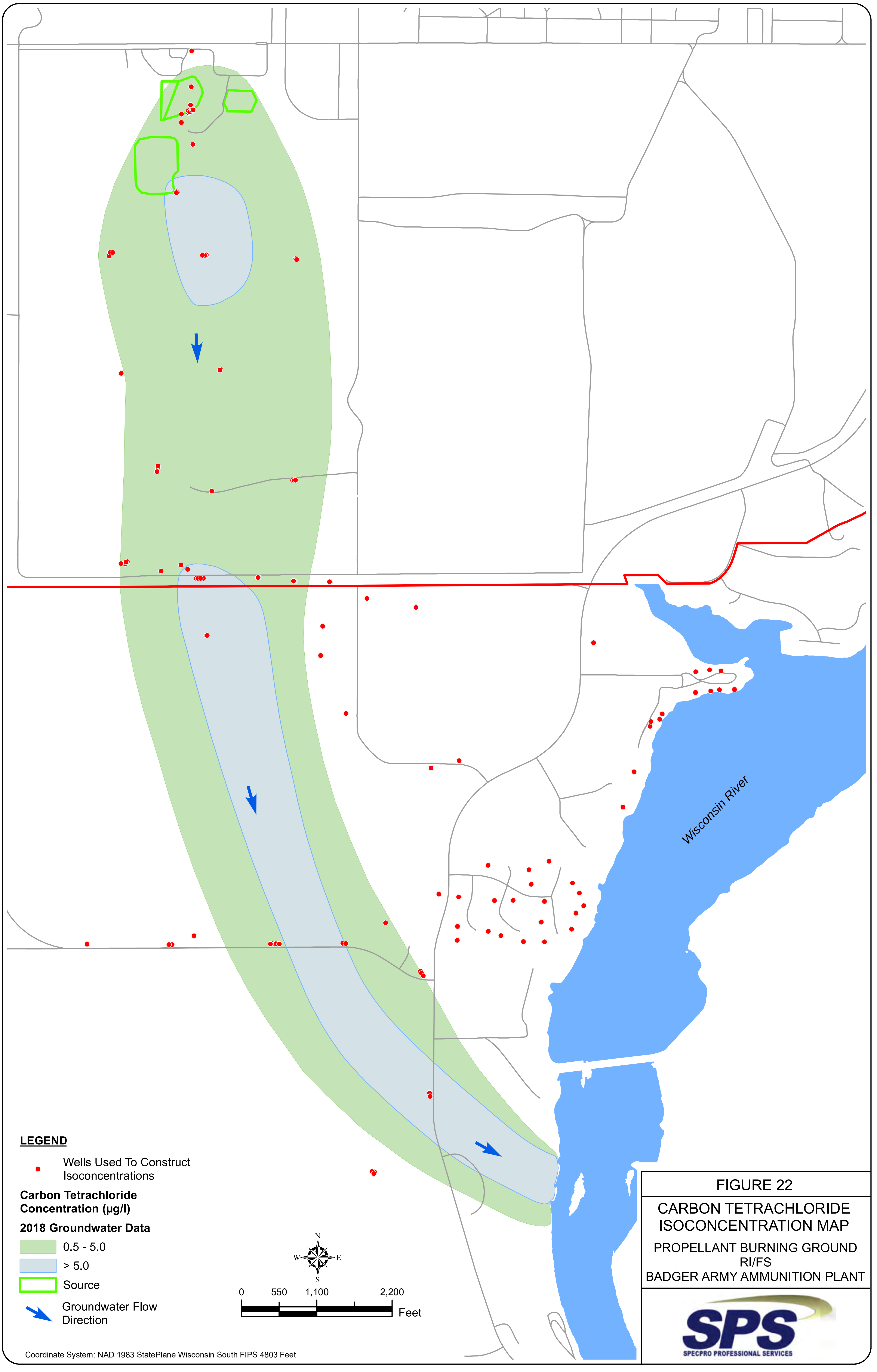
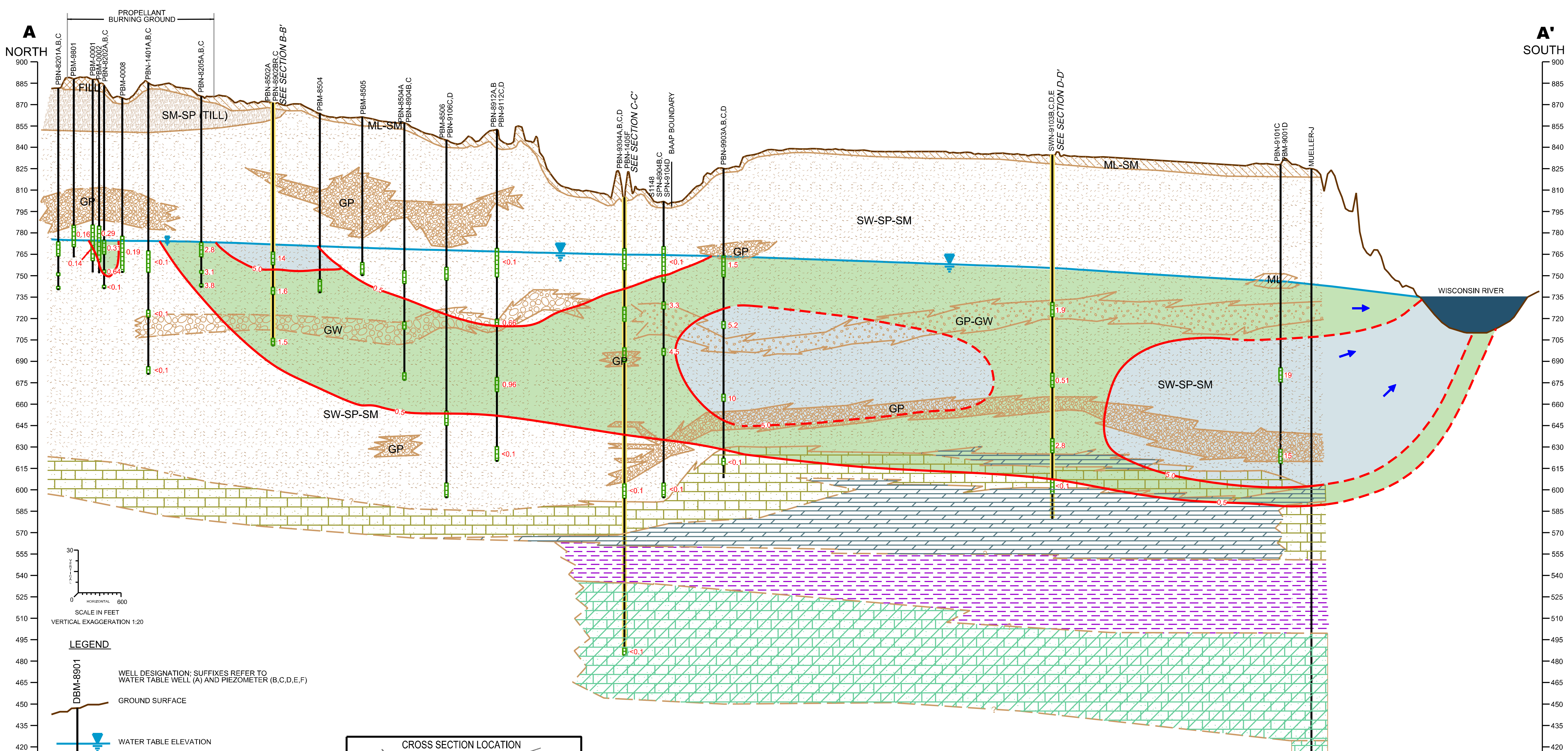



Figure 20

Residential Well Locations
RI/FS
Badger Army Ammunition Plant


Figure 21
Well Sampling Frequency Map
RI/FS
Badger Army Ammunition Plant
Legend
Monitoring Well Sampling Frequency
Quarterly Sampling
Semi-Annual Sampling
Annual Sampling
Biennial Sampling
Residential Well Sampling Frequency
Quarterly Sampling
Annual Sampling
Sample Frequency Descriptions:
Quarterly (four times per year)
Semi-Annual (twice per year)
Annual (once per year)
Biennial (once every two years)
Notes: ES = NR 140 Enforcement Standard
PAL = NR 140 Preventive Action Limit
Plume boundaries are approximate and based on Total DNT, Carbon Tetrachloride, Ethyl Ether & Trichloroethene data from 2018.
Groundwater Plume (Exceeding PAL)
Groundwater Plume (Exceeding ES)
Groundwater Flow Direction
Road
BAAP Boundary
1 inch = 750 feet
0
1,400
2,800
4,200
5,600
Feet
0
0.2
0.4
0.6
0.8
Miles
SPS
Nitrocellulose Production Area Plume
Deterrent Burning Ground Plume
Central Plume
Propellant Burning Ground Plume
Wisconsin River
Weigand's Bay
Gruber's Grove Bay
The Water's Edge subdivision
Dam
12
78


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Carbon Tetrachloride Concentration (µg/l)
2018 Groundwater Data
0.5 - 5.0
> 5.0
Source
Groundwater Flow Direction
N
W
E
S
0
550
1,100
2,200
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 22
CARBON TETRACHLORIDE ISOCONCENTRATION MAP
PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES




LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

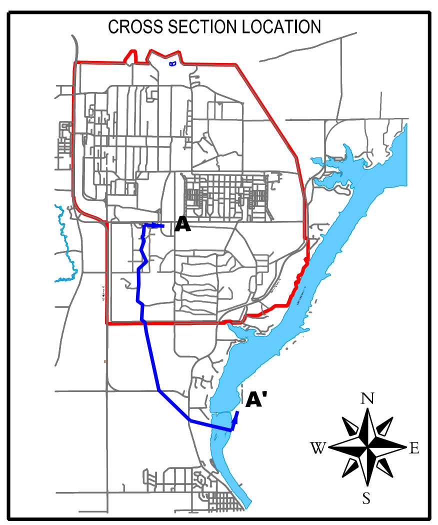
4.1 — CARBON TETRACHLORIDE CONCENTRATION µg/l

BOTTOM OF EXPLORATION

0.5 — CARBON TETRACHLORIDE ISOCONCENTRATION LINE (µg/l)

CARBON TETRACHLORIDE CONCENTRATION (µg/l)

- >5.0
- 0.5 - 5.0




GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| | MT. SIMON FORMATION (SANDSTONE) |

NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. CARBON TETRACHLORIDE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 23

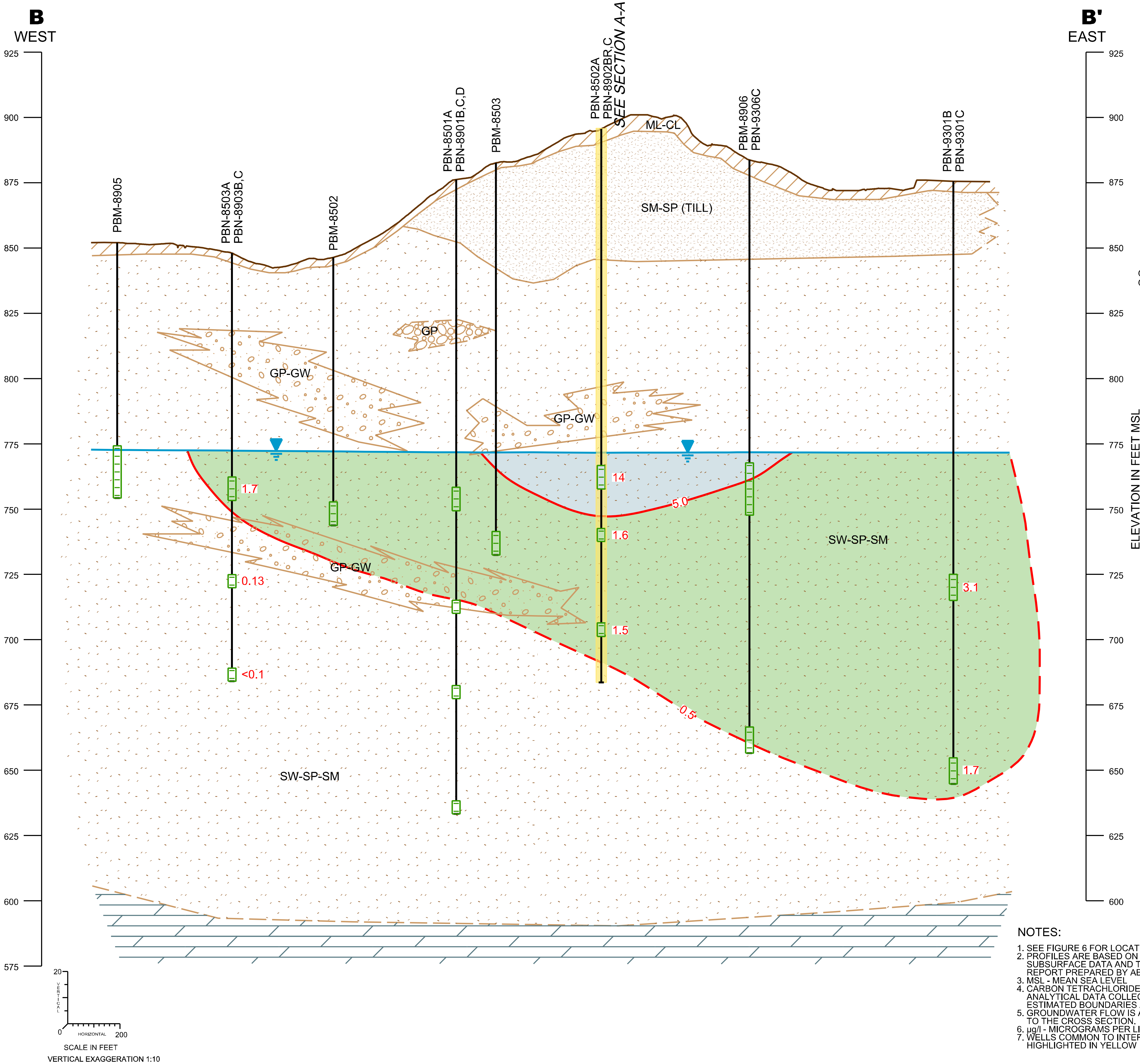
# CARBON TETRACHLORIDE ISOCONCENTRATION CROSS SECTION A-A'

PROPELLANT BURNING GROUND

RI/FS

BADGER ARMY AMMUNITION PLANT

SPS SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

2.3 — CARBON TETRACHLORIDE CONCENTRATION µg/l

BOTTOM OF EXPLORATION

5.0 — CARBON TETRACHLORIDE ISOCONCENTRATION LINE (µg/l)

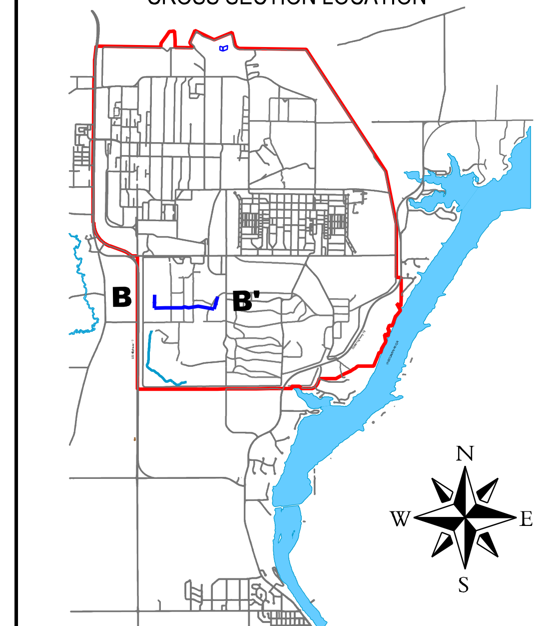
CARBON TETRACHLORIDE CONCENTRATION (µg/l)

- >5.0
- 0.5 - 5.0

GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |

CROSS SECTION LOCATION




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. CARBON TETRACHLORIDE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

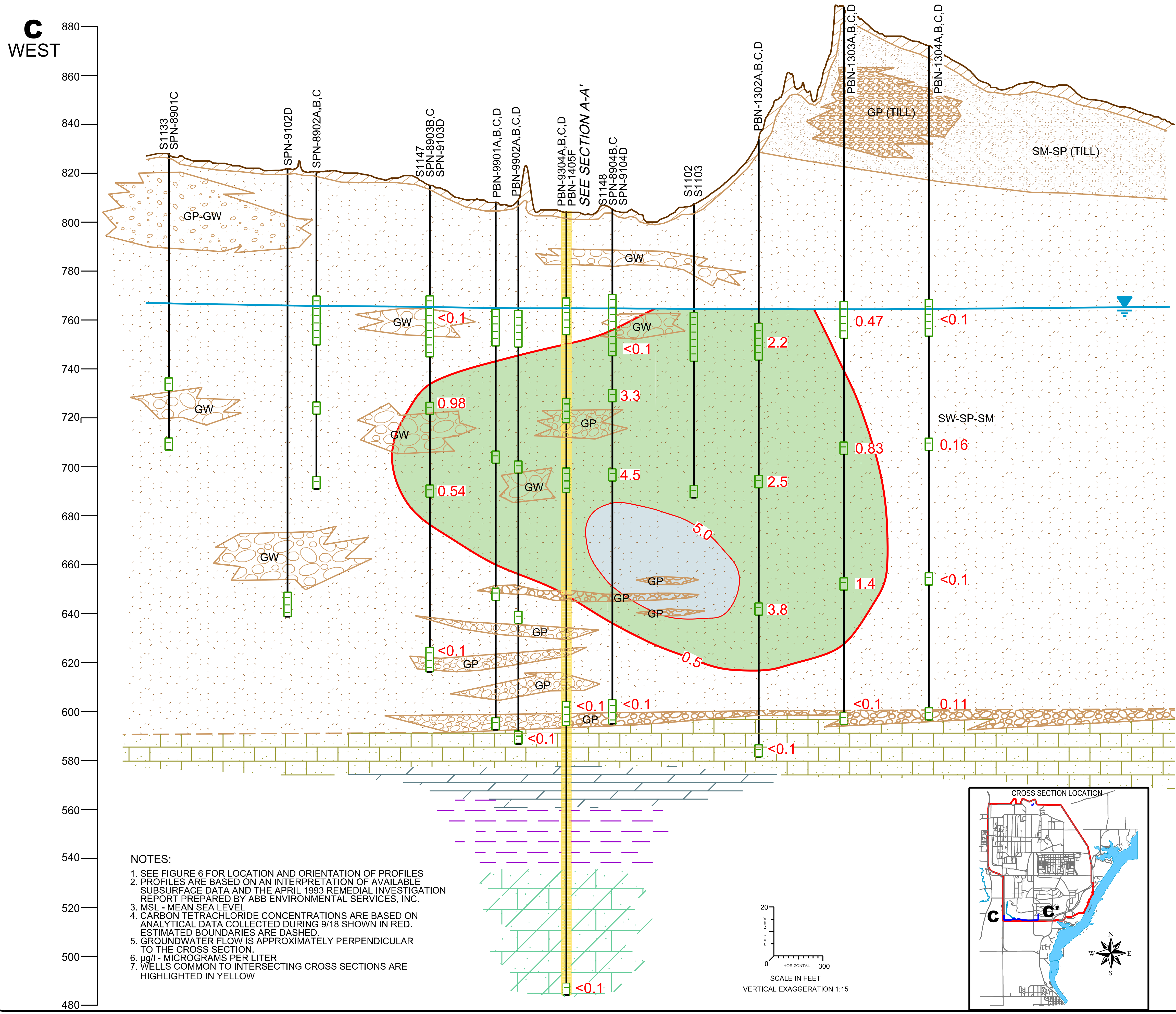
FIGURE 24

CARBON TETRACHLORIDE ISOCONCENTRATION CROSS SECTION B-B'

PROPELLANT BURNING GROUND RI/FS

BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
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3. MSL - MEAN SEA LEVEL
4. CARBON TETRACHLORIDE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

LEGEND

- DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)
- GROUND SURFACE
- WATER TABLE ELEVATION
- SCREENED INTERVAL
- 0.13 — CARBON TETRACHLORIDE CONCENTRATION µg/l
- BOTTOM OF EXPLORATION
- 0.5 — CARBON TETRACHLORIDE ISOCONCENTRATION LINE µg/l

CARBON TETRACHLORIDE CONCENTRATION (µg/l)

- >5.0
- 0.5 - 5.0

GEOLOGIC DESCRIPTIONS:

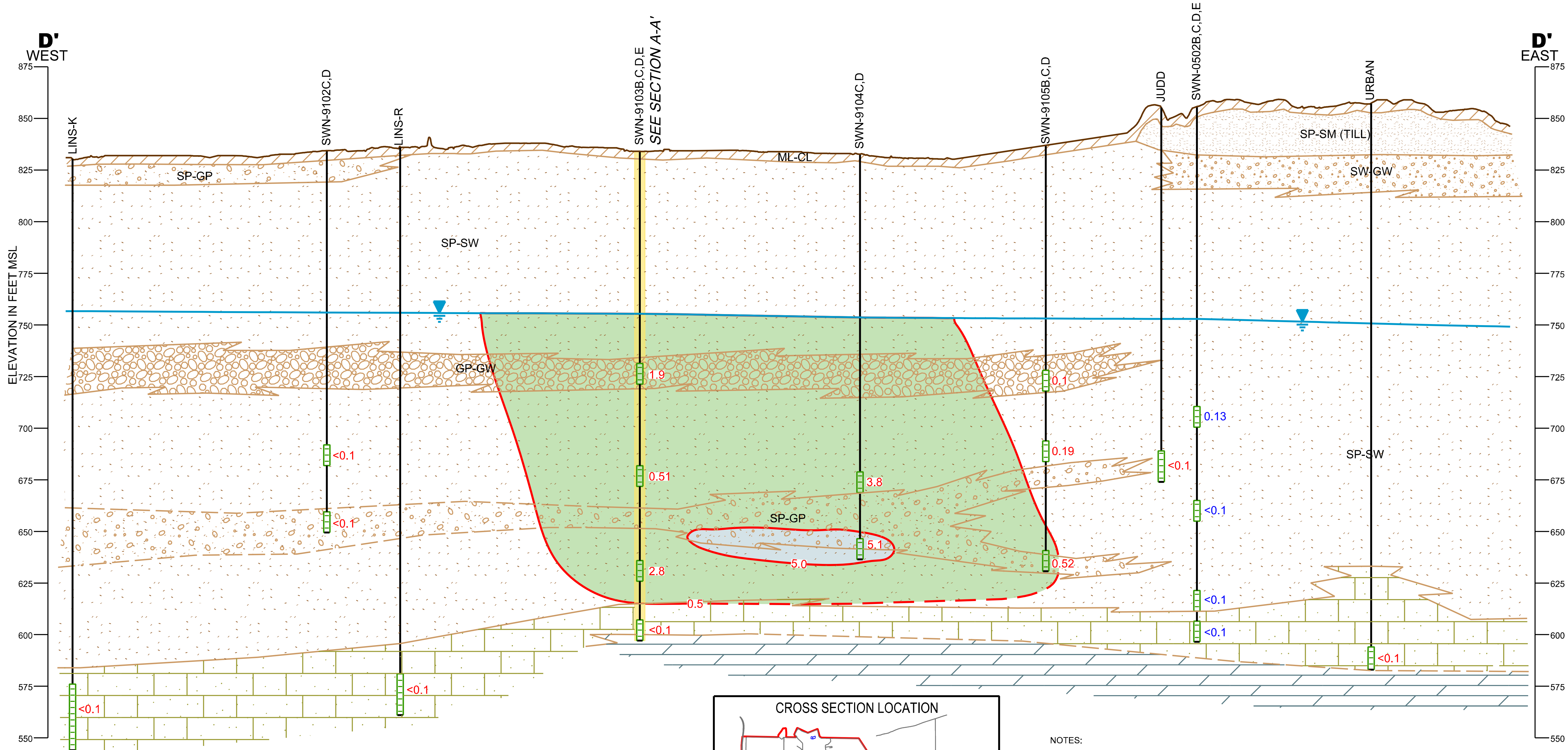
- FILL — FILL MATERIAL
- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP — GRAVEL, POORLY GRADED, GLACIAL TILL
- GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
- GW — GRAVEL, WELL GRADED, GLACIAL OUTWASH
- GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)
- BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
- BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE)
- BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE)

FIGURE 25

CARBON TETRACHLORIDE ISOCONCENTRATION CROSS SECTION C-C'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

3.2 / 0.13 CARBON TETRACHLORIDE CONCENTRATION µg/l

BOTTOM OF EXPLORATION

0.5 CARBON TETRACHLORIDE ISOCONCENTRATION LINE (µg/l)

## GEOLOGIC DESCRIPTIONS:

ML-CL SILT AND CLAY MIXTURE, LOESS

SP-SM SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL

SP-GP SAND AND GRAVEL, GLACIAL OUTWASH

SW-GW SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH

SP-SW SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH

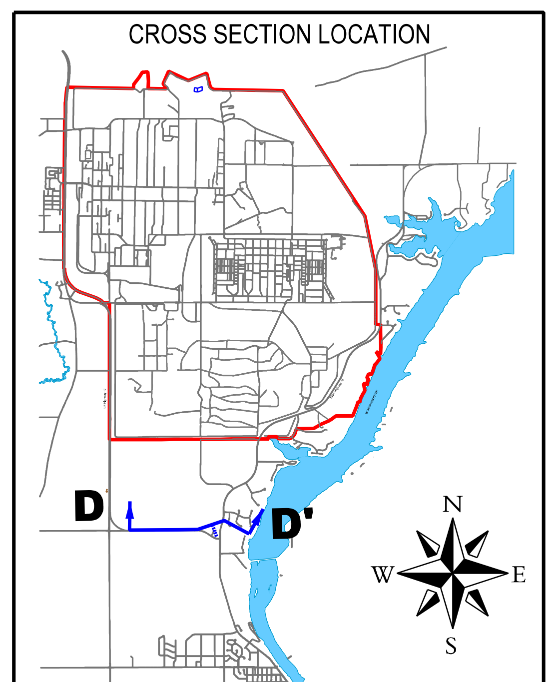
GP-GW GRAVEL, GLACIAL OUTWASH

BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)

BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)

CARBON TETRACHLORIDE CONCENTRATION (µg/l)

0.5 - 5.0    >5.0




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. CARBON TETRACHLORIDE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED AND 11/14 SHOWN IN BLUE.
   ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

25 VERTICAL 0 HORIZONTAL 250

SCALE IN FEET

VERTICAL EXAGGERATION 1:10

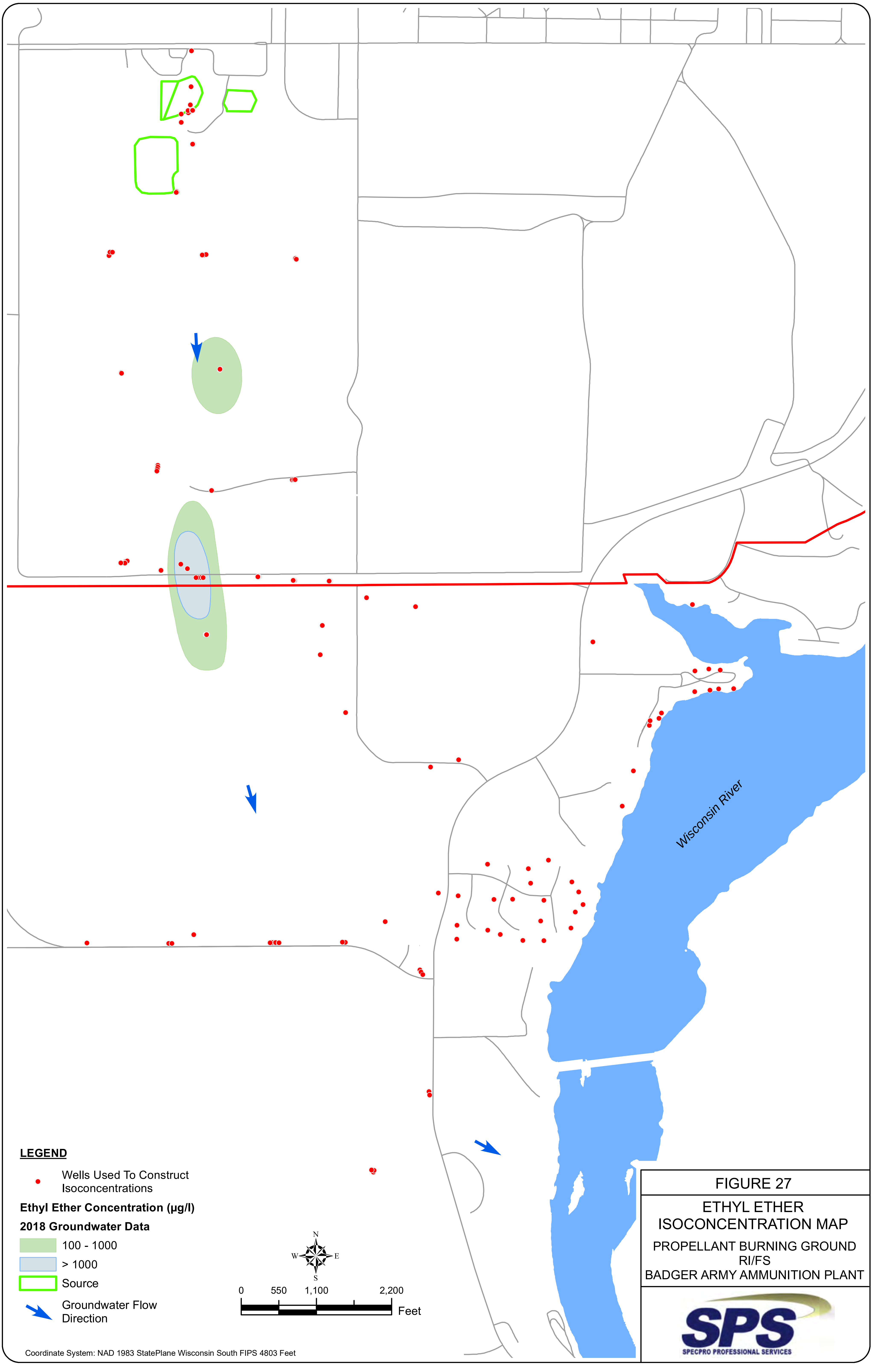
FIGURE 26

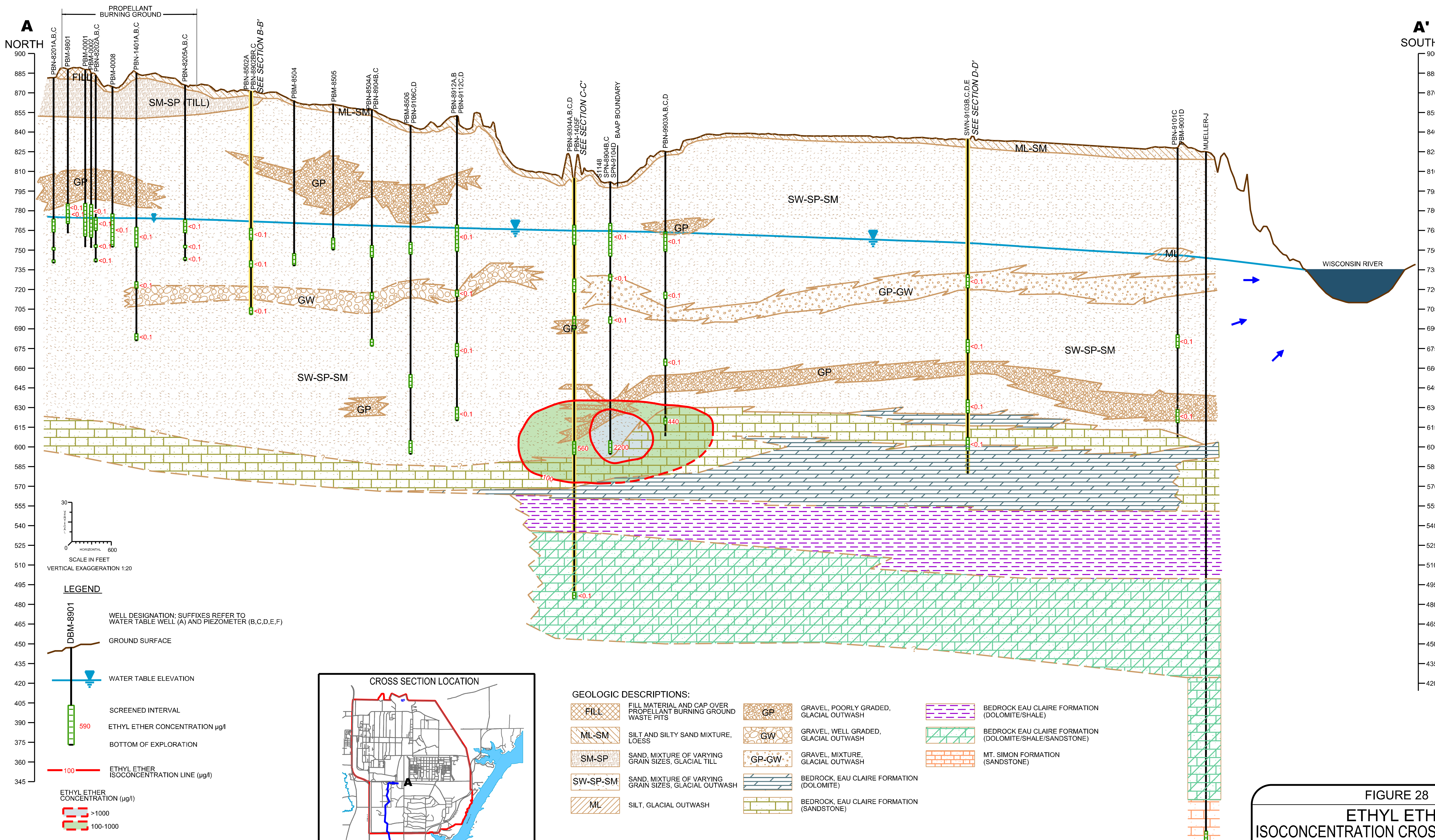
CARBON TETRACHLORIDE ISOCONCENTRATION CROSS SECTION D-D'

PROPELLANT BURNING GROUND RI/FS

BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Ethyl Ether Concentration (µg/l)
2018 Groundwater Data
100 - 1000
> 1000
Source
Groundwater Flow Direction
N
W
E
S
0
550
1,100
2,200
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 27
ETHYL ETHER ISOCONCENTRATION MAP
PROPELLANT BURNING GROUND RI/FS
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:

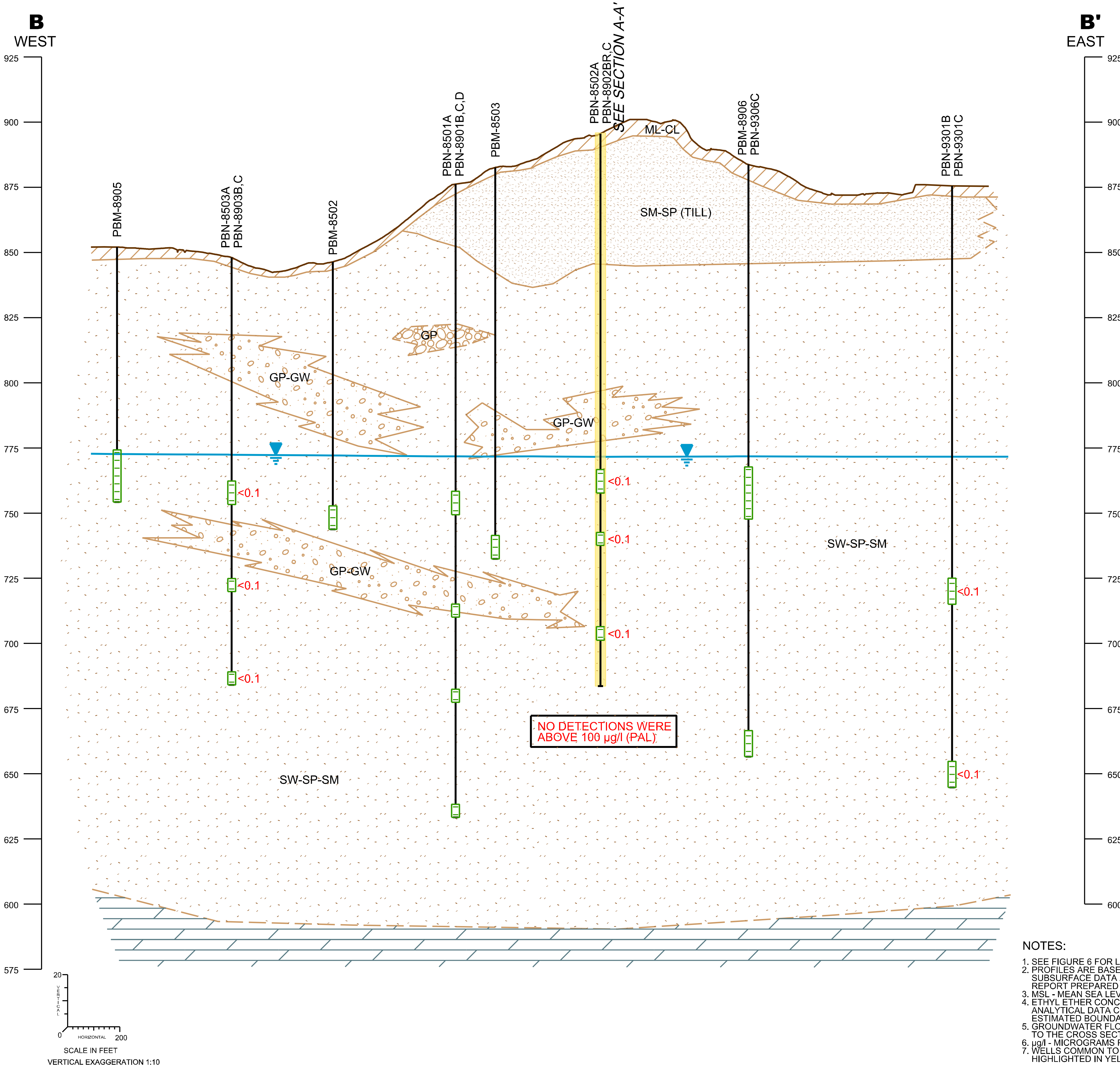
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. ETHYL ETHER CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 28

# ETHYL ETHER ISOCONCENTRATION CROSS SECTION A-A'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

<0.1 — ETHYL ETHER CONCENTRATION µg/l

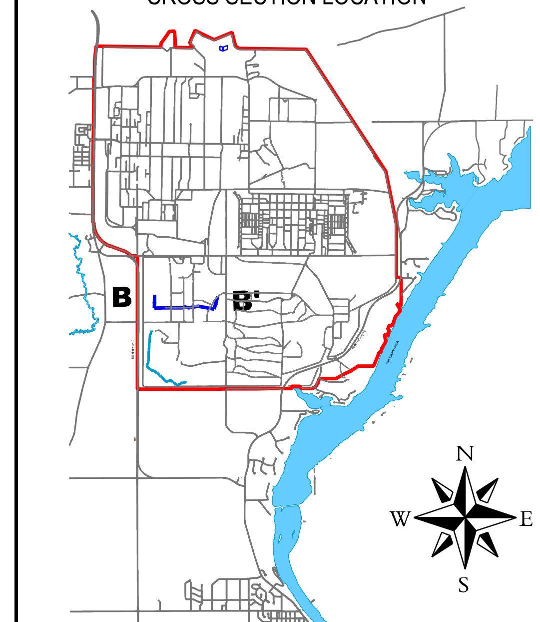
BOTTOM OF EXPLORATION

100 — ETHYL ETHER ISOCONCENTRATION LINE (µg/l)

### GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
- GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)

CROSS SECTION LOCATION




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. ETHYL ETHER CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 29

ETHYL ETHER
ISOCONCENTRATION CROSS SECTION B-B'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES

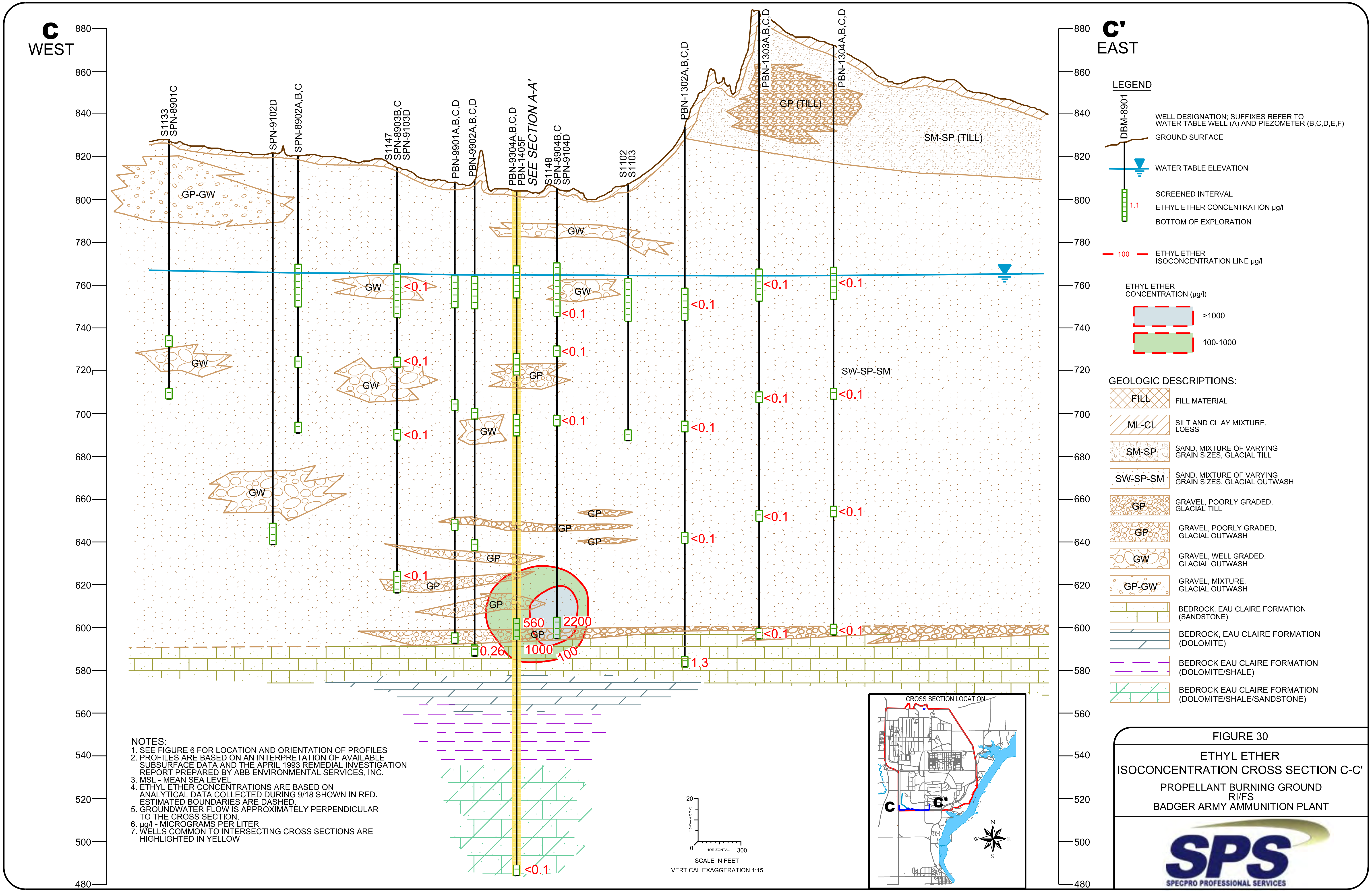
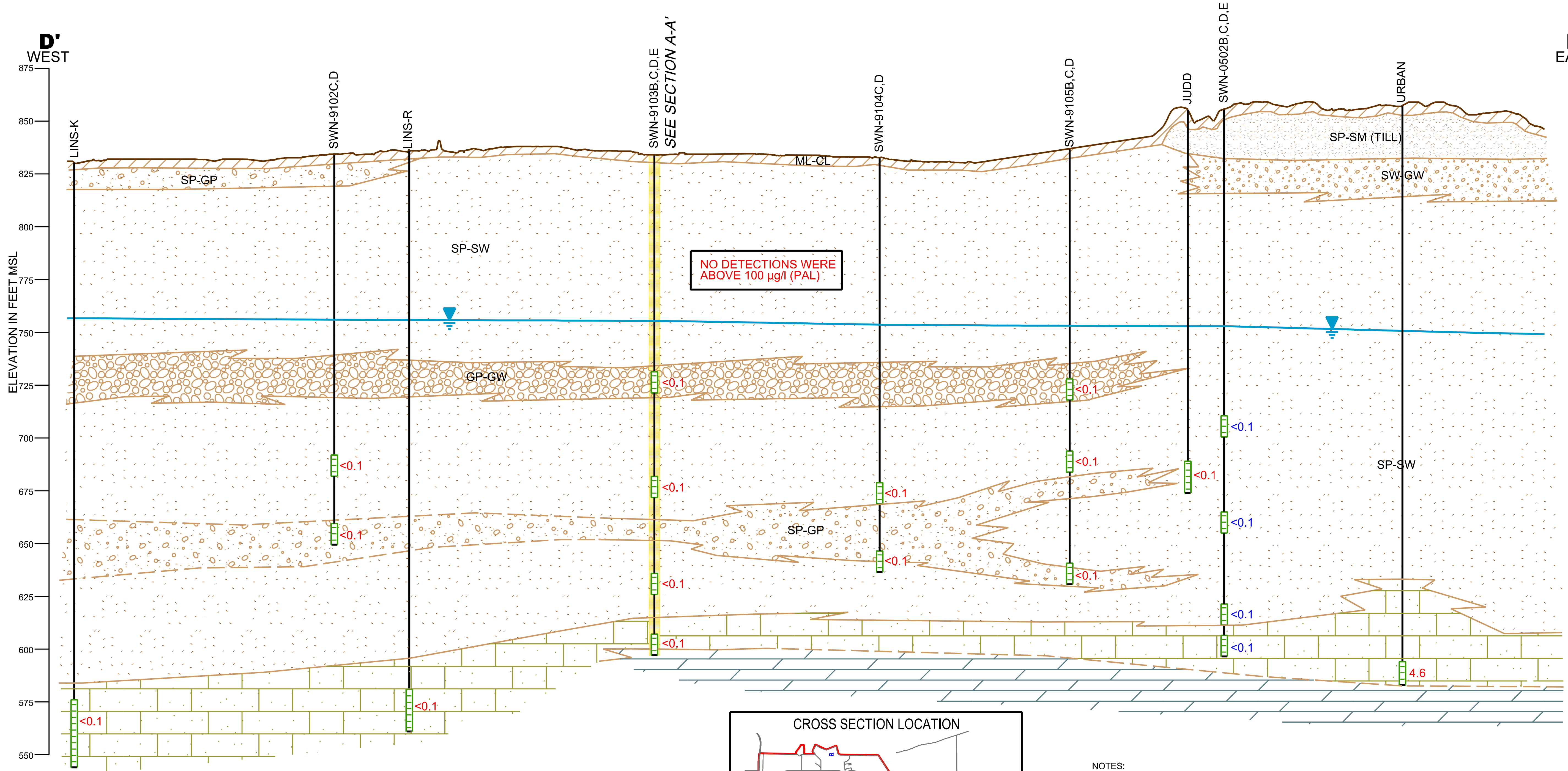



FIGURE 30

ETHYL ETHER
ISOCONCENTRATION CROSS SECTION C-C'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

<0.1 — ETHYL ETHER CONCENTRATION µg/l

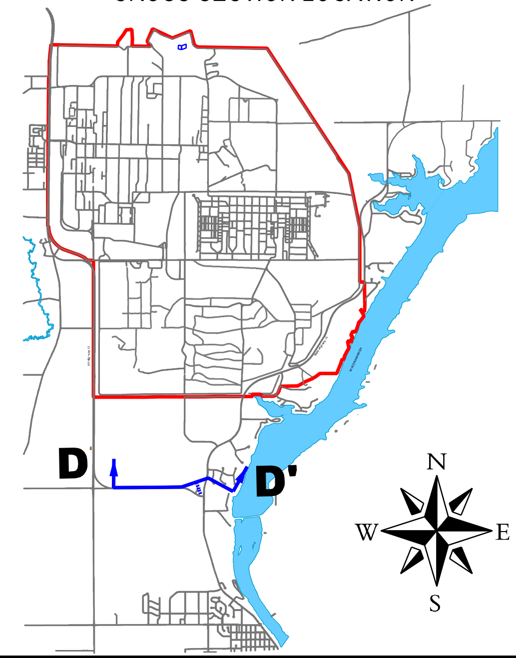
BOTTOM OF EXPLORATION

100 — ETHYL ETHER ISOCONCENTRATION LINE (µg/l)

## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SP-GP | SAND AND GRAVEL, GLACIAL OUTWASH |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SP-SW | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| GP-GW | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |

## CROSS SECTION LOCATION




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. ETHYL ETHER CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED AND 11/14 SHOWN IN BLUE. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

25 VERTICAL 0 HORIZONTAL 250

SCALE IN FEET

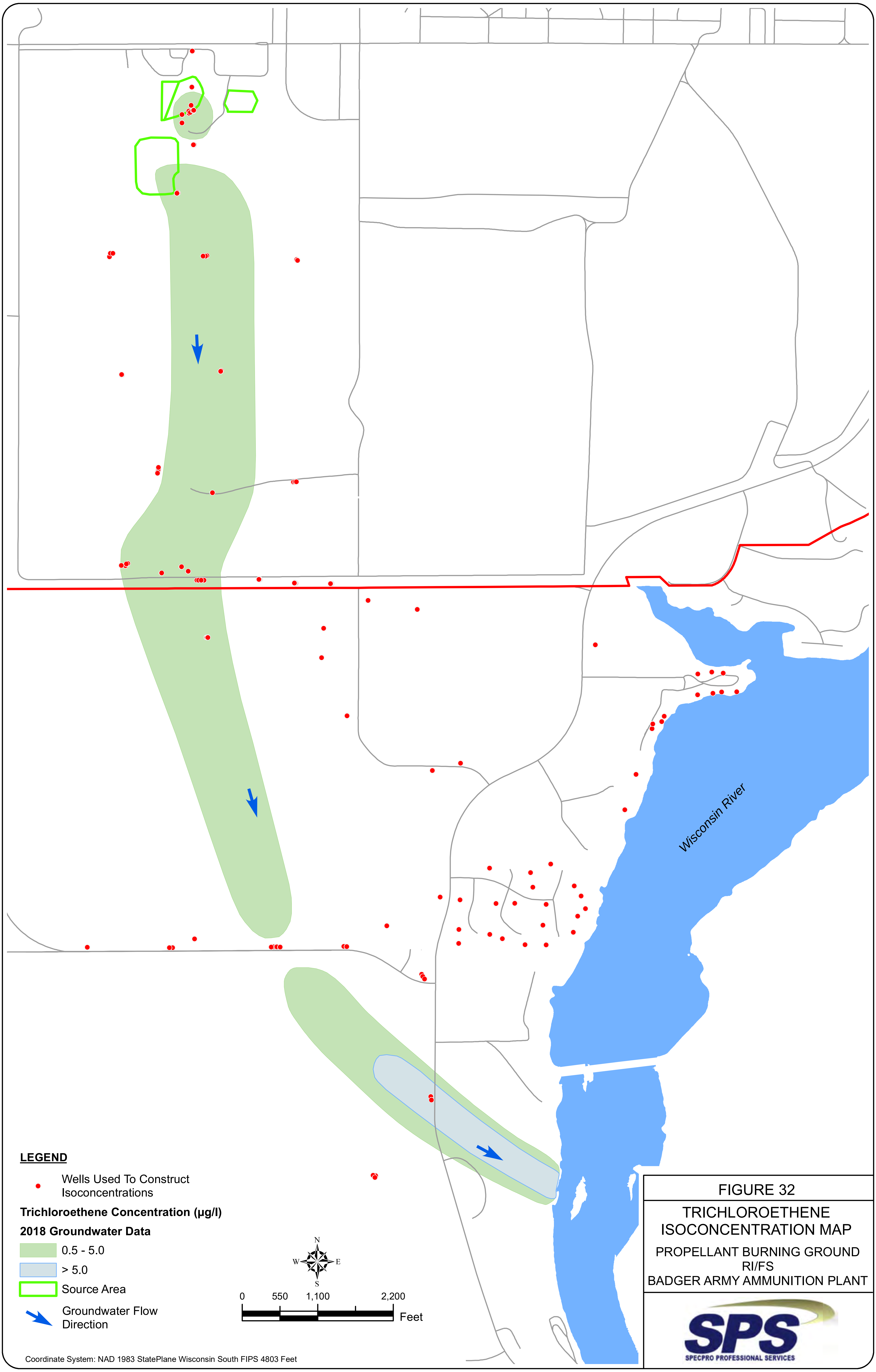
VERTICAL EXAGGERATION 1:10

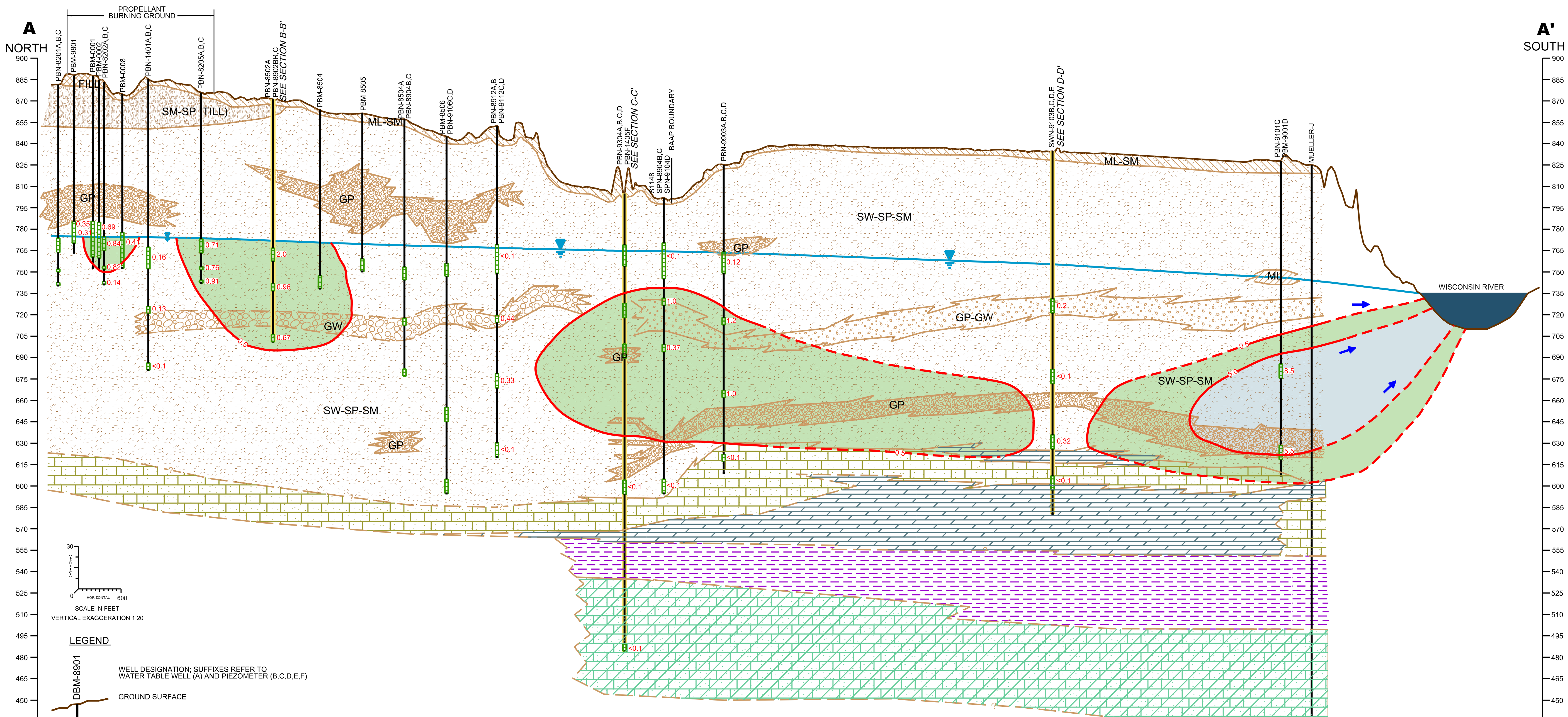
FIGURE 31

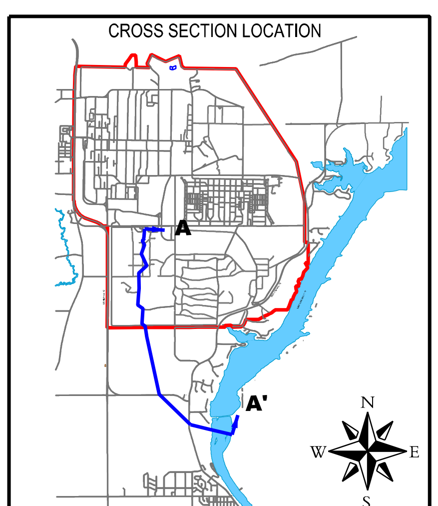
ETHYL ETHER
ISOCONCENTRATION CROSS SECTION D-D'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS SPECPRO PROFESSIONAL SERVICES


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Trichloroethene Concentration (µg/l)
2018 Groundwater Data
0.5 - 5.0
> 5.0
Source Area
Groundwater Flow Direction
N
W
E
S
0
550
1,100
2,200
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 32
TRICHLOROETHENE ISOCONCENTRATION MAP
PROPELLANT BURNING GROUND RI/FS
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES




GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| | MT. SIMON FORMATION (SANDSTONE) |

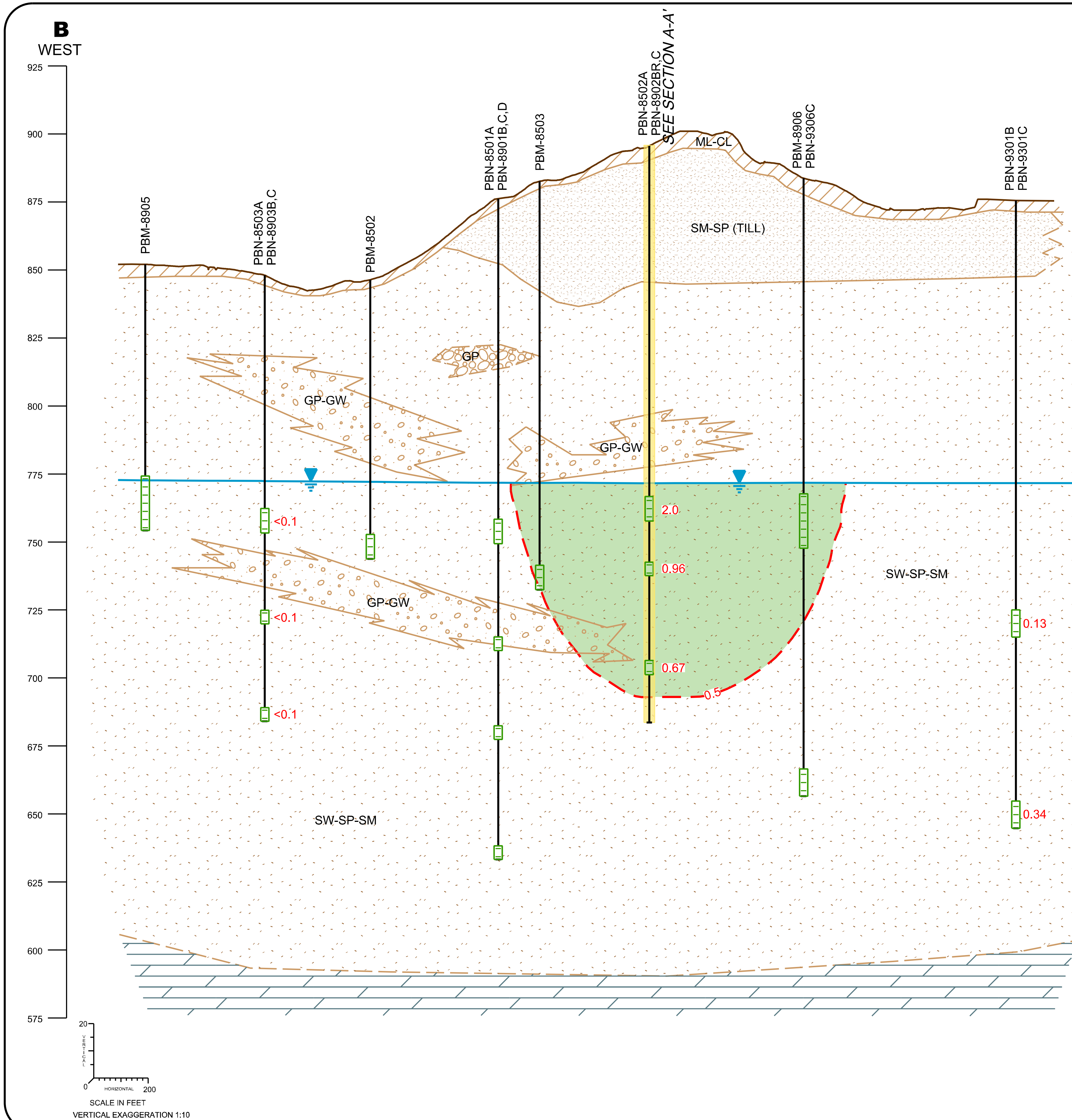
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TRICHLOROETHENE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

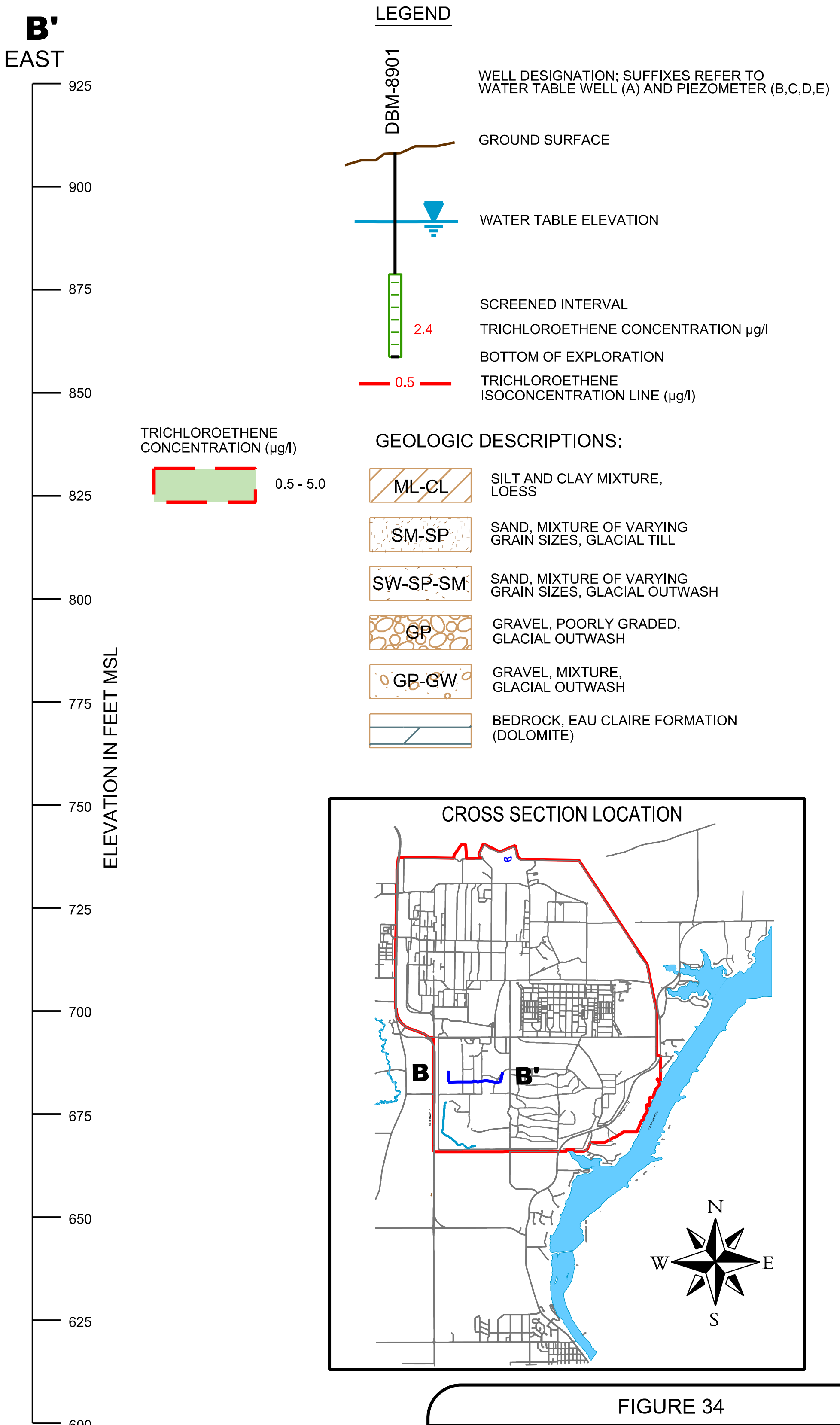
FIGURE 33

# TRICHLOROETHENE ISOCONCENTRATION CROSS SECTION A-A'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:

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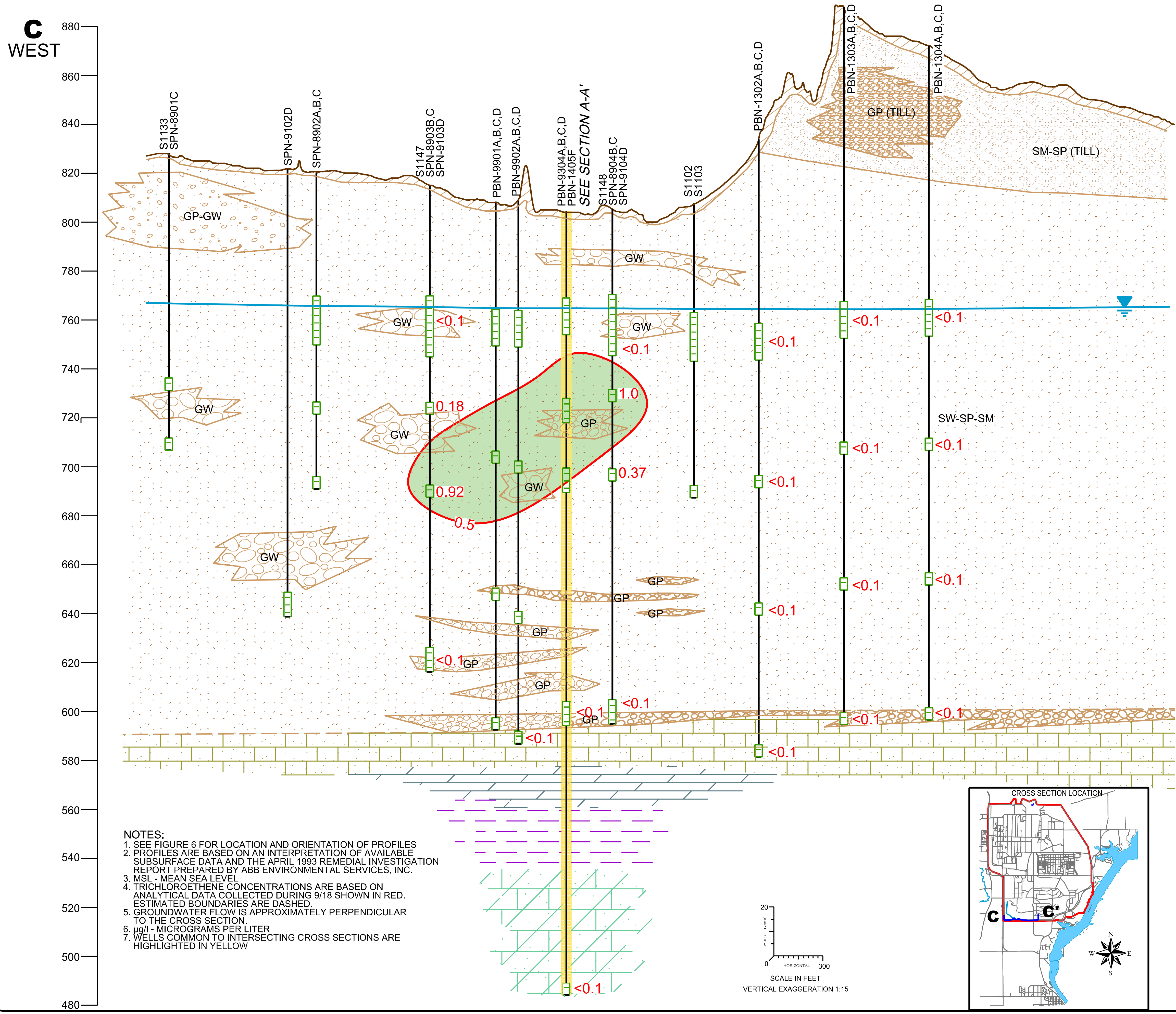
4. TRICHLOROETHENE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 34

TRICHLOROETHENE ISOCONCENTRATION CROSS SECTION B-B'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:
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3. MSL - MEAN SEA LEVEL
4. TRICHLOROETHENE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

SCALE IN FEET
VERTICAL EXAGGERATION 1:15

CROSS SECTION LOCATION

LEGEND

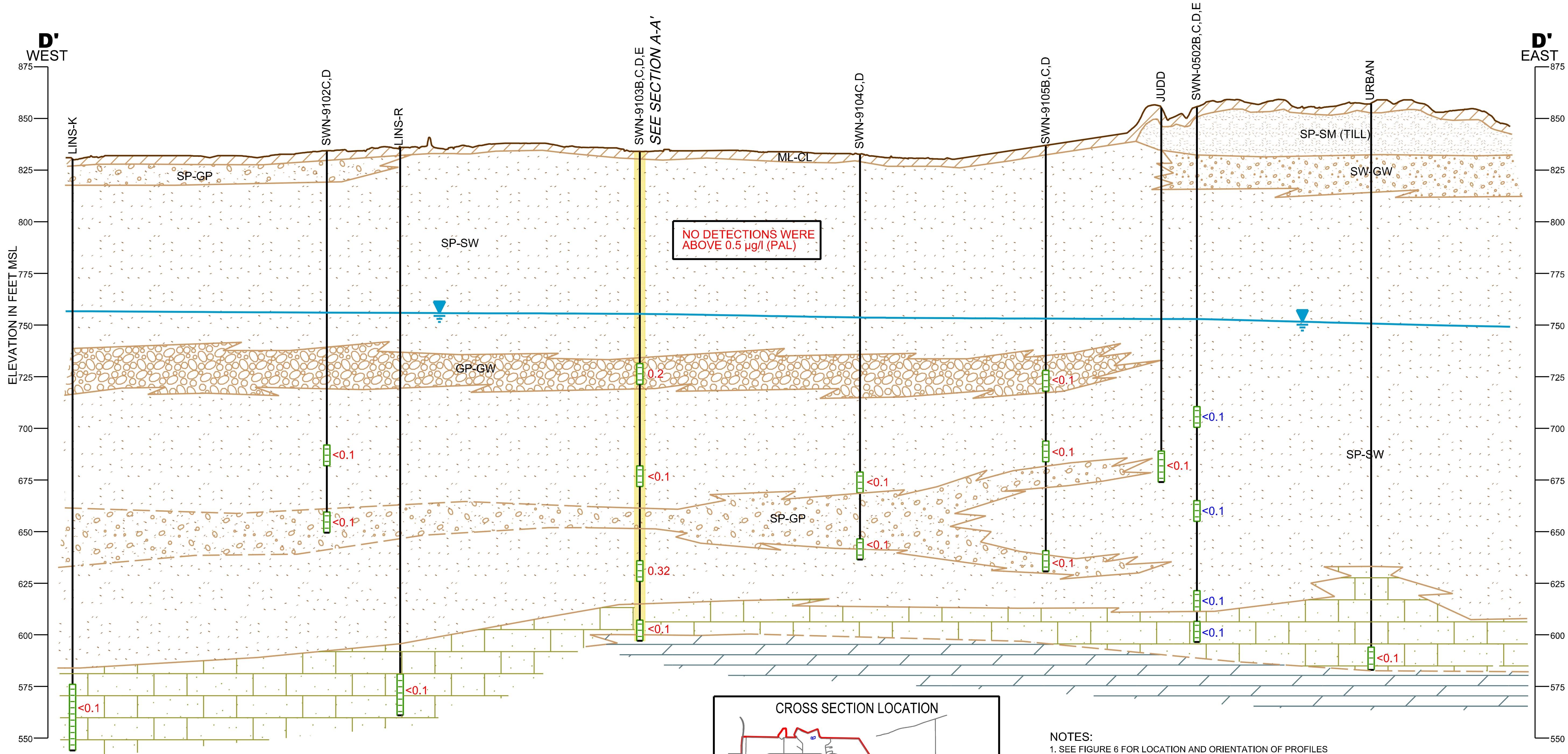
DBM-8901 WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)
GROUND SURFACE
WATER TABLE ELEVATION
SCREENED INTERVAL
0.36 TRICHLOROETHENE CONCENTRATION µg/l
BOTTOM OF EXPLORATION
0.5 TRICHLOROETHENE ISOCONCENTRATION LINE µg/l

TRICHLOROETHENE CONCENTRATION (µg/l)
0.5 - 5.0

GEOLOGIC DESCRIPTIONS:
FILL — FILL MATERIAL
ML-CL — SILT AND CL AY MIXTURE, LOESS
SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
GP — GRAVEL, POORLY GRADED, GLACIAL TILL
GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
GW — GRAVEL, WELL GRADED, GLACIAL OUTWASH
GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)
BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE)

FIGURE 35
TRICHLOROETHENE ISOCONCENTRATION CROSS SECTION C-C'
PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




# LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

1.2 — TRICHLOROETHENE CONCENTRATION µg/l

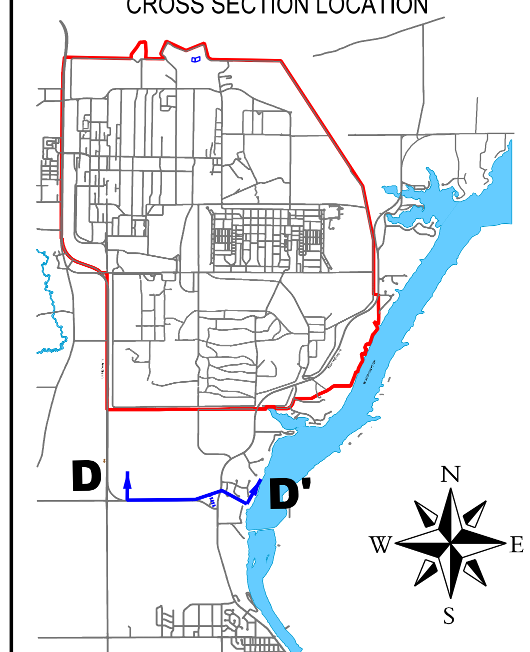
BOTTOM OF EXPLORATION

0.5 — TRICHLOROETHENE ISOCONCENTRATION LINE (µg/l)

# GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SP-GP — SAND AND GRAVEL, GLACIAL OUTWASH
- SW-GW — SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH
- SP-SW — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP-GW — GRAVEL, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
- BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)

## CROSS SECTION LOCATION




## NOTES:

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2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TRICHLOROETHENE CONCENTRATIONS ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 SHOWN IN RED AND 11/14 SHOWN IN BLUE.
   ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO THE CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

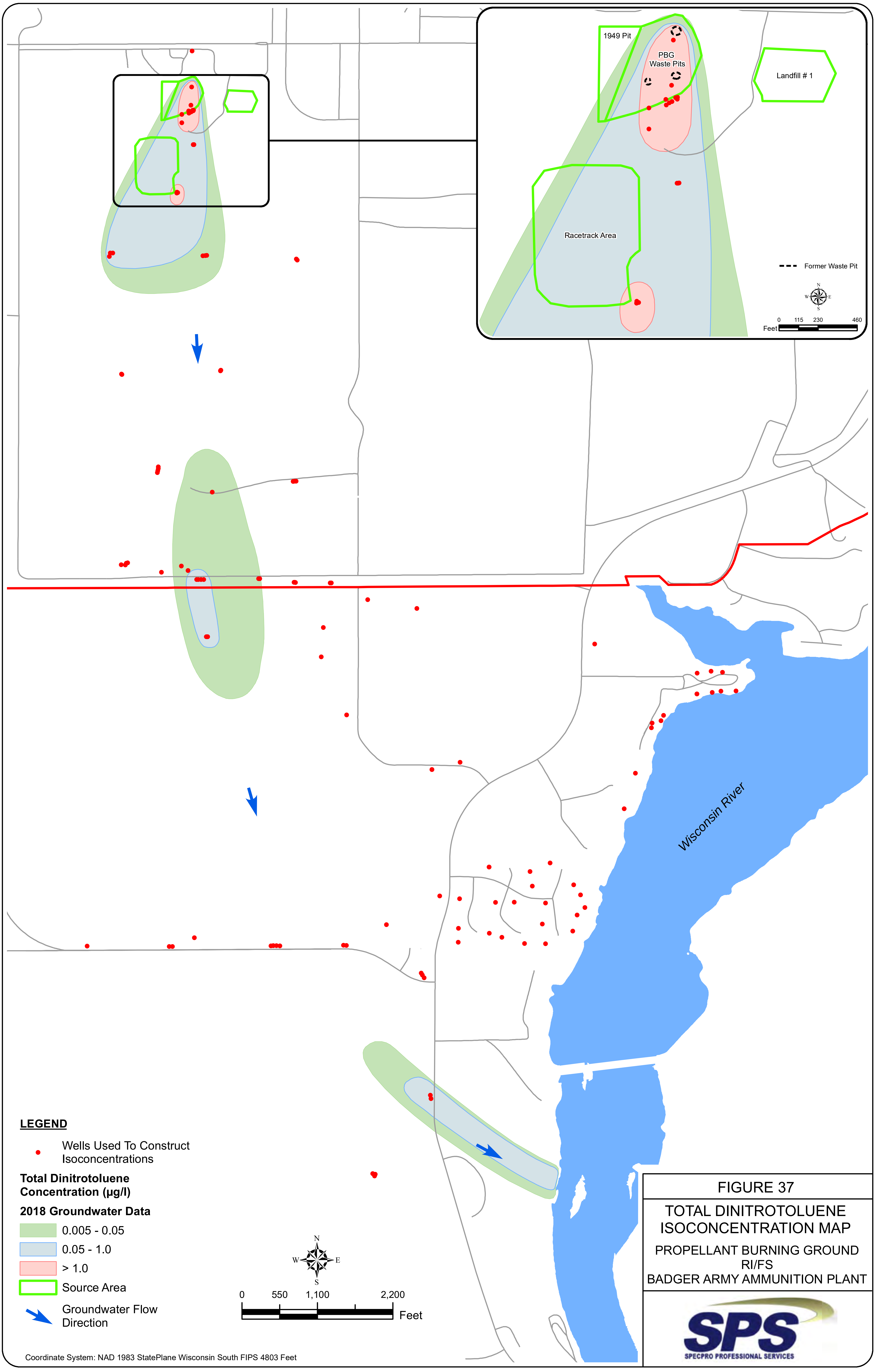
25 VERTICAL 0 HORIZONTAL 250
SCALE IN FEET
VERTICAL EXAGGERATION 1:10

FIGURE 36

TRICHLOROETHENE
ISOCONCENTRATION CROSS SECTION D-D'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




LEGEND

Wells Used To Construct Isoconcentrations

**Total Dinitrotoluene Concentration (µg/l)**

**2018 Groundwater Data**

0.005 - 0.05

0.05 - 1.0

> 1.0

Source Area

Groundwater Flow Direction

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet

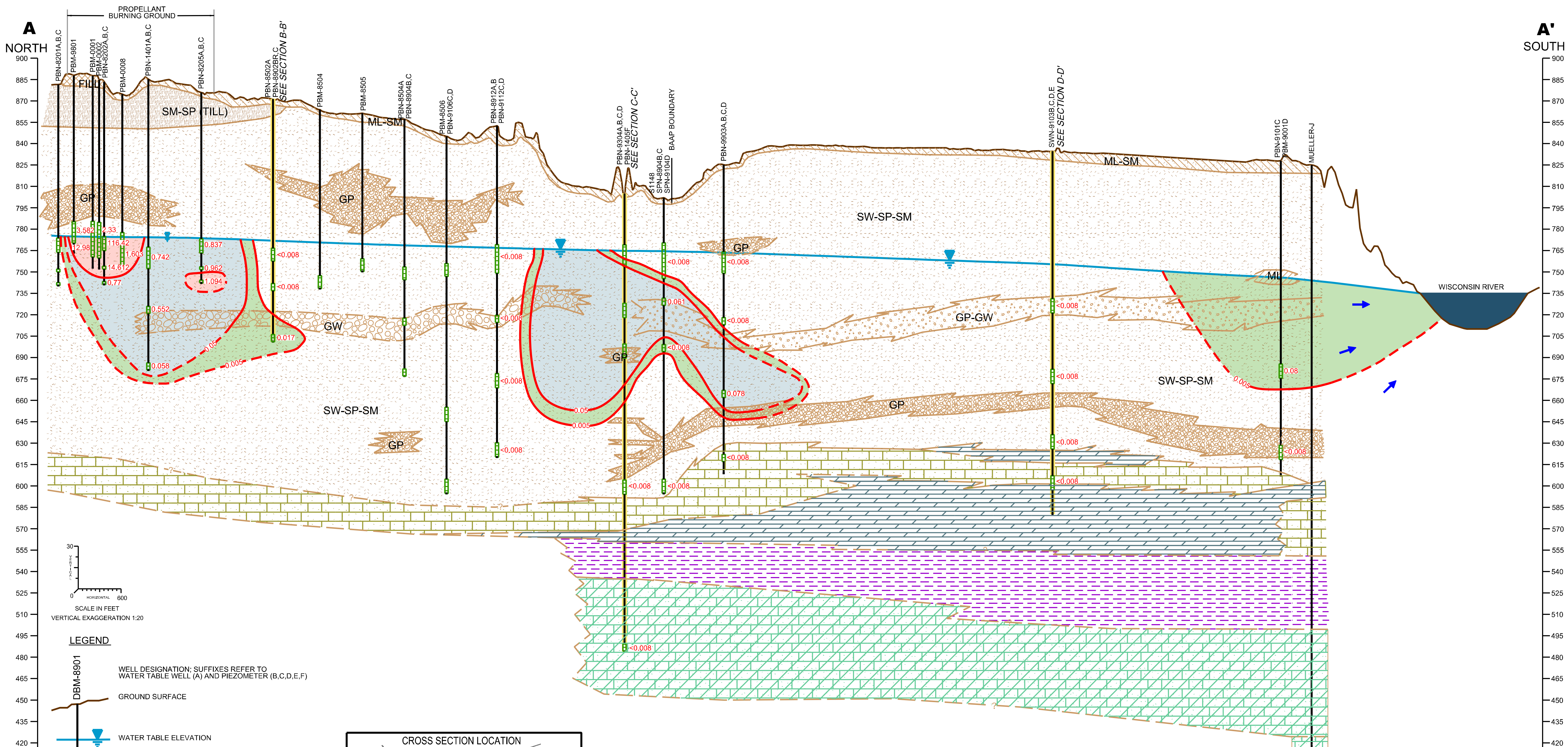
FIGURE 37

TOTAL DINITROTOLUENE ISOCONCENTRATION MAP

PROPELLANT BURNING GROUND RI/FS

BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

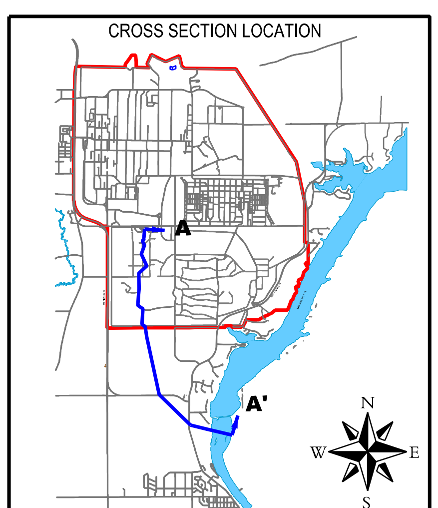
0.008 — TOTAL DINITROTOLUENE CONCENTRATION µg/l

BOTTOM OF EXPLORATION

0.005 — TOTAL DINITROTOLUENE ISOCONCENTRATION LINE (µg/l)

TOTAL DINITROTOLUENE CONCENTRATION (µg/l)

- >1.0
- 0.05 - 1.0
- 0.005 - 0.05




## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH |
| GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH |
| GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| | MT. SIMON FORMATION (SANDSTONE) |

## NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

FIGURE 38

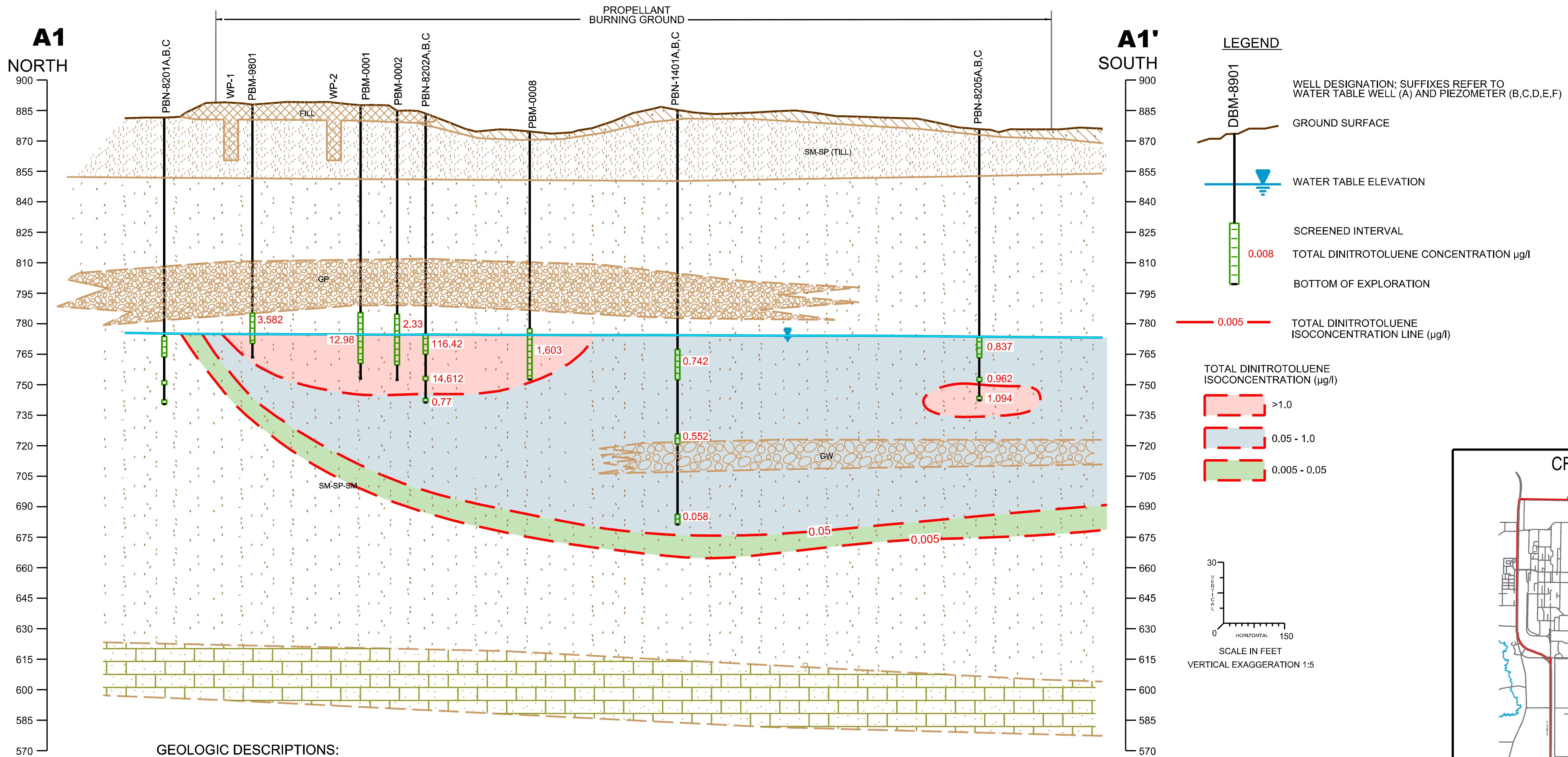
# TOTAL DINITROTOLUENE ISOCONCENTRATION CROSS SECTION A-A'

PROPELLANT BURNING GROUND

RI/FS

BADGER ARMY AMMUNITION PLANT

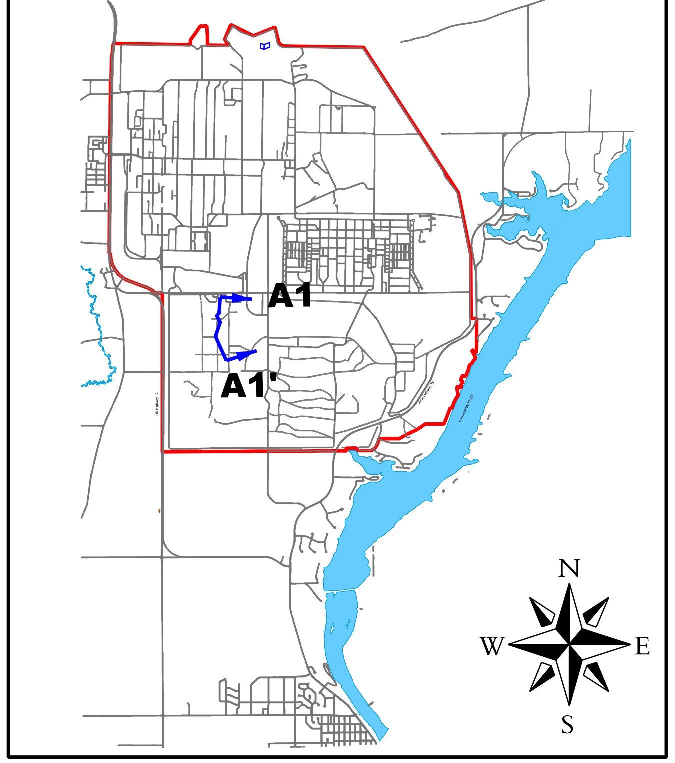
SPS SPECPRO PROFESSIONAL SERVICES




GEOLOGIC DESCRIPTIONS:

| | | | | | |
|---|---|---|---|---|---|
| FILL | FILL MATERIAL AND CAP OVER PROPELLANT BURNING GROUND WASTE PITS | GP | GRAVEL, POORLY GRADED, GLACIAL OUTWASH | | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE) |
| ML-SM | SILT AND SILTY SAND MIXTURE, LOESS | GW | GRAVEL, WELL GRADED, GLACIAL OUTWASH | | BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE) |
| SM-SP | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL | GP-GW | GRAVEL, MIXTURE, GLACIAL OUTWASH | | MT. SIMON FORMATION (SANDSTONE) |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH | | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) | | |
| ML | SILT, GLACIAL OUTWASH | | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) | | |

CROSS SECTION LOCATION



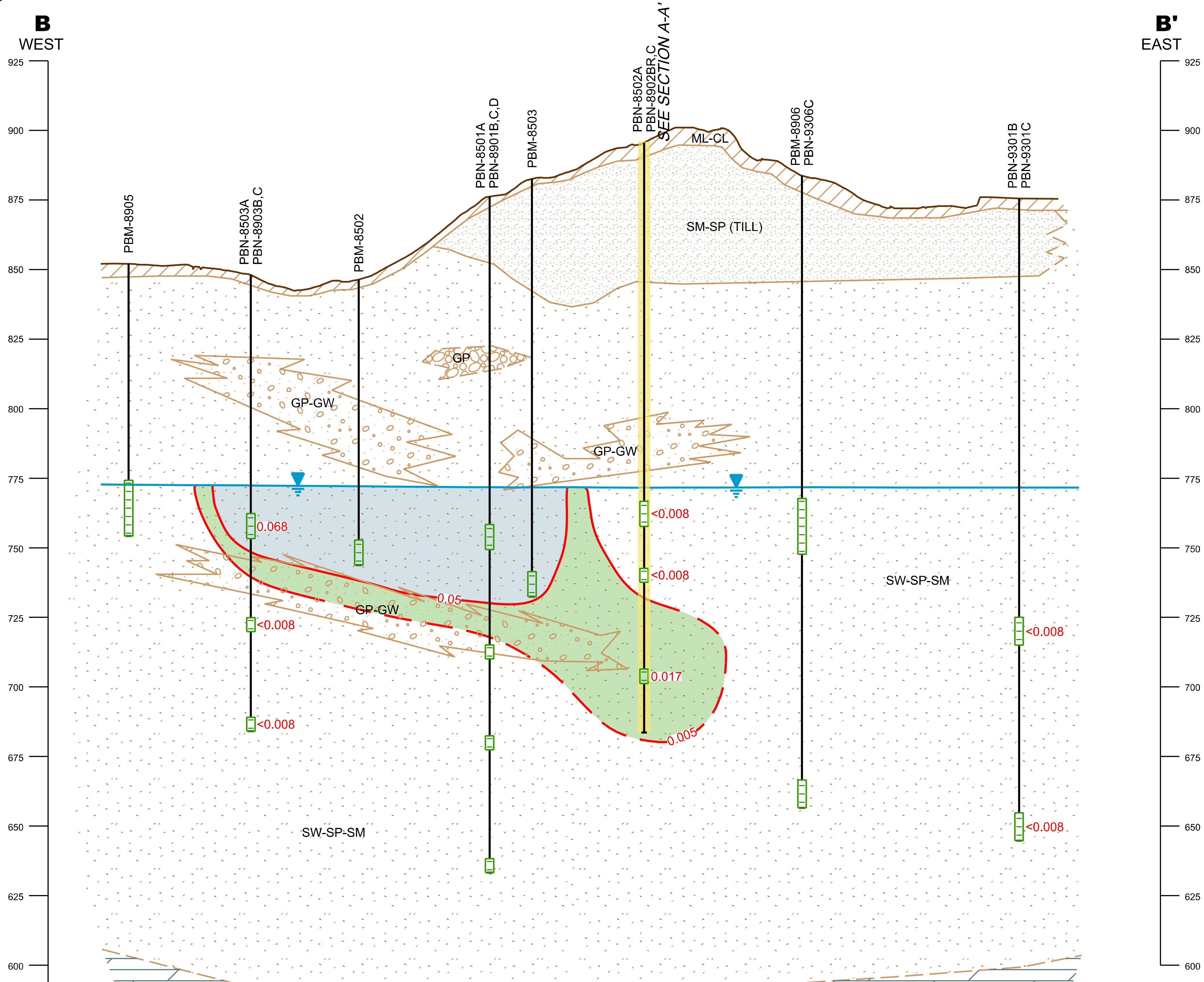

NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

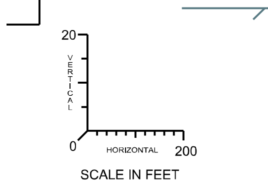
FIGURE 39

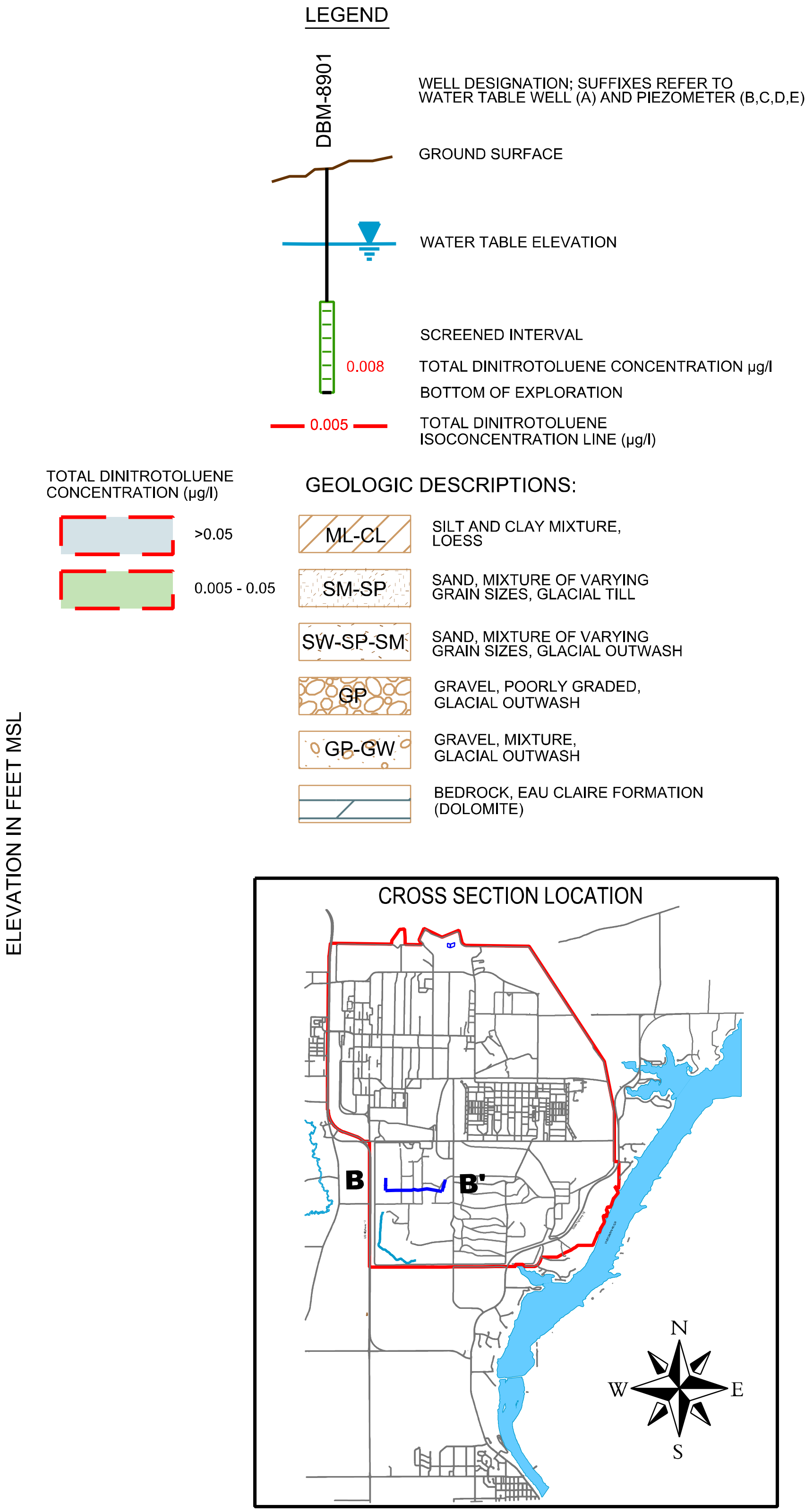
# TOTAL DINITROTOLUENE ISOCONCENTRATION CROSS SECTION A1-A1'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




NOTES:

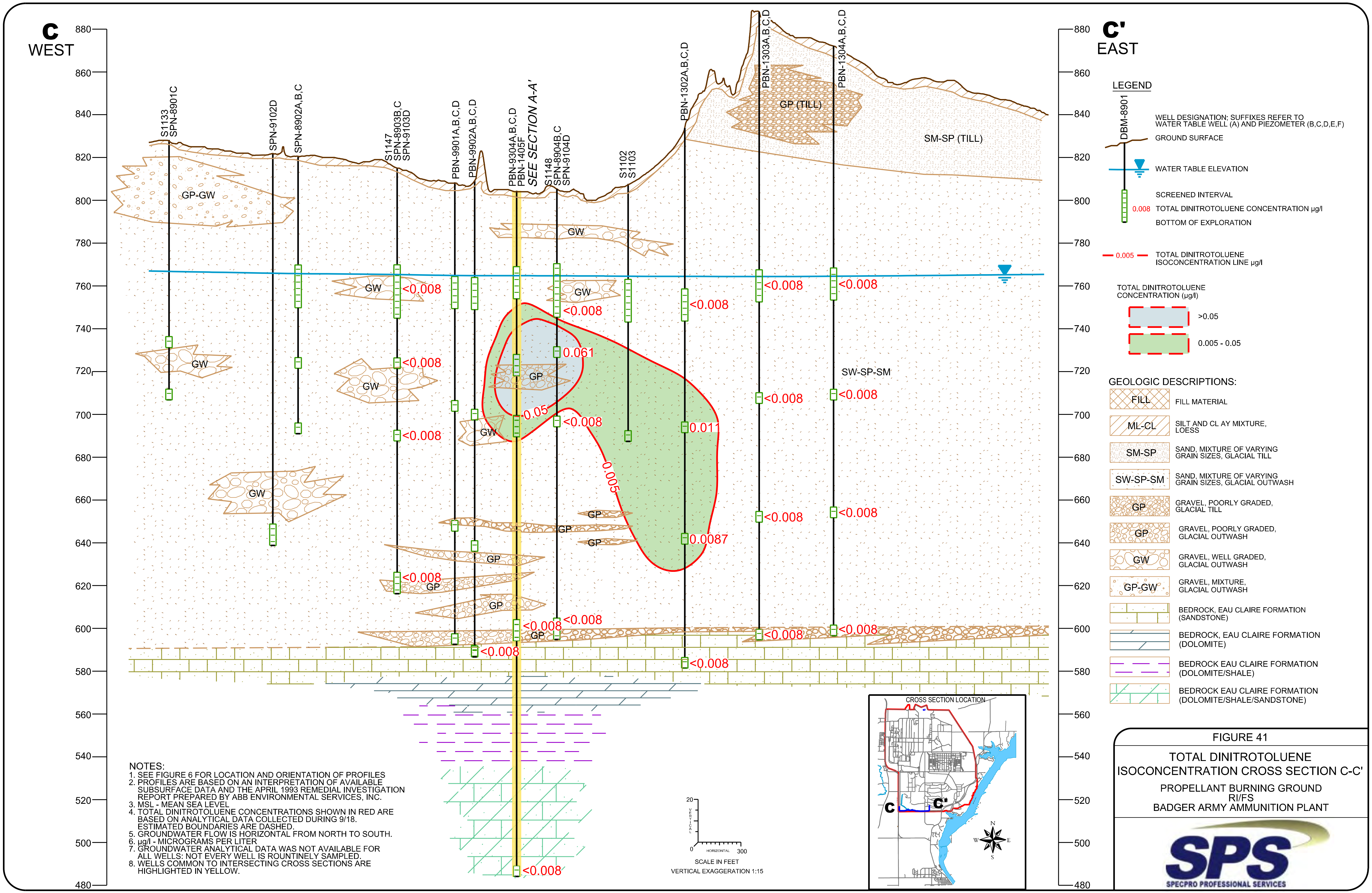
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

FIGURE 40

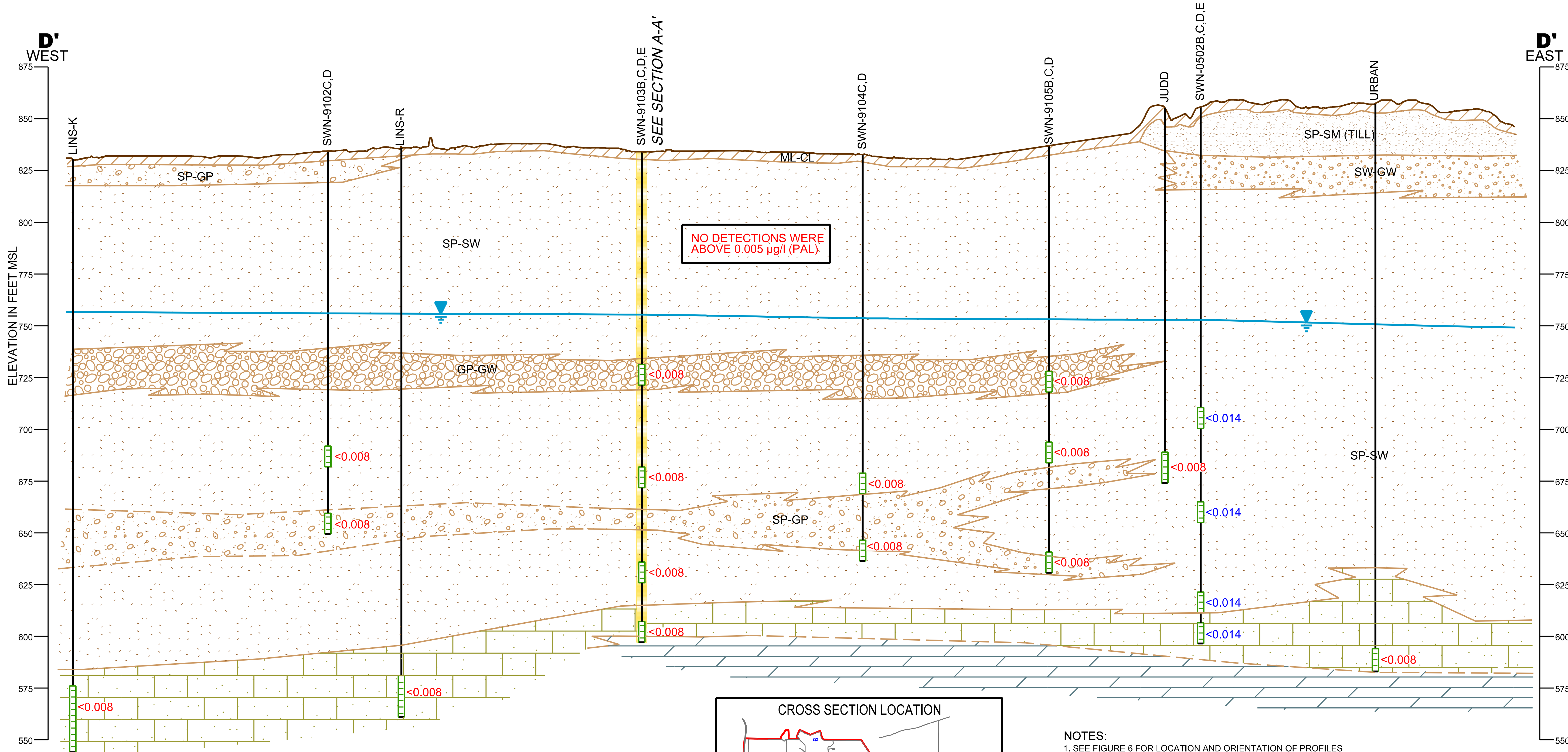
TOTAL DINITROTOLUENE
ISOCONCENTRATION CROSS SECTION B-B'

PROPELLANT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES



C
WEST
C'
EAST
880
860
840
820
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
S1133
SPN-8901C
SPN-9102D
SPN-8902A,B,C
S1147
SPN-8903B,C
SPN-9103D
PBN-9901A,B,C,D
PBN-9902A,B,C,D
PBN-9304A,B,C,D
PBN-1405F
SEE SECTION A-A'
S1148
SPN-8904B,C
SPN-9104D
S1102
S1103
PBN-1302A,B,C,D
PBN-1303A,B,C,D
PBN-1304A,B,C,D
GP-GW
GW
GP
GP (TILL)
SM-SP (TILL)
SW-SP-SM
<0.008
0.061
0.05
0.011
0.005
0.0087
LEGEND
DBM-8901
WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E,F)
GROUND SURFACE
WATER TABLE ELEVATION
SCREENED INTERVAL
0.008 TOTAL DINITROTOLUENE CONCENTRATION µg/l
BOTTOM OF EXPLORATION
0.005 TOTAL DINITROTOLUENE ISOCONCENTRATION LINE µg/l
TOTAL DINITROTOLUENE CONCENTRATION (µg/l)
>0.05
0.005 - 0.05
GEOLOGIC DESCRIPTIONS:
FILL — FILL MATERIAL
ML-CL — SILT AND CL AY MIXTURE, LOESS
SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
GP — GRAVEL, POORLY GRADED, GLACIAL TILL
GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
GW — GRAVEL, WELL GRADED, GLACIAL OUTWASH
GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)
BEDROCK, EAU CLAIRE FORMATION (DOLOMITE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE)
BEDROCK EAU CLAIRE FORMATION (DOLOMITE/SHALE/SANDSTONE)
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS; NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.
20
VERTICAL
0
HORIZONTAL
300
SCALE IN FEET
VERTICAL EXAGGERATION 1:15
CROSS SECTION LOCATION
C
C'
N
S
E
W
FIGURE 41
TOTAL DINITROTOLUENE ISOCONCENTRATION CROSS SECTION C-C'
PROPELLANT BURNING GROUND RI/FS
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES




## LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

0.008 — TOTAL DINITROTOLUENE CONCENTRATION µg/l

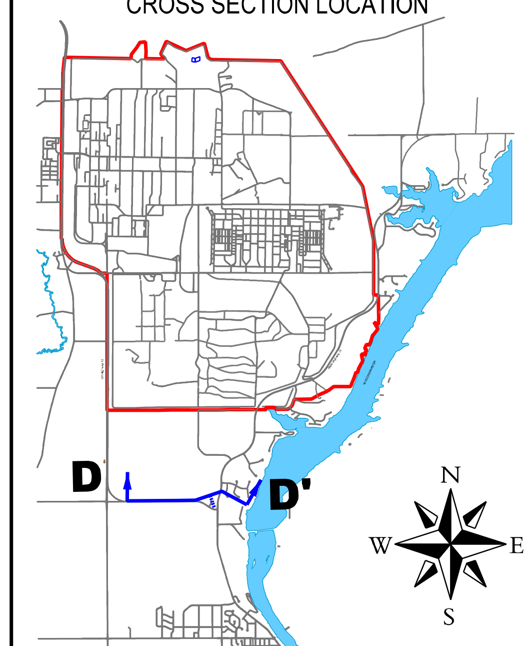
BOTTOM OF EXPLORATION

0.005 — TOTAL DINITROTOLUENE ISOCONCENTRATION LINE (µg/l)

## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SP-GP | SAND AND GRAVEL, GLACIAL OUTWASH |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SP-SW | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| GP-GW | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, EAU CLAIRE FORMATION (DOLOMITE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |

## CROSS SECTION LOCATION




## NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18 AND BLUE COLLECTED DURING 11/14 ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

25 VERTICAL 0 HORIZONTAL 250

SCALE IN FEET

VERTICAL EXAGGERATION 1:10

FIGURE 42

TOTAL DINITROTOLUENE ISOCONCENTRATION CROSS SECTION D-D'

PROPELLANT BURNING GROUND

RI/FS

BADGER ARMY AMMUNITION PLANT

SPS

SPECPRO PROFESSIONAL SERVICES

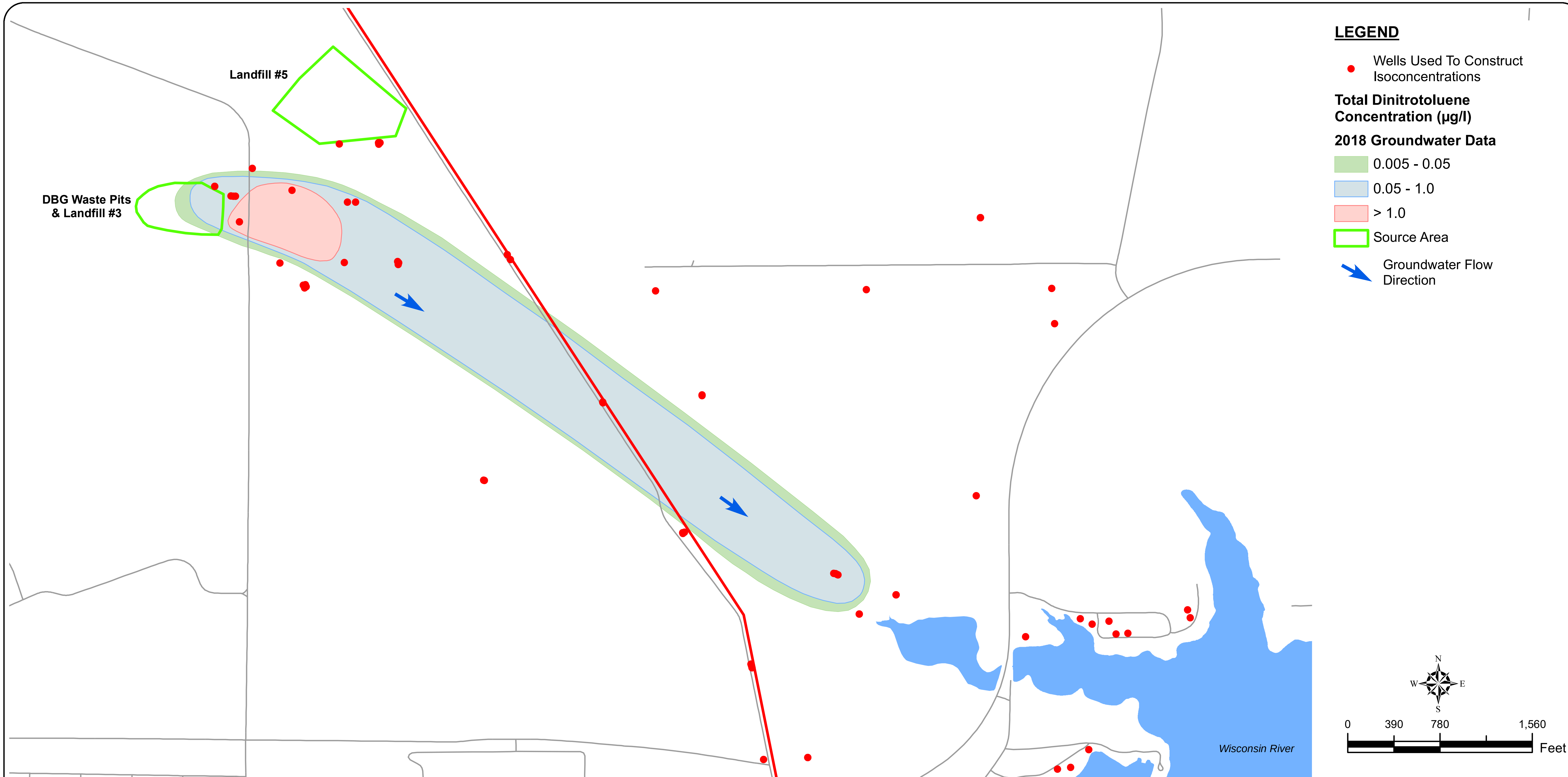
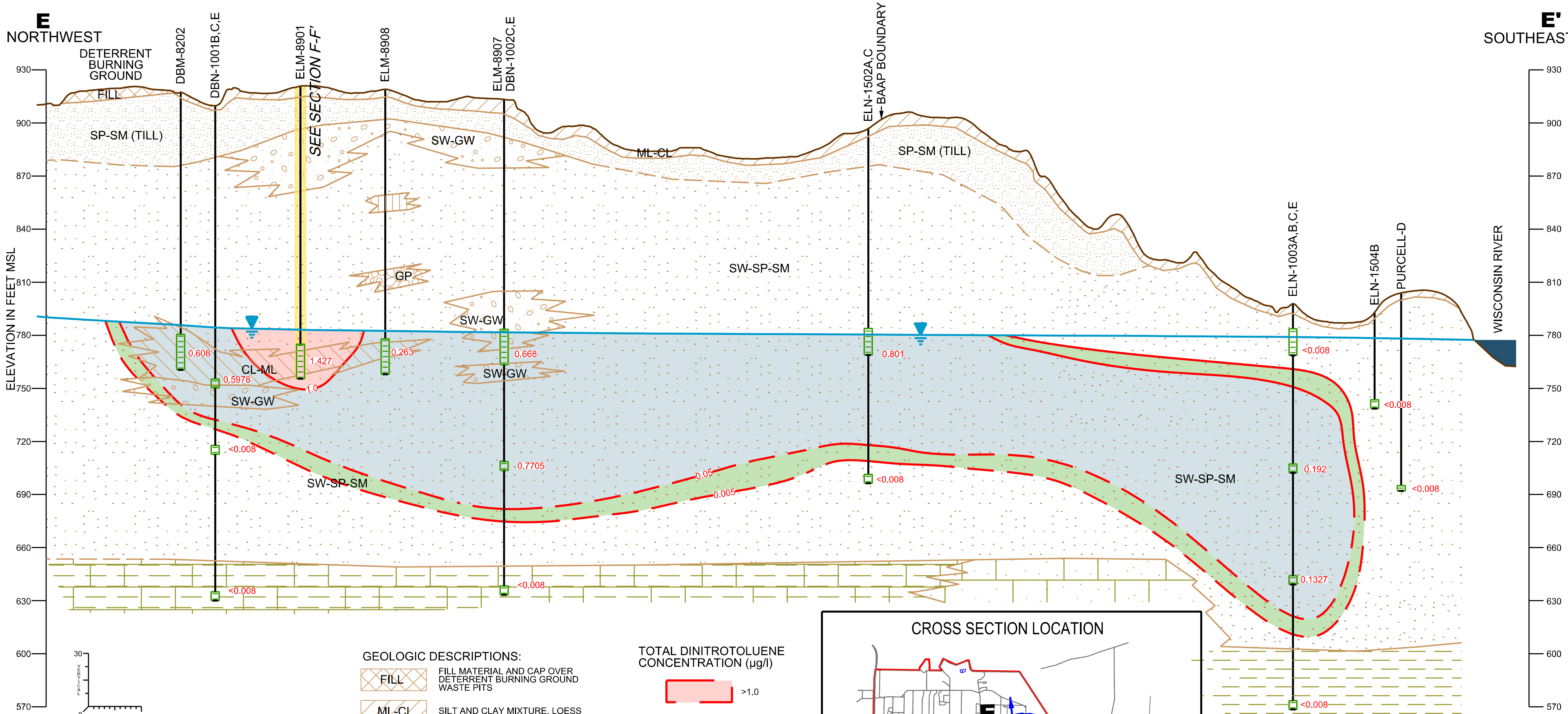



FIGURE 43

TOTAL DINITROTOLUENE ISOCONCENTRATION MAP

DETERRENT BURNING GROUND RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




## GEOLOGIC DESCRIPTIONS:

| | |
|---|---|
| FILL | FILL MATERIAL AND CAP OVER DETERRENT BURNING GROUND WASTE PITS |
| ML-CL | SILT AND CLAY MIXTURE, LOESS |
| SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL |
| SW-GW | SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH |
| SW-SP-SM | SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH |
| ML | SILT, GLACIAL OUTWASH |
| CL-ML | LAYERED CLAY AND SILT, GLACIAL OUTWASH |
| GP | GRAVEL, GLACIAL OUTWASH |
| | BEDROCK, SHALE, EAU CLAIRE FORMATION (INTERBEDDED SANDSTONE) |
| | BEDROCK, EAU CLAIRE FORMATION (SANDSTONE) |
| | BEDROCK, SHALE, EAU CLAIRE FORMATION (INTERBEDDED SILTSTONE) |

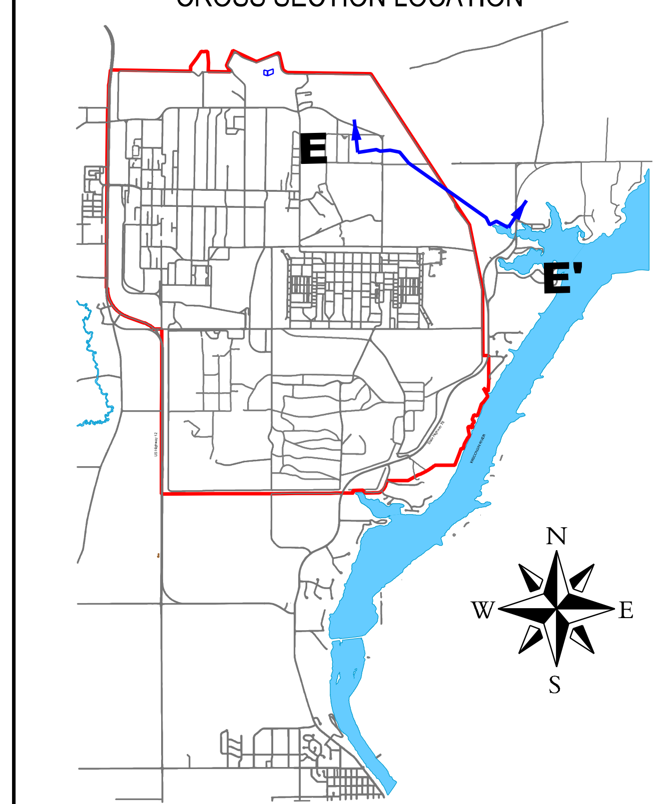
## TOTAL DINITROTOLUENE CONCENTRATION (µg/l)

- >1.0
- 0.05 - 1.0
- 0.005 - 0.05

## LEGEND

- DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)
- GROUND SURFACE
- WATER TABLE ELEVATION
- SCREENED INTERVAL
- 0.024 — TOTAL DINITROTOLUENE CONCENTRATION µg/l
- BOTTOM OF EXPLORATION
- 0.005 — TOTAL DINITROTOLUENE ISOCONCENTRATION LINE (µg/l)

## CROSS SECTION LOCATION




## NOTES:

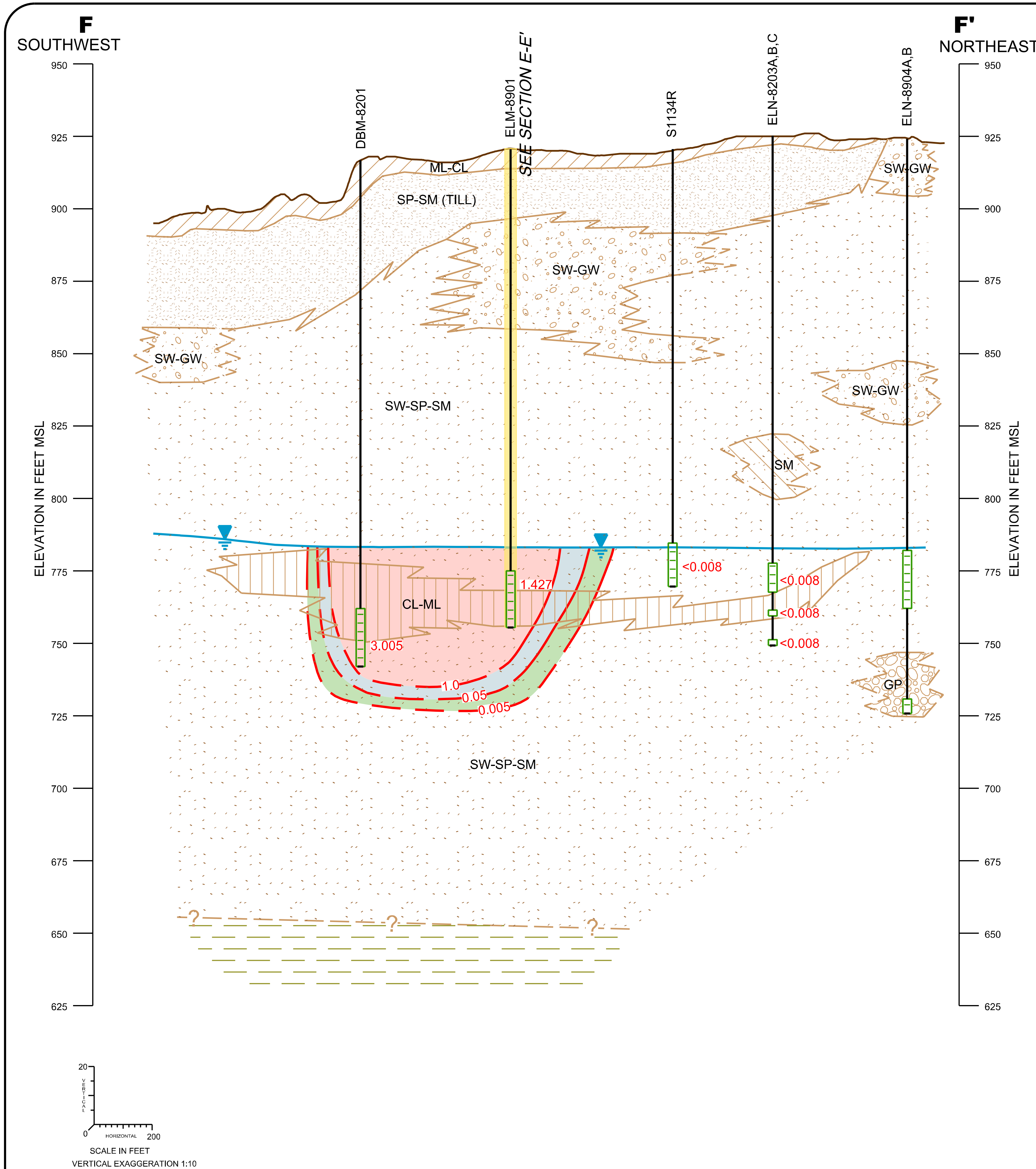
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTHWEST TO SOUTHEAST.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

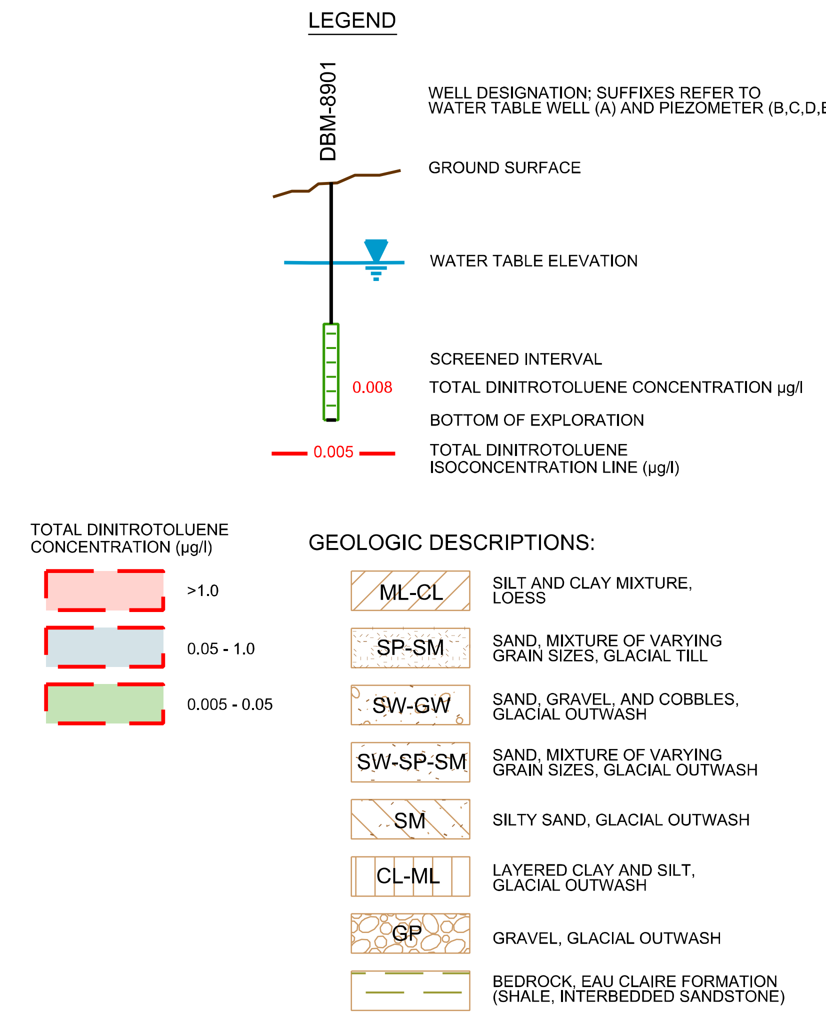
FIGURE 44

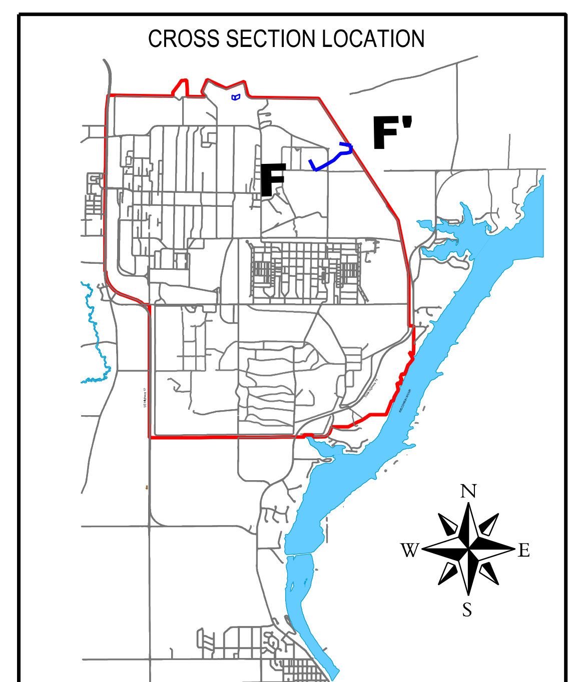
# TOTAL DINITROTOLUENE ISOCONCENTRATION SECTION E-E'

DETERRENT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:

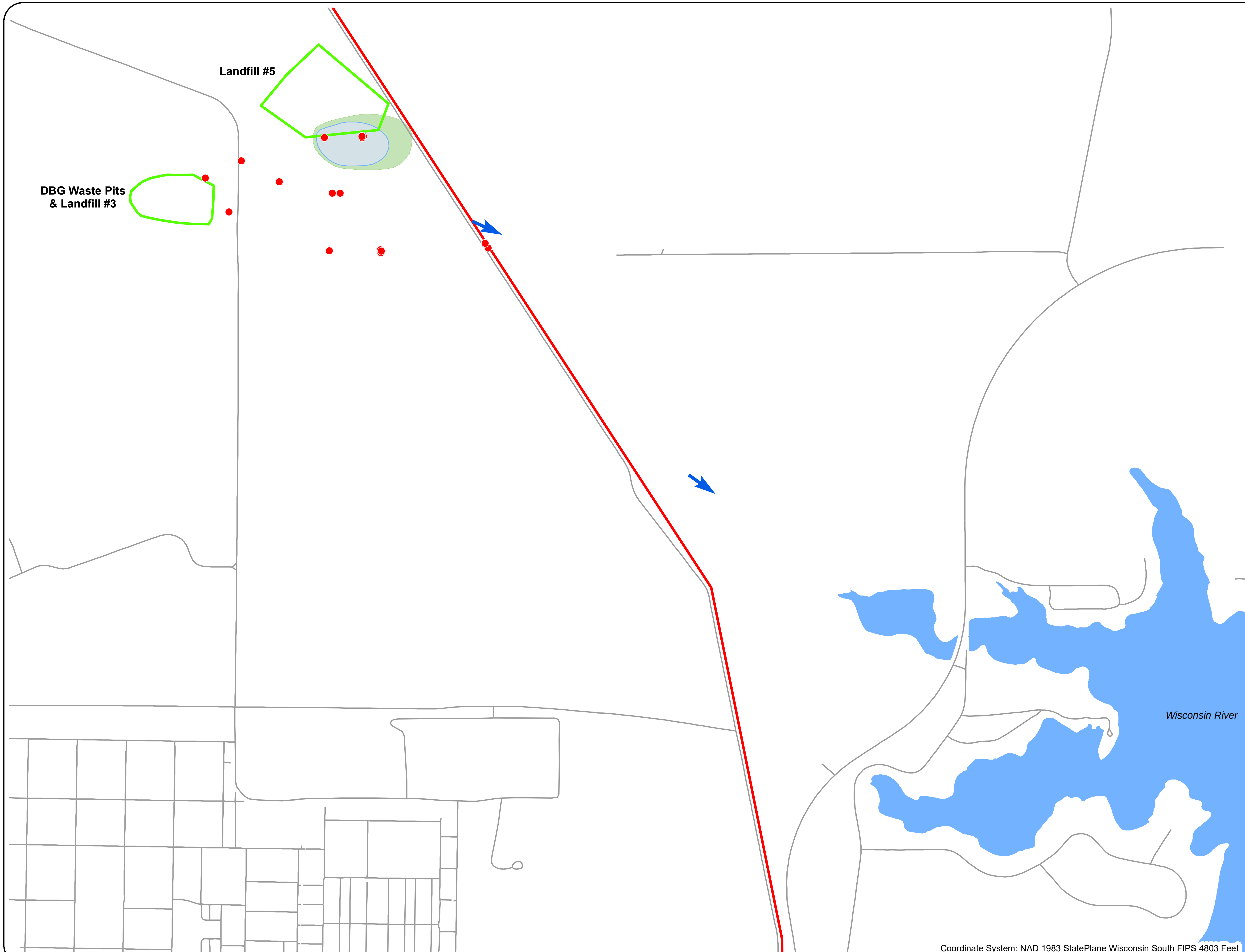
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS APPROXIMATELY PERPENDICULAR TO CROSS SECTION.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

FIGURE 45

# TOTAL DINITROTOLUENE ISOCONCENTRATION SECTION F-F'

DETERRENT BURNING GROUND
RI/FS
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES




**LEGEND**

- Wells Used To Construct Isoconcentrations

**Sulfate Concentration (mg/l)**

**April 2018**

- 125 - 250
- > 250
- Source Area
- Groundwater Flow Direction

Notes: The sulfate isoconcentrations in milligrams per liter (mg/l) are interpreted from groundwater data collected during 2018. Wisconsin has a "secondary" NR 140 Public Welfare Groundwater Quality Standard. The sulfate groundwater standard is based on a taste threshold and not considered to present a risk to human health. The NR 140 Preventive Action Limit is 125 mg/l and Enforcement Standard is 250 mg/l.

N W E S

0 390 780 1,560 Feet

FIGURE 46

SULFATE ISOCONCENTRATION MAP

DETERRENT BURNING GROUND & LANDFILL #5 RI/FS BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES

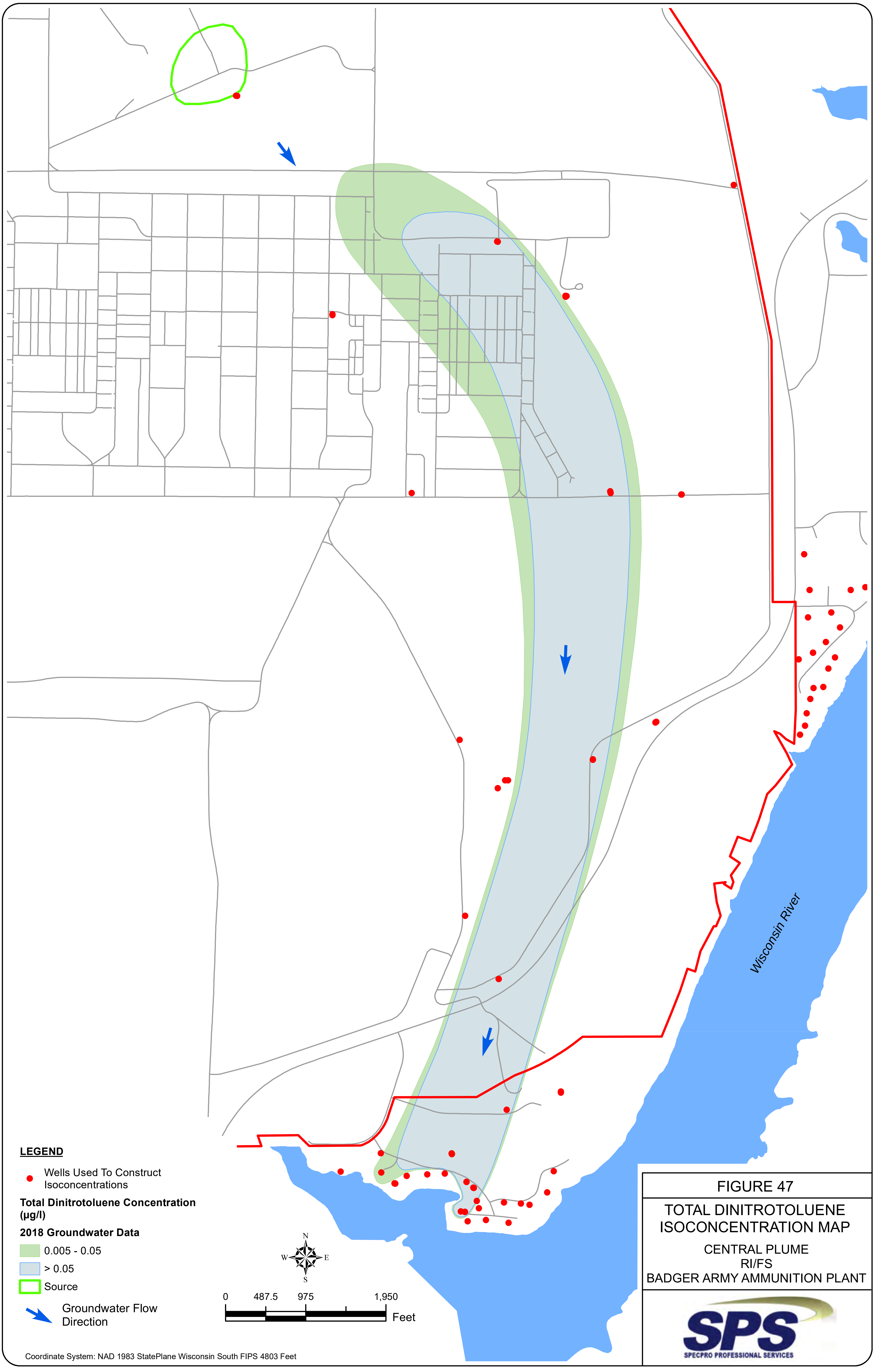
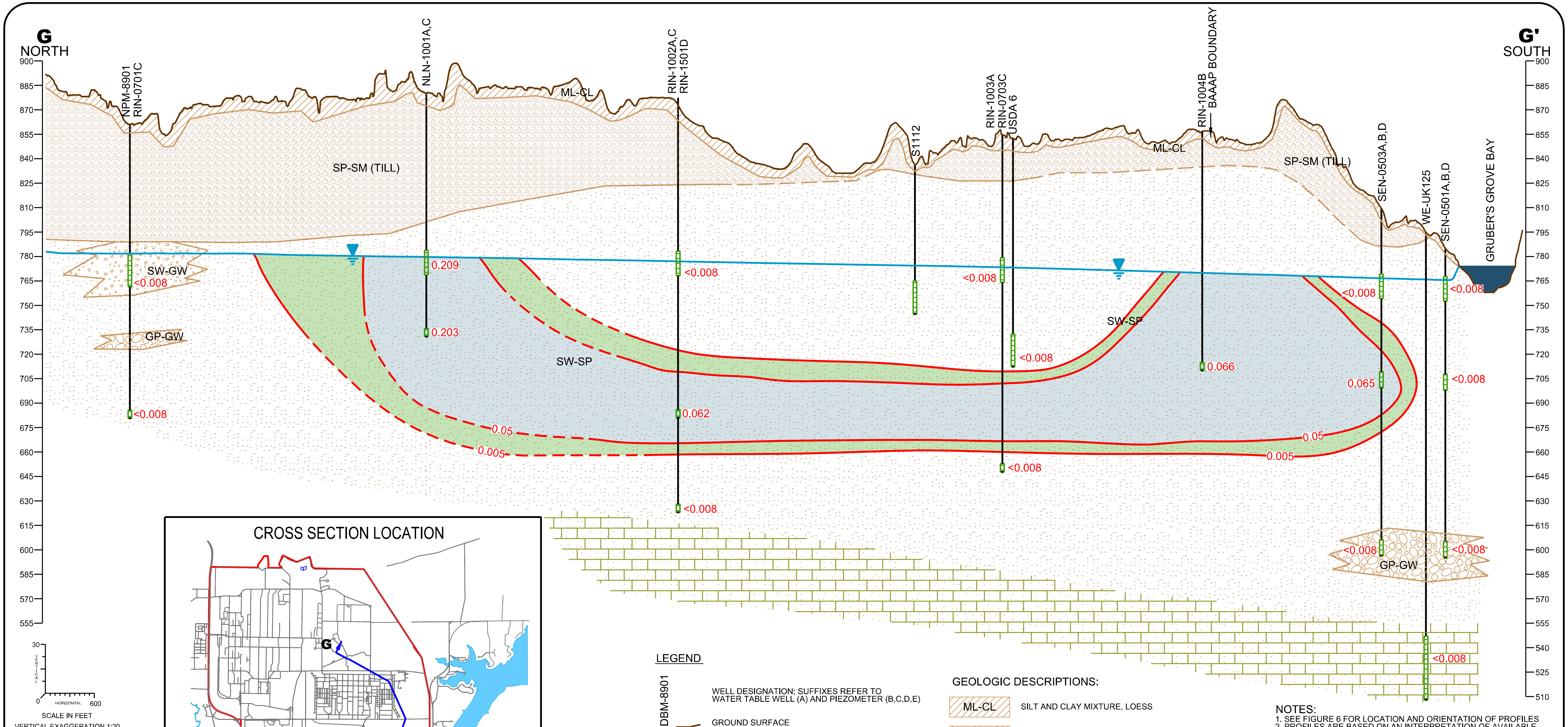


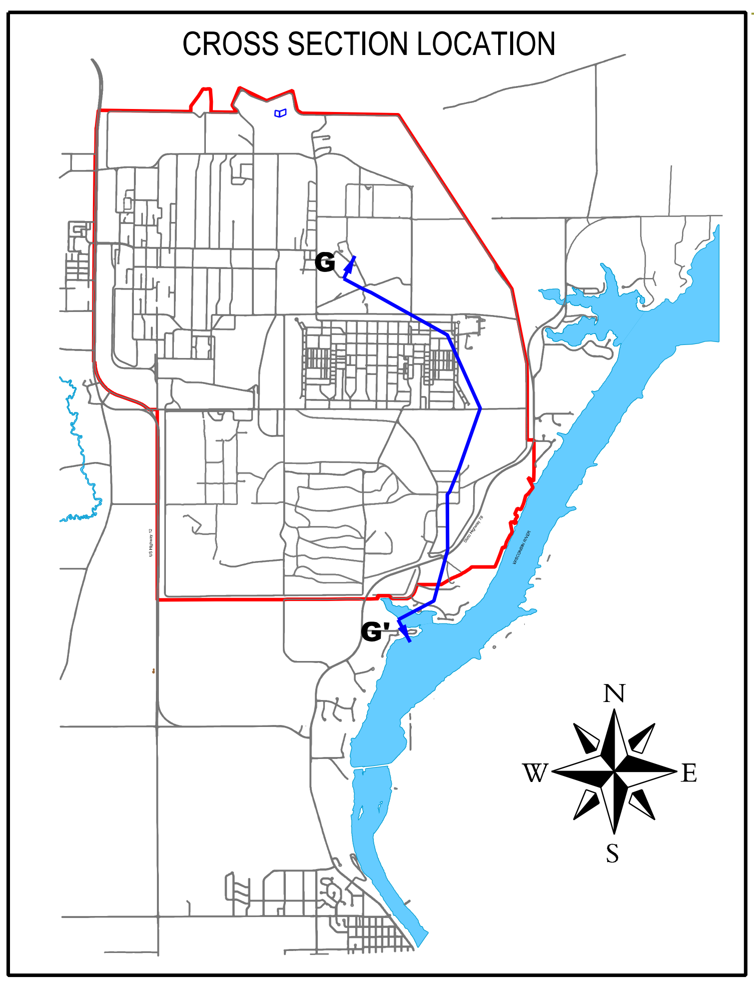

FIGURE 47

TOTAL DINITROTOLUENE ISOCONCENTRATION MAP

CENTRAL PLUME
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES




LEGEND

DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)

GROUND SURFACE

WATER TABLE ELEVATION

SCREENED INTERVAL

0.008 — TOTAL DINITROTOLUENE CONCENTRATION µg/l

BOTTOM OF EXPLORATION

0.005 — TOTAL DINITROTOLUENE ISOCONCENTRATION LINE (µg/l)

GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-GW — SAND, GRAVEL, AND COBBLES, GLACIAL OUTWASH
- SW-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP-GW — GRAVEL, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)

TOTAL DINITROTOLUENE CONCENTRATION (µg/l)

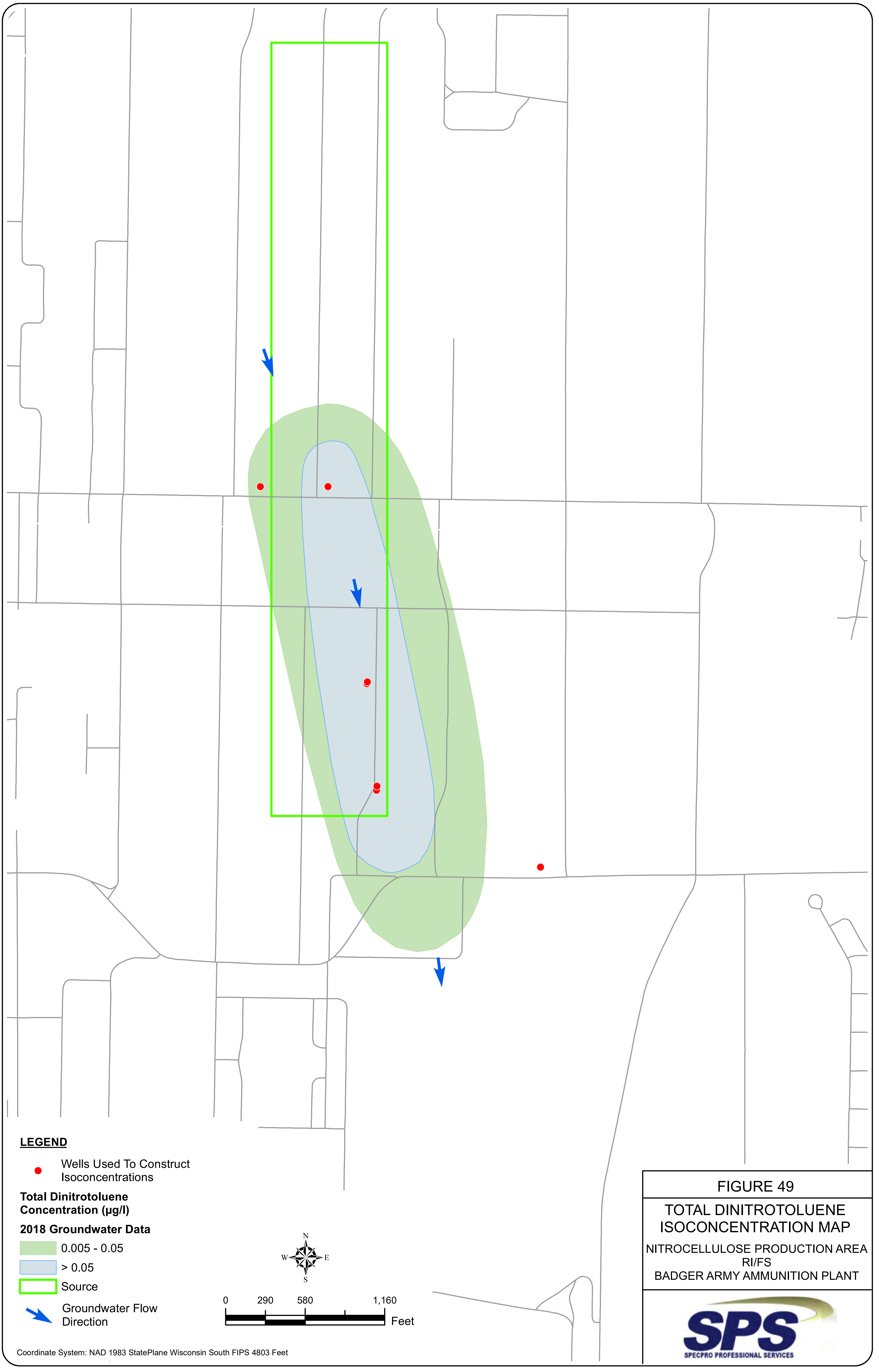
- >0.05
- 0.005-0.05

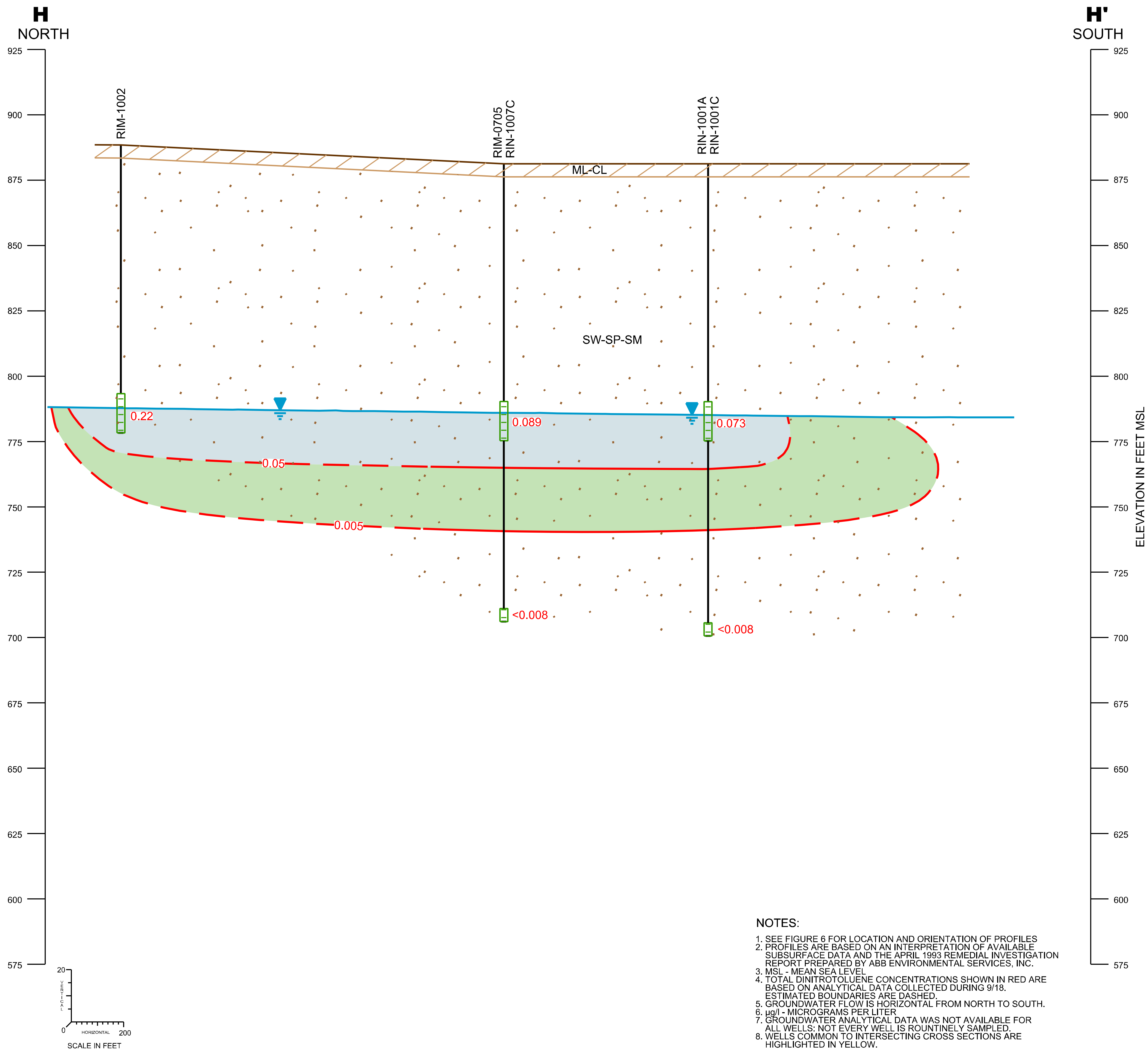
NOTES:
1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 6/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS; NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

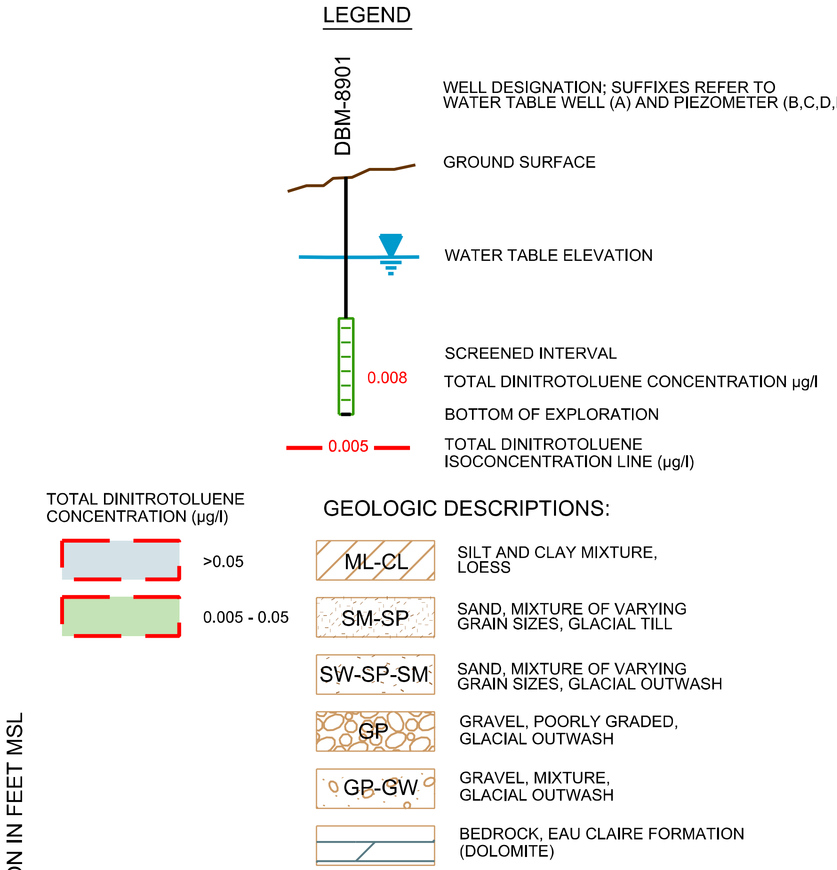
FIGURE 48

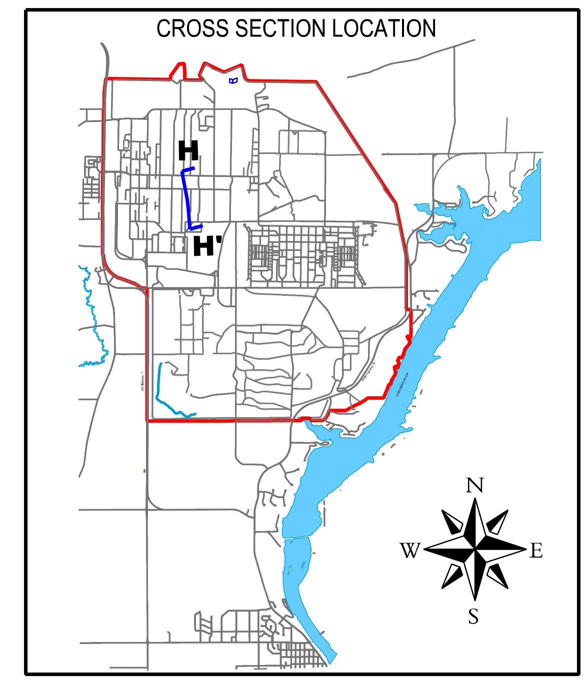
TOTAL DINITROTOLUENE ISOCONCENTRATION SECTION G-G'
CENTRAL PLUME
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES


LEGEND
Wells Used To Construct Isoconcentrations
Total Dinitrotoluene Concentration (µg/l)
2018 Groundwater Data
0.005 - 0.05
> 0.05
Source
Groundwater Flow Direction
N
E
S
W
0
290
580
1,160
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 49
TOTAL DINITROTOLUENE ISOCONCENTRATION MAP
NITROCELLULOSE PRODUCTION AREA
RI/FS
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES




NOTES:

1. SEE FIGURE 6 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. MSL - MEAN SEA LEVEL
4. TOTAL DINITROTOLUENE CONCENTRATIONS SHOWN IN RED ARE BASED ON ANALYTICAL DATA COLLECTED DURING 9/18. ESTIMATED BOUNDARIES ARE DASHED.
5. GROUNDWATER FLOW IS HORIZONTAL FROM NORTH TO SOUTH.
6. µg/l - MICROGRAMS PER LITER
7. GROUNDWATER ANALYTICAL DATA WAS NOT AVAILABLE FOR ALL WELLS: NOT EVERY WELL IS ROUNTINELY SAMPLED.
8. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW.

FIGURE 50

# TOTAL DINITROTOLUENE ISOCONCENTRATION SECTION H-H'

NITROCELLULOSE PRODUCTION AREA
RI/FS
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES