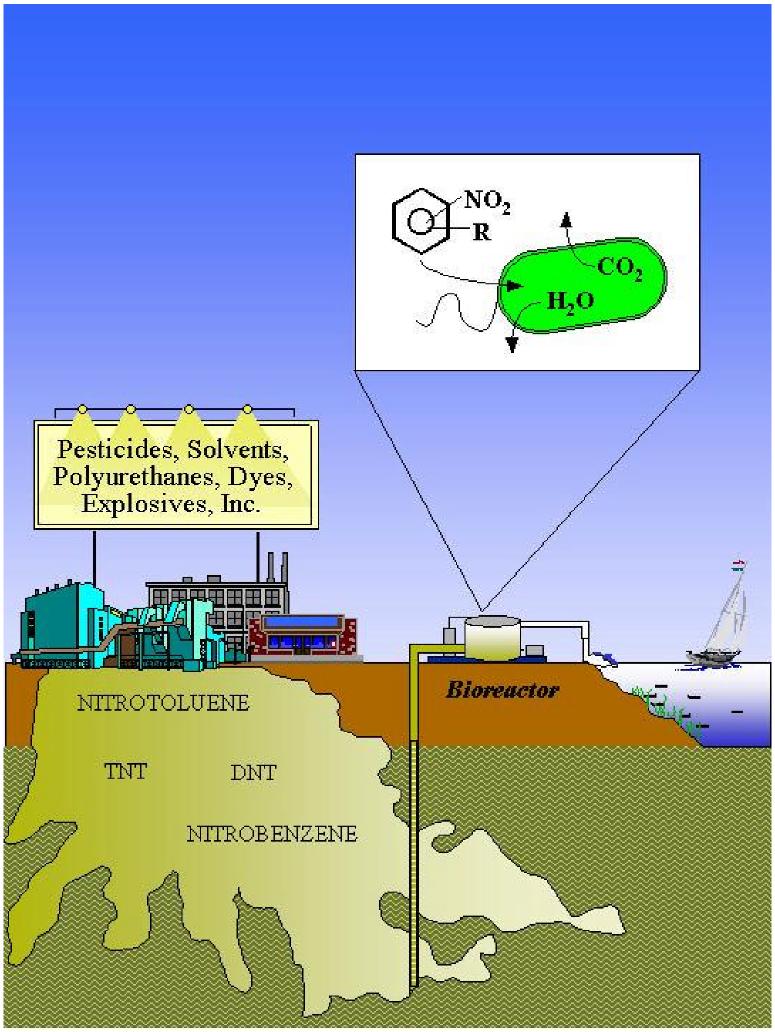
TECHNOLOGY STATUS REVIEW: BIOREMEDIATION OF DINITROTOLUENE (DNT)



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Technology Status Review: Bioremediation of Dinitrotoluene (DNT)

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Purpose

Recent advances in the understanding of how bacteria biodegrade dinitrotoluenes (DNT) under aerobic conditions has led to the development of remediation systems that can dramatically reduce clean up costs of DNT-contaminated soil and ground water. This document summarizes the latest information on bioremediation technologies that exploit the ability of aerobic bacteria to mineralize 2,4- and 2,6-dinitrotoluene (2,4-DNT, 2,6-DNT) to yield energy, harmless minerals and biomass (1). It is based on a recent review of the relevant literature (8). Sources for further information are provided below.

Background

Biodegradation can result in either mineralization or transformation of DNT. Mineralization, the complete catabolism of a compound to its inorganic components is the preferred goal of bioremediation systems (2). Energy derived from the catabolic process provides a selective advantage to the degradative organism. Transformation (cometabolism) (1) is much less desirable for several reasons. The requirement for a primary substrate and the absence of a selective advantage renders cometabolic systems more expensive and difficult to control than systems that rely on mineralization. Transformation also produces organic derivatives of the parent molecule whose identity and toxicity must be established for each individual situation. Transformation of DNT leads to partial reduction and formation of amines.

Both mono- and dinitrotoluenes are susceptible to aerobic microbial degradation, and the catabolic pathways are known (8). Bacteria that grow on the predominant DNT isomers as sole carbon, nitrogen and energy source have been isolated from contaminated systems worldwide (7-9, 13). In a few instances the genes that encode the degradative enzymes have been cloned and sequenced. Given the knowledge of the degradative pathways and the physiological requirements of the degradative microorganisms, systems can be designed to meet the growth requirements of the organisms and to control or monitor the catabolic process.

Productive anaerobic pathways for degradation of mono- and dinitrotoluenes are not known. However, cometabolic reduction of the nitro group occurs under both anaerobic and aerobic conditions. The reductive transformations are attributed to the activity of non-specific nitroreductases (3). The cultures are generally grown with simple sugars or alcohols to provide growth substrates and electron donors. In studies in which the products of anaerobic bacterial reduction of 2,4-DNT were carefully analyzed (5, 6), nitroso-, aminonitro-, and diamino-compounds predominated. Cometabolic reduction and acetylation of 2,4-DNT has also recently been demonstrated under aerobic conditions as well as anaerobic conditions in *Pseudomonas aeruginosa* cultures (10). In general, non-specific reduction does not lead to ring cleavage and further transformation of the metabolites. Thus aerobic treatment seems much more effective.

Applicability and Limitations

Mineralization of mixtures of 2,4-DNT and 2,6-DNT has been demonstrated at bench-, pilot- and field-scale in a variety of soil and ground water systems, both in situ and ex situ. The presence of specific DNT-degrading bacteria at sites that are chronically contaminated with DNT raises the possibility of natural attenuation as a DNT remediation alternative. Biodegradation of DNT will generally occur under the following conditions:

1. O_2 concentration > 1 mg/L
2. Adequate and stable moisture
3. pH between 6.5 and 8.5
4. Moderate soil/water temperatures
5. Adequate macronutrients (phosphate, sulfate)
6. Appropriate bacterial biomass

There are a number of factors that must be considered before bioremediation of DNT can be used. DNT degradation is negligible under anaerobic conditions. When more readily degradable carbon sources such as simple alcohols or sugars are present, cometabolic transformation rather than mineralization will be the predominant microbial process. If an in situ remedy is under consideration, the finding that indigenous bacteria will degrade rather than transform DNT indicates that cometabolic transformations will not be substantial as long as conditions are aerobic. A large excess of 2,4-DNT over 2,6-DNT can prevent simultaneous degradation of the two isomers necessitating a sequential system to fully degrade 2,6-DNT. The low C/N ratio of the DNT molecule can result in the accumulation of excess nitrite that lowers the pH of the system, and can pose disposal problems if the initial DNT concentrations are high. Ex situ bioremediation allows a high degree of control of the significant environmental variables. Recent experience (discussed below) has shown that the limitations discussed above can be managed in appropriately engineered ex situ treatment systems. In situ treatment, though far less expensive, offers less control of the key limiting factors, and therefore more careful analysis is required early in the design process to ensure the effectiveness of the treatment system.

Examples

Fluid bed reactors for ground water remediation

The Volunteer Army Ammunition Plant (VAAP) near Chattanooga, TN was a TNT manufacturing plant from 1941 until 1977 (14). DNT contamination of soil and ground water is quite heterogeneous and concentrations of nitrotoluenes in ground water vary with rainfall. Studies conducted with contaminated ground water from VAAP revealed how mixtures of mono- and dinitrotoluenes are degraded in fluidized bed reactors (FBR) at bench- and pilot-scale.

A preliminary demonstration was performed in a bench-scale FBR inoculated with a mixed culture of DNT-degrading strains (4, 12). Removal efficiencies for DNT were greater than 98% at hydraulic retention times greater than 1.5 h. The study yielded insight about the configurations and limitations of FBRs for DNT degradation. The retention of the induced biomass was critical to the success of the system. With a large induced biomass and complete mixing of the biomass and feed, the concentration of DNT within the reactor vessel was always at a very low level. Therefore, the two DNT isomers were degraded simultaneously with no apparent inhibition by either isomer. When ground water containing 2-NT and 4-NT in addition to 2,4- and 2,6-DNT was used as the feed, acclimation of the biomass to degrade the mononitotoluenes required 10 days. The bench-scale studies demonstrated the feasibility of simultaneously degrading mixtures of mono- and dinitrotoluenes at high rates.

A pilot-scale field study was conducted based upon the parameters established by the laboratory-scale FBR. The reactor contained a granular activated carbon biocarrier inoculated with a mixed culture of 2,4-DNT, 2,6-DNT, 2-NT and 4-NT-degrading strains (14). The removal efficiencies for 2,4-DNT, 2-NT, and 4-NT were always high, and removal of TNT fluctuated in a narrow range around 50% depending on hydraulic retention time. 2,6-DNT removal started slowly but there was a dramatic improvement after 4 months of operation. During the time when 2,6-DNT was degraded poorly in the primary reactor, it could be degraded effectively in a subsequent extended aeration vessel. The fluidized bed reactor technology is a more cost effective treatment method for DNT than either UV/ozone treatment or liquid phase granular activated carbon adsorption when the total nitrotoluene concentrations are relatively high. Recently developed strategies to improve the efficiency of 2,6-DNT degradation can improve the economies considerably.

Soil slurry reactors

Studies with field contaminated soils showed that DNT contamination over 50 years old can be effectively removed from soil by degradative bacteria (9). Bench-scale experiments demonstrated that bioremediation of DNT in aged field-contaminated soils was rapid and extensive. Pilot-scale studies have established the reactor configurations and operational conditions for scale-up of slurry reactor systems for the treatment of DNT-contaminated soils (16). Airlift bioreactors (Eimco 70-L) were used to treat DNT contaminated soils from VAAP and from the Badger Army Ammunition Plant (BAAP) near Baraboo, WI. The BAAP soil contained 2,4-DNT (11 g/kg) and 2,6-DNT (0.2 g/kg). The VAAP soil had similar levels of 2,4-DNT, but higher 2,6-DNT concentrations (1 g/kg) and significant amounts of TNT (0.4 g/kg). Degradation of 2,4-DNT was rapid, predictable and easily established for both soils at initial concentrations up to 11.2 mM (2.0 g/L) 2,4-DNT (Fig. 1). At concentrations > 5 mM (0.9 g/L), 2,4-DNT was degraded at 0.9 – 1.4 g/L/d. At concentrations < 2 mM (0.36 g/L), the rate ranged from 0.2 – 0.3 g/L/d. Nitrite toxicity became a problem at very high soil loading levels, and limited the soil loading rate.

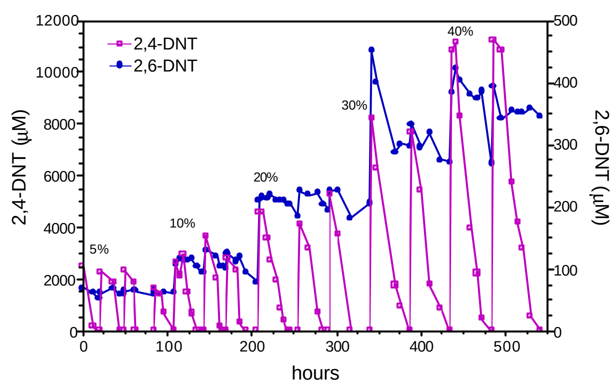

Fig. 1. Slurry-phase concentrations of DNT in Eimco reactor fed BAAP soil at 5, 10, 20, 30, and 40% nominal soils loading rates. [Modified from (16)]

Initially, 2,6-DNT was not degraded in the bioreactors. Shake flask studies showed that high ratios of 2,4-DNT to 2,6-DNT inhibited 2,6-DNT degradation. The problem was overcome by conducting the 2,6-DNT degradation phase in a separate reactor placed in series. After separation of the two degradation processes and an acclimation period, 2,6-DNT was degraded efficiently (Fig. 2). At concentrations between 150 and 300 µM, 2,6-DNT was degraded at 0.11 – 0.29 g/L/d. Low residual concentrations of DNT remained in the treated slurry following both single and sequential reactor treatment, but the sequential treatment reduced the residuals to below the EPA treatment standard limits (40 CFR 268.48). The 2,6-DNT-degrading bacteria were much more tolerant of nitrite accumulation than the 2,4-DNT-degrading cultures and the high nitrite levels that were carried over from the 2,4-DNT reactors into the 2,6-DNT reactors had no effect on 2,6-DNT degradation. It is clear that 2,4-DNT inhibits 2,6-DNT degradation, but the mechanism is not known. Separation of the two operations can enhance the efficiency of the overall bioremediation system. The bench-scale and pilot-scale experiments indicate that inoculation with specific DNT-degrading bacteria can hasten the development of a stable DNT-degrading population even in the presence of an indigenous population. Inoculation is particularly valuable for 2,6-DNT degradation where long acclimation periods appear to be the norm.

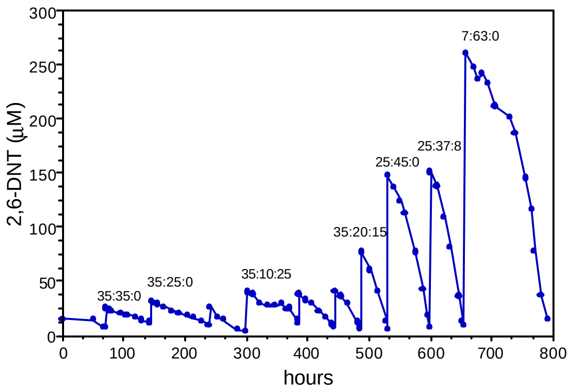

Fig. 2. Concentration of 2,6-DNT in reactor fed effluent from reactor in Fig. 1. Ratios denote volume remaining from previous cycle, volume of fresh effluent added, volume of tap water diluent. [Modified from (16)]

A small residual fraction of the DNT can persist in the treated solids when DNT is no longer detectable in the aqueous phase. Field-contaminated soils, but not the laboratory-contaminated soil or artificially-contaminated clay aggregates (11), retain low levels of acetonitrile-extractable DNT after treatment. The residual DNT seems not to be bioavailable or extractable with water. Treatment of DNT-contaminated soil in bench-scale bioreactors greatly reduced the toxicity (9); however, similar tests should be conducted to determine whether the residual DNT in soils from bioremediation systems requires further treatment. About half of the initial TNT in the VAAP soil disappeared during the bioreactor treatment. A small amount of the missing TNT was detected as aminodinitrotoluene. Strategies to remove or immobilize residual TNT and TNT metabolites should be incorporated into the overall remediation plan when soils contain both DNT and TNT.

In situ applications

The discovery of bacteria in the environment that are able to degrade nitroaromatic compounds strongly suggests that natural attenuation or other in situ processes can be suitable remediation strategies for nitroaromatic contaminants. At BAAP, waste materials from the reprocessing of single-base propellants were deposited into large in-ground waste pits. Six waste pits, each roughly 40 feet in diameter and extending 100 feet down to the water table contain soil heavily contaminated with 2,4-DNT (15). One of the waste pits is the source of a DNT-contaminated ground water plume. DNT concentrations in the ground water plume decrease in downgradient wells. 2,3-Dinitrotoluene (2,3-DNT) does not decrease at the same rate as 2,4- and 2,6-DNT. 2,3-DNT has not been demonstrated to be biodegradable and can thus be considered a conservative tracer that reflects the effects of abiotic processes. The much greater decrease in 2,4- and 2,6-DNT concentrations can therefore be attributed to biological activity. 2,4-DNT-degrading bacteria have been isolated from monitoring well water from the site and 2,4-DNT disappears with stoichiometric release of nitrite from microcosms constructed with DNT-contaminated soil from the site. The understanding of the 2,4-DNT catabolic pathway taken with laboratory studies with soil from the site, disappearance of DNT from the monitoring wells, and the isolation of bacteria able to degrade DNT from the same wells, provide evidence that natural attenuation is taking place at the site. Stoichiometric release of nitrite demonstrates complete mineralization of DNT which precludes formation of significant amounts of amino compounds. Similar results have been obtained from two industrial sites contaminated with DNT.

DNT contamination in the vadose zone at BAAP where 2,4-DNT occurs at concentrations up to 28% by weight (15), is currently being treated by in situ bioremediation. A pilot-scale treatment system, designed by Stone & under the direction of the U.S. Army Corps of Engineers, is based on the results of bench-scale treatability tests in which ground water was recirculated through contaminated soil columns. In the pilot-scale system, ground water from the bottom of one of the waste pits is reintroduced to the top of the waste pit through an infiltration gallery just below ground level. Air is introduced via sparge wells in the waste pit. Approximately 75% of the water is recirculated. Nitrite released by DNT degradation is removed by denitrification in an anoxic reduction zone established down gradient. Preliminary results from the pilot system demonstrate that: 1) 2,4-DNT is rapidly degraded in situ, 2) acclimation following inoculation with indigenous microorganisms is rapid, 3) the system is very stable and robust, 4) nitrite is oxidized to nitrate by indigenous bacteria which limits the accumulation of toxic levels of nitrite, and 5) no cosubstrates are required for DNT degradation. Based on early results of the pilot-scale treatment system, the Army Corps of Engineers has approved the design and implementation of a full-scale treatment system. More information about work at BAAP and other related Army sites can be found at http://www.badgeraap.org/index.shtml.

Further Considerations

The studies cited above raise a few issues that require further consideration. The first is that simultaneous degradation of 2,4-DNT and 2,6-DNT is unpredictable. However, sequential degradation of the two isomers is reliable once an adapted population is established. Second, accumulation of nitrite/nitrate must be considered both to meet regulatory standards for any effluents generated, and to prevent inhibition of DNT degradation by nitrite accumulation. The oxidation of nitrite to nitrate is unpredictable and has only been observed in two instances during numerous laboratory studies and one field study. Third, the distribution of degradative bacteria must be considered, particularly if in situ strategies are under consideration. Nitrotoluene-degrading bacteria are not ubiquitous, and neither the mechanism nor the time course of the evolution or distribution of such bacteria are currently understood. To date they have been found at most contaminated sites, but the presence of bacteria with the ability to degrade DNT must be verified at each site. Fourth, the endpoints for bioremediation of DNT are not well established. And fifth, TNT is not substantially degraded during aerobic treatment of DNT.

Summary

Bioremediation can be an effective method for treating DNT-contaminated soil and ground water, and is less costly than competing accepted technologies. 2,4-DNT is more easily degraded than 2,6-DNT, and sequential treatment systems may be needed to treat soil or water containing both isomers. TNT is far less biodegradable than these DNT isomers, and the presence of TNT may make bioremediation more difficult or expensive. 2,3-DNT is apparently not biodegradable.

Site-specific laboratory testing is essential prior to selection and design of a bioremediation system. Key issues for laboratory tests include: 1) appropriate chemical and physical conditions (pH, redox, nutrients); 2) verification of the presence of bacteria capable of DNT mineralization; 3) presence of indigenous nitrite oxidizing bacteria; and 4) whether achievable endpoints are acceptable in terms of toxicity and risk. Laboratory tests may also be needed to estimate DNT degradation rates, to establish maximum DNT concentrations that can be biodegraded, and to design strategies to biodegrade mixtures of DNT isomers and/or mononitrotoluenes.

In situ bioremediation is possible at sites where: 1) aerobic conditions are present or can be engineered; 2) appropriate organisms are present or can be introduced effectively; 3) the potential for nitrite or nitrate accumulation can be managed. Ex situ bioremediation is more expensive but may be needed at sites that do not meet the above criteria. Fluidized bed reactors have been demonstrated for treatment of DNT in water, and soil slurry reactors are effective for contaminated soils. In either case, significant effort must be spent on the engineering design to ensure that DNT treatment will be successful and cost-effective, particularly when mixtures of 2,4-DNT and 2,6-DNT are present.

Acknowledgments

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ENERGY, INSTALLATIONS,
AND ENVIRONMENT

September 3, 2024

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, NATIONAL GUARD BUREAU (JOINT STAFF, J3/4/7)
DIRECTOR, DEFENSE LOGISTICS AGENCY (INSTALLATION MANAGEMENT)

SUBJECT: Prioritization of Department of Defense Cleanup Actions to Implement the Federal Drinking Water Standards for Per- and Polyfluoroalkyl Substances Under the Defense Environmental Restoration Program

On April 26, 2024, the Environmental Protection Agency (EPA) published a final National Primary Drinking Water Regulation (NPDWR) establishing nationwide drinking water standards for certain per- and polyfluoroalkyl substances (PFAS) under the Safe Drinking Water Act (SDWA). This rule applies to public drinking water systems. DoD remains committed to fulfilling our PFAS-related cleanup responsibilities and will take necessary actions to incorporate SDWA levels into our cleanup program, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (40 C.F.R. Part 300). The CERCLA process can take time to complete, but also provides a consistent, science-based approach across the Nation for cleanup and includes federal and state environmental regulator review and public participation. This memorandum describes DoD's plans to incorporate the drinking water rule into DoD's ongoing PFAS cleanups and prioritize actions to address private drinking water wells with the highest levels of PFAS from DoD activities.

EPA's drinking water rule includes enforceable maximum contaminant levels[1] (MCL) for five PFAS: perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), hexafluoropropylene oxide dimer acid (HFPO-DA, commonly known as GenX), and perfluorohexane sulfonic acid (PFHxS). It also includes a Hazard Index (HI) MCL, for a mixture of at least two or more of PFHxS, PFNA, perfluorobutane sulfonic acid (PFBS), and HPFO-DA (GenX) chemicals. The rule provides five years for regulated public water systems to comply with these MCLs as specified below.

- Individual MCLs in parts per trillion (ppt):
  - PFOS = 4 ppt
  - PFOA = 4 ppt

[1] SDWA defines a "maximum contaminant level" or MCL to be "the maximum permissible level of a contaminant in water which is delivered to any user of a public water system." 42 U.S.C. § 300f(3).

- HFPO-DA = 10 ppt
- PFNA = 10 ppt
- PFHxS = 10 ppt

- Hazard index[2] MCL for PFHxS, PFNA, PFBS, and HFPO-DA = 1 (unitless)

DoD's Cleanup Program

The Defense Environmental Restoration Program (DERP) statute provides DoD authorities to perform and fund cleanup actions and requires they be carried out in accordance with CERCLA. Under CERCLA, the DoD addresses releases or threatened releases of hazardous substances, pollutants, or contaminants from DoD activities, including PFAS. DoD is working to integrate the MCL values established in EPA's final SDWA rule into its cleanup process. Under CERCLA, MCLs can be used as a risk trigger level to take interim actions (i.e., removal actions), but exceeding an MCL does not in itself trigger a removal action. CERCLA also incorporates federal or state cleanup requirements, called Applicable or Relevant and Appropriate Requirements (ARARs), to develop final cleanup levels. ARARs are determined on a site-specific basis, but in most cases, MCLs are used as the final cleanup standard to be attained for groundwater used for drinking water.

As of March 31, 2024, DoD has completed preliminary assessments/site inspections to evaluate potential releases of PFAS from DoD activities at 710 of 717 installations. DoD identified 578 installations that require further investigation. DoD has initiated remedial investigations at over 350 of these installations and plans to begin over 150 more within the next two fiscal years. Remedial investigations provide important information enabling the Department to take additional interim actions to prevent further PFAS plume migration as well as address impacted drinking water wells. At 55 installations, DoD took interim actions to address off-base drinking water wells/systems where levels of PFOS and PFOA were above 70 ppt (the level DoD previously used to trigger an interim action).

Interim Actions (i.e., Removal Actions)

The Department recognizes the need to take quick actions to address PFAS in drinking water. To ensure cleanup begins as quickly as possible, the DoD Components will initiate removal actions to address private drinking water wells impacted by PFAS from DoD activities where concentrations are known to be at or above three times the MCL values (i.e., PFOA = 12 ppt; PFOS = 12 ppt; PFHxS = 30 ppt; GenX = 30 ppt; PFNA = 30 ppt; HI = 3). This approach prioritizes action where PFAS levels from DoD releases are the highest (i.e., at or above three times the MCL values), rather than delay action at these locations while ongoing remedial investigations continue. Whenever possible, the DoD Components will use a CERCLA "Time Critical Removal Action[3]" for these efforts. This is DoD's initial step to prioritize cleanup

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[2] The hazard index is defined in 40 C.F.R. § 141.2 and explained in EPA's factsheet "Understanding the Final PFAS National Primary Drinking Water Regulation Hazard Index Maximum Contaminant Level" at https://www.epa.gov/system/files/documents/2024-04/pfas-npdwr_fact-sheet_hazard-index_4.8.24.pdf

[3] A time critical removal action is used, when after an evaluation of the site, the lead agency determines there is less than six months of planning time available for removal activities.

actions in private drinking water wells, including private drinking water wells located off-base at the 55 installations, where DoD has previously taken action for wells with levels of PFOS and PFOA above 70 ppt. As DoD works to complete actions to address off-base drinking water at the 55 installations with the highest known levels of PFAS, the Department will continue to identify and address private drinking water with PFAS above three times the MCLs from DoD releases at additional locations. DoD will then initiate remedial actions to address drinking water wells and public water systems with concentrations below three times the MCL value as described in the remedial action section of this guidance.

DoD anticipates a significant number of private drinking water wells will require interim actions to reduce PFAS levels. To expedite implementation of more enduring solutions, the DoD Components will focus on sustainable solutions when considering alternatives. The DoD Components will consider in prioritized order: providing connections to public water systems; installing whole house treatment systems; providing point of use treatment systems; and providing bottled water.[4]

DoD also intends to expedite action at public water systems where authorized, prioritizing the most impacted sites for earlier action. For public water systems above the MCLs impacted by PFAS from DoD activities, the DoD Components will work with those systems and regulators to address PFAS impacts. These actions will assist the public water systems as they work to meet the requirements for compliance with the PFAS NPDWR as soon as possible but not later than April 2029.

This policy is intended to expedite remediation of private drinking water wells, and public water systems impacted by DoD PFAS releases, prioritizing the most impacted sites for earlier action. The Military Departments will ensure that robust communication occurs before, during, and after actions are taken to address PFAS on and around DoD installations, Base Realignment and Closure locations, and National Guard facilities.

Long-Term Remedial Actions

CERCLA requires a site-specific risk assessment during the remedial investigation to establish risk-based cleanup levels. This includes considerations of "background" levels of chemicals present at a site, which can be highly variable across the country. Throughout the CERCLA process DoD coordinates with both EPA and state regulators and EPA and DoD jointly select remedies at National Priorities List sites. Accordingly, DoD will work with EPA and state regulators, as appropriate, to evaluate background levels of PFAS on a site-specific basis to determine a final cleanup level.

For remedial actions, the DoD Components will address drinking water down to the MCLs or background, in accordance with CERCLA, once the DoD Component has established

[4] The DoD Components will only provide bottled water when: 1) more sustainable alternatives, such as drinking water treatment, are technically infeasible due to site-specific conditions and in these cases, the DoD Component will request a waiver from the DASD(EMR) prior to the provision of bottled water; 2) the levels of PFOS and PFOA in drinking water are above 70 ppt; or 3) bottled water was already being provided prior to the issuance of this guidance and levels are at or above three times the MCLs.

background PFAS levels using EPA's CERCLA policies on this matter.[5] If the outcome of the CERCLA background assessment conducted during the remedial investigation is that background levels of PFAS are below the MCLs, then DoD Components will take remedial actions to address PFAS that will meet the MCLs as the final cleanup levels.[6] If background levels of PFAS are found above an MCL at a site, DoD Components will work collaboratively with regulators and transparently with the public to determine the appropriate remedial goals (i.e., final cleanup levels) at that site.

This guidance is the first step in a prioritized approach that enables DoD to take quick action to address private drinking water wells, and public water systems where possible, where known levels of PFAS from DoD activities are the highest while the Department continues to gather information through remedial investigations to prioritize future actions. DoD continues to review existing data and collect new information to assess where PFAS plumes may have migrated from an installation and impacted drinking water and will be prioritizing those locations for response actions as the next step. DoD believes this is the best approach for the long-term protection of human health and the environment and the Department will continue to accelerate DoD's cleanup efforts Nationwide in accordance with federal law and in partnership with regulatory agencies and affected communities.

The Department will update this guidance periodically, as necessary, as investigations continue and more sampling data is received.

The point of contact for this matter is Ms. Alexandria Long at 703-571-9061 or alexandria.d.long.civ@mail.mil.

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Brendan M. Owens

[5] EPA, Role of Background in the CERCLA Cleanup Program, OSWER 9285.6-07P (2002)(available at https://www.epa.gov/risk/role-background-cercla-cleanup-program); EPA, Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites, EPA 540-R-01-003 (September 2002) (located at: https://www.epa.gov/risk/guidance-comparing-background-and-chemical-concentrations-soil-cercla-sites)).
[6] Where MCLs have been identified as relevant and appropriate under the circumstances of the release.

FINAL

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

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Appendix K

Army Response to Comments on RI/FS

Army Response to Comments on Groundwater RI/FS

Comments from WDNR

Item	Comment	Response	Action	Army Acceptance (A/NA/P/R) [1]
1.	Overall, the RI/FS is well written. It presents a good summary of site conditions. The data tables consolidate information from many years of investigation and monitoring and the figures clearly depict known site hydrogeologic conditions and contaminant plume locations.	Acknowledge comment	No action needed.	NA
2.	The Groundwater Human Health Risk Assessment indicates that the Army conducted vapor intrusion pathway analyses for all of the groundwater contaminant plumes in 2012 using the Department's vapor intrusion guidance (PUB-RR-800, dated December 2010). Based on significant advances in the science of vapor intrusion, substantial revisions were made to this guidance and an updated version was published in January 2018. We request that the Army review its assessment of potential vapor intrusion using the updated guidance.	The Army has reviewed the WDNR's January 2018 Vapor Intrusion Guidance (PUB-RR-800) and determined that vapor intrusion still does not pose a risk to area residents. The WDNR's January 2018 guidance references the Wisconsin Vapor Quick Look-up Table for Vapor Action Levels (VAL) and Vapor Risk Screening Levels (VRSL) related to commonly encountered contaminants at cleanup sites. These levels are based on USEPA Regional Screening Levels dated November 2017. Using the updated guidance, the Army determined the VAL and calculated the November 2017 VRSL for deep soil gas related to carbon tetrachloride, chloroform, and trichloroethene. The calculated November 2017 VRSL values were higher than the VRSL values used in the 2012 Vapor Intrusion Pathway Analysis Report. Based on this information, the Army believes that additional investigation of the vapor pathway is not warranted.	The Army has reviewed its assessment of potential vapor intrustion using the 2018 WDNR Vapor Intrustion Guidance and sees no risk to area residents through vapor intrusion.	A
3.	Based on the Human Health Risk Assessment (HHRA), no constituents of concern (COCs) were identified for the Nitrocellulose Production Area Plume because no existing, nearby receptors were identified for this plume. Based on the lack of COCs, this plume was subsequently not addressed in the Remedial Alternatives Analysis (RAA) despite the presence of chemical constituents in the plume above Wis. Admin. Code NR 140 (NR 140) enforcement standards (ESs). The contamination in this plume must be addressed. State law (Wis, State Statute 292.11(3)) requires "A person who possesses or controls a hazardous substance which is discharged or who causes the discharge of a hazardous substance shall take the actions necessary to restore the environment to the extent practicable and minimize the harmful effects from the discharge to the air, lands or waters of this state." This response must be done in accordance with applicable regulations (Wis. Admin. Code NR 700 series as authorized in Wis, State Statute 292.31(2). Therefore, we request that the Army include this plume in the RAA and evaluate remedial options consistent with the other contaminant plumes at the site.	The human health risk assessment did not identify risk above the risk management criteria for the NC Area Plume. Therefore, groundwater remedial alternatives were not considered by the Army for the NC Area Plume. For environmental cleanup decision-making, the Army must follow both CERCLA guidance and the Department of Defense (DoD) Manual 4715.20 (March 9, 2012). The DoD Manual outlines the policies and procedures the Army must follow when conducting environmental restoration under the Defense Environmental Restoration Program (DERP). DERP guidance (b.(5)a.3.h.) states, "If prior to the FS, the DoD Component determines that the site is protective of human health and the environment, the DoD Component is not required to complete an FS or a response action, and will not evaluate ARARs pursuant to subsection 9621(d)(2)(A) of CERCLA." The Army is committed to monitoring the groundwater contamination associated with the NC Area Plume.	The document requires no changes. The Army will continue to review and revise the groundwater monitoring program to ensure it remains protective of human health. The Army will discuss future groundwater monitoring of the NC Area Plume with the WDNR.	R
4.	Consideration should be given to including analysis of major ions (e.g,, calcium, sodium, magnesium, iron, chloride, sulfate, bicarbonate, and nitrate) for groundwater samples collected from select monitoring wells along the longitudinal axis of the plume and from select private wells in areas near the plume boundaries. This may allow better identification of the plume extent and migration in advance of COCs being detected. These indicator parameters may also be helpful in identifying local sources of COCs (particularly VOCs) and differentiating those originating the plumes emanating from the site.	These are not site related contaminants of concern. Depending on the selected remedy monitoring for the major ions may be included in post-ROD remedial activities.	The document requires no changes. The Army will continue to review and revise the groundwater monitoring program to ensure it remains protective of human health.The Army will discuss future groundwater monitoring of the plumes with the WDNR.	A
5.	The characterization of the downgradient extent of the Central Plume is inadequate. The fact that this plume is impinging upon a residential area accentuates the need for additional study. The hydrogeologic flow patterns (particularly at depth) near Grubers Grove Bay and beyond are poorly defined. The likely ultimate fate of this plume, if it were to continue to propagate, needs to be better defined.	For the past 15 years, the Army has been closely monitoring the groundwater in the downgradient portion of the Central Plume. Throughout this time, the Army has also made a commitment to monitor the homeowner's drinking water and replace impacted wells. During 2018 and 2019, the Army sampled the residential wells located south of Gruber's Grove Bay and potentially downgradient of the Central Plume. Dinitrotoluene (six isomers) was not detected in these residential wells, indicating there was no likely migration of the Central Plume beneath Gruber's Grove Bay. The Army will consider these recommendations and discuss them with the WDNR.	The document requires no changes.	P
6.	Detections of COCs in monitoring wells near the downgradient edges of the Deterrent Burning Ground Plume and Central Plume suggest plume expansion in those areas. An enhanced monitoring network for those areas should be developed and installed. Long term use of residential wells as the primary means of plume delineation is unacceptable.	The Army has been working with the USGS to evaluate the current groundwater monitoring network. The Army will use the USGS' recommendations to enhance the monitoring well network in the downgradient portion of the Deterrent Burning Ground and Central Plumes.	The document requires no changes. The Army will continue to review and revise the groundwater monitoring program to ensure it remains protective of human health.The Army will discuss the USGS' recommendations with the WDNR.	A
7.	Remedial Alternative 4 (injection of emulsified vegetable oil to promote anerobic biodegradation of CVOCS and DNTs) is conceptually attractive. However, the technical basis regarding injection point locations, spacing and depth are not well defined. The proposed depths of the injections were not indicated and the spacing was based upon groundwater rather than contaminant velocity. Some additional detail should be provided as the density of the injection network can have a large effect on the cost estimate.	The depths of the injection points will encompass the vertical extent of the DNT contaminant plumes. Specific details regarding the horizontal and vertical spacing of the injection points will be determined after a remedy is selected during the remedial design phase. If necessary, the Army will conduct a field-scale pilot test to evaluate the performance and capabilities of using emulsified vegetable oil to treat contaminated groundwater at BAAP.	If Alternative 4 is selected, the Army would further define specifications for implementation in the remedial design phase.	A
8.	Active remediation (as opposed to relying solely on monitored natural attenuation) may be necessary in the PBG source area and the downgradient portion of the DBG plume due to the rising contaminant concentrations.	Active remediation in the PBG source area was proposed in Alternatives 3, 4 & 6. Active remediation in the downgradient portion of the DBG Plume was proposed in Alternatives 3 & 4. The Army will select the most appropriate groundwater remedy.	No change to document.	A

Comments from WDNR				
Item	**Comment**	**Response**	**Action**	**Army Acceptance (A/NA/P/R) (1)**
9.	Continued evaluation of contaminant concentrations and groundwater elevations is necessary in the PBG source area to determine whether rising DNT concentrations are the result of increased groundwater elevations or cap integrity issues.	The Army has increased testing the monitoring wells near the PBG source area (PBG Waste Pits) to better understand the increase of dinitrotoluene in the shallow groundwater. The Army plans to also increase monitoring the groundwater elevations/depth near the PBG source area. In September 2020, the Army sampled an additional 107 monitoring wells both near the PBG source area and downgradient. In conjunction with the regularly scheduled September 2020 sampling of 79 monitoring wells, the Army sampled all monitoring wells associated with the PBG Plume. The Army will continue work with the USGS to re- evaluate the groundwater monitoring program for the PBG Plume. The PBG final cover system was constructed in two phases (1998 & 2008) and consists of compacted clay, 60-mil geomembrane, drainage layer sand, geotextile filter barrier, general fill and topsoil. The final cover construction activities have received WDNR approval. Cap and cover areas are inspected annually for erosion, settlement, undesirable vegetation, and other deficiencies and maintained as necessary. Annual cap and cover maintenance reports are submitted to the WDNR and USEPA.	The Army conducted a comprehensive sampling of the PBG Plume and will continue to discuss future groundwater monitoring of the PBG Plume with the WDNR.	A

Notes:
(1) Acceptance: A – Accepted, NA - Not Applicable, P - Partially Accepted, R – Rejected

Comments from RAB				
Item	Comment	Response	Action	Army Acceptance (A/NA/P/R) [(1)]
1.	Remedial goals and calculations of risk should fully comply with state and federal environmental regulations, standards, guidance and health advisories (Duplicated in TAPP Questions, item 6, May 7, 2020).	The Army follows the risk based CERCLA process. If there is risk, the Army will comply with state regulations that have been properly identified as ARARs. EPA has put out guidance and procedures on how federal organizations will comply with CERCLA. The Army follows the EPA guidelines. These guidelines can be found online at: *https://www.epa.gov/enforcement/comprehensive-environmental- response-compensation-and-liability-act-cercla-and-federal*	The document requires no change. The Army will follow all federal regulations and state ARARs.	A
2.	Remedial goals and calculations of risk should be the same both on-site and off-site as consistent with Wisconsin's environmental regulations, standards, guidance and health advisories (Duplicated in TAPP Questions, item 23, May 7, 2020).	Groundwater access restrictions for the BAAP property (on-site) 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." In off-site areas, where the Army does not have control over the use of the groundwater as a drinking water source, the Army taskes a more conservative and protective stance, a cumulative cancer risk greater than 1x10-6 is cause for potential action or additional evaluation. For areas on-site, 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.	The document requires no change.	R
3.	The WDNR, the State legislature, the State Attorney General's Office and the Governor should assure that remedial goals and calculations of risk to public health and environmental are fully compliant with all state environmental regulations, standards, guidance and health advisories (Duplicated in TAPP Questions, item 25, May 7, 2020).	The Army follows the CERCLA process. CERCLA is a risk-based process. If there is risk, the Army will comply with state regulations that have been properly identified as ARARs. EPA has put out guidance and procedures on how federal organizations will comply with CERCLA. The Army follows the EPA guidelines.	The document requires no change. The Army has forwarded this comment to the WDNR for response	A
4.	The Wisconsin Groundwater Enforcements Standard for DNT is based on Total DNT, i.e. the summed total concentration of 6 forms of DNT. The Army's evaluation of risk should be consistent with this and other state standards (Duplicated in TAPP Questions, item 22, April 14, 2020).	The State of Wisconsin has three different NR 140 Enforcement Standards (ES) for DNT: 2,4 DNT, 2,6 DNT and Total DNT. All three have the same NR 140 ES equal to 0.05 micrograms per liter. The Army will comply to the extent those standards have been identified as ARARs.	The document requires no change. The Army will comply with all federal regulations and state ARARs.	A
5.	A final decision on the selected remedy for groundwater should be deferred until the RAB, the public, regulators and the Army have had an opportunity to review and comment the pending U.S. Geological Survey studies (Duplicated in TAPP Questions, items 1 and 2, April 14, 2020).	Concurrent with the RI/FS report preparation, yet independent of this effort, the United State 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 can 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. The remedy will not be chosen until after the RI/FS Report is finalized, and the Proposed Plan and subject comment period is completed. After consideration of public comments, the selected remedy will be documented in a record of decision (ROD) that will be published in the Administrative Record.	The document requires no change. The Army will consider all USGS recommendations and use all available USGS reports in implementation of its groundwater monitoring program. Every alternative in the RI/FS includes continuation of a groundwater monitoring program. Any changes to the Groundwater Monitoring Plan will be reviewed by WDNR before implementation. The proposed changes will also be briefed to the RAB and available for public review once submitted to WDNR. The Army will continuously update its groundwater monitoring program as more data becomes available.	P
6.	We support the USGS recommendation for continuous real-time groundwater-level monitor to be located near the waste pits and other source areas (Duplicated in TAPP Questions, item 8, April 14, 2020).	The Army has installed real-time groundwater level monitoring equipment and continues to work with the WDNR on monitoring strategies.	The document requires no changes.	A
7.	The discussion and effectiveness of using vegetable oil (EVO) as a bioremediation tool at BAAP seems to be overstated. There appears to be an assumption that using EVO would be effective in remediating the COC's at BAAP although there is no reference to previous studies or in situ use of EVO for the BAAP COC's showing that it would be effective. It is referenced that a pilot study would be used before overall implementation. If there are studies showing the effectiveness of EVO with these COC's, it should be referenced. If not, any selection of this alternative should be supplemented with a secondary alternative in case the pilot effort does not result in effective bioremediation of the COC's. In addition, there are differences in the plumes based on chemistry and geology, thus a pilot study in the nitrocellulose production plume may indicate effective reduction, but that might not be the case in another plume such as the Central Plume. Pilot studies for EVO use should be conducted in several plume locations. Data collection is needed to determine if the right conditions are present for effective degradation (proper microbes, porosity, redox, and so forth).	Emulsified vegetable oil (EVO) is a proven technology to effectively treat chlorinated solvents and energetics. If necessary, the Army will conduct a field-scale pilot test to evaluate the performance and capabilities of using EVO to treat contaminated groundwater at BAAP. The Army has had success remediating many sites using EVO. In situ bioremediation of groundwater is a widely used technology for contaminated site treatment because of its relatively low cost, adaptability to site- specific conditions, and effectiveness. The CERCLA process will be followed throughout and it provides a mechanism for revisions to the selected remedy if not proven effective. Modifications to the remedial design based on site specific constraints as it relates to each plume will be considered to the degree necessary to increase effectiveness.	The document requires no change. IAW CERCLA and EPA guidance, the cleanup approaches are re-evaluated throughout cleanup as remedy effectiveness is evaluated and site conditions change. If appropriate, remedies may change.	A
8.	It appears that the cost estimates for annual O&M in Alternatives 2 and 5 for all of the contaminant plumes (PBB, DBG and central) may be significantly underestimated in Sections 9, 10 and 11 for the reasons below. Therefore, the cost estimates associated with Alternatives 2 and 5 should be adjusted accordingly to consider the long-term monitoring and testing costs which could be significantly higher than stated in the current document. The timeframes in the Alternatives need to reflect reality at BAAP and not simply be adjusted to what appears to be an arbitrary 30-year timeline. Otherwise, this skews the cost analysis and misrepresents the economics of final cleanup which will be a significant factor in the decision process.	For environmental cleanup decision-making, the Army must follow both CERCLA guidance and the Department of Defense (DoD) Manual 4715.2 (March 9, 2012). 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 Defense Environmental Restoration Program (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."	Text was added to the FS to clarify 30 years.	P

Comments from RAB				
Item	**Comment**	**Response**	**Action**	**Army Acceptance (A/NA/P/R) (1)**
8. a.b.c.	In using the groundwater flow calculations contained in Section 4.4.4 of the subject document, a single flushing of distance from the source area to the release point at the Wisconsin River/Lake would be approximately 44 yrs. for the PBG, 69 yrs. for DBG and 56 yrs. for the central plume. All of the flow times significantly exceed the 30 yr timeframe assumed in the draft final RI/FS. It is well known that a single flushing of groundwater does not totally eliminate contaminants in groundwater environments due to many variables (e.g. pH, temperature, adhesion, ion state, mineralization, etc). It is assumed that the objective is to get the concentration of the COC's below the PAL or ES. However, there is no scientific basis for assuming that this would be accomplished in 30 years or within a single flushing period. It would be helpful to have a scientific estimate of the effectiveness of the flushing effect of the contaminants of concern that is specific to the known geology at BAAP.	Groundwater flow calculations will continue to be refined as necessary during the remedial design.	The document requires no change. The Army has contracted with USGS to provide accurate groundwater flow data/mapping and will use actual BAAP groundwater flow data when calculations are made in the remedial design. 30 years was used in the comparison of FS alternatives, as directed by DERP guidance.	P
9.	There is considerable apprehension on the part of homeowners who are in the path of or directly adjacent to any of the contaminant plumes (See insert B of Fig. 20). These homeowners are being affected irrespective of whether their water exceeds either the PAL or ES limits since the value and salability of their property is negatively affected. Given that the Army has backed away from its previous proposal to construct a rural water supply system, the following would be a proactive and reasonable approach that would be a positive step for the community: (Comment duplicated in comment from Chris Hanson)	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.	The document requires no change. The Army will continue to review and revise the groundwater monitoring program to ensure it remains protective of human health.	A
9. a.	Develop and maintain a residential well testing program for all residential wells that are directly in the path or immediately adjacent to any of the plumes.(Comment duplicated in comment from Chris Hanson)	The Army's sampling program is designed to identify and be protective of the residential wells that could be potentially impacted. A total of 54 residential wells are sampled at varying frequencies each year. The current groundwater sampling program of residential wells is being conducted according to sampling plans agreed upon by the Army and WDNR. The sampling plan is routinely modified based on requests from the WDNR.	The document requires no change. The Army has contracted with the USGS to collect additional data related to groundwater at BAAP. Where it is relevant, that data will be incorporated into the process.	A
9. b.	Expand Alternative 5 (Well Replacement) for all plumes to include well replacement for any residential well that is directly in the path of a plume, exceeds the PAL for any contaminant, and groundwater modeling shows that it has a high likelihood of being contaminated in the future. (Per conversation with Mike Kelly on 12/5/19, this approach would be within the Army's authority). (Comment duplicated in comment from Chris Hanson)	Related to Alternative 5, well replacement criteria are as follows, "If sampling results indicate an increasing trend for a plume's COC in three consecutive rounds and the data shows that the plume is migrating toward a residential well, the Army will evaluate if well replacement is necessary." Army headquarters may authorize replacement of a well in advance of contamination if data shows contamination is very likely in the future.	When contamination of a residential well is estimated to be imminent, circumstances may allow well replacement in advance. Army headquarters would review data and may authorize well replacement in advance on a case-by-case basis.	A
10.	Why has the Army not asked for authority to build the water system? It seems that a price tag almost 3 times higher for Army's preferred solution(s) would be justification enough.	A public water system does not treat the groundwater contamination. The purpose of the RI/FS is to determine remedial actions based on risk.	The document requires no change.	R
11.	Are the source-area caps intended to be permanent? Do any remediation alternatives apply directly to the contamination underneath the caps? We support the USGS recommendation for "Source Area Treatment". However, we do not support remedial actions that will actively push more contamination to groundwater and placing nearby drinking water wells and surface water at greater risk. (in response to USGS TAPP Questions, items 12 and 14, April 14, 2020).	Yes, source area caps and/or covers are permanent. Maintenance and monitoring of the conditions of each cap and cover are conducted annually. None of the groundwater remedial actions address soil contamination under the caps. The caps were the final remedial action agreed upon with the WDNR to close the sites. This RI/FS only pertains to groundwater contamination. Active remediation in the PBG source area was proposed in Alternatives 3, 4 & 6. Active remediation in the DBG source area was proposed in Alternatives 3, 4 & 6.	The document requires no change.	A
12.	The U.S. Army Corps of Engineers conducted five-year reviews of the PBG and DBG in 2013 and 2019. According to the RI/FS, the 2019 reports were not yet available. When will the 2019 reports be available?	The status of the five-year review is pending final approval and will be available to the public thereafter.	The Army will provide the five-year review to the RAB once it has been finalized.	NA
13.	More information is needed regarding sewer lines and drainage ditches. Have all historic sewer lines been remediated? Has contaminated soil from all the open drainage ditches been disposed of?	This RI/FS only pertains to groundwater contamination. The historic sewer lines and drainage ditches throughout the former BAAP production areas have been remediated under previous actions. All contaminated soil and sewer piping related to these cleanup actions were disposed of in the on-site licensed Landfills 3118 and 3646.	The document requires no change.	R
14.	Rising groundwater is a potential threat to capped contaminant source areas in the PBG and DBG source areas. Continuous, real-time groundwater level monitoring stations at selected wells near the source areas are recommended as part of a potential treatment and monitoring plan. These stations would help monitor recharge from precipitation events, effects of pump and treat on groundwater levels, and provide early warning about rising groundwater levels that might come in contact with contaminated soils. Collection of groundwater samples downgradient of the source areas could be coordinated with rises in groundwater levels.	The design phase is when the Army will consider the use of real- time groundwater monitoring and its value to the remediation effort. Additionally, the Army has increased testing the monitoring wells near the PBG source area (PBG Waste Pits) to better understand the increase of dinitrotoluene in the shallow groundwater. The Army plans to also increase monitoring the groundwater elevations/depth near the PBG source area.	The document requires no change. During September 2020, the Army sampled an additional 107 monitoring wells both near the PBG source area and downgradient. In conjunction with the regularly scheduled September 2020 sampling of 79 monitoring wells, the Army sampled all monitoring wells associated with the PBG Plume. The Army will work with the USGS to re-evaluate the groundwater monitoring program for the PBG Plume.	A

Comments from RAB				
Item	**Comment**	**Response**	**Action**	**Army Acceptance (A/NA/P/R) [1]**
15.	The U.S. Army should further pursue identification of the source of the Central Plume (Duplicated in TAPP Questions, item 13, April 14, 2020).	Based on the groundwater flow direction and the groundwater contaminant detections, the source of contaminated groundwater related to the Central Plume was believed to be in the north- central portion of BAAP where nitroglycerin, rocket paste, and rocket propellant were produced. 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. Based on historical document reviews, the investigation of the source of DNT contamination focused on the Rocket Paste production area. The WDNR was provided with multiple reports on the investigation and remedial soil activities. The WDNR provided the Army with multiple case closure letters. The Army is not performing any additional soil investigations at BAAP.	The document requires no change.	R
16.	Could contamination have moved under or across the River? To help alleviate this concern, it is recommended that sampling under, or across the River be included as part of the monitoring program.	Regarding groundwater contamination in the PBG Plume, Woody Myers from the WDNR conducted a presentation on groundwater flow near the Wisconsin River during a RAB meeting in March 2015. Mr. Myers did not recommend sampling groundwater on the other side of the Wisconsin River. Mr. Myers referenced a preliminary groundwater model from the Wisconsin Geological and Natural History Survey (WGNHS) showing that groundwater on the east/south side of the Wisconsin River, at all depths, flows west towards the River. Regarding groundwater contamination in the Central Plume, during 2018 and 2019, the Army sampled the residential wells located south of Gruber's Grove Bay/Wisconsin River and potentially downgradient of the Central Plume. Dinitrotoluene was not detected in these residential wells, indicating there was no likely migration of the Central Plume beneath Gruber's Grove Bay. Regarding groundwater contamination in the DBG Plume, the Army has been working with the USGS to evaluate the current groundwater monitoring network.	The document requires no change. The Army will use USGS recommendations to enhance the monitoring well network in the downgradient portion of the DBG Plume and evaluate if contamination has migrated into the Weigand's Bay/Wisconsin River. The Army has continued to work with the USGS regarding sampling groundwater on the eastern side of the Wisconsin River. The Army will conduct this effort in calendar year 2021.	R
17.	The U.S. Army should regularly test all drinking water wells located within or very near known groundwater contaminant plumes, including but not limited to the Ron Lins home.	The Army's sampling program is designed to identify and be protective of the residential wells that could be potentially impacted. A total of 54 residential wells are sampled at varying frequencies each year. The current groundwater sampling program of residential wells is being conducted according to sampling plans agreed upon by the Army and WDNR. The sampling plan is routinely modified based on requests from the WDNR.	The document requires no change. The Army has contracted with the USGS to collect additional data related to groundwater at BAAP. Where it is relevant, that data will be incorporated into the process.	P
18.	Soil samples collected in 2019 from the settling ponds and spoil disposal areas in the vicinity of the deterrent burning ground area show a relatively high concentration of total mercury. This is an area that contributed runoff to Grubers Grove Bay, which also contains high concentrations of mercury in bed sediment. It is recommended that groundwater sampling be performed for mercury in nearby monitor and residential wells.	The purpose of the RI/FS is to address contaminants of concern in groundwater as they pertain to risk to human health. The USGS study for mercury was based on sediment cleanup standards and conducted to help refine the source of mercury in Gruber's Grove Bay. There is no evidence that mercury in the soil at the Settling Ponds has migrated into the groundwater. The Army has no plans to sample the groundwater for mercury at BAAP.	The document requires no change.	R

Notes:
(1) Acceptance: A – Accepted, NA - Not Applicable, P - Partially Accepted, R – Rejected

Comments from CSWAB				
Item	**Comment**	**Response**	**Action**	**Army Acceptance (A/NA/P/R) (1)**
1.	**Private Well Testing at and near the Propellant Burning Ground Plume** The groundwater pump-and-treat system at the southern boundary of Badger was installed and operated to prevent the migration of contaminants beyond the property boundary. Now that the system has been shut down, this protective barrier is gone and contaminant movement is no longer inhibited. Further, we disagree with the Army's reliance on sampling conducted prior the cessation of active groundwater remediation, particularly in light of the significant increases in groundwater contaminant levels at the Propellant Burning Grounds and exceedances at the southern plant boundary including ethyl ether. We ask that the Army be required to regularly test down-gradient drinking water wells located in or near estimated plume margins which – despite the tidy maps in the RI/FS – are not static.	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.	The document requires no changes. The Army will continue to review and revise the groundwater monitoring program to ensure it remains protective of human health.	P
2.	**PFAS Investigations & Testing** The Army has indicated that the pending Preliminary Assessment/Site Investigation (PA/SI) for PFAS at Badger may be limited to only PFOA and PFOS. a) We strongly support the Wisconsin Department of Natural Resources (WDNR) request that the PA/SI evaluate all 36 PFAS compounds for which the Department has requested drinking water standards. We recognize that the 2018 sampling effort by the Army did not include all of these but did include 18 compounds. b) We also ask that the RI/FS not be finalized until the PA/SI has been submitted to and formally reviewed by the WDNR for completeness and consistency with non-military site investigations in Wisconsin. c) In September 2018, area residents collectively asked that the U.S. Army prioritize public and private well testing in its planned investigation for PFAS – a group of highly toxic compounds that has not been included in any of the Army's previous environmental studies. More than 100 people, including members of the community's Restoration Advisory Board, signed a resolution asking that the Army test all public drinking water systems within a four-mile radius of Badger for PFAS. The resolution also asked that the Army include PFAS analysis in its upcoming testing of approximately 300 residential wells near the former military base. This testing should be completed before any remedy selection begins. d) In addition to firefighting foam, PFAS have been found in solid waste, landfills and surrounding environmental media (soil, groundwater), leachates, landfill gas, wastewater effluents, and biosolids. A scientific study of U.S. municipal landfill leachate detected PFAS in over 50% of the landfills tested. As the majority of land disposal sites at Badger are unlined and without leachate collection systems, any PFAS present will inevitably migrate off-site with the potential to contaminate groundwater. PFAS are highly soluble and do not degrade in the environment. The RI/FS for groundwater should be amended to include PFAS testing at all 10 landfills and other pertinent land disposal sites at Badger.	2a) There are currently no methods available to test for all 36 compounds, as far as we are aware. There is currently only enough data to determine risk for three (PFOS, PFOA, PFBS). 2b) The PA/SI is a separate document to determine if further action is necessary to address potential risks related to PFAS. The Amy will address all risks related to previous activities at BAAP. 2c) Based on information collected in the PFAS PA/SI, the Army does not see itself as a source of PFAS contamination. The Army is unable to legally test private wells for contaminants not related to its activities. Because PFAS compounds are so prevalent in nature, it would not be reasonable to test private wells and directly attribute PFAS contamination to government activities at BAAP. 2d) Based on information collected in the PFAS PA/SI, the Army does not have a record of PFAS containing materials being placed in any of the BAAP landfills. This includes soils, packaging and processing materials which would have been used during operation of the installation. Therefore there would be no reason to assume these materials would have made their way into the landfills or wastewater effluents.	The document requires no changes. The PA/SI is a separate document.	NA
3.	**Aesthetic water quality** The Army has and proposes to replace impacted residential well replacement with deeper wells which invariably have very poor aesthetic quality. Water from these wells is often heavy in iron concentrations requiring household treatment for the life of the well, long after active remediation is complete. The RI/FS should indicate how residents will be compensated in this regard.	The Army will work with homeowners to replace any impacted residential well. If water quality requires a household treatment system, the Army will provide one, but the Army can not compensate residents for long-term operation of their well system under the Defense Environmental Restoration Program.	The document requires no change.	R
4. a.	**Contaminants of Concern** The Wisconsin River acts as a discharge point for groundwater east and south of Badger. Based on historical groundwater sampling data, groundwater is contaminated by chlorinated solvents and explosives from the Propellant Burning Grounds. The RI/FS states: "While other contaminants of concern were detected, it is unlikely these contaminants are site related." The RI/FS should be amended to list ALL detected contaminants of concern in groundwater at Badger and the range of concentrations (minimum and maximum) for each. This request includes (but is not limited to) vanadium, tetrahydrofuran, nitrates, pesticides/herbicides, PFAS, PCBs, dioxins and asbestos.	The RI/FS does contain tables listing all the detected contaminants of concern in groundwater during 2018. All groundwater data collected from Badger is provided to the WDNR and available at the WDNR's GEMS website: *https://dnr.wi.gov/wastemgmt/gotw/webpages/UserAgreement.aspx.* The Army does sample monitoring wells for tetrahydrofuran when volatile organic compounds (VOCs) are analyzed and nitrates on select wells in the PBG Plume. Based on the currently WDNR approved groundwater monitoring sampling plan, the Army does not sample groundwater for vanadium, pesticides/herbicides, PFAS, PCBs, dioxins or asbestos. These compounds have not been identified as contaminants of concern due to Army legacy operations.	The Executive Summary in the RI/FS report has been revised to provide clarity regarding contaminants of concern.	P
4. b.	EPA estimates that 90% of 1,4-dioxane produced was for use as a stabilizer for chlorinated solvents including 1,1,1-TCA and carbon tetrachloride. The RI/FS should address the potential for solvent stabilizers to be present at Badger.	During April 2017, the Army sampled three monitoring wells for 1,4- dioxane. A well was sampled downgradient from the DBG (ELM-8901), Landfill #5 (ELN-8203A) and the PBG (PBN-8205A). 1,4-Dioxane has not been detected above 0.24 micrograms per liter (µg/l). Because the concentrations of chlorinated stabilizers is low at BAAP, the potential for solvent stabilizers is also low. The Army will continue to sample monitoring wells for both 1,1,1-TCA and carbon tetrachloride when volatile organic compounds (VOCs) are analyzed. Monitoring wells downgradient of the DBG, Landfill #5, and the PBG are analyzed for VOCs.	The document requires no change.	P

Comments from CSWAB				
Item	Comment	Response	Action	Army Acceptance (A/NA/P/R) (1)
5.	**DNT – A Mixture of 6 Isomers** According to the RI/FS (page 5), remedy Alternative 3 (Pump and Treat), Alternative 4 (Anaerobic Bioremediation) and Alternative 6 (Source Area Treatment) for the Propellant Burning Ground groundwater contaminant plume will target elevated levels of only one form of DNT (2,6-DNT). However, all six forms of DNT (2,4-, 2,6-, 2,3-, 2,5-, 3,4- and 3,5-DNT) have been detected in groundwater at Badger. Similarly, the calculation of cumulative cancer and non-cancer risk is limited to only 2,6-DNT at the Propellant Burning Ground (off-site and on-site) and the Central Plume (off-site) – which are both impacting neighboring residential areas. This is a signification omission as degradation of identified contaminants of concern is a significant consideration in the majority of proposed alternative remedies and the minor forms of DNT do NOT biologically or chemically degrade. In fact, the Army evaluated the groundwater capture of the MIRM (groundwater pump-and-treat system) by tracking 2,3-DNT because it was "more persistent and could be used as an indicator within the entire PBG plume whereas the 2,4- and 2,6- were only being detected in the source area." Moreover, consideration of all six isomers is necessary to be consistent with Wisconsin's Groundwater Enforcement Standard of 0.05 ug/l for the summed total concentration of all six DNT isomers. Therefore we ask that all six isomers of DNT are included as Contaminants of Concern in groundwater both inside and outside the facility.	The risk-based COCs identified in the **PBG Plume** were chloroform, CTET, ethyl ether, TCE, and 2,6-DNT. The Screening Level Groundwater Risk Evaluation (Appendix G) identified that both 2,6-DNT and total DNT had an on-site cancer risk and noncancer risk above the risk management criteria; with 2,6-DNT having higher risk values. The Army reports only 2,6-DNT in the RI/FS as it is the most conservative and cleanup of 2,6-DNT will also affect total DNT levels. The risk-based COCs identified in the **Central Plume** were benzene, chloroform, 1,2-dichloroethane, and 2,6-DNT. The Screening Level Groundwater Risk Evaluation (Appendix G) identified that only 2,6-DNT had an off-site cancer risk above the risk management criteria. Total DNT had an off-site cancer risk that was below the risk management criteria. The risk-based COCs identified in the DBG Plume were chloroform, 1,1,2-TCA, TCE, and total DNT. Total DNT was identified as having an off-site cancer risk above the risk management criteria. The HHRA did not identify any human health risk related COCs for the **NC Area Plume**. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). The Army does follow Wisconsin's NR 140 Groundwater Enforcement Standard of 0.05 ug/l for total DNT as it relates to monitoring the groundwater plumes.	The relevant portions of the RI/FS report were updated to reflect the following statement: The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).	A
6.	**Total Mass of DNT in Source Areas** The Army's calculation of the remaining total mass of residual DNT contamination in the plume source areas is based on soil data for only two of the six isomers present at Badger. As a result, the remaining mass of total DNT is significantly underestimated. Moreover, actual field data is necessary to accurately quantify and substantiate the estimated risk to human health and the environment. The WDNR previously ordered and then deferred soil testing for all forms of DNT pending action by EPA nearly 10 years ago and is no longer relevant. WDNR should now reinstate its order to the Army to test (fully characterize) contaminated soils in plume source areas for all six forms of DNT.	The Army's calculation of the remaining total mass of DNT is based on the best available information to date. Depending upon the chosen remediation alternative, additional DNT mass calculations may be necessary in the remedial design phase.	The document requires no changes. The Army will address total mass of DNT as necessary in the remedial design phase.	P
7.	**Vapor Intrusion** The Army's evaluation of vapor intrusion as a potential route of exposure should be amended to include degradation products of DNTs. Scientific studies indicate that o-nitrotoluene (2-nitrotoluene; CAS 88722), for example, is sufficiently toxic and volatile to be considered a vapor intrusion threat.	EPA'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], specifies the following regarding a chemical's volatility. 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 m3 mol-1). The Army evaluated the vapor pressure and Henry's law constant for 15 possible degradation products of DNT. All 15 compounds have a vapor pressure below 1 mm Hg. Only 2- nitrotoluene had a Henry's law constant above 10-5 atm m3 mol-1; it was 1.25 10-5 atm m3 mol-1. If the Henry's law constant is above 10-5 atm m3 mol-1 then that compound could volatilize from water into soil and pose a potential vapor intrusion risk. The Army did conduct DNT degradation groundwater sampling, including 2-nitrotoluene, near the PBG waste pits from 2008 to 2014. 2-Nitrotoluene concentrations were not sufficient to pose a vapor intrusion threat.	The document requires no changes.	R
8.	**Surface water, natural springs and wetlands** The Clean Water Act, 33 U.S.C. ss 1251 et seq., was enacted by Congress to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Id. ss 1251(a). Wisconsin has an EPA-approved NPDES permitting program, and the WDNR is the agency that issues NPDES permits to point-source dischargers within the State. For this reason, Wisconsin issued WPDES permits containing effluent limitations for the discharge of treated groundwater from the IRM/MIRM to Lake Wisconsin. In comments on the previous RI/FS for groundwater, the WDNR noted that one possible concern about contaminated groundwater seeping into Lake Wisconsin/Wisconsin River might be for carbon tetrachloride, particularly at the groundwater/surface water interface. Enforceable limitations will also help assure that the discharge of contaminated groundwater to spring-fed wetlands at Weigand's Bay does not negatively impact this aquatic ecosystem and fisheries. The same recommendation applies to groundwater discharge to the Lower Wisconsin Riverway through "seeps" in the river bank. Given the State has not enforcement groundwater standards outside the Badger property literally for decades, the public cannot rely on this mechanism alone to protect aquatic ecosystems. Therefore, we ask that the State apply the SAME effluent limitations required for the IRM/MIRM discharge to the discharge of contaminated groundwater to all surface water, natural springs and wetlands near Badger.	The Army under the CERCLA process is not required to obtain state permits, including NPDES. However, we will comply with those properly identified substantial provisions as ARARs.	Since this comment requests action by the state, it has been forwarded to the WDNR.	NA

Comments from CSWAB				
Item	**Comment**	**Response**	**Action**	**Army Acceptance (A/NA/P/R)** [(1)]
9.	**Soils as a Source of Groundwater Contamination** The presented alternative remedies are limited to groundwater primarily because the Army maintains that contaminated soils in source areas have been addressed "to the maximum extent possible" and that the WDNR has issued site closure for soil cleanup. However, these regulatory approvals are contingent on the ability of the remedy to protect human health and the environment by achieving compliance with state and federal standards and all specific conditions outlined in closure documents. Therefore, we ask that the WDNR formally review current site conditions and make a determination as to whether or not compliance with source area closure conditions (for soil) at Badger are currently and fully achieved. If not compliant, we ask that the WDNR require the Army to complete an RI/FS (or equivalent) examining technologies and methods that could improve the control of source areas.	All soil source areas were closed in accordance with Wisconsin law and have appropriate closure documents. This RI/FS only pertains to groundwater contamination.	Since this comment requests action by the state, it has been forwarded to the WDNR.	R
Notes: (1) Acceptance: A – Accepted, NA - Not Applicable, P - Partially Accepted, R – Rejected				

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Via E-mail (luke.lampo@wisconsin.gov)

January 2, 2024

Mr. Luke Lampo
Remediation and Redevelopment Program
Wisconsin Department of Natural Resources
3911 Fish Hatchery Road
Fitchburg, WI 53711-5397

Subject: Response to DNR Comments on Draft Desktop Supplemental Remedial Investigation (RI)
Badger Army Ammunition Plant, Gruber's Grove Bay, Baraboo, WI
DNR BRRTS Activity #02-57-001002

Dear Mr. Lampo:

Please find the attached responses from the Army to the Wisconsin Department of Natural Resources (DNR) correspondence dated November 14, 2023. This submittal responds to DNR comments that will be incorporated in the Final Desktop Supplemental RI Report and future deliverables for the project.

If you have any questions, please contact Tat Ebihara at 847.902.1519.

Yours sincerely,

Tat Ebihara, PhD
Senior Project Manager
Tat.Ebihara@aecom.com

Billy Rhymes
Project Manager
billy.rhymes@aecom.com

Attachment:
Attachment A – Army Response to WDNR Comments dated November 14, 2023.

cc: Judy Fassbender, DNR
Issac Ross, DNR
Xiaochun Zhang, DNR
Quang Nguyen, Army
Jessica Hoppman, USACE
Ryan Tefft, USACE
Brian Mastin, AECOM

ARMY RESPONSE TO WDNR COMMENTS DATED NOVEMBER 14, 2023
GRUBER'S GROVE BAY, BADGER ARMY AMMUNITION PLANT, BARABOO, WISCONSIN

Document Date: 22-Dec-2023

SUBJECT: Response to DNR Comments on Draft Desktop Supplemental Remedial Investigation Badger Army Ammunition Plant, Gruber's Grove Bay, Baraboo, WI DNR BRRTS Activity #02-57-001002

AECOM and the U.S. Army is providing the following comment responses to the Wisconsin Department of Natural Resources (DNR) from their November 14, 2023 correspondence and attachment. The responses to comments describe the scope of the revised and updated elements of the Final Desktop Supplemental Remedial Investigation Report and subsequent report deliverables associated with this project.

Approved by:

Tatsuji Ebihara, PhD
AECOM
Project Manager

Ryan Tefft
U.S. Army Corps of Engineers – Omaha District
Project Manager

The Wisconsin Department of Natural Resources (DNR) has received and reviewed the document entitled "Draft Desktop Supplemental Remedial Investigation Badger Army Ammunition Plant Gruber's Grove Bay, WI" (Report), dated July 2023, prepared for the United States Army Corps of Engineers (USACE) and U.S. Army Environmental Command (Army) by AECOM Technical Services, Inc. (AECOM).

DNR appreciates the helpful summary of post-2000 documentation regarding site assessment and remedial action. The data files further assisted our understanding of the assessment. Considering the project purpose and ultimate remedial objectives for the site, in general, DNR offers the following recommendations:

- The previously established most probable background contamination (MPBC) of 0.36 mg/kg total mercury (THg) in sediment was approved in 2000 by the Badger Army Ammunition Plant (BAAP) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA), National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Resource Conservation and Recovery Act (RCRA), and AR200-l as captured in the 2000 Decision Document (DD). Calculation of a new background threshold value (BTV) for evaluation of the extent of contamination was not approved by DNR. The dataset used in the BTV calculation included data collected in 2019 from Lake Wisconsin which represents a riverine system, not representative of a bay environment. Additionally, the sampling and analysis methods were also different from those used for site characterization of Gruber's Grove Bay (GGB). DNR requests to continue using the approved MPBC for evaluation of sediment contamination in GGB.

  COMMENT 1 RESPONSE: ***The Army understands the 2000 Decision Document Basis for the most probable background concentration (MPBC) of 0.36 mg/kg. While the USGS data from upstream sediment sampling locations document mercury concentrations above the MPBC in the Wisconsin River upstream of GGB, the Final Desktop Supplemental RI report will proceed on the 2000 Decision Document Basis.***

- Please define data quality objectives for collecting additional samples. The data quality objectives should be clearly identified and may include 1) providing better delineation of the horizontal and vertical extent of contamination; 2) further assessing potential existing sources, specifically mercury present in Settling Pond 4 and the ditch area; and 3) evaluating migration of mercury into the Wisconsin River.

  COMMENT 2 RESPONSE: ***Data quality objectives will be addressed in the updated Quality Assurance Project Plan (QAPP) for additional data gap investigation (DGI) sampling and sediment characterization proposed for this site.***

- The risk assessment results demonstrated that the site poses risks to ecological and human health. Although substantial uncertainties exist, the uncertainties are understood to be the result of variations in physical, chemical, and biological data, assumptions, and endpoints evaluated. Attempts to reduce those uncertainties will require extensive efforts to collect and reevaluate additional data. Other lines of evidence are available that eliminate the need for additional data collection for risk assessment. Additional assessment will not significantly change remedial action requirement to improve the sediment and water quality. Such conclusion has already been well explained in the 2000 DD. DNR recommends that no additional studies, i.e., assessment of biological community, be conducted for risk assessment at this time.

  COMMENT 3 RESPONSE: ***In light of the inherent uncertainties associated with GGB and the need to keep progressing the project toward FS activities, the Army agrees with DNR that no additional biological community and risk assessment field sampling studies will be conducted as part of the Final Desktop Supplemental RI report. The recommended scope for additional benthic characterization will be removed from Section 6.9 the final RI report.***

- DNR believes adequate characterization has been completed within GGB and recommends the team move forward with a feasibility study for remediation of sediment in GGB.

  COMMENT 4 RESPONSE: ***The Army will finalize the Deskstop Supplemental RI Report without additional sediment characterization. A DGI report will provide supplemental sediment physical property characterization following the Final Desktop Supplemental RI report.***

- Evaluate the potential for on-going migration of contaminants from possible source areas including Settling Pond 4 and the adjacent ditch area. Consider additional sampling from Settling Pond 4 and the ditch area as part of the evaluation. Evaluate the potential for contaminants to migrate further into the Wisconsin River downstream of GGB.

  COMMENT 5 RESPONSE: ***The Army does not plan to perform additional sampling related to Settling Pond 4 as this scope is not approved in the USACE budgeting plans for upcoming fiscal year. However, the DGI report deliverable will include additional existing documentation supporting the absence of a pathway for contaminant migration into GGB via buried culverts and surface runoff associated with Settling Pond 4.***

Additional details regarding DNR's recommendations are provided in the enclosed Attachment.

DNR Attachment from November 14, 2023 Correspondence

The purpose of this attachment is to provide information to explain the analyses and evaluation that support the recommendations as summarized above as well as some specific questions and comments on the report. This attachment is organized in four components: 1) new background threshold value (BTV); 2) conceptual site model; 3) potential existing sources; 4) fate and transport of contaminated sediment and gelatinous materials; 5) human health and ecological and risk assessment; 6) comments on recommendations in the report.

1. New background threshold value (BTV)

Historically, Wiegands Bay has been used as the background site to establish the most probable background contamination (MBPC) of 0.36 mg/kg of total mercury (THg) for assessment and remediation at Gruber's Grove Bay (GGB). The Report presented a new value of 0.49 mg/kg in sediment as the BTV for evaluation of the extent of contamination in GGB. The BTV was calculated based on mercury concentrations in the top 0.16 ft of sediment samples collected in 2019 by the United States Geological Survey (USGS) from two reference sites, Wiegands Bay and Lake Wisconsin which is located upstream of Wiegands Bay. Different sampling and analytical methods applied by the USGS was the factor that precluded the use of the USGS data for this remedial investigation within GGB as stated in the Report. In addition, the effect of using the BTV of 0.49 mg/kg instead of the MPBC of 0.36 mg/kg of THg on delineation of spatial distribution of contaminated sediment at the site is insignificant. The difference using the BTV on evaluation of spatial extent can be illustrated by adding another class of 0.36-0.49 mg/kg in Figures 2-3 and 2-4. Please modify the figures with classifications including the class of 0.36-0.49mg/kg.

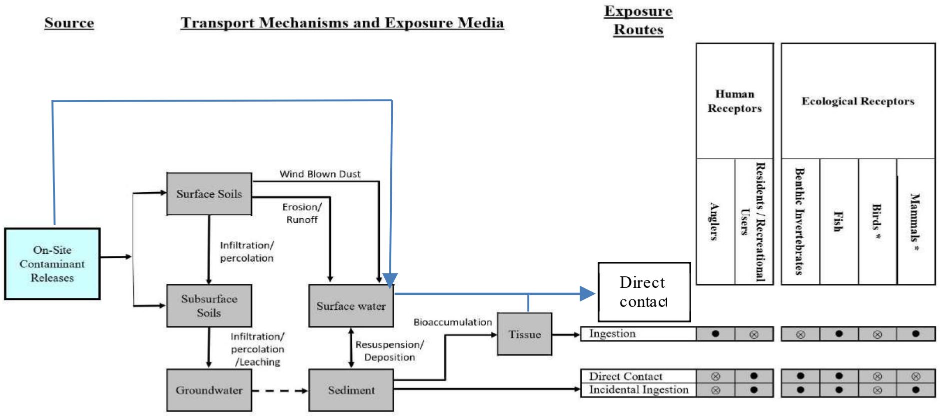
COMMENT 6 RESPONSE: ***The Army will modify Figures 2-3 and 2-4 for sediments in the 0.36 to 0.49 mg/kg range as requested by DNR. It should be noted that since upstream Lake Wisconsin sediments (USGS, 2019) are greater than the 0.36 mg/kg MPBV, the use of the 0.49 mg/kg BTV may become important for delineating the extent of total mercury at the mouth of GGB for remediation alternatives.***

2. Conceptual site model (CSM)

Clarification is required to define whether the conceptual site model as illustrated in Figure 3-1 (adopted below) represents the site history or the current condition. Historically, the on-site contaminant release directly discharged to surface water in GGB. The CSM needs to include surface water as a media for direct exposure and through bioconcentration and bioaccumulation even if the risk to human health is insignificant as assumed in the Report. Connectors should be added to Figure 3-1 as indicated to illustrate the surface water exposure pathway under historical condition.

COMMENT 7 RESPONSE*:* ***Surface water will be added to Figure 3-1 as a potential pathway as requested by DNR.***

If the CSM reflects the current condition, then it must be modified to include potential discharges from Settling Pond 4 and the ditch area through buried culverts and surface runoff to surface water and sediment in the bay. Mercury (Hg) concentrations up to 8.2 mg/kg were detected in soil samples collected from Settling Pond 4 by the USGS (2019). According to the environmental impact statement and report (Owen Ayres & Associates 1973), potentially there are fifteen 24" diameter culverts buried under the old State Highway 78. During heavy precipitation and snowmelt, the ponded water may discharge to GGB via the culverts.



COMMENT 8 RESPONSE: ***See response to Comment 5 regarding additional documentation that will be provided about water discharges into GGB in the DGI Report.***

The Report needs to develop and refine a CSM that considers sediment stability as requested in the Performance Work Statement (USACE, 2022). Mercury in dissolved and particulate phases may continue to migrate out of GGB to the Wisconsin River especially because higher concentration of mercury is associated with gelatinous materials which is more mobile than other sediment material.

COMMENT 9 RESPONSE: ***The existing datasets, as summarized in the Desktop Supplemental RI did not allow for sediment stability evaluation. The Army agrees that it is acceptable to move on to the FS evaluation with a DGI pending. As discussed in the draft RI report, an assessment of sediment transport and changing concentrations over time is not possible using data collected to date. Sampling locations from 2009 do not align with sample locations from 2016 and 2018, thus changes over time could not be determined. Additionally, samples collected in 2016 were collected from the surface only, whereas samples collected in 2018 were primarily subsurface. The 2016 and 2018 samples were assessed together to get an overall picture of elevated total mercury (THg) concentrations in GGB.***

3. Fate and transport of contaminated sediment and gelatinous materials

The presence of gelatinous material in GGB has been well documented through site investigation and previous remediation activities. These materials are indictive of discharge from the BAAP wastewater treatment processes and are associated with high mercury concentrations as well as other contaminants of concern. Low shear strength of 0 kg/cm^2 was reported in 5 out of 6 top surface samples and a range of 0.05 to 0.15 0 kg/cm^2 at 1 ft below sediment surface (SpecPro, 2009). With such low shear strength, small disturbances, whether naturally induced or as a result of human activity, the materials may easily mix vertically and resuspend from sediment to water column that result in redistribution within the bay and transport out of the bay. Therefore, the dynamic sediment transport processes can cause temporal changes of spatial distribution of the gelatinous materials. Results from various assessments have shown that the materials tend to “focus” in deeper water areas in the bay. The increase of surface area weighted concentration (SWAC) from 0.72 mg/kg in 2009

(SpecPro, 2009) to 1.11 mg/kg in 2011 (SPS, 2016) may be attributed to sediment redistribution within GGB. This also leads to concerns of mercury loading from GGB to the Wisconsin River downstream of GGB. In addition, with historical discharge averaging in approximately 18 million gallons per day (MGD) based on 1972 data (Owen Ayres & Association, 1973), gelatinous materials associated with contaminants of concern in suspended form might have left the bay and deposited in the Wisconsin River.

COMMENT 10 RESPONSE: ***As noted in the response to Comment 9, existing datasets do not allow for a sediment stability evaluation. As noted in the Desktop Supplemental RI Report, sediment transport into or out of GGB could not be quantified since sampling locations have not been repeated over time. Furthermore, use of the 2009 sediment data is not recommended to evaluate change over time since different sampling procedures were used in the 2009 sampling event, confounding any conclusion that could be drawn by comparing results, including SWAC values, to other years. Samples collected in 2009 involved some compositing of the soft "gelatinous" materials with the underlying thicker fine-grained sediment, resulting in an inconsistency of the type of material sent for analysis. Samples were then homogenized and sent for analysis using USEPA Method 7471A. As noted in Section 2.1, Data Useability, six split samples collected by WDNR at the time of the 2009 event included only the gelatinous portion of the sediment; differences in analytical results between SPS and WDNR were noted in Table 3 of the 2009 report (SPS, 2009). This resulted in the area of mercury background exceedances for the 2009 dataset being far less than the area of background exceedances for the 2016/2018 dataset and likely contributed to a much lower SWAC value for 2009.***

4. Human health and ecological risk assessment

Mercury contamination in sediment of GGB after the second remedial action in 2006 has been assessed multiple times. It is anticipated that remediation has improved sediment quality, unfortunately sediment samples collected from 2009 through 2018 revealed mercury concentrations up to 12.4 mg/kg which is not significantly different from 16.7 mg/kg in 2005 samples (AECOM, 2023). Based on a 2016 site assessment, over 50% of the surface sediment in the bay is potentially covered with material containing mercury concentrations greater than 1 mg/kg.

In 2000, BAAP approved remedial objectives and selected remedial option as documented in the 2000 DD. Several key specific decisions are worth reiterating: 1) *an expanded problem formulation plan (EPFP) was developed in lieu of a full ecological risk assessment (ERA)*; 2) *the EPFP concluded that it is unlikely that a site- specific ERA would support a cleanup level significantly different from the WDNR's proposed most probable background contamination (MPBC) level of 0.36 mg/kg of total mercury*; 3) *site risks are associated predominantly with ecological receptors in direct contact with the sediments and the food chain pathway.*

Although ecological communities have not been evaluated since 2006, the presence of Hg with relatively higher percent of methylmercury in GGB compared to the reference site, exceedance of surface water criteria for wildlife, and the mere presence of gelatinous materials indicate that the sediment quality has not returned to support a healthy biological condition at the bay. The decision made in the 2000 DD to use the conclusion from the EPFP for managing the site is still valid. It is recommended that no additional data collection and assessment effort be carried out to further evaluate risks prior to remedial action, however, some specific comments and recommended changes in the Report are included below.

COMMENT 11 RESPONSE: ***The DNR comment is acknowledged and specific comments on the risk assessments are provided in the responses to Comments 12 to 20. While it is understood that the approved MPBC is the preferred clean up level by WDNR, the USGS evaluation indicated that mercury concentrations in upstream sediments in the Wisconsin River were present above the MPBC and that particulate matter from the Wisconsin River contributed to mercury within GGB sediments. Therefore, future data collection or habitat***

characterization efforts may be warranted in the future to support the scope of the remedial action alternatives analysis.

Human Health Risk Assessment

- Surface water exposure

  The surface water exposure pathway should be included in the CSM. The USGS reported of THg concentration in surface water in the bay with a maximum concentration of 1.4 ng/l, slightly lower than the human health criterion of 1.5 ng/l (NR105). However, the samples were collected under conditions without turbulence. Mercury concentrations in surface water is expected to increase under turbulent conditions and may exceed the criterion after sediment is resuspended. The disturbed gelatinous materials will take a long time to settle; therefore, potential exposure through surface water may be present.

  COMMENT 12 RESPONSE: ***USACE disagrees with WDNR's comment that the USGS suspended particulate matter (SPM) data collected for surface water was not representative of long-term, post-dredging quiescent conditions (e.g. what would be accomplishable after remediation) which would be representative of conditions within GGB. During the Nov. 17, 2023 teleconference, WDNR expressed that "this comment was meant to be line of evidence that sediment is the target for remediation."***

  Only four surface water samples were collected from within the Bay in 2019 and all of the USGS samples were collected as 'suspended particulate matter' samples (e.g., sample volumes of 18 to 36 liters filtered and material on the filter analyzed) rather than more typical 1 L grab surface water samples. Maximum THg concentrations in GGB were higher than in Wiegands Bay (n=4), but lower than in all of the upstream reference locations (n=3). USGS indicated that THg in GGB was significantly higher than Wiegands Bay, but not higher than the other upstream reference locations. USGS also indicated that water column particulate matter from the Wisconsin River contributes to mercury within GGB.

- Concentration Terms

  Provide clarification on why the USGS 2019 sediment data were included in the upper confidence limit (UCL) calculations but excluded from the assessment of the extent of contamination.

  The risk assessment is not adequately conservative. The 2018 assessment (SPS, 2019) reported a maximum concentration of 12.4 mg/kg in the gelatinous sediment layer in a depth interval of 0.5-1.5 ft. The sediment concentration term for the risk assessment did not include this maximum concentration. A conservative assessment should have combined results from 2016 with the results in subsurface sediment but characterized as gelatinous materials. This non-conservative factor has been identified but no further risk assessment evaluation is requested.

  COMMENT 13 RESPONSE: ***The USGS data from 2019 was not included in the UCL calculations used in the HHRA and the ERA (see Appendix D for data used for the UCLs). The text in Section 4.1.3.1 that refers to the 2019 dataset will be corrected. The USGS data were not included in the risk assessments because the analytical methods (modified EPA Method 1630) and sampling depths (0-5 cm increments to varying depths at the same location) were different from the data collected from within the Bay as part of the 2016 and 2018 sediment sampling activities.***

  It should also be noted that the 12.4 mg/kg maximum detected concentration referenced in the

second part of the WDNR comment was included in the UCL calculation for the subsurface sediment (>0.5 ft; see Table 4-1 and Appendix D).

- Fish tissue burden of mercury

  Historically, methylmercury in sediment was detected at the site in the highest level across the state water bodies (DD, 2000). Bioaccumulation and bioconcentration of methylmercury from sediment and surface water is a concern. The assessment conducted is based on fish tissue mercury data collected in a single year. The uncertainties could be high with the limited data. In general, multiple years of sampling data may be needed for assessment so that the results are statistically significant, however, DNR does not recommend collecting additional fish samples for remediation purpose because other lines of evidence exist for decision making at the site.

  COMMENT 14 RESPONSE: ***It is recognized that the fish tissue dataset is limited by the availability of data from a single year. In recognition of this limitation, the maximum fish tissue concentration was considered in the risk assessment.***

  As recommended by WDNR, no additional biological sampling is warranted at this time, so any uncertainties related to the fish tissue dataset will not be addressed at this time.

- Toxicity Assessment

  It is acknowledged that although the reference dose (RfD) for assessment of direct dermal contact to inorganic mercury in sediment may be based on the form of mercury chloride as a default, other forms of mercury can exist in sediment at the site.

  Although it might be of low significance, the surface water exposure pathway was not included in estimating the cumulative hazard index (HI).

  COMMENT 15 RESPONSE: ***As indicated in Section 4.1.6.2, surface water exposures were not quantitatively evaluated in the HHRA as exposures have been shown to be negligible and not pose unacceptable risks. Surface water exposure pathways will be added to the CSM figure; however, human exposures to surface water are expected to be insignificant relative to other exposure pathways. This will be further addressed in the Final Desktop Supplemental RI report narrative.***

  The EPFP indicated that ingestion of surface water would be at an intake level lower than the intake level of sediment and that ingestion of surface water may be excluded for mercury. Sampling in 2005 indicated that average surface water concentrations of metals were below DNR ambient water quality criteria and that GGB sediment may not be impacting water concentrations. Sampling within the Bay has primarily focused on sediment, thus, a current surface water dataset is not available.

<u>Ecological Risk Assessment</u>

- Two of the four surface water samples (USGS, 2019) exceeded wildlife criterion of 1.3 ng/l for mercury (NR105) while these samples were collected under quiescent conditions. The criterion is for protection of bald eagle, herring gull, mink and otter and other mammalian species. In addition, there is a clear decreasing trend of mercury concentration in surface water from 1.44 to 1.03 ng/l from the head to the mouth of GGB in four samples collected by the USGS in 2019. That trend is an indication that the influence of the Wisconsin River flow on GGB is perhaps limited to the region close to the mouth of the bay.

COMMENT 16 RESPONSE: ***The water quality criteria is very conservative because it assumes that the higher level consumers and predators are obtaining all of their diet from GGB. In addition, the decreasing trend identified by WDNR based on 3 USGS samples is not considered statistically significant given the small sample size.***

As indicated by USGS, water column particulate matter from the Wisconsin River contributes to mercury within GGB. Within the Bay itself, USGS in 2019 estimated that more than 50% of sediment mercury was sourced from the BAAP, but in surface sediment at the GGB margin, non-BAAP riverine sources contributed up to 75% of the sediment mercury. It is noted that total mercury concentrations in waters collected by USGS from upstream reference locations were also above the 1.3 ng/L criterions indicating that upstream, non-BAAP sources may also affect water quality and could represent continuing sources to the GGB after remedial actions are completed.

Toxicity reference values (TRVs) for fish tissue obtained from Dillon et al. (Dillon et al., 2010) were based on endpoints related to mortality or lethality-equivalent endpoints without consideration of other important biological endpoints, for instance the effects of mercury on inhibition of growth and to behavioral changes of organisms. Therefore, the conclusion should be modified to clarify the limited endpoints using results from Dillon et al.

COMMENT 17 RESPONSE: ***The conclusions will be updated to indicate that the fish-tissue TRVs are based on endpoints including fish mortality, failure to spawn, failure to hatch, and lethal developmental abnormalities and that other sublethal endpoints may be more sensitive.***

- **Section 4.2.6 Ecological Risk Characterization**: Note that not all benthic organisms burrow through sediment.

COMMENT 18 RESPONSE: ***A statement will be added to indicate that benthic invertebrates may also live in the sediment surface.***

- **4.2.6.3 Risk Description:** It is appropriate to use 'co-occurrence' sediment quality guidelines (SQGs) of threshold effect concentrations (TEC) and probable effect concentrations (PEC) to evaluate sediment quality at GGB. Sediment or gelatinous materials present at the site is a result of discharge from wastewater treatment process, potentially including flocculated sludge. According to an earlier assessment in 2000 (cross referenced by AECOM, 2023), in addition to mercury, copper and lead coexist in sediment with concentrations up to 277 mg/kg and 1,200 mg/kg, respectively. In addition, the gelatinous materials may contain chemicals that have not been analyzed but could cause adverse impacts on the biological community, further transformed, and potentially magnified to higher trophic organisms. Selection of mercury as the primary contaminant of concern or an indicator for assessment and remediation is because of the assumption that when the site is remediated based on mercury contamination, the risk posed by other co-existing chemicals will also be reduced. Therefore, it is recommended that the 'co-occurrence' sediment quality guidelines of TEC and PEC (SQGs) for mercury be used for the toxicity prediction.

COMMENT 19 RESPONSE: ***The WDNR TEC & PEC have been used to quantitatively evaluate sediment quality at GGB. However, it is relevant to point out that other benchmarks are available from mercury-spiked studies and mercury contaminated sites (which may also include lower levels***

of other contaminants) and that toxicity testing conducted in 2005 (which would have included other co-located contaminants) identified less toxicity than would be suggested by the mercury PEC exceedances.

Text will be added that the use of the mercury TEC and PEC is assumed to be appropriate for the GGB evaluation due to the potential for other co-located contaminants to also be present within the Bay.

- The statement of "*[t]his potential lack of a benthic invertebrate community would reduce the potential for mercury to move up into the food web since there would be no connection between mercury in sediment and invertebrates that would serve as a prey base for fish*" is not supported. First, absence or reduced population of benthic organisms in a sediment site is an indicator of impairment of sediment and water quality. Second, benthic invertebrates are not the sole source of food for fish, particularly those that feed on plants.

  COMMENT 20 RESPONSE: ***The text will be modified to indicate that a lack of benthic invertebrate community due to the presence of the gelatinous sediment and unstable substrate represents an impairment based on physical conditions. The text will also be modified to indicate that these substrate limitations may not limit the growth of plants or reduce foraging opportunities for herbivorous fish. However, if the benthic community is not currently present due to substrate limitations, then movement of mercury from sediment to benthic invertebrates to fish and high trophic level receptors is not a significant migration pathway.***

5. Comments on recommendations in the Report

Additional sampling: Data related to the thickness of soft sediment or gelatinous materials available from 2009 through 2018 should be reviewed and integrated into the assessment of the horizontal and vertical extent of contamination. Additional sampling should be recommended, if needed, based on the results of the review. Distribution of sediment (gelatinous materials) is significantly affected by the sediment hydrodynamic processes in the bay. Areas with high uncertainties of mercury concentrations as illustrated in Figures 2-5 and 2-6 may be correlated with lack of deposition of contaminated materials. Therefore, additional sampling efforts may not provide useful data for delineation of horizontal and vertical extent of contamination.

As a part of feasibility study, sediment probing might be helpful to define volume of contaminated sediment at the site.

COMMENT 21 RESPONSE: ***See response to Comment 10 above regarding the 2009 dataset. The Army agrees that additional horizontal and vertical delineation is need to address data uncertainties. Additional delineation will be included in the DGI and FS scope of work for priority locations toward definition of the contaminated sediment volume.***

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

25 November 2024

SUBJECT: Army Response to WDNR Comments on Proposed Plan for Site-Wide Groundwater at the Former Badger Army Ammunition Plant, Baraboo, WI (DNR BRRTS Activity #02-57-001002, 02-57-562629, 02-57-526445)

Luke Lampo
Wisconsin Department of Natural Resources
South Central Region, Remediation & Redevelopment Program
3911 Fish Hatchery Road
Fitchburg, WI 53711-5397

Dear Mr. Lampo:

U.S Army Environmental Command (USAEC) has reviewed the Wisconsin Department of Natural Resources (WDNR) letter dated October 17, 2024, with comments on the Proposed Plan for Site-Wide Groundwater at the former Badger Army Ammunition Plant (BAAP). The Proposed Plan for Site-Wide Groundwater at Former Badger Army Ammunition Plant was sent to WDNR in July 2024.

The Proposed Plan uses a $1x10^{-4}$ cancer risk threshold for on-site groundwater monitoring wells where property transfer documents restrict groundwater access within the boundaries of BAAP and a $1x10^{-6}$ cancer risk threshold for off-site residential and groundwater monitoring wells where the Army has no control over the land/groundwater. In cases where specific contaminants are present on and off-site, the cancer risk for those contaminants were evaluated at the more conservative $1x10^{-6}$ risk level. This approach is consistent with the guidance set forth in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which governs response actions at this site. This approach was also stated in the June 2021 Final RI/FS report.

In the Army's implementation of the Defense Environmental Restoration Program (Title 10, United States Code Ch 160) at CERCLA sites, state requirements are considered only after unacceptable risk has been identified. CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; Part 300 of title 40, Code of Federal Regulations), do not provide for considering or applying state regulations in the evaluation of risk. Risk was evaluated at the Nitrocellulose (NC), Propellant Burning Ground (PBG), Deterrent Burning Ground (DBG), and Central Plumes to understand both on and off-site risks. The RI report found risk and identified numerous COCs for the PBG, DBG, and Central Plumes that are addressed in the Proposed Plan and will be targeted in the subsequent remedial action. The NCP identifies acceptable exposure levels to known or suspected carcinogens as "…generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}…" (40 CFR §300.430(e)(2)(i)(A)). United States Environmental Protection Agency (EPA) guidance further explains that where the cumulative carcinogenic risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4} and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted, (*Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, pages 4-5, EPA, Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30, April 22, 1991 and *Rule of Thumb for Superfund Remedy*

Selection, page 7, EPA, OSWER Directive 9355.0-69, August 1997). The maximum of the most recent observed concentration of each contaminant was used for the risk screening. This results in a conservative calculation that overestimates the actual risk to human health and the environment. A state human health risk regulation does not modify the risk range generally defined as acceptable in the NCP. The contaminants that were not included in the list of COCs for PBG, DBG, and Central Plumes that WDNR has requested the Army to reevaluate were found entirely within the boundary of the former BAAP and below the $1x10^{-4}$ risk level. However, the preferred remedy for the COCs of anerobic bioremediation will remediate the additional contaminants that WDNR is requesting in addition to the targeted COCs.

Under the NCP, potential ARARs are first identified during the Remedial Investigation then clarified in the Feasibility Study and Proposed Plan (40 CFR §300.430(d)(3)). However, compliance with ARARs only arises under CERCLA when there is a determination that unacceptable risk is present, and an onsite remedial action is required. There were no risk-based COCs identified within the NC Plume, which is contained entirely within the former BAAP boundary and is not migrating off-site. Therefore, a risk screening value of $1x10^{-4}$ was used for the entirety of the NC Plume. Where site conditions are determined to be protective of human health and the environment and no response action is required to reduce, control or mitigate exposure, compliance with ARARs is not required, (*ARAR's Q's & A's: General Policy, RCRA, CWA,SDWA, Post-ROD Information, and Contingent Waivers*, page 2, EPA OSWER Directive 9234.2-01/FS-A, June 1991). The Army is legally unable to conduct further analysis or remedial action where there is no unacceptable risk to human health or the environment under CERCLA. Therefore, while WDNR utilizes a $1x10^{-6}$ cancer risk threshold for all groundwater, the Army is not utilizing these requirements in determining risk, and therefore COCs, for site-wide groundwater within the boundary of the former BAAP.

Since this is the only comment received from WDNR on the Proposed Plan, the proposed plan therefore will be considered final and we will move to public comment.

USAEC appreciates the WDNR's continued support and collaboration at the former BAAP. If there are any additional questions following receipt of this letter feel free to contact Ms. Laura Powell, Environmental Support Manager for BAAP, (520) 684-6058 or laura.z.powell2.civ@army.mil.

Scott Benson
Environmental Support Manager
Midwest and Central America Division

ASTSWMO, Providing Pathways to Our Nation's Environmental Stewardship Since 1974

Identifying and Considering ARARs at Federal Facility Cleanups

APRIL 2023

Remediation and Reuse Focus Group
Federal Facilities Research Center

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ASTSWMO is an organization supporting the environmental agencies of the States and Territories. ASTSWMO's mission is to enhance and promote effective State and Territorial programs and to affect relevant national policies for waste and materials management, environmentally sustainable practices, and environmental restoration. The mission of the Remediation and Reuse Focus Group is to identify and investigate issues arising from the remediation, reuse, and long-term management of federal facilities. This includes researching and developing resource documents, issue papers, and other tools on the implementation of alternative or innovative remediation policies and strategies; site closeout and transfer; reuse and redevelopment of federal facilities; and long-term stewardship.

ASTSWMO thanks the following members for their participation in developing this paper:

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I. INTRODUCTION

In September 2021, ASTSWMO's Federal Facilities Subcommittee asked its membership, which includes the 50 States, five Territories, and the District of Columbia (States) to identify current challenges to completing cleanups at federal facility sites. The main challenge identified was the process of identification of and federal agency acceptance of States' Applicable or Relevant and Appropriate Requirements (ARARs) in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanups. In January 2022, ASTSWMO conducted a roundtable with the membership, which further discussed concerns States are having with ARARs at federal facilities. Twenty-nine States identified ARARs as a concern in preparation of the roundtable.

To address our members' concerns, the ASTSWMO Remediation & Reuse Focus Group (RRFG) developed this paper to assess the inclusion of State ARARs at CERCLA cleanups by federal agencies who manage cleanups under the authority of Executive Order (E.O.) 12580. The regulatory requirements regarding inclusion of State and federal ARARs are detailed in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), which was revised to include CERCLA (Superfund program) and the Superfund Amendments and Reauthorization Act (SARA). In addition to reviewing statutory requirements, ASTSWMO reviewed available regulatory policies, guidance, decision documents, and studies from EPA, other federal agencies, and other sources. These resources are compiled in Appendix A.

ASTSWMO will use the following terms and definitions in this paper:

- **Federal Facility**: a property, installation, or facility currently or formerly owned by, or constructed or manufactured for the purpose of leasing to, the federal government.

- **Federal Agency:** any federal government executive branch agency. This does not include the U.S. Environmental Protection Agency (EPA).

- **Applicable requirements** are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or State environmental laws or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site.

- **Relevant and appropriate requirements** are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or State environmental laws 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.

Background

Federal agencies identified as responsible parties are liable for addressing contamination at federal facilities by conducting assessments, investigations, and remediation of properties they currently or formerly owned, operated, or controlled. According to E.O. 12580, federal agencies are the lead agency at these federal facilities. At National Priority List (NPL) sites, the EPA is the lead regulator. In most cases State regulators are included in a Federal Facilities Agreement (FFA) and support the EPA at NPL sites. Because many federal facilities are not on the NPL, States are often the lead regulatory agency responsible for overseeing the federal agency and enforcing compliance with federal and State regulations at these sites. EPA and State agencies are regulators but are also known as support agencies for federal facilities.

The process of identifying, determining, and accepting or rejecting State(s) laws and regulations as ARARs in CERCLA cleanups by the federal agencies is complicated. CERCLA §121(d)(2)(A) provides that any State promulgated standard, requirement criteria, or limitation that is identified in a timely manner and that is more stringent than any federal standard, requirement, criteria, or limitation may be considered applicable or relevant and appropriate. States identify ARARs on a site-specific basis when a State environmental law or regulation is "applicable" or "relevant and appropriate". The inclusion of ARARs in site documents, particularly decision documents, is critical because the ARARs define a threshold that must be met to assure CERCLA cleanups protect human health and the environment.

As a site progresses through the CERCLA process, the technical and legal staff for the agencies should identify potential ARARs as early as possible and work collaboratively to resolve disputes. The federal agency should request the State identify ARARs for review and incorporation into the decision document in a timely manner. States must provide a citation for each ARAR submitted to the federal agency that identifies only the substantive requirements of the environmental law or regulation. It is not appropriate to refer to an entire statute or chapter of regulations. While only the substantive requirements are included as ARARs, federal agencies must comply with laws and regulations to the same extent as non-federal entities when conducting CERCLA cleanups.[1,2]

In addition to ARARs, other State or federal advisories, guidance, and criteria that are not promulgated or legally binding but may be useful in developing CERCLA remedies or interpreting State laws may be classified as "To-be-Considered" materials (TBCs). Examples of TBCs may include a State's reference doses, additive effects, and guidance documents, or proposed regulations that States develop and release regarding contaminants of emerging concern (CEC), which takes significant time to promulgate. TBCs are not considered ARARs but should be evaluated along with ARARs because they provide supplemental information that

[1] Substantive requirements are those requirements that pertain directly to actions or conditions in the environment. Administrative requirements are those mechanisms that facilitate the implementation of the substantive requirements of a statute or regulation (https://clu-in.org/conf/tio/FFAcademy11_120722/).
[2] On March 1, 2023, EPA released a memorandum and guidance, *Documenting Applicable, or Relevant and Appropriate Requirements in Comprehensive Environmental Response, Compensation, and Liability Act Response Action Decisions*, which includes recommendations and template for documenting ARARs.

may be necessary to evaluate whether the remedy protects human health and the environment.

Applying TBCs addresses future concerns as any new State regulations promulgated after the decision document must be evaluated as part of a five-year review (FYR) to determine if the selected remedy remains protective. For sites that achieve Unrestricted Use/Unrestricted Exposure (UU/UE) and a new cleanup standard (e.g., CEC) is issued, federal agencies may have to go back and reassess the protectiveness of the remedy. For example, after EPA revised polyfluoroalkyl substances (PFAS) health advisory and screening levels and several States developed PFAS regulations, federal facilities were required to conduct a new Preliminary Assessment/Site Inspection (PA/SI) for PFAS at sites with known or potential contamination.

The NCP requires that the administrative record for a site contain documents that form the basis for the selection of a response action, which include remedial and removal actions. Federal agencies comply with this requirement by releasing decision documents identified as Record of Decision (ROD), Interim ROD, No Action ROD, and Removal Action Memorandum, which must include ARARs established for any selected response action. A subsequent decision document is necessary when an Interim ROD or Removal Action Memorandum is issued, as these documents have a focused objective and typically occur during the remedial investigation (RI).

Defining ARARs at federal facilities can result in contentious situations between the State, EPA, and the federal agency when ARARs are not accepted by the federal agency. This is further complicated by the CERCLA process, which identifies different processes for including ARARs in the various types of CERCLA required documents. The following sections present when and how State ARARs are included in the process of developing each of these decision documents by highlighting regulations, identifying challenges, and, when necessary, administrative actions that can be applied.

II. CERCLA REMOVAL ACTIONS (NCP §300.415)

A removal action under CERCLA is generally defined as a short-term response designed to stabilize or clean up an uncontrolled hazardous waste site that poses an immediate threat to human health or the environment. NCP §300.525(e) requires EPA to consult with States on all NPL removal actions to be conducted in that State. At non-NPL sites, the lead agency will discuss removal actions directly with the State.

Removal actions include:

- emergency responses to accidental releases of hazardous substances (action is required within hours),
- time-critical removal actions (TCRA) (required within 6 months), and
- non-time critical removal actions (NTCRA) (planning period of more than 6 months is available).

All potentially responsible parties (PRPs), including lead federal agencies at federal facilities, are required to issue a Removal Action Memorandum for all removal actions. Removal Action Memorandums document ARARs at the site, but the timing in which Memorandums are issued will vary depending on whether the removal action is an emergency response, TCRA or NTCRA. During a removal action, ARARs are required to be attained to the extent practicable.

Interpreting "Extent Practicable"

In general, compliance with most federal and State ARARs will be practicable during removal actions, which will help to achieve the long-term goal for the site. However, in some situations as noted in the NCP, identifying and/or complying with ARARs will not be practicable during a removal action or the criteria for a waiver of the ARAR will be satisfied (see Section IV). Under such circumstances, compliance with the ARAR is not required.

The NCP identifies two factors that should be considered in determining whether identifying and complying with ARARs is practicable: (1) the urgency of the situation, and (2) the scope of the removal action to be taken.

Urgency of the Situation:

During most removal actions, sufficient time exists for OSCs to identify ARARs and plan response actions that comply with them. For example, in most cases, OSCs can acquire drums, tanks, and overpacks, and construct storage facilities that meet ARARs (e.g., basic Resource Conservation and Recovery Act (RCRA) storage requirements) before RCRA hazardous waste is removed from leaky tanks or soil is excavated and stored. In cases where the degree of threat warrants a truly immediate response to protect public health and environment from an imminent threat, full compliance with ARARs could cause On-Scene Coordinators (OSCs) to delay a response, compromising the protection of public health and the environment. In such urgent cases, compliance with ARARs may not be practicable.

Scope of the Removal Action:

Actions required by ARARs often will be within the scope of the designed removal action. For example, when a removal action calls for treatment of aqueous material from an on-site sludge pit and discharge of the treatment effluent to an on-site stream, compliance with substantive National Pollutant Discharge Elimination System (NPDES) discharge limits would be within the scope of the designed action and, therefore, would be practicable. Similarly, when a removal action calls for the on-site incineration of waste, compliance with incinerator operation and performance standards under RCRA and other applicable regulations are necessary and likely practicable. However, in some cases, compliance with ARARs is outside the scope of the removal action because the ARAR requires a degree of cleanup that would be inappropriate or inconsistent with the limited scope and purpose of the removal action, e.g., site stabilization and mitigation of near-term threats or removal of leaky drums without addressing the contaminated soil.

Identification of State ARARs for Removal Actions

EPA and federal agencies should notify States verbally and in writing as soon as a removal action is contemplated, or an emergency response is initiated to provide States with the opportunity to identify and provide State ARARs in a timely manner. Because of the short duration between the proposal for a removal and the actual removal, States have limited time to identify ARARs. For example, emergency responses and TCRAs may not provide significant opportunities for States to provide ARARs as they typically occur quickly and are intended to remove an immediate threat.

On the other hand, during NTCRAs, sufficient time should be available to determine ARARs based upon a reasonable understanding of site characteristics. Preparing the engineering evaluation/cost analysis (EE/CA) should allow consideration of ARARs in the development of the response action. NTCRA conducted after an EE/CA must attain ARARs of federal and State environmental and public health laws to the extent practicable as this will meet the requirement to efficiently correspond with performance of long-term remedial actions. This requirement, along with NCP section NCP §300.415(b)(1), which permits a removal action to eliminate the release or threat of a release, provides the authority to the lead agency to incorporate ARARs when defining the objectives for a removal action as ARARs are a threshold requirement for remedial actions that must be evaluated as part of the Feasibility Study.

NCP §300.415(b)(4)(i) requires an EE/CA to identify objectives for removal actions and to analyze alternatives with regards to cost, effectiveness, and implementability. The protectiveness of alternatives developed in an EE/CA can be assessed in terms of protection of human health and the environment and compliance with ARARs. The Action Memorandum provides general information and site background, potential threats to the public health and the environment posed by the site, including expected changes if no action is taken or if the action is delayed, enforcement activities related to the site, and estimated EE/CA costs.

Regardless of the type of removal action, EPA and federal agencies should also consult with States often throughout the CERCLA removal process. All removal actions should be consistent with any long-term remedial action at the site and the removal action completion report should identify if ARARs were obtained or not obtained, to the extent practicable.

State Concerns at Removal Actions

ASTSWMO members have reported that federal agencies may give preference to conducting removal actions and do not follow up with subsequent remedial actions. While removal actions may be an effective means of reducing the immediate risks and should attain ARARs to the extent practicable, they cannot be the final action. Conducting removal actions to the exclusion of subsequent remedial actions raises several concerns including:

- Removal actions may allow for less State involvement;
- Removal actions may leave some waste in place.

- Ecological risk assessments are often not conducted for removal actions;
- Removal actions do not trigger FYRs under CERCLA; and
- Removal actions are only required to comply with ARARs to the extent practicable.

Federal agencies dictate the scope of a removal action and determine what ARARs are to be attained, which can complicate the inclusion of State ARARs.

States understand that compliance with State ARARs (e.g., soil cleanup criteria) may not be achieved during a source removal action (e.g., focused excavation that only removes grossly contaminated soil within a dry well), but ARARs should be evaluated to determine if they can easily be achieved or to what practicable extent they can be achieved during the removal action. This would be supported by federal regulations as this action would contribute to the future remedial action or potential no further action determination. For example, the US Navy indicates that "[o]pportunities to improve performance and to evaluate green and sustainable remediation practices shall be considered and implemented throughout all phases of remediation regardless of the regulatory framework under which cleanup may occur." This is further supported by the US Navy's Environmental Restoration Program Manual which indicates that "[e]conomic considerations also may impact the extent of the action that is taken. In some cases, expanding the scope of the removal action may allow the action to be the final remedy" and "[t]he removal action should be compatible with future remedial actions and should strive to meet ARARs." Because the end goal is to achieve a comprehensive remedy, these statements imply that State ARARs are acceptable removal action objectives and permit the US Navy to use technical judgment to define cleanup objectives for the removal action that best fit the site and comply with the NCP.

Examples of State ARARs Applied to Removal Actions

Joint Base Cape Cod

On October 2, 2020, the Massachusetts Department of Environmental Protection (MassDEP) promulgated final regulations in 310 Code of Massachusetts Regulations [CMR] 22.00 establishing a Massachusetts Maximum Contaminant Level (MMCL) for drinking water for the sum of six PFAS at a level of 20 parts per trillion (ppt). In response to PFAS contamination that had been released into soil and groundwater at Joint Base Cape Cod (JBCC) due to historic uses of aqueous film-forming foam (AFFF), a letter was drafted by MassDEP to the Air Force Civil Engineer Center (AFCEC) on October 28, 2020, requesting the implementation of the sum of six PFAS MMCL as an ARAR during the RI phase for the Installation Restoration Program (IRP) groundwater response actions occurring at JBCC. In September 2021, the United States Air Force (USAF) agreed to conduct a NTCRA in response to identified exceedances of the sum of six PFAS MMCL in utilized drinking water sources within the Ashumet Valley JBCC groundwater plume area.

The JBCC decisions appear to have influenced the Department of Defense (DoD) removal action procedures as DoD released a memorandum, dated December 22, 2021, "DoD Guidance on

Using State Per- and Polyfluoroalkyl Substances Drinking Water Standards" ("DoD PFAS Guidance"), which states:

> DoD may initiate a removal action where DoD is responsible for a confirmed release with perfluorooctane sulfonic acid (PFOS)/perfluorooctanoic acid (PFOA) concentrations above the EPA Lifetime Health Advisory (LHA) levels in drinking water (i.e., groundwater currently used for drinking water). Removal actions may extend to drinking water wells that are currently below the EPA PFOS/PFOA LHA levels when site specific hydrogeological conditions are expected to result in an exceedance of that level without a removal action.

The DoD PFAS Guidance also states that, "…a state drinking water standard may qualify as an "Applicable or Relevant and Appropriate Requirement" (ARAR) for remedial action in accordance with CERCLA § 121(d)(2)(A)." The Guidance claims that

> [w]hile DoD is not required to attain ARARs as part of a removal action, the National Oil and Hazardous Substances Pollution Contingency Plan at Section 300.415(j) of Title 40, Code of Federal Regulations (CFR) identifies that EPA Superfund-financed removal actions shall, to the extent practicable considering the exigencies of the situation, attain ARARs. DoD is adopting this approach for its DoD-funded removal actions which it believes is consistent with existing National Defense Authorization Act provisions. As a matter of policy, once initiation of a removal action is triggered as set out above, and DoD as the lead agency identifies a properly promulgated, consistently implemented state PFAS drinking water standard as an ARAR for the specific removal action, DoD may use the state PFAS drinking water standard when determining the cleanup level to be attained at the completion of the removal action.

As a result, the USAF identified the existence of an imminent and substantial risk to public health or welfare at JBCC, particularly Ashumet Valley, due to the presence of PFOS/PFOA above the EPA LHA in drinking water and at locations with current sum of six PFAS MMCL exceedances that are anticipated to result in future EPA LHA exceedances at municipal and residential wells used to supply drinking water from the same aquifer at JBCC. Removal actions include municipal water connection, Granular Activated Carbon (GAC) wellhead treatment, and Ion Exchange (IX) wellhead treatment.

Brookhaven National Laboratory

Another example of State ARARs being considered for a removal action at a federal facility is the Department of Energy (DOE) TCRA Action Memo to install groundwater treatment systems to address PFAS from two source areas on the Brookhaven National Laboratory (BNL) site in New York. A major ARAR governing the BNL site is the classification of the groundwater at and down gradient of the site as a "sole source aquifer" containing a source of drinking water as defined by New York State. The New York drinking water standards for PFOS at 10 ppt and PFOA at 10 ppt (promulgated in August 2020) were selected as the cleanup goals. A State Pollutant Discharge Elimination System (SPDES) equivalency permit was issued for the systems.

Plattsburgh Air Force Base

Plattsburgh Air Force Base (PAFB) in New York presents an example of DoD reviewing and applying State PFAS ARARs before and after the issuance of DoD PFAS Guidance. The DoD indicated that State ARARs would be accepted as part of the FS if determined to be an ARAR, but not during a removal action. The DoD conducted a removal action at private potable wells that contained PFOS and PFOA above EPA's LHA but declined to provide the same removal action to other properties where State ARARs were exceeded at concentrations below the LHA. In these types of situations, the DoD fails to appropriately assess and contribute to the efficient performance of any future remedial action to the extent practicable as required by NCP §300.415(d). The State performed a separate removal action that installed a point of entry treatment (POET) system for each remaining impacted private well, which was similar to DoD's removal action, and intended to recover costs from the federal agency. This resulted in multiple discussions between the State and DoD, which redirected resources from site remediation activities. Based on the DoD PFAS Guidance, the DoD is currently preparing an EE/CA regarding the inclusion of the New York POET systems with the PAFB POET systems.

PAFB removal action followed the DoD PFAS Guidance, which indicates that DoD will, to the extent practicable considering the exigencies of the situation, attain State ARARs as required for EPA Superfund fund-financed removal actions. This is a movement in the right direction, but DoD must comply with the NCP §300.415(d) requirement to contribute to the efficient performance of any future remedial action to the extent practicable. DoD removal actions must also protect public health, animals, food chain and sensitive ecosystems from site pollutants. NCP §300.415(b)(2)(i and ii), does not identify chemicals (e.g., PFOS/PFOA, lead, or 1,4-dioxane) or media (e.g., drinking water, surface soil, or soil vapor) as limited by the DoD PFAS Guidance. Even with the urgency and scope of the removal action, the inclusion of State ARARs is consistent with CERCLA and NCP requirements to support future remedial action(s) to the extent practicable.

Federal facilities should provide early notification to States of an impending removal action and should consult with States often in the CERCLA removal process. All removal actions should be consistent with any long-term remedial action at the site. The removal action completion report should identify if ARARs were obtained or not obtained, to the extent practicable.

Best Practices and Recommendations

To help eliminate potential problems during removal actions:

- Lead and support agencies should identify potential ARARs triggered by site characteristics during the removal site evaluation phase;
- Lead agencies should contact States as early as possible to identify State ARARs, particularly when there is the potential for public exposure and risk to human health and the environment;

- Lead agencies should identify additional ARARs as potential supplemental actions are developed; and
- Where site conditions or circumstances preclude efforts to identify and attain ARARs, these conditions should be documented.

A good example of federal agency policy to comply with ARARs during removal actions can be found in the 1995 DOE memo "Policy on Decommissioning Department of Energy Facilities Under CERCLA," where it states that "EPA and DOE intend to work with authorized States to coordinate RCRA and CERCLA authorities to the maximum extent practicable in order to prevent unnecessary duplication or delay in decommissioning projects subject to both authorities…" and "[d]ecommissioning activities should comply with relevant and appropriate standards to the extent practicable, as provided by the NCP, and as necessary to contribute to the efficient performance of any long term remedial action."

III. CERCLA REMEDIAL ACTIONS (NCP §300.430)

Remedial actions are those actions that implement a permanent remedy instead of, or in addition to, a removal action. Remedial actions are usually determined necessary after the completion of a PA/SI that indicates further investigation is needed. Under the NCP, the initial list of ARARS is provided during the RI scoping phase of the remedial action process.

The use of ARARs during the SI scoping phase is encouraged, but not required. For instance, if the State has ARARs for screening levels, acceptable drinking water levels, or soil standards, it will be important for detection limits (DLs) established during the SI to be below those screening levels or standards. Otherwise, locations with contaminant levels above the standards but below DLs will be left out of subsequent investigations.

Table 1 identifies the CERCLA process from PA/SI to the ROD and timing within each CERCLA phase for identifying, considering, and selecting ARARs, and Figure 1 provides a flow chart highlighting specific coordination activities during each phase of the CERCLA process. Because many ARARs apply to multiple sites it may be beneficial for States to compile a list of potential ARARs that can be referred to during Steps 1 and 2, RI scoping and performance. Some States have compiled potential ARARs and posted them to a public website. Examples from Nebraska, New York, and Ohio are provided in Appendix A.

Table 1: CERCLA Remedial Action ARARs Steps

STEP	CERCLA Phase	ARARs	Notes
	Preliminary Assessment	ARARs not required.	
	Site Inspection	ARARs not required.	ARARs are not required but can be useful for determining investigation parameters such as detection limits and data quality objectives.
1	Remedial Investigation scoping	Scoping discussion as required by NCP - Initial List of ARARs drafted and issues resolved. Chemical and location specific ARARs are discussed between all parties as part of the RI Work Plan.	NCP §300.515(h)(2) - *The lead and support agencies shall discuss potential ARARs during the scoping of the RI/FS.* ARARs are used to define the nature and extent of contamination and perform a Baseline Risk Assessment (BRA). The application of State ARARs during the RI saves the federal agency, EPA, and the State significant time and resources as site figures are prepared during the RI, whereas the FS applies the information presented in the RI to evaluate remedial alternatives.
2	Remedial Investigation performed	At end of site characterization data collection, lead agency officially asks support agency for (chemical and location-specific prioritized) ARARs. Support agency has 30 days to respond.	NCP §300.515(h)(2) - *The lead agency shall request potential ARARs from the support agency no later than the time that the site characterization data is available. The support agency shall communicate in writing those potential ARARs to the lead agency within 30 working days of receipt of the lead agency request for these ARARs.* *In addition to applicable or relevant and appropriate requirements, the lead and support agencies may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular release (NCP §300.400 (g)(3)).*

STEP	CERCLA Phase	ARARs	Notes
3	Feasibility Study	At the early stages of FS and prior to the comparative analysis the lead and support agency must identify chemical, location and action specific ARARs. The support agency should also identify any other ARARs not already identified after the initial screening of alternatives and requested by the lead agency. Support agency has 30 days to respond.	NCP §300.515(d)(1) & §300.515(h)(2) and §300.430(e)(8). During preparation of the FS the lead agency must formally notify the support agency if the lead agency intends to waive ARARs or does not agree with support agency that a certain standard is an ARAR. The lead agency must respond to State comments on waivers from or disagreements about State ARARs.
4	Feasibility Study	Lead agency provides draft FS with list of ARARs. Support agency has 10-15 days to respond.	NCP §300.430(e)(9) Compliance with ARARs. The alternatives shall be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and State environmental or facility siting laws or provide grounds for invoking one of the waivers under paragraph NCP §300.430 (f)(1)(ii)(C) of this section. NCP §300.515(d)(3) requires lead agency to formally notify support agency if lead agency intends to waive support agency ARARs or does not agree with support agency that a certain standard is an ARAR -should appear in transmittal letter and NCP §300.515(h)(3).
5	Final Feasibility Study	Lead agency releases Final FS	NCP §300.515(d)(4) requires lead agency to respond to State comments on waivers from or disagreements about State ARARs, which support the ARARs set for the site.
6	Proposed Plan	Lead agency provides Draft Proposed Plan (PP). Support agency has 10 days to respond.	NCP §300.515(d)(3) and (4) requires lead agency to formally notify support agency if lead agency intends to waive support agency ARARs or does not agree with support agency that a certain standard is an ARAR should appear in transmittal letter and in draft PP and NCP §300.515(h)(3).

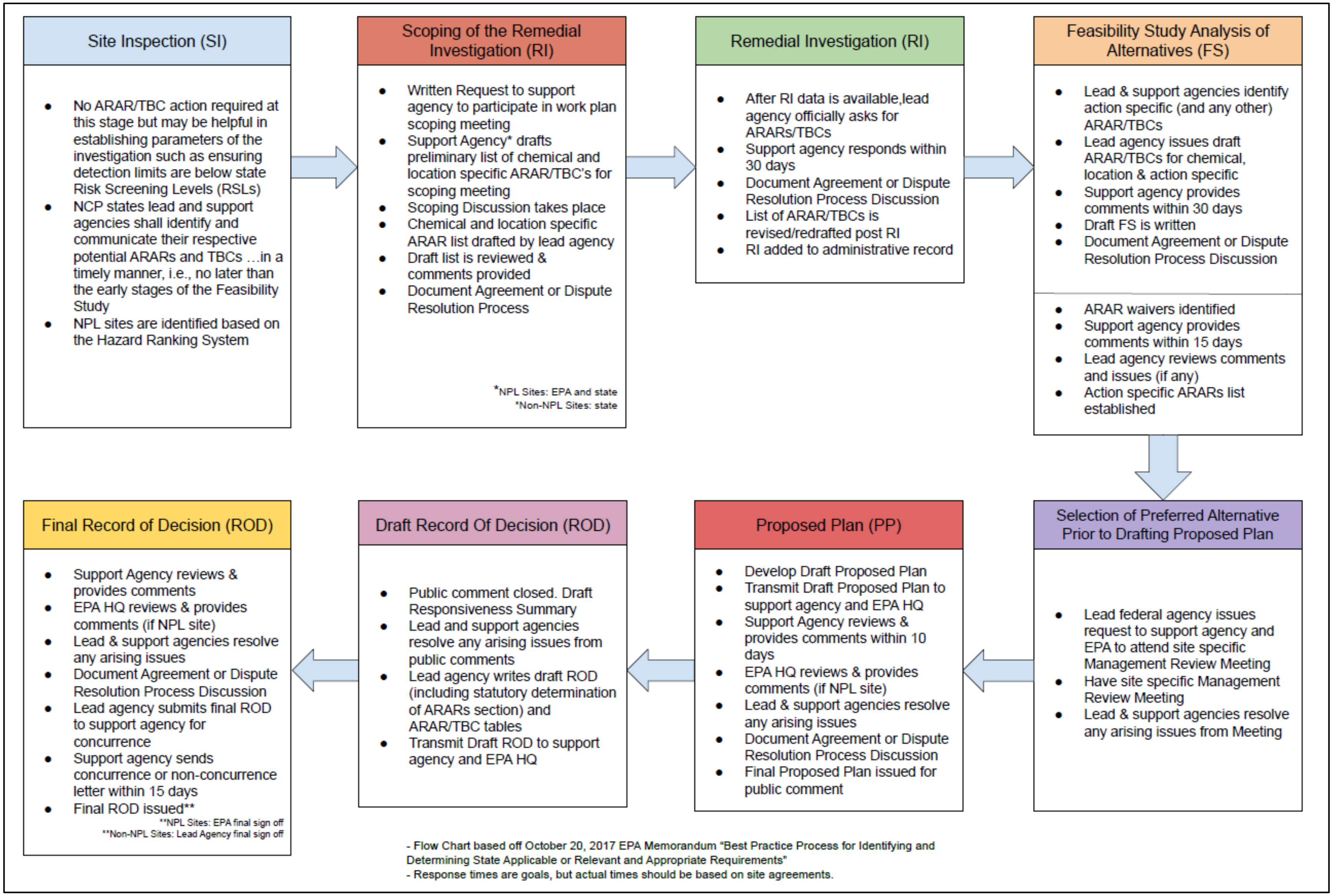
STEP	CERCLA Phase	ARARs	Notes
7	Proposed Plan	Lead agency issues PP for public comment with ARARs.	NCP §300.515(f)(3).
8	Record of Decision	Lead agency provides draft ROD (including statutory determination of ARARs section) and ARAR tables to support agency. Support agency has 10-15 days to respond.	NCP §300.515(h)(3).
9	Record of Decision	Lead agency submits final ROD to support agency for concurrence. Support agency has 10-15 days to concur or non-concur.	NCP §300.515(h)(3).
10	Record of Decision	Final ROD issued.	Includes final ARAR list for the remedy.

Notes:

1. A State Memorandum of Agreement (SMOA) or FFA may extend the review periods noted. Also, if an additional review period is needed this should be discussed with federal agencies as they tend to be receptive if informed ahead of time.

2. This table is developed from a more detailed table in EPA's October 20, 2017, memo, "Best Practice Process for Identifying and Determining State Applicable or Relevant and Appropriate Requirements Status Pilot".

Figure 1: CERCLA Remedial Action ARARs Flow Chart



Interim Remedial Actions

Interim remedial actions may be needed prior to the implementation of the final remedy at a site on occasion to mitigate the continued migration of contaminants or to protect human health and the environment from actual or threatened releases of hazardous substances into the environment. In these cases, an Interim Record of Decision (IROD) will be published that details the protective actions selected for the site prior to the development of the final remedy. The IROD may apply to the entire site or a portion of the site. As IRODs generally result in contaminant levels remaining on-site at concentrations above UU/UE, statutory FYRs still apply. Common uses of an IROD include, but are not limited to, supplying clean drinking water to affected populations or mitigation of a primary source area. For more information on the benefits and uses of IRODs, see the 2017 Final ASTSWMO Interim ROD Paper.

The IROD should identify current issues at the site that are not being addressed and specify that the Final ROD will address these issues. For example, the IROD for the Community of Moose Creek and Eielson Air Force Base in Alaska addressed only alternative drinking water supply to the Moose Creek community but specified that the "identification of principal threat waste (PTW) and approaches to address any identified PTW will be addressed in the Final ROD." As such, the selected ARARs for the IROD were limited to drinking water protection and groundwater human health protection regulations and standards.

An IROD will identify performance criteria for the interim actions. It is common for an interim RI/FS to be completed if there is time, though States need to be aware that while interim RI/FSs they are not required to complete an IROD. However, to fulfill the administrative record requirements set out in the NCP, there must be documentation that supports the rationale for the action outlined in the IROD. States should ensure that this documentation identifies ARARs that are pertinent for the interim actions.

The federal agency will request State ARARs and the subsequent IROD will include the federal and State ARARs that were developed during the interim FS. For example, the *IROD: Interim Remedial Action for Installation-Wide Groundwater at Redstone Arsenal in Alabama* addressed concerns from Alabama regarding RODs being prepared for surface media remedies and deferring decisions on the groundwater remedies until a later date when groundwater sites were evaluated. The interim land use controls (LUCs) were to prohibit use of groundwater for drinking water purposes, control the use of groundwater for non-potable uses and to initiate formal coordination with local government agencies who may conduct activities on or off property involving potentially contaminated groundwater. The IROD also stated that the selected interim remedy action will meet all ARARs (maximum contaminant levels [MCLs]) specifically associated with this limited scope and, in combination with the final actions at the groundwater sites, will either achieve compliance with ARARs or a waiver will be requested.

An interim remedy waiver may be appropriate where an ARAR cannot be met as part of the interim remedy but will be attained by the final remedy (CERCLA §121(d)(4)(A) and NCP §300.430(f)(1)(ii)(C)(1)). For example, the selected remedy for Operable Unit (OU)-1 Hanscom Air Force Base in Massachusetts included the continued operation of the existing groundwater collection and treatment system, institutional controls, and groundwater and surface water monitoring to contain the migration of groundwater contaminants and reduce the extent of the groundwater plume. Chemicals of concern (COC) concentrations in OU-1 groundwater exceeded federal drinking water standards, State drinking water standards and State groundwater risk characterization standards at many locations, resulting in an unacceptable risk to human health from groundwater ingestion. The IROD states that:

> …under Section 121(d)(4)(A) of CERCLA, the Regional Administrator concurs with the decision to waive attainment of the following ARARs within the groundwater plume on the basis that this action is an interim measure and will become part of a total remedial action that will meet or attain ARARs when it is completed: the federal Safe Drinking Water Act (SDWA) MCLs, the SDWA MCL Goals, the Massachusetts Drinking Water Standards, and the Massachusetts Contingency Plan (MCP) Method 1 GW-1 groundwater standards. Due to the nature of OU-1, full compliance with these requirements will not be attained in the existing groundwater contaminant plume in the short-term.

No Action Record of Decision

For CERCLA sites that do not require removal or remedial action, the federal agency will develop a No Action ROD after completing the RI. No Action RODs do not require ARARs in the final decision document, however, an evaluation of ARARs should be conducted as part of the Baseline Risk Assessment (BRA) and/or RI that is used to support the final decision. Failure to do so could result in a No Action decision that does not address all environmental hazards at the site.

There are three circumstances under which a lead agency may determine that no action is warranted. No action in these circumstances is described as "no treatment, engineering controls, or institutional controls" but may include monitoring only (however, monitored natural attenuation is not a "no action" decision). These are:

1. When the site or a specific problem or area of the site (i.e., an OU) poses no current or potential threat to human health or the environment;

2. When CERCLA does not provide the authority to take remedial action; or

3. When a previous response(s) has eliminated the need for further remedial response.

Under the second circumstance, a threat to human health and the environment may be present, but it does not fall under the authority of CERCLA (e.g., in the case of a petroleum hazard). In that circumstance, additional response action(s) may be required under other federal and/or State environmental regulations, which should then be addressed in a non-CERCLA decision document or order.

The first and third circumstances indicate that there is no threat, or no longer a threat, to human health or the environment at the site. However, even under these two circumstances, the determination that there is no threat, or no longer a threat at the site does not necessarily mean that the site has achieved UU/UE conditions. This is because the BRA conducted either as part of the RI in the first circumstance, or at the conclusion of the response action in the third circumstance (e.g., in a confirmation sampling assessment), may be based on site-specific current and predicted future land use conditions that may not include a UU/UE scenario. It is important for States to agree with the BRA conclusions that form the basis of the No Action ROD. The regulator should evaluate whether the BRA can be relied upon for making the No Action decision if ARARs were not considered when conducting the response action or the RI, or if the BRA conclusions appear to contradict State ARARs.

It should not automatically be assumed that a UU/UE designation is appropriate if the BRA does not consider State ARARs for potential exposure to the most sensitive receptors. In this case, the State should not accept the conclusion of the RI or the request for a No Action ROD without further evaluation of potential future risks and/or a remedy that includes some form of future management or monitoring.

If the State agrees with the No Action ROD determination for these two circumstances, the No Action ROD should include a statement about whether FYRs are necessary when the site does not reach UU/UE. FYRs are not typically required as part of No Action RODs because it is presumed that UU/UE has been achieved and there is no need for future review of the remedy. A No Action decision may be obtained by simply requiring FYRs, which will provide for a reassessment of the protectiveness of the remedy every five years (i.e., “monitoring only”). FYRs address both unpredicted future site conditions or land use and future changes to ARARs (e.g., the identification of new CECs). Requiring a FYR may also be negotiated with the lead agency in place of a LUC requirement if deemed appropriate. If there is a potential for future ARARs that may apply to the site, as with CECs, then including a FYR in the No Action ROD may also be prudent.

There are potential challenges when the State environmental regulations, if ARARs, are not considered when making the “No Action” decision or if the “No Action” decisions are based on incomplete or flawed BRAs. Generally, compliance with ARARs is not required for No Action decisions. However, this statement is not *entirely* accurate. No Action RODs generally do not include a FS wherein ARARs that apply to the remedy are typically finalized. The logic is that ARARs apply to the remedy, and if there is no remedy then there are no ARARs. However, because an RI is required and ARARs are preliminarily identified during RI scoping (Table 1) ARARs should also be included in the evaluation of the data that supports the No Action ROD alternative. At this step in the CERCLA process, it cannot be assumed that a No Action remedy will be selected, so all potential ARARs must still be evaluated. If a No Action remedy is not consistent with potential ARARs, then it should not be selected, and other actions should be considered. When a previous response action occurs prior to the RI that results in the elimination of environmental risk at the facility, then it is possible that a RI will not occur. In that case, consideration of ARARs should have been a part of the evaluation of the response action. For example, compliance with ARARs is required for a removal action to the extent practicable. If compliance with ARARs was not achieved during the removal action or the scope of removal action was limited, this should be considered when evaluating protectiveness of the response and whether a No Action ROD is appropriate.

The State may also request that known potential future ARARs be considered in the RI and BRA. For example, New York has identified PFAS and 1,4 dioxane as CECs. Currently, federal agencies are evaluating PFAS nationally, but 1,4 dioxane has not achieved the same level of recognition. It would be prudent for federal agencies to sample for 1,4 dioxane during the RI at facilities where it may be present so that its presence or absence can be considered in preparing the BRA and in evaluating the appropriateness of a No Action ROD. This could prevent the need for future re-investigation of the facility in response to future promulgation of 1,4 dioxane clean-up requirements. At a minimum, in this situation, the State should require that FYRs be conducted at the site to assess the applicability of future chemical-specific ARARs for 1,4 dioxane.

In some cases, a site may be investigated in the PA/SI step of the CERCLA process and a decision may be made by the federal agency that no further action is necessary based on finding no evidence of a hazard at the site. This scenario is ***not*** an example of a No Action ROD because no RI or response action has been performed. A No Action ROD requires that an RI or previous response action, inclusive of an adequate BRA, be conducted. Some States have voiced concerns about sites potentially being “closed” following a PA/SI without sufficient investigation or consideration of ARARs. For example, Army National Guard is currently evaluating their properties for potential PFAS contamination, but they are only evaluating the SI findings against EPA drinking water criteria for three PFAS constituents even though several States have more stringent standards that are inclusive of a wider range of PFAS chemicals and receptors. In these cases, the State regulators have concerns that the site may be closed following the PA/SI without considering State ARARs. States recommend that State ARARs be included as part of the PA/SI evaluation, or the site should proceed to an RI where State ARARs will be included and evaluated. This is further complicated as EPA releases revised/new PFAS risk screening levels, which will result in re-evaluating decisions at sites.

States provide State ARARs during the RI as required by the NCP, but State ARARs are not formally accepted by the lead agency until the FS, when they are used as part of the evaluation of alternatives. A No Action ROD based on a BRA utilizing EPA risk screening levels may put a State in an awkward position because the State ARARs were provided, which could identify an issue that will not be addressed. If this situation occurs, the State must evaluate the risks and determine if the site should be included in a State environmental clean-up program as a non-NPL site. This may result in a State-led investigation and subsequent legal action against the federal agency to recover costs and require cleanup. As indicated previously, States recommend that the BRA utilize State ARARs, that all responsible parties must follow, to better understand risks from the site.

State Concerns at Remedial Actions

State concerns with the identification and consideration of State ARARs vary and arise during many phases of the CERCLA remedial action process. If the lead agency preparing a FS and ROD did not include the State ARARs stating that their inclusion would delay the release of the ROD, the State should not agree with the ROD to facilitate the project moving forward. Federal agency funding can take years to obtain, which will delay implementing the selected remedy. The rush to complete the ROD without State ARARs will likely cause future issues and delays.

Other challenges occur when, during the FS and ROD processes, the agency declares that the State identified ARARs are not applicable and only considered procedural requirements. For example, some DoD installations have rejected the Colorado environmental covenant statute as an ARAR asserting that the statutory provisions are procedural only. However, other DoD installations recognize the statute as an ARAR and have issued environmental covenants. Colorado's position remains that while the statute outlines a process for creating the environmental covenant, the outcome of the process is substantive and the statute is an ARAR.

Promulgated standards that are not identified in a timely manner need not be included in the ROD and therefore, may not be considered by the responsible party. Regulations promulgated following issuance of the ROD may be considered during the FYR if response actions were not cleaned up to UU/UE. If the State is unable to identify ARARs "in a timely manner" every effort should be made to communicate with the federal agency to request an extension and the ARARs should be identified as quickly as possible. RODs that don't include State ARARs may result in remedies that do not meet State cleanup standards.

It is also worth considering whether a State will agree to a remedy when the result of the cleanup action will meet the State standard even if the standard is not listed as an ARAR. For instance, while the remediation goal stated in the ROD for a soil excavation may be above the State standard, if the contamination has a distinct boundary the excavation may result in the removal to a non-detect level. The State needs to decide if it is willing to move forward with a final ROD that does not include the State standard as an ARAR if the response action will eliminate unacceptable risk. The State may decide that this is an unacceptable precedent or can identify this condition in the response letter.

Note that the lead agency may (and often does) disagree with a State's list of ARARs. In Region 1, a federal agency stated, "[s]imply because a law or regulation must be complied with doesn't make it an ARAR..." This is true insofar as State ARARs must be more stringent than federal regulations and have a nexus to the response action. However, when presented with a list of State ARARs, the federal agency rejected many because they did not establish "a requirement that is a CERCLA cleanup standard or standard of control that specifically addresses a CERCLA hazardous substance, pollutant, or contaminant." The NCP does not restrict ARARs to standards that specifically address a CERCLA hazardous substance, pollutant or contaminant. Rather, as indicated above, relevant and appropriate requirements include

> ... 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.

States with non-promulgated cleanup standards (TBCs, not ARARs) may have difficulty getting the federal agency to comply with the standards that are more stringent than federal standards. Federal agencies do not need to comply with TBCs even if they are widely applied at State-led sites. It can be a challenge to persuade federal agencies to acknowledge certain TBCs as useful for implementing the remedy. Therefore, it is critical to have open communication between the State and federal agencies.

Despite the challenges discussed above, the federal agency can also be amenable to observing State TBCs, even though they are not promulgated. The US Navy has also demonstrated flexibility by achieving the State TBCs in cleanup actions without argument. Note that the US Navy has also refused to acknowledge TBCs in remedial action documents. Often, these differences in approach can vary from office to office (e.g., active installation vs Base Realignment and Closure [BRAC] site) and even from remedial project manager (RPM) to RPM.

It should be recognized that prior to any hazardous substance listing for PFAS, the DoD has investigated PFOS and PFOA as pollutants and contaminants since at least 2016. This has allowed the DoD to conduct response actions for PFAS in a much timelier manner than other responsible parties. The DoD has included the EPA's 2016 LHA for PFOS and PFOA as a TBC to conduct cleanup for drinking water.

Finally, it is important to ensure that ARARs that are agreed upon throughout the screening process from RI scoping to the FS make it to the PP and ROD without revision. In some States, agreements that were memorialized in the FS were changed in both the PP and ROD by the federal agency without consultation with the State.

IV. ARAR WAIVERS

ARAR waivers are applied in limited circumstances and should not be routinely used.[3] There are circumstances in which ARAR waivers may be appropriate during response actions. NCP §300.430(f)(1)(ii)(C) and EPA guidance identifies six ARAR waivers, described below, that can be invoked under certain circumstances for a removal action or a remedial action.

1. The alternative is an interim measure (e.g., removal action) and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or State requirement. For example, complying with the RCRA land disposal restriction storage prohibition at a non-NPL site may be inappropriate if the waste is drummed and overpacked, and future site actions will involve treatment of the waste that will comply with all land disposal restrictions;

2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;

[3] In December 2022, an EPA Federal Facilities Training summarized that 38 ARAR waivers have been approved at federal facility sites from 1992 to 2020. Technical impracticability (16) and interim action (16) waivers were the most used types of waivers.

3. Compliance with the requirement is technically impracticable from an engineering perspective, such as when a State surface water discharge standard requires treatment of some wastewater contaminants to below non-detectable levels;

4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach. However, a technology-based standard may not be replaced by a risk-based analysis (55 Federal Register 8748);

5. An otherwise applicable or relevant and appropriate State requirement is not an ARAR and need not be attained when that requirement has not been applied consistently to hazardous waste sites or facilities throughout the State (CERCLA as well as non-CERCLA sites). For example, at a battery recycling site, EPA waived a State requirement for leachate testing and management of lead-contaminated waste when EPA determined that the State was not enforcing the same requirement at State cleanup sites; or

6. For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment. This is typically not applied to federal agencies.

As part of the detailed analysis within a PP, the federal agency must include a discussion regarding State acceptance that provides rationale for excluding State ARARs and application of ARAR waivers. The waiver decision will be approved if appropriate documentation is provided that clearly focuses the waiver, see EPA Overview of ARARs Focus on ARAR Waivers document dated October 1989 for additional information.

V. DISPUTE RESOLUTION

CERCLA §121(a)(4) states that State promulgated laws concerning response actions, including laws regarding enforcement, apply to federal facility actions if the State law is not more stringent for federal facilities than for private facilities. The requirements for compliance with ARARs apply to both NPL and non-NPL federal facility CERCLA cleanups. Specifically, if the CERCLA remedy does not address the contamination in accordance with other State laws, independent State action under those laws is not prohibited, so long as what is required under the State laws does not interfere with the CERCLA remedy. While States may bring independent enforcement actions, many States have agreements in place that require administrative actions, such as dispute resolution (DR), prior to bringing any claim.

Most States that are acting as the lead regulatory agency for cleanup of environmental contamination at DoD sites have entered into a Department of Defense and State Memorandum of Agreement (DSMOA) that defines the process for the reimbursement of State costs. When the DSMOA was initiated, the DoD emphasized the need for cooperation and communication for the success of the DSMOA Cooperative Agreement (CA) program.

Specifically, the *DoD Components' Cooperation with the States for CAs and Site Cleanups memorandum dated July 18, 1989*, stressed that "a cooperative effort with the states, to include mutual consideration of each other's comments and program objectives, is key to cost-effective and timely execution of the Defense Environmental Restoration Program." While cooperation and communication are the keys to a successful State and DoD partnership in CERCLA cleanups, there are times when the State and federal agencies may not agree, especially when dealing with the issue of State ARARs.

Accordingly, the CA includes provisions for DR as the process governing how the State and the DoD resolve disputes that arise at individual sites.[4] The DR process promotes resolving disputes at the lowest possible level of authority as expeditiously as possible, which means resolving the dispute at the RPM and the State agency coordinator (SAC) level. However, if the RPM and the SAC cannot reach agreement, the DR process provides for three elevated levels of review to resolve the dispute generally ending with the Governor and the Service Secretary. If the RPM and SAC cannot resolve the dispute, they should refer it to the supervisory level for resolution as soon as they are unsuccessful in their attempts for resolution to try and expedite the DR process.

For the DOE sites, most States enter into site specific Memorandum of Agreements (MOA) that detail the roles and responsibilities of the agencies. Generally, these agreements contain a provision for resolving interagency disputes like the dispute resolution process in the DSMOA, whereby disputes should be resolved at the lowest level with the project manager and then elevates to senior level officials and then referred on from there.

The DR process will vary depending on whether the site is listed on the NPL and what agencies are involved. For example, if the site is on the NPL, there may also be a FFA that outlines a DR process. For NPL sites, EPA may be the agency required to resolve a dispute that continues to get elevated. Like the MOA with DOE, some States have State MOAs with the EPA that outline a process for resolving disputes. It is encouraged to enter into similar agreements with other federal agencies, such as the Department of Interior and Department of Agriculture, as this will help resolve issues on a more consistent and timelier basis.

The DR process may be used to resolve ARAR disputes for both removal and remedial actions. However, if DR is unsuccessful, the State retains any enforcement authority it may have under State or federal law. Specifically, if DR fails and the State has exhausted the required administrative remedies under the DSMOA or other agreement, a State may seek other administrative or judicial remedies for claims covered by the DSMOA, or other agreement, to require compliance with State and federal law related to the CERCLA remedy.[5]

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[4] The 2017 DSMOA CA Guide provides processes for formal and informal dispute resolution. If you do not have a Dispute Resolution Process, the NCP Preamble Subpart F (55 FR 8781) includes an example dispute resolution process during the RI/FS stage that encourages the prompt resolution of disputes at the project manager level.

[5] See letter dated August 25, 1993, from Deputy Under Secretary of Defense to Colorado Department of Health.

In addition, not all disputes for compliance are specific to an ARAR challenge. For example, some CERCLA remedies fail to address all environmental contamination at the site or fail to meet the State standards. Under these situations, States have independent authority to bring claims against federal agencies for failure to comply with State law.

For remedial actions, as the lead regulatory agency for environmental cleanup at federal facilities, if the federal agency fails to include the State identified ARARs in the ROD, the State can also refuse to concur with the ROD. The State's concurrence or non-concurrence with the recommended alternative must be included in the PP that is published for public comment. NCP §300.515 discusses the requirements for State involvement in the preparation and publication of the PP. See also *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* at Section 3.3.9. State concurrence is not a pre-requisite to selecting the remedy, but it is a good idea to have documentation in the administrative record of the basis for the State's non-concurrence. The basis for non-concurrence can be a useful tool in bringing an independent action for compliance with State laws.

For NTRCAs, the DR process should also be used to resolve ARAR disputes. Unfortunately, for TCRAs, the DR process may not be the best approach, as the DR process usually results in significant delays and the federal agency will likely proceed without State concurrence. In this situation, the State should still follow the CERCLA process and timely identify all ARARs to the federal agency to be included in the decision document (EE/CA/AM/etc.). If the federal agency, as the lead agency, does not include the State's identified ARARs, the State should prepare a written statement that includes the ARARs and its concerns to be included in the decision document/administrative record. Additionally, because CERCLA requires federal agencies to comply with all State laws concerning removal and remedial actions, including enforcement, the State may take an independent enforcement action to require the

Case Example:
Rocky Mountain Arsenal, Colorado

The Rocky Mountain Arsenal (RMA) contains a hazardous waste landfill, subject to RCRA. The hazardous waste landfill, while located on the RMA, is not a remedy component and is required to comply with State laws. The Army disputed Colorado's regulatory authority claiming that because the RMA became a Superfund Site, the State did not have RCRA authority.

The Tenth Circuit District Court disagreed, holding Colorado was not barred from issuing a RCRA compliance order because it was not a challenge to the Army's CERCLA response action, affirming that CERCLA works in conjunction with other environmental laws. United States. V. Colorado, 990 F.2d 1565 (10th Cir. 1993), cert. denied 114 S. Ct. 922 (1994) ("Given that RCRA clearly applies during the closure period of a regulated facility … the ARAR's provision cannot be the exclusive means of State involvement in the cleanup of a site subject to both RCRA and CERCLA authority").

More recently, the Supreme Court held that State courts have jurisdiction to hear State law claims relating to ongoing Superfund remedial actions, even if such claims constitute a "challenge" to [the] remedy. Atlantic Richfield Company v. Christian, 140 S. Ct. 1335 (2020) (CERCLA does not strip the Montana courts of jurisdiction over landowner's suit against a smelter owner for common law nuisance, trespass and strict liability because the claims arose under Montana law and not CERCLA).

federal agency comply with its State laws. While this action may not be timely, the State could take the necessary response actions to comply with the State laws and file a lawsuit for cost recovery (although, here, success is not guaranteed). Alternatively, because many removal actions result in additional remedial action, the State can work with the federal agency to ensure compliance with State ARARs during the remedial action.

VI. CONCLUSIONS AND RECOMMENDATIONS

The requirements for compliance with ARARs apply to both NPL and non-NPL federal facility CERCLA cleanups. State promulgated laws concerning removal and remedial actions apply to federal facility response actions if the State law is more stringent than federal law and is applied equally to federal facilities and private entities. While in most cases State ARARs are incorporated into federal agency decision documents, States have faced a variety of challenges related to ARARs throughout the CERCLA process in both removal and remedial actions.

States experience unique challenges when they are the lead regulatory authority or support agency for environmental cleanup under CERCLA at federal facilities. States will identify ARARs and TBCs that are applied to other regulated parties within State programs. Federal agencies are delegated lead agency authority under E. O. 12580 to conduct environmental cleanup at federal facilities, which creates an inherent conflict. As the lead agency, but also as the responsible party, the federal agency applies its interpretation of the applicability and relevance of regulations at federal facilities and determines which State laws and regulations become ARARs in their final decision documents. Like all responsible parties, federal agencies are required to meet the ARARs for the environmental remedy to be complete. Accordingly, it is essential that States timely identify ARARs early and revisit them often throughout the CERCLA process.

DOE, US Navy and EPA have documents that support the use of State ARARs along with federal ARARs (e.g., NPDES and RCRA) during removal actions when appropriate. These removal action documents generally reflect the State's interpretation of federal regulations and promote effective cleanups as site resources are directed at the problem.

For all removal actions, ARARs are expected to be met to the extent practicable. At times, federal agencies rely on this language either to not include ARARs in the decision document or as an excuse for not meeting ARARs. The removal completion report should identify compliance, or lack thereof, with identified ARARs. There is usually sufficient time for States to identify ARARs. However, depending on the urgency of the situation, the threat to public health and the environment may result in an immediate response, where the State cannot identify ARARs or compliance with ARARs may be impracticable. Specifically, for emergency removals and TCRAs, States may not be afforded enough time to identify ARARs for the removal action memorandum or other decision document. In situations where the State is unable to identify ARARs in a timely manner, States should still work with the federal agency to ensure the State laws and regulations are met during a removal action, if practicable. In such cases, the State should provide the federal agency with its State ARARs as soon as possible, even after the decision document is finalized, if necessary.

For NTCRAs, where the federal agency is developing an EE/CA, States have more time to provide the State ARARs to be considered in the removal action. For all removal actions, States should also consider whether the removal action will remove all contamination or leave waste behind for a remedial action. If the removal is not intended to clean up all of the environmental contamination, States should consider whether an ARAR waiver may be appropriate during the removal action and if a future action will result in compliance with the State ARARs.

For remedial actions, compliance with ARARs must be attained for the remedy to be complete, unless an ARAR waiver is granted. ARARs should be discussed with the federal agency early in the cleanup process. Table 1 details the stages of a remedial action and the timing for identification of State ARARs. The NCP requires the State and federal agency to initiate the discussion on the location and chemical specific ARARs as part of the RI/FS scoping, which helps to define the nature and extent of contamination as well as assist with the performance of the BRA. The application of State ARARs during the RI saves the federal agency, EPA, and the State significant time and resources as site figures are prepared during the RI, whereas the FS applies the information presented in the RI to evaluate remedial alternatives. The ARARs and TBCs identified in the FS will be applied to the selected remedy presented in the ROD and Interim ROD. The State regulator should ensure that the ARARs and details of the remedy are carried through to the final decision document.

The NCP does not require discussion or identification of ARARs during the SI or for No Action RODs. However, during the SI, ARARs may be a useful tool for determining the investigation parameters. Further, for No Action RODs, States should consider whether State laws and regulations were considered during the BRA. States recommend that the BRA utilize State ARARs to better understand risks from the site that all responsible parties must follow. At times, the RI relies solely on federal laws and regulations, which may not be as stringent as State laws, and may not be appropriate for a No Action ROD.

If agreement is not reached, States have a number of tools they can use to work towards consensus. For example, if a State does not agree with the ROD or the ROD does not include necessary State ARARs, the State may issue a non-concurrence letter, which is required to be included in the PP and the administrative record for the federal facility. The State may also initiate dispute resolution under their cooperative agreement, the NCP, an MOA, FFA or another governing document. For issues related to compliance with State laws that would not interfere with the CERCLA remedy, the State may initiate an enforcement action for compliance with its laws. Finally, for property being transferred out of federal ownership, a State may withhold approval of the property transfer when the federal agency has not addressed site contamination issues identified by the State.

Public display of State ARARs on a website clearly shows the application of State ARARs to other responsible parties, but also provides federal agencies an understanding of ARARs present within the State and allows the public to see that the State ARARs are being attained. Further, this will permit the federal agency to identify State ARARs from various State programs as information is available in one location. This resource can also be used by the State project manager assigned to the site because they are likely the point of contact responsible for identifying State ARARs when requested by the federal agency. State project managers are familiar with site conditions and can use this resource to reach out to other State programs to verify ARARs that should be identified.

Many challenges that arise when identifying ARARs at federal facilities for remedial actions and removal actions can be resolved if a good working relationship exists between the State and the federal agency. When a positive working relationship exists, the federal agency may acknowledge the benefit of meeting State standards (such as avoiding dispute resolution), even if it requires additional resources. However, there are times when, regardless of the working relationship, the State and federal agency do not agree on ARARs.

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ASSISTANT SECRETARY OF DEFENSE
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ENERGY, INSTALLATIONS,
AND ENVIRONMENT

September 3, 2024

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, NATIONAL GUARD BUREAU (JOINT STAFF, J3/4/7)
DIRECTOR, DEFENSE LOGISTICS AGENCY (INSTALLATION MANAGEMENT)

SUBJECT: Prioritization of Department of Defense Cleanup Actions to Implement the Federal Drinking Water Standards for Per- and Polyfluoroalkyl Substances Under the Defense Environmental Restoration Program

On April 26, 2024, the Environmental Protection Agency (EPA) published a final National Primary Drinking Water Regulation (NPDWR) establishing nationwide drinking water standards for certain per- and polyfluoroalkyl substances (PFAS) under the Safe Drinking Water Act (SDWA). This rule applies to public drinking water systems. DoD remains committed to fulfilling our PFAS-related cleanup responsibilities and will take necessary actions to incorporate SDWA levels into our cleanup program, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (40 C.F.R. Part 300). The CERCLA process can take time to complete, but also provides a consistent, science-based approach across the Nation for cleanup and includes federal and state environmental regulator review and public participation. This memorandum describes DoD’s plans to incorporate the drinking water rule into DoD’s ongoing PFAS cleanups and prioritize actions to address private drinking water wells with the highest levels of PFAS from DoD activities.

EPA’s drinking water rule includes enforceable maximum contaminant levels[1] (MCL) for five PFAS: perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), hexafluoropropylene oxide dimer acid (HFPO-DA, commonly known as GenX), and perfluorohexane sulfonic acid (PFHxS). It also includes a Hazard Index (HI) MCL, for a mixture of at least two or more of PFHxS, PFNA, perfluorobutane sulfonic acid (PFBS), and HPFO-DA (GenX) chemicals. The rule provides five years for regulated public water systems to comply with these MCLs as specified below.

- Individual MCLs in parts per trillion (ppt):
    - PFOS = 4 ppt
    - PFOA = 4 ppt

[1] SDWA defines a “maximum contaminant level” or MCL to be “the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.” 42 U.S.C. § 300f(3).

- HFPO-DA = 10 ppt
- PFNA = 10 ppt
- PFHxS = 10 ppt

- Hazard index[2] MCL for PFHxS, PFNA, PFBS, and HFPO-DA = 1 (unitless)

DoD's Cleanup Program

The Defense Environmental Restoration Program (DERP) statute provides DoD authorities to perform and fund cleanup actions and requires they be carried out in accordance with CERCLA. Under CERCLA, the DoD addresses releases or threatened releases of hazardous substances, pollutants, or contaminants from DoD activities, including PFAS. DoD is working to integrate the MCL values established in EPA's final SDWA rule into its cleanup process. Under CERCLA, MCLs can be used as a risk trigger level to take interim actions (i.e., removal actions), but exceeding an MCL does not in itself trigger a removal action. CERCLA also incorporates federal or state cleanup requirements, called Applicable or Relevant and Appropriate Requirements (ARARs), to develop final cleanup levels. ARARs are determined on a site-specific basis, but in most cases, MCLs are used as the final cleanup standard to be attained for groundwater used for drinking water.

As of March 31, 2024, DoD has completed preliminary assessments/site inspections to evaluate potential releases of PFAS from DoD activities at 710 of 717 installations. DoD identified 578 installations that require further investigation. DoD has initiated remedial investigations at over 350 of these installations and plans to begin over 150 more within the next two fiscal years. Remedial investigations provide important information enabling the Department to take additional interim actions to prevent further PFAS plume migration as well as address impacted drinking water wells. At 55 installations, DoD took interim actions to address off-base drinking water wells/systems where levels of PFOS and PFOA were above 70 ppt (the level DoD previously used to trigger an interim action).

Interim Actions (i.e., Removal Actions)

The Department recognizes the need to take quick actions to address PFAS in drinking water. To ensure cleanup begins as quickly as possible, the DoD Components will initiate removal actions to address private drinking water wells impacted by PFAS from DoD activities where concentrations are known to be at or above three times the MCL values (i.e., PFOA = 12 ppt; PFOS = 12 ppt; PFHxS = 30 ppt; GenX = 30 ppt; PFNA = 30 ppt; HI = 3). This approach prioritizes action where PFAS levels from DoD releases are the highest (i.e., at or above three times the MCL values), rather than delay action at these locations while ongoing remedial investigations continue. Whenever possible, the DoD Components will use a CERCLA "Time Critical Removal Action[3]" for these efforts. This is DoD's initial step to prioritize cleanup

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[2] The hazard index is defined in 40 C.F.R. § 141.2 and explained in EPA's factsheet "Understanding the Final PFAS National Primary Drinking Water Regulation Hazard Index Maximum Contaminant Level" at https://www.epa.gov/system/files/documents/2024-04/pfas-npdwr_fact-sheet_hazard-index_4.8.24.pdf

[3] A time critical removal action is used, when after an evaluation of the site, the lead agency determines there is less than six months of planning time available for removal activities.

actions in private drinking water wells, including private drinking water wells located off-base at the 55 installations, where DoD has previously taken action for wells with levels of PFOS and PFOA above 70 ppt. As DoD works to complete actions to address off-base drinking water at the 55 installations with the highest known levels of PFAS, the Department will continue to identify and address private drinking water with PFAS above three times the MCLs from DoD releases at additional locations. DoD will then initiate remedial actions to address drinking water wells and public water systems with concentrations below three times the MCL value as described in the remedial action section of this guidance.

DoD anticipates a significant number of private drinking water wells will require interim actions to reduce PFAS levels. To expedite implementation of more enduring solutions, the DoD Components will focus on sustainable solutions when considering alternatives. The DoD Components will consider in prioritized order: providing connections to public water systems; installing whole house treatment systems; providing point of use treatment systems; and providing bottled water.[4]

DoD also intends to expedite action at public water systems where authorized, prioritizing the most impacted sites for earlier action. For public water systems above the MCLs impacted by PFAS from DoD activities, the DoD Components will work with those systems and regulators to address PFAS impacts. These actions will assist the public water systems as they work to meet the requirements for compliance with the PFAS NPDWR as soon as possible but not later than April 2029.

This policy is intended to expedite remediation of private drinking water wells, and public water systems impacted by DoD PFAS releases, prioritizing the most impacted sites for earlier action. The Military Departments will ensure that robust communication occurs before, during, and after actions are taken to address PFAS on and around DoD installations, Base Realignment and Closure locations, and National Guard facilities.

Long-Term Remedial Actions

CERCLA requires a site-specific risk assessment during the remedial investigation to establish risk-based cleanup levels. This includes considerations of "background" levels of chemicals present at a site, which can be highly variable across the country. Throughout the CERCLA process DoD coordinates with both EPA and state regulators and EPA and DoD jointly select remedies at National Priorities List sites. Accordingly, DoD will work with EPA and state regulators, as appropriate, to evaluate background levels of PFAS on a site-specific basis to determine a final cleanup level.

For remedial actions, the DoD Components will address drinking water down to the MCLs or background, in accordance with CERCLA, once the DoD Component has established

[4] The DoD Components will only provide bottled water when: 1) more sustainable alternatives, such as drinking water treatment, are technically infeasible due to site-specific conditions and in these cases, the DoD Component will request a waiver from the DASD(EMR) prior to the provision of bottled water; 2) the levels of PFOS and PFOA in drinking water are above 70 ppt; or 3) bottled water was already being provided prior to the issuance of this guidance and levels are at or above three times the MCLs.

background PFAS levels using EPA's CERCLA policies on this matter.[5] If the outcome of the CERCLA background assessment conducted during the remedial investigation is that background levels of PFAS are below the MCLs, then DoD Components will take remedial actions to address PFAS that will meet the MCLs as the final cleanup levels.[6] If background levels of PFAS are found above an MCL at a site, DoD Components will work collaboratively with regulators and transparently with the public to determine the appropriate remedial goals (i.e., final cleanup levels) at that site.

This guidance is the first step in a prioritized approach that enables DoD to take quick action to address private drinking water wells, and public water systems where possible, where known levels of PFAS from DoD activities are the highest while the Department continues to gather information through remedial investigations to prioritize future actions. DoD continues to review existing data and collect new information to assess where PFAS plumes may have migrated from an installation and impacted drinking water and will be prioritizing those locations for response actions as the next step. DoD believes this is the best approach for the long-term protection of human health and the environment and the Department will continue to accelerate DoD's cleanup efforts Nationwide in accordance with federal law and in partnership with regulatory agencies and affected communities.

The Department will update this guidance periodically, as necessary, as investigations continue and more sampling data is received.

The point of contact for this matter is Ms. Alexandria Long at 703-571-9061 or alexandria.d.long.civ@mail.mil.

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Brendan M. Owens

[5] EPA, Role of Background in the CERCLA Cleanup Program, OSWER 9285.6-07P (2002)(available at https://www.epa.gov/risk/role-background-cercla-cleanup-program); EPA, Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites, EPA 540-R-01-003 (September 2002) (located at: https://www.epa.gov/risk/guidance-comparing-background-and-chemical-concentrations-soil-cercla-sites)).
[6] Where MCLs have been identified as relevant and appropriate under the circumstances of the release.

CSWAB

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July 27, 2007

VIA ELECTRONIC MAIL AND U.S. MAIL

Hank Kuehling
Wisconsin Department of Natural Resource
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Madison, WI 53711
Ph. 608-275-3286
Email: Harlan.kuehling@wisconsin.gov

Re: Preliminary Determination of Final Remedy for Propellant Burning Ground Waste Pits Subsurface Soils, Badger Army Ammunition Plant

Dear Mr. Kuehling,

Citizens for Safe Water Around Badger is a non-profit environmental organization that was formed in 1990 by neighbors of the Badger Army Ammunition Plant in support of a healthy and sustainable future that will protect and restore the integrity of soil, water, air, and biological diversity. We appreciate the opportunity to present these comments on the proposed remedy and the modification of the Department's Plan Modification Approval issued on June 1, 1995. These comments are an amendment to our prior comments dated June 4, 2007.

I. THE PROPOSED REMEDY AND PERMIT MODIFICATION MUST ENSURE THAT GROUNDWATER CONTAMINATION DOES NOT THREATEN PUBLIC HEALTH AND WELFARE.

- **The Proposed Remedy and Modification must achieve and require compliance with the PAL and other applicable standards to the extent practicable, within a reasonable timeframe, and to minimize the harmful effects of the contamination to the air, land, and waters of the state.[1]**

[1] Wis. Admin. Code NR § 722.02(3)(a).

Dinitrotoluene (DNT) is a hazardous chemical substance used extensively in ammunition production at Badger Army Ammunition Plant (Badger) during the 1960s and 1970s.[2] Records indicate hazardous wastes, including solvents and DNT, were discarded into unlined pits at the Propellant Burning Grounds. Environmental testing by the Army indicates that these pits are the source of groundwater contaminant plumes that extend past the facility's boundaries, affecting private residences to the south,[3] and discharging to the Wisconsin River.

The U.S. Environmental Protection Agency (EPA) has concluded that DNT is a major health concern. Studies indicate that human exposure to DNT through contact, inhalation, or ingestion can result in serious adverse health problems including nervous system disorders and heart disease.[4]

The EPA has classified two DNT isomers, 2,4-DNT and 2,6-DNT, as class 2B human carcinogens.[5] Laboratory bioassay and animal studies often found that 2,4-DNT caused kidney cancer and that mixtures of 2,4-DNT and 2,6-DNT caused liver cancers.[6]

High exposure to carbon tetrachloride can cause liver, kidney, and central nervous system damage. These effects can occur after ingestion or breathing carbon tetrachloride, and possibly from exposure to the skin. The liver is especially sensitive to carbon tetrachloride because it enlarges and cells are damaged or destroyed.[7]

Drinking small amounts of trichloroethylene for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear.[8]

Like carbon tetrachloride and trichloroethylene, chloroform has been classified as Group B2 (probable human) carcinogen by EPA based on "sufficient evidence" of carcinogenicity in animals. Chloroform can enter your body if you breathe air, eat food, or drink water that contains chloroform. Chloroform easily enters your body through the skin. Therefore, chloroform may also enter your body if you take a bath or shower in water containing chloroform.[9]

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[2] Badger Army Ammunition Plant: Environmental Restoration Advisory Board, Meeting Minutes (Oct. 16, 2006) (meeting held at Badger Army Ammunition Plant, Baraboo, WI).
[3] *Id.*
[4] Department of Health and Human Services: Agency for Toxic Substances and Disease Register (Updated Jan. 31, 2007), http://www.atsdr.cdc.gov/toxprofiles/phs109.html.
[5] Department of Health and Human Services: Agency for Toxic Substances and Disease Register, http://www.atsdr.cdc.gov/toxprofiles/tp109-c7.pdf.
[6] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells,* Badger Army Ammunition Plant, page 9, September 30, 2006.
[7] ATSDR, *ToxFAQs for Carbon Tetrachloride*, August 2005.
[8] ATSDR, *ToxFAQs for Trichloroethylene*, July 2003.
[9] ATSDR, *Public Health Statement forChloroform*, September 1997.

Infants who are fed water or formula made with water that is high in nitrate can develop a condition that doctors call methemoglobinemia. The condition is also called "blue baby syndrome" because the skin appears blue-gray or lavender in color. This color change is caused by a lack of oxygen in the blood.

All infants under six months of age are at risk of nitrate poisoning. Some babies may be more sensitive than others. Infants suffering from "blue baby syndrome" need immediate medical care because the condition can lead to coma and death if it is not treated promptly.[10]

Some scientific studies have found evidence suggesting that women who drink nitrate-contaminated water during pregnancy are more likely to have babies with birth defects. Nitrate ingested by the mother may also lower the amount of oxygen available to the fetus.[11]

People who have heart or lung disease, certain inherited enzyme defects, or cancer may be more sensitive to the toxic effects of nitrate than others. In addition, some experts believe that long-term ingestion of water high in nitrate may increase the risk of certain types of cancer. [12]

- **The Proposed Remedy and Modification for subsurface soils at the Propellant Burning Grounds must not be artificially segmented from the connected groundwater contaminant plume/s.**

  In accordance with the National Environmental Policy Act (NEPA)[13] and WEPA, the WDNR should consider the "whole" or integrated project. NEPA further requires consideration of the whole of the proposed action, even if the agency is only permitting a portion of it. The proposed remedy is an interdependent part of the overall environmental impact of the Propellant Burning Grounds and should be considered and assessed as one project.

- **The WDNR must require evaluation of Partial Excavation and other viable remedies not carried forward for consideration.**

  Decisions subject to WEPA cannot be made without appropriate environmental impact information and analysis that includes a discussion of meaningful alternatives.[14]

  Soil borings conducted in 2005 show that the vast majority of residual 2,4-Dinitrotoluene contamination in subsurface soils is contained within the remaining top

[10] Wisconsin Department of Natural Resources, *Nitrate in Drinking Water,* Publication WS-001, undated.
[11] Wisconsin Department of Natural Resources, *Nitrate in Drinking Water,* Publication WS-001, undated.
[12] Wisconsin Department of Natural Resources, *Nitrate in Drinking Water,* Publication WS-001, undated.
[13] 40 CFR 1508.25(a).
[14] Wis. Admin. Code NR § 150.025(2)(d).

11-19 feet of Waste Pit 1, the top 12-30 feet of Waste Pit 2, and the top 7-17 feet of Waste Pit 3.[15]

Based on prior excavations at these sites (which ranged from 13 to a maximum of 23 feet below grade), the remaining contaminated soils are "readily accessible". If the perimeters of the waste sites were increased sufficiently to allow safe access of machinery to the original waste pit site periphery, excavation of the majority of contamination could be readily achieved (based on the facility's assumption that other site contaminants are co-located).

Unfortunately, the Army only evaluated removal of entire soil column down to the water table and did not evaluate the potential for a more moderate approach to source removal which would have a far greater comparative environmental benefit per dollar expended. Moreover, improved source removal (additional excavation) would be expected to reduce the number of years groundwater extraction is required, resulting in a significant cost savings in excess of $1 million per year.

- **Before finalizing the Proposed Remedy and Modification, the Department must consider whether or not the proposed remedy is effective by first evaluating the remedy at the Deterrent Burning Ground.** [16]

  The requirement for a detailed evaluation of a proposed remedial action addressing hazardous substances present at a site is contingent on the proven effectiveness and success and experience gained at other sites with similar site characteristics and conditions. [17]

  Although the Deterrent Burning Grounds and Existing Landfill were covered with a RCRA cap/cover in 2003,[18] recent testing indicates that DNTs in groundwater are higher than expected and correspond with increasing trends both in source and boundary monitoring wells at the NE corner of Badger.

  The 3,4-DNT isomer was reported at 1.74 ug/l (micrograms per liter) in groundwater monitoring well ELM-8908 and 0.098 ug/l in ELM-9501 in December 2006. In March 2007, 2,3-DNT was detected at 0.018 ug/l and 3,4-DNT was detected at 0.139 ug/l in monitoring well ELM 9501.

[15] U.S. Army Corps of Engineers Omaha District, Draft Alternative Feasibility Study Propellant Burning Ground Waste Pits Subsurface Soil, Badger Army Ammunition Plant Baraboo, Wisconsin, Revision 1, Appendix C, Table 1, *Summary of Soil Analysis Data BAAP Propellant Burning Grounds*, *Soil Borings Performed 2005,* April 6, 2006. See also: Figures 4 ,5, and 6: Propellant Burning Ground *Cross Sections, Extent of DNT Contamination* for Pits 1,2, and 3 accordingly.
[16] Wis. Admin. Code NR § 722.07(3)(b)2.a.
[17] Wis. Admin. Code NR § 722.07(3)(b)2.a.
[18] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells,* Badger Army Ammunition Plant, page 2, September 30, 2006.

At the Deterrent Burning Grounds, the 2,4-DNT and 2,6-DNT isomers exceeded the groundwater enforcement standard in DBM-8201 – contaminant levels were 0.119 and 0.107 ug/l respectively in March 2007. At this same monitoring well, 2,3-DNT was detected at 2.2 ug/l in groundwater, 3,4-DNT was detected at 9 ug/l , and 3,5-DNT was detected at 1.27 ug/l.

Monitoring well ELM-9501 is located at the plant boundary just west of the Dan Purcell farm and more than 3,000 feet from the Deterrent Burning Grounds hazardous waste disposal site.

The Enforcement Standard for 2,4-DNT and 2,6-DNT is only 0.05 ug/l. The Interim Drinking Water Health Advisory Level for the sum of all six DNT isomers is 0**.**05 ug/l.[19]

Waste disposal activities at the Propellant and Burning Grounds were very similar. According to Army records, during the period of 1968-1975, a liquid chemical waste, extracted from a process which reclaims nitrocellulose from unusable ball powder, was poured into unlined pits in both the north and south burning grounds.

According to interviews with former Badger Army Ammunition Plant employees, approximately 500 gallons per week of deterrent was dumped in pits located in the Propellant Burning Grounds from 1966 to 1970. After 1970, deterrent was dumped and burned Deterrent Burning Grounds.[20] According to historical Army reports, this deterrent contained: "the following toxic chemicals: dinitrotoluene, diphenylamine, dibutylphthalate, benzene, trinitrotoluene, and suspected carcinogens".[21]

- **The Proposed Remedy and Modification must require an enforceable Five-Year Site Review for a minimum of 40 years.**

- **The Proposed Remedy and Modification must require quarterly monitoring for ALL isomers of DNT in groundwater.**

We were very surprised to find that the BEST System database[22] did not contain ANY data for 2,5-DNT, 3,4-DNT, and 3,5-DNT. As this was the same data provided to the WDNR, neither regulators not the public were provided with all necessary data to fully evaluate the proposed remedy. The missing data alone is sufficient cause to not approve the proposed remedy.

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[19] Linda Knobeloch, Ph.D., Wisconsin Division of Public Health, *Drinking Water Health Advisory for Dinitrotoluenes*, June 14, 2007.
[20] U.S. Army Environmental Center, Final Remedial Investigation Report, Volume I, page 7-1, April 1993.
[21] Department of Army, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland, *Water Quality Special Study No. 24-0039-78, Part I – Geohydrology, Badger Army Ammunition Plant, Baraboo, WI, 12 – 17 June 1977.*
[22] Shaw Environmental & Infrastructure, BEST System Database, Badger Army Ammunition Plant, March 2007.

Evaluating levels and trends in 2,3-DNT was difficult as the Level of Quantification (LOQ) varied so significantly. The LOQ ranged from 1,300 to 0.02 ug/l. Nonetheless, it is clear that 2,3-DNT levels in groundwater remain very high. On March 6, 2006, 2,3-DNT was detected at 48 ug/l. The Interim Drinking Water Health Advisory Level for the summed concentration of all six DNT isomers is only 0.05 ug/l.[23]

Both 2,4-DNT and 2,6-DNT have a low affinity for organic particulate matter and are considered "highly mobile" in soil.[24] The relatively low volatility and moderate solubility of DNT indicate that it will remain in water for long periods of time. DNT is degraded by light, oxygen, and biota. As a result, it can be transported to groundwater or surface water (ATSDR, 1998). [25]

The 2,-3 DNT isomer has not been shown to biodegrade.[26] No studies have been conducted to demonstrate that 3,4-DNT, 3,5-DNT, or 2,5-DNT will biodegrade in soils or groundwater.

Technical grade DNT, which is a mixture of six isomers, is known to cause cancer in animals. All six isomers have shown mutagenic effects in short-term studies. Published studies indicate that the four less common isomers of DNT are "as toxic or more toxic than 2,4-DNT and 2,6-DNT".[27]

- **The Proposed Remedy and Modification must require and assure compliance with the PAL both at Badger and in the neighboring community.**

Preventive action limits are intended to provide regulator agencies time to take preventive measures to ensure that the enforcement standard is not attained or exceeded.[28]

The U.S. Army at Badger Army Ammunition Plant, as the party responsible for the disposal and discharge of carcinogenic and hazardous substances at the Propellant Burning Grounds (PBG) and to the environment is required to take action necessary to

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[23] Linda Knobeloch, Ph.D., Wisconsin Division of Public Health, *Drinking Water Health Advisory for Dinitrotoluenes*, June 14, 2007.
[24] U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene*, Proposal Draft, August 2006.
[25] U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene*, Proposal Draft, page 13, August 2006.
[26] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, pages 2 and 5, February 2001.
[27] Linda Knobeloch, Ph.D., Wisconsin Division of Public Health, *Drinking Water Health Advisory for Dinitrotoluenes*, June 14, 2007.
[28] Wisconsin Department of Natural Resources, Wisconsin Groundwater Standards, *An Explanation of Chapter 160. Wis. Stats*., undated.

restore the environment to the extent practicable and minimize the harmful effects from the discharge to the air, lands, or waters of the state.[29]

At the PBG, DNT has been consistently found in groundwater, with concentrations ranging between 0.04 ug/l and 43,000 ug/L (micrograms per liter).[30] DNT is rapidly degraded by sunlight and bacteria, but when DNT reaches groundwater, it tends to undergo very little degradation.[31]

Preventive action limits are applicable both to controlling new releases of contamination as well as to restoring groundwater quality contaminated by past releases of contaminants.[32] Although a preventive action limit is not intended to always require remedial action, activities affecting groundwater must be regulated to minimize the level of substances to the extent technically and economically feasible, and to maintain compliance with the preventive action limits unless compliance with the preventive action limits is not technically and economically feasible.[33]

To the extent practicable, contaminated groundwater must be restored to comply with the PAL[34] and remedial actions must be designed to regain and maintain compliance with the Preventative Action Limit.[35] When substances are detected in groundwater for which a standard does not exist in ch. NR 140, the WDNR may require clean-up of the groundwater to the extent practicable which may "be overly conservative depending upon the actual toxicity of the substance detected".[36]

Waiting until an exceedance occurs in drinking water resources is not protective of human health as it does not prevent exposures to levels at or above the ES.

- **Monitoring of potential degradation products of DNT and other Contaminants of Concern must have a Level of Detection consistent with the PAL or the Lowest Possible Level of Detection for "unregulated"[37] groundwater contaminants.**

Laboratories testing groundwater are required to select the analytical methodology which is specified in rules or approved by the regulatory agency, is appropriate for the concentration of the sample, and has a limit of detection and limit of quantitation below

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[29] Wis. Stats. § 292.11(3).
[30] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells*, Badger Army Ammunition Plant, page 2, September 30, 2006,.
[31]EPA, Integrated Risk Information System (IRIS). 2,4-Dinitrotoluene (CASRN 121-14-12), August 22, 2002.
[32] Wis. Admin. Code NR § 140.02(3).
[33] Wis. Admin. Code NR § 140.02(3).
[34] Wis. Admin. Code NR § 722.09(2)b.1.
[35] Wis. Admin. Code NR § 722.09(2)b.1. Notation.
[36] Scott Hassett, Secretary Wisconsin DNR, Correspondence/Memo to Members of the Natural Resources Board, *Background Memo – Proposed amendments to Wisconsin Administrative Code Chapter NR 140, Groundwater Quality*, February 26, 2007.
[37] For the purpose of this paper, an "unregulated" groundwater contaminant is one that does not have health-based Enforcement Standard pursuant to Wis. Admin. Code NR § 140.

the preventive action limit, or produces the lowest available limit of detection and limit of quantitation if the limit of detection and limit of quantitation are above the preventive action limit.[38]

- **The Proposed Remedy and Modification must require quarterly monitoring of all residential wells when levels of regulated contaminants attain the PAL near the Badger boundary or beyond.**

While there have been substantial investigations of groundwater on and around Badger, it appears the degree and extent of DNT contamination in groundwater has not been fully characterized.[39] DHFS supports the ongoing groundwater investigations being conducted by the Army, and recommends the continued testing of nearby private wells in order to ensure that the public is not being exposed to unsafe levels of DNT in drinking water. [40]

Given the serious threat DNT poses to human health, its documented use at the Badger facility, and the recent detection of several forms of DNT in residential wells down-gradient from the plant, the Remedy and Modification should take all precautions by monitoring for all DNT isomers at all discharges.

In the end, the only way to know if a residential well is safe to use is to actually test the well. While monitoring wells are vital tools in assessing groundwater quality and movement, they are not a legitimate replacement for testing private well water.

- **The Proposed Remedy and Modification must require the attainment of the lowest possible concentration of "unregulated" groundwater contaminants.**

The WDNR is authorized to take action necessary to protect public health and welfare or prevent a significant damaging effect on groundwater or surface water quality for present or future consumptive or non-consumptive uses, <u>whether or not an enforcement standard and preventive action limit for a substance have been adopted under Wis. Admin. Code NR 140</u>. [41]

For substances which do not have an established standard in ch. NR 140, the department may take or require the responsible parties to conduct any necessary actions, such as developing site-specific environmental standards in cooperation with the department of health and social services, to protect public health, safety and welfare or to prevent a significant damaging effect on groundwater or surface water quality for present or future consumptive or non-consumptive uses.[42]

[38] Wis. Admin. Code NR § 140.16(2)
[39] U.S. Department of Health and Human Services, Public Health Service, Health Consultation: Dinitrotoluene in Private Wells, Badger Army Ammunition Plant, September 30, 2006, page 7.
[40] U.S. Department of Health and Human Services, Public Health Service, Health Consultation: Dinitrotoluene in Private Wells, Badger Army Ammunition Plant, September 30, 2006, page 7.
[41] Wis. Admin. Code NR § 140.02(4).
[42] Wis. Admin. Code NR § 722.09 (2)(b)2.

Wisconsin Stat. §144.76(3) (1977) requires those in violation of its provision to "take the action necessary to restore the environment to the extent practicable and minimize the harmful effects from any discharge to the air, lands or waters of the state." In a 1998 opinion, the Supreme Court of Wisconsin determined that use of this phrase "restore the environment to the extent practicable" necessary implication reveals an intent to address past conduct. Even when conduct predated the Spills Law, the responsible party must perform remediation of a spill site to "make the environment whole again". [43]

This is further consistent with intent of the legislature which directs the Department of Natural Resources to promote environmental performance that voluntarily exceeds legal requirements related to health, safety, and the environment and that results in continuous improvement in Wisconsin's environment, economy, and quality of life.[44]

In March 2007, groundwater monitoring wells corresponding with License Number 2814 (Propellant Burning Grounds) detected 2,4-DNT at concentrations ranging from no detect (ND) to 4.5 ug/l. The 2,6-DNT isomer was detected at concentrations ranging from ND to 2.7 ug/l. By comparison, the other isomers were detected at much higher concentrations. The 2,3-DNT was detected at concentrations as high as 63.3 ug/l and 3,4-DNT levels were as high as 71.7 ug/l. The 3,5-DNT isomer was detected at 9.7 ug/l and 2,5-DNT levels were as high as 2.2 ug/l.

At the Deterrent Burning Grounds – a similar site that has been capped since 2003 – has followed the same pattern. The 2,4-DNT isomer was detected at 0.017 ug/l, and the highest reported concentration of 2,6-DNT was 0.119 ug/l. By comparison, 2,3-DNT was detected at 9 ug/l and 3,4-DNT concentrations were as high as 9 ug/l. The 3,5-DNT isomer was reported at 1.27 ug/l and 2,5-DNT was not detected.

These findings are not surprising as the 4 less common isomers of DNT (2,3-DNT, 2,5-DNT, 3,4-DNT, and 3,5-DNT) have not been shown to biodegrade.

- **The Proposed Remedy and Modification must require quarterly monitoring of nearby residential wells when "unregulated" contaminants are detected near the Badger boundary or beyond.**

- **The Proposed Remedy and Modification must stipulate that quarterly groundwater and residential well monitoring will continue after termination of the groundwater pumping and treatment system to assure that compliance with applicable standards is sustained now and in the future.**

[43] Supreme Court of Wisconsin, Case No. 96-1158 State of Wisconsin, Plaintiff-Appellant v. Chrysler Outboard Corporation, June 19, 1988.
[44] Wis. Stats. § 299.83 **(1m)** (b).

- **The Proposed Remedy and Modification must require a comprehensive monitoring plan to assure that groundwater and nearby residential wells do not exceed Nitrogen Limits as a result of releases from Badger.**

  Accumulation of nitrite/nitrate resulting from biodegradation of DNTs must be considered both to meet regulatory standards for any effluents generated.[45] In situ bioremediation of DNTs is viable at sites where: (1) aerobic conditions are present or can be engineered; (2) appropriate organisms are present or can be introduced effectively; and (3) the potential for nitrite or nitrate accumulation can be managed.[46] Transformation of DNT leads to partial reduction and formation of amines. [47]

  Accumulation of nitrite/nitrate, generated as a result of degradation of DNT, must be considered both to meet regulatory standards for any effluents generated. [48]

  Even after the BEST system was shut down, nitrates continue to exceed the ES. In June 2006, nitrates at the Propellant Burning Grounds were reported as high as 23 mg/l[49] exceeding the groundwater and safe drinking water standard of 10 mg/l. Combined with nitrates released to groundwater by the sanitary wastewater system, ongoing exceedance of the groundwater standard will occur.

  Groundwater monitoring conducted in November 2003 and continuing through August 2004 found high concentrations of nitrate + nitrite, with the average concentration in two boundary wells exceeding the enforcement standard (ES) of 10 milligrams per liter (mg/l). Testing at these two wells resulted in readings of 16.2 mg/l and 10.1 mg/l.[50] NR 140.10 Wis. Admin. Code states that nitrate + nitrite is "a substance of public health concern," as it relates to groundwater.[51] Therefore, the WDNR is required by law to prevent groundwater concentrations of nitrate + nitrite from exceeding the enforcement standard (ES) of 10 mg/L as a result of surface effluent discharge. [52]

  Yet, rather than requiring Badger to comply with existing effluent limits, the WDNR in June 2005 granted Badger an exemption for nitrate + nitrite standards under NR 140.28(2) Wis. Admin. Code. The exemption, however, was subject to several

[45] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida, *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 5, February 2001.
[46] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida, *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 5, February 2001.
[47] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida, *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 1, February 2001.
[48] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 5, February 2001.
[49] Shaw Environmental & Infrastructure, BEST System Database, Badger Army Ammunition Plant, March 2007.
[50] Letter from Joan Kenney, Installation Director, Badger Army Ammunition Plant, to Mr. Osipoff, Wisconsin DNR, Fitchburg, WI (March 31, 2005) (concerning Total Nitrogen Variance Request; refer to Table 1. Total nitrogen in quarterly WPDES wells).
[51] Wis Admin. Code NR § 140.10 (2007) (refer to Table 1. Public Health Groundwater Quality Standards).
[52] Wis Admin. Code NR § 140.10 (2007) (refer to Table 1. Public Health Groundwater Quality Standards).

limitations. Pursuant to NR 140.28(2)(a) Wis. Admin. Code, "the WDNR may grant an exemption [to groundwater quality standards only if]…the existing or anticipated increase in the concentration of that substance does not present a threat to public health and welfare." In granting this exemption, the WDNR assumes that nitrogen is effectively removed from the water prior to it reaching down-gradient residential wells.

The WDNR, however, has no data on hand establishing the extraction wells' success in removing the nitrogen, nor has it provided evidence to support its finding that the concentration of nitrate + nitrite in the groundwater is below that which threatens the public's health and welfare. If WDNR has no historical data and does not require regular monitoring of nitrogen concentrations at the extraction wells, the surface water discharge at Outfall 004, or groundwater monitoring wells that could be installed along the length of Final Creek, the decision to exempt Badger from meeting groundwater quality standards is based in part on speculation. The WDNR has simply assumed that the MIRM system adequately removes the nitrogen from the groundwater.

This is especially disconcerting since Badger plans to decommission those very wells that it relies on to protect public health and welfare.[53]

The implementation of comprehensive monitoring now will provide valuable insight regarding nitrogen limits in the soil and groundwater when the MIRM extraction wells are taken offline. Monitoring will also help in setting nitrogen effluent limits for Outfall 002 necessary to maintain compliance with NR 140.10 Wis. Admin. Code.

- **The Proposed Remedy and Modification must incorporate and address potential synergistic and additive risks associated with multiple contaminants in both groundwater and residential wells.**

At sites or facilities where there may be synergistic effects of contamination, multiple pathways of exposure or both that pose an unacceptable threat to public health, safety or welfare or the environment, responsible parties shall attain more stringent, facility or site-specific numeric standards to ensure that public health, safety and welfare and the environment are protected. In such a situation, the department may require that the responsible parties develop a site-specific numeric or performance standard, or both, that is protective of public health, safety and welfare and the environment for the specific media, migration or exposure pathways and contamination.[54]

Like nitrates, both newborns and the unborn are more sensitive than adults to certain chemicals such as DNT which also causes methemoglobinemia. It is well documented that DNT is reduced in the digestive tract and then oxidizes the iron in hemoglobin to form methemoglobin, which prevents the transport of oxygen by the blood.[55] Infants

[53] WPDES Permit Fact Sheet for Badger Army Ammunition Plant, p. 2 (May 8, 2007).
[54] Wis. Admin. Code NR § NR 722.09 (3)
[55] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells*, Badger Army Ammunition Plant, page 16-17, September 30, 2006.

appear to be 10 times more sensitive than adults to nitrate-related methemoglobinemia and it is expected that DNT would have a similar ratio.

- **The Proposed Remedy and Modification must have a Contingency Plan in anticipation that groundwater contaminant levels will increase.**

  Even with capping to reduce infiltration of clean surface water through residual contaminated soils to groundwater, continued monitoring of soil moisture and groundwater quality after the cap is placed will be critical so there must be some contingency in the plan if the cap is found not to work properly.

  One of the aspects of an inactive Propellant Burning Grounds (PBG) infiltration will likely be increased concentrations. As less water is passed through the PBG soils, contaminant concentrations in groundwater may be expected to increase. While the rate of movement may be reduced, soils will still release mass into the groundwater. If the cap operates as expected, without fresh water passing through or near the soils, the groundwater DNT concentrations will tend to climb.

  The Proposed Remedy and Modification should estimate not only concentrations, but how fast water is leaving the area through groundwater. Cutting off a portion of the groundwater flow by a cap (to reduce infiltration) is only part of the long-term management of the site.

  Long-term management of the PBG, including continued plans for source control (pumping) in the area, and monitoring plans (including soil moisture) should be tied to groundwater management as the PBG may affect groundwater quality for some time.

  Tracking concentrations in groundwater is not enough, the Proposed Remedy and Modification must require an assessment of the rate of contaminant release from the PBG area into the groundwater. Calculating downstream concentrations will be indicative of the mass released in a given amount of time.

- **The Proposed Remedy and Modification must establish Design Management Zones that shall consider and include likely methods for abatement if an enforcements standard (which includes the PAL) is exceeded or "unregulated" contaminants are detected.**

  The Proposed Remedy and Modification must establish Points of Standards Application for the purpose of determining whether the Preventive Action Limit or the Enforcement Standard is attained or exceeded beyond the Badger property as necessary to protect future groundwater uses and the public interest in the waters of the state.[56]

[56] Wis. Stats. § 160.21(2)(a)2. and Wis. Stats. § 160.21(2)(b)1.b.

Points of Standards Application must also be established for "unregulated" groundwater contaminants which require remediation to the extent practicable.[57]

Points of Standards Application must include all private drinking water wells, municipal wells, offsite groundwater monitoring wells, current and future areas of development, and irrigation and livestock water wells. These points all apply as they have or will be monitored to determine if a Preventative Action Limit or Enforcement Standard has been attained or exceeded.[58]

"Point of standards application" means the specific location, depth or distance from a facility, activity or practice at which the concentration of a substance in groundwater is measured for purposes of determining whether a preventive action limit or an enforcement standard has been attained or exceeded.[59] A "design management zone" means a 3-dimensional boundary surrounding each regulated facility, practice or activity established under s. NR 140.22 (3).[60]

A point of standards application shall include any point of present groundwater use; any point beyond the boundary of the property on which the facility, practice or activity is located; and any point within the property boundaries beyond the 3-dimensional design management zone if one is established by the department at each facility, practice or activity.[61]

- **The Proposed Remedy and Modification must establish Design Management Zones that consider anticipated future uses of land and groundwater.** [62]

- **In response to exceedances of the PAL, near or beyond the Badger property, the Proposed Remedy and Modification must evaluate the existing effects and potential risk of contaminants on potable water supplies.**

The WDNR shall consider the current and anticipated future extent of groundwater contamination in 3 dimensions. If water supplies are affected or threatened, the department shall evaluate the existing effects and potential risks of the substance on the potable water supplies. If the extent of contamination is not known, the department may require further documentation of the extent of contamination.[63] This includes proximity to private and public water supplies, including current and potential use of the aquifer (including agriculture, recreation, and conservation), development to the north of the Village of Prairie du Sac, and the municipal well for Prairie du Sac.

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[57] Wis. Admin. Code NR § 140.02(4).
[58] Wis. Admin. Code NR § 140.22(1)(d).
[59] Wis. Admin. Code NR § NR 140.05(15)
[60] Wis. Admin. Code NR § NR 140.05(6)
[61]Wis. Admin. Code § NR 140.22(2)(b)
[62] Wis. Stats. § 160.21(d)
[63]Wis. Admin. Code § NR 140.24(1)(c)9.

NR 722.07(4)(a)4 requires consideration of the proximity of contamination to receptors. Anthropogenic types of receptors include local pumping wells (eg., domestic, irrigation, industrial and public wells), dewatering activities, and conduits of preferential flow-paths (eg., utilities). Natural receptors include surface water discharge points (eg., lakes, streams, wetlands and springs). The relevance of such potential receptors depends upon their location (upgradient, side gradient or downgradient from the plume), their distance from the plume and projected contaminant travel times, the number of receptors, the receptors effects on local groundwater flow gradients (eg., well pumping rates and volumes, connection between hydrogeologic layers, geologic characteristics, etc.), and the likelihood that local pumping regimes and other receptors will change over time. If the potential exists for near-term or future impacts to existing or "planned" receptors due to plume migration, then more aggressive remedies are required in order to meet the reasonable period of time requirement in NR 140.

Further, the Department may direct or enter into a contract with any person to take action to establish a program of long-term care, as necessary, for a site or facility which is repaired or isolated. [64]

- **The Proposed Remedy and Modification must stipulate that boundary groundwater extraction and monitoring wells shall be kept on-line and in operating order until the proposed new configuration of the groundwater extraction system configuration (utilizing only the SCW-1 and SCW-2, without operating extraction wells at the plant boundary) has been shown to be sufficient to capture all discharges and assure long-term compliance (40 years) with Preventative Action Limits for regulated contaminants and until "unregulated" contaminants are no longer detected now and in the future.**

Source control measures are only considered adequate if, in addition to other factors, the groundwater plume margin is stable or receding, and after case closure, groundwater contamination exceeding ch. NR 140 preventive action limits does not migrate beyond the boundaries of any property for which a PAL exemption has been granted.[65]

Source control measures are only considered adequate if, in addition to other factors, there is <u>no existing or anticipated threat</u> to public health, safety or welfare, or the environment.[66]

Source control measures are only considered adequate if, in addition to other factors, the concentration and mass of a substance and its breakdown products in groundwater have been reduced due to naturally occurring physical, chemical and biological processes as necessary to adequately protect public health and the environment, and

[64] Wis. Stats. § 292.31 (3)(b) and (3)(b)6.
[65] Wis. Admin. Code NR § 726.05(2)(b)3.a.
[66] Wis. Admin. Code NR § 726.05(2)(b)5

prevent groundwater contamination from migrating beyond the boundaries of the property or properties for which groundwater use restrictions have been recorded.[67] The points of standards application, or PSA, for hazardous substance discharge is anywhere groundwater is monitored (NR140.22(2)} both inside and outside of a site's property boundary.[68]

At Badger, the contaminant plume that has migrated offsite contains solvents, multiple isomers of DNT, nitrates, and other contaminants.

The IRM and then the MIRM have operated by the Army since 1990 in an effort to stop additional groundwater contamination from leaving the site. In March 2007, the highest reported level of carbon tetrachloride – 24.4 micrograms per liter (ug/l) – was found in a groundwater monitoring wells along County Z, nearly 2 miles from the Propellant Burning Grounds. Along the plant boundary, carbon tetrachloride was found in SPN-8904C at 20.2 ug/l. Even with dilution as the only factor, one would expect offsite monitoring wells to detect some improvement in groundwater quality. Instead, carbon tetrachloride levels are comparable to those at the plant boundary. The same holds true in previous rounds. In June 2006, the highest levels of carbon tetrachloride were detected offsite and along County Z at more than 30 ug/l.

It is therefore plausible that shutting down boundary wells could result in even higher concentrations of persistent groundwater contaminants such as solvents and the less common isomers of DNTs which do not biodegrade.

Compared to other sites nationwide, the levels of carbon tetrachloride in groundwater in adjacent neighborhoods are exceedingly high. Less than 1% of all groundwater-derived drinking water systems have levels of carbon tetrachloride greater than 0.5 ug/l.[69]

- **The Proposed Remedy and Modification must require that monitoring wells and residential wells are tested utilizing test methods with a level of detection (LOD) level of quantification (LOQ) below the Preventative Action Limit or that produces the lowest available LOD and LOQ.**[70]

- **Given the disparity in data at Gruber's Grove Bay, we encourage the WDNR to conduct its own tests of groundwater at several critical points as a requisite measure of quality assurance.**

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[67] Wis. Admin. Code NR § 726.05(2)(b)1.f.
[68] WDNR Bureau for Remediation and Redevelopment, Interim Guidance for Selection of Natural Attenuation for Groundwater Restoration and Case Closure under Section NR 726.05(2)(b), PUBL RR-530-97, page 19n, March 1997.
[69] ATSDR, *Toxicological Profile for Carbon Tetrachloride*, page 179, August 2005.
[70] Wis. Admin. Code NR § NR 140.16(2)(c)1,2.

Despite a second multi-million dollar cleanup effort by the Army last summer, the WDNR found mercury concentrations more than 25 times the required cleanup goal and almost 400 times higher than levels reported by the Army in sediments at Gruber's Grove Bay on Lake Wisconsin. WDNR test results for mercury ranged from 0.24 to more than 9 ppm. The Army's contractors tested 65 sediment samples from the same areas of the bay and reported that all were well below the required cleanup goal; their results ranged from 0.006 to 0.34 ppm.

II. THE PROPOSED REMEDY AND MODIFICATIONS MUST ENSURE THAT MASS CONTAMINATION IN SUBSURFACE SOILS DOES NOT THREATEN PUBLIC HEALTH AND WELFARE.

- **Uptake by plants in the vicinity of the Propellant Burnings Grounds, especially agricultural crops and certain indigenous prairie species with very deep root systems, should be evaluated as a potential route of exposure to animals and to people through the human food chain.**

Each remedial action option identified may be utilized to address more than one contaminated medium or migration or exposure pathway if that remedial action option would be protective of public health, safety and welfare and the environment for each media and migration or exposure pathway that it is proposed to address.[71]

Land adjacent to the Propellant Burning Grounds is presently used for agriculture, mainly growing crops of alfalfa, corn, and beans. This land use is anticipated to continue in the future.[72] Alfalfa roots grow about 6 feet per year in loose soil. Metabolically active alfalfa roots have been found 60 feet or more below ground level.[73]

Both 2,4-DNT and 2,6-DNT are quite soluble in water and is expected to "accumulate readily" in plants via root uptake from soils (ATSDR, 1998).[74]

- **WDNR Must Maintain And Enforce Remedial Goals For All Contaminants of Concern in Subsurface Soils and Groundwater Contained in the Infield Conditions Approval.**

[71] Wis. Admin. Code NR § 722.05(5) Notation.
[72] U.S. Army Corps of Engineers Omaha District, Draft Alternative Feasibility Study Propellant Burning Ground Waste Pits Subsurface Soil, Badger Army Ammunition Plant Baraboo, Wisconsin, Revision 1, page 1-6, April 6, 2006.
[73] Deborah A. Samac et al, USDA-ARS, St. Paul, MN, *Alfalfa Root Health and Disease Management: A Foundation for Maximizing Production Potential and Stand Life*, April 16, 2007.
[74] Agency for Toxic Substances and Disease Registry. *Toxicological Profile for 2,4- and 2,6-Dinitrotoluene*, 1998.

Exempting the Army from the Remedial Goals established for the Propellant Burning Grounds will set an unfavorable precedent and provide the basis for the facility to argue in favor of modified cleanup levels at the Settling Ponds and other major contaminated areas of the plant.

A compromised level of cleanup also undermines the Badger Reuse Plan in which the WDNR and other parties endorsed a final level of cleanup that would not restrict future use and pose no risk to people or the environment, including soil, water, air, and biodiversity.[75]

III. HIGH EXPLOSIVES, DEGRADATION AND TRANSFORMATION PRODUCTS OF HIGH EXPLOSIVES, AND OTHER CARCINOGENIC WASTES MUST NOT THREATEN PUBLIC HEALTH

If, after a remedial action selected in accordance with the requirements of ch. NR 722 is implemented, the soil cleanup standards in ch. NR 720 or the groundwater quality standards in ch. NR 140 are modified by the department to be more stringent, or if soil or groundwater quality standards are promulgated for additional substances, the department shall require responsible parties to comply with the new or modified soil or groundwater quality standards if the department determines that, for a specific site or facility, compliance with the more stringent standards is necessary to ensure that the interim action or remedial action will be protective of public health, safety and welfare and the environment.[76]

- **The Proposed Remedy and Modification Must Require an Investigation to Establish and Define the Extent of Potential Residual High Explosives (TNT, RDX, HMX, and Tetryl) Contamination At and Near the Propellant Burning Grounds.**

According to Army records, during the period of 1968-1975, a liquid chemical waste, extracted from a process which reclaims nitrocellulose from unusable ball powder, was poured into unlined pits in both the north (PBG) and south (DBG) burning grounds**.** This chemical waste called deterrent contained "the following toxic chemicals: dinitrotoluene, diphenylamine, dibutylphthalate, benzene, <u>trinitrotoluene</u>, and suspected carcinogens".[77]

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[75] Badger Reuse Committee, *Badger Reuse Plan*, Value and Criteria, Criterion 2.3, March 28, 2001.
[76] Wis. Admin. Code NR § NR 724.19(1)
[77] Department of Army, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland, *Water Quality Special Study No. 24-0039-78, Part I – Geohydrology, Badger Army Ammunition Plant, Baraboo, WI, 12 – 17 June 1977.*

The EPA has determined that 2,4,6-trinitrotoluene is a possible human carcinogen.[78] Workers involved in the production of explosives who were exposed to high concentrations of 2,4,6-trinitrotoluene in workplace air experienced several harmful health effects, including anemia and abnormal liver function. Similar blood and liver effects, as well as spleen enlargement and other harmful effects on the immune system, have been observed in animals that ate or breathed 2,4,6-trinitrotoluene. [79]

It is not known whether 2,4,6-trinitrotoluene can cause birth defects in humans. However, male animals treated with high doses of 2,4,6-trinitrotoluene have developed serious reproductive system effects. [80]

TNT is not substantially degraded during aerobic treatment of DNT. [81] Solid chunks of 2,4,6-trinitrotoluene buried in soil or exposed on the soil surface can persist for many years.[82]

Degradation products of TNT include 4-ADNT (4-amino-2,6-dinitrotoluene) and 2-ADNT (2-amino-4,6-dinitrotoluene) and diamines.[83] Transformation products in soils were detected under both oxidized and reduced conditions.[84]

TNT is also a constituent of technical grade DNT (Tg-DNT). Analysis of Tg-DNT reveals the following composition: 76.49% 2,4-DNT, 18.83% 2,6-DNT, 0.65% 2,5-DNT, 2.43% 3,4-DNT, 1.54% 2,3-DNT, 0.040% 3,5-DNT, 0.050% trinitrotoluene (TNT), 0.005% cresols, 0.003% mononitrobenzene, and 0.003%, 0.0005%, and 0.006%, for ortho-, meta-, and para-, mononitrotoluenes, respectively (Hazardous Substances Data Bank [HSDB], 2004a,b,c). [85]

RDX stands for Royal Demolition eXplosive. It is also known as cyclonite or hexogen. The chemical name for RDX is 1,3,5-trinitro-1,3,5-triazine. It is used as an explosive and is also used in combination with other ingredients in explosives.[86] RDX dissolves very slowly in water, and it also evaporates very slowly from water. It does not cling

[78] ATSDR, ToxFAQs for 2,4,6-Trinitrotoluene (TNT), September 1996. Available online at: http://www.atsdr.cdc.gov/tfacts81.html
[79] ATSDR, ToxFAQs for 2,4,6-Trinitrotoluene (TNT), September 1996. Available online at: http://www.atsdr.cdc.gov/tfacts81.html
[80] ATSDR, ToxFAQs for 2,4,6-Trinitrotoluene (TNT), September 1996. Available online at: http://www.atsdr.cdc.gov/tfacts81.html
[81] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 5, February 2001.
[82] Rosenblatt DH. 1980. Toxicology of explosives and propellants. In: Kaye SM, ed. Encyclopedia of explosives and related items. Vol. 9. Dover, NJ: U.S. Army Armament Research and Development Command, 332-345 (as cited in ATSDR's Toxicological Profile for 2,4,6-Trinitrotoluene, page 103, June 1995).
[83] ATSDR, Toxicological Profile for 2,4,6-Trinitrotoluene, page 104, June 1995.
[84] Pennington JC, Patrick WH Jr. 1990. Adsorption and desorption of 2,4,6-trinitrotoluene by soils. J Environ Qua1 19(3):559-567 (as cited in ATSDR's Toxicological Profile for 2,4,6-Trinitrotoluene, page 99, June 1995).
[85] U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene*, Proposal Draft, pages 6 and 9, August 2006.
[86] ATSDR, ToxFAQs for RDX, September 1996.

to soil very strongly and can move into the groundwater from soil. RDX can be broken down in air and water in a few hours, but it breaks down more slowly in soil. [87]

The EPA has determined that RDX is a possible human carcinogen.[88] RDX can cause seizures (a problem of the nervous system) in humans and animals when large amounts are inhaled or eaten.

The Army's April 1993 Remedial Investigation did not recommend carrying high explosives (RDX, HMX, TNT, and Tetryl) forward for further study because (1) the 1988 Master Environmental Plan (MEP) "data summaries did not indicate the presence of these types of explosive-type compounds", and (2) because the facility's known operating history indicated that military explosives such as TNT, RDX, HMX, and Tetryl "were not manufactured, used, stored, or disposed of" at Badger. [89] As a result, environmental samples conducted as part of the Remedial Investigation (RI) at the Propellant Burning Grounds "did not include analysis for these explosives compounds".[90]

Both these reasons, however, are faulty and misleading. First, while the RI states that the data summaries in the Master Environmental Plan did not identify high explosives at Badger – the text from this report certainly did. And second, the presence of high explosives at Badger is recorded as early as 1987 in the A.T. Kearney Report for Badger.

The referenced 1988 Master Environmental Plan for Badger reports that a soil sample was collected from a drain pipe "in a runoff area approximately 25 feet southwest of the burning pads".[91] This runoff area is Badger land that was leased for farming. The land had been plowed shortly before and was being fertilized at the time of the sampling. Five additional background samples were also taken to determine the explosives content of background samples at the Propellant Burning Grounds waste pits.

The drain pipe sample showed concentrations of 2.5 parts per million (ppm) 2,4,6-TNT, 1.8 ppm 2,6-DNT, and 3.1 ppm 2,4-DNT.[92] The explosives HMX and RDX were found under Phase 4 in some samples from pad 1, the area west of pad 2, refuse pit 2, and waste pit 1. The depths of the samples ranged from 10 to 40 feet. Up to 25.3 ppm RDX was measured. These contaminants were also found in pad 1. [93]

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[87] ATSDR, ToxFAQs for RDX, September 1996.
[88] ATSDR, ToxFAQs for RDX, September 1996.
[89] U.S. Army Environmental Center, Final Remedial Investigation Report, Volume I, page 6-3, April 1993.
[90] U.S. Army Environmental Center, Final Remedial Investigation Report, Volume I, page 6-4, April 1993.
[91] S.Y. Tsai et al, Master Environmental Plan for Badger Army Ammunition Plant, Volume 2: Appendix B (U), September 1987, page 139.
[92] S.Y. Tsai et al, Master Environmental Plan for Badger Army Ammunition Plant, Volume 2: Appendix B (U), September 1987, page 139.
[93] S.Y. Tsai et al, Master Environmental Plan for Badger Army Ammunition Plant, Volume 2: Appendix B (U), September 1987, page 139.

EPA officials have recently commented that historical studies at Badger that identified explosives (and other contaminants not carried forward for study) may not be reliable especially when compared to current methodologies.[94] For groundwater testing methods, this is especially true. In 1984, the level of detection for RDX in groundwater was only 30 ug/l.[95] By comparison, the federal health advisory for RDX in drinking water is only 2 ug/l.

Most propellants may be grouped as single-based, double-based, or multi-based propellants. Single-based propellants contain nitrocellulose; double-based propellants contain nitrocellulose and nitroglycerine; and multi-base propellants usually contain nitrocellulose, nitroglycerine, and nitroguanidine. Composite propellants are usually a physical mixture of a fuel such as a metallic aluminum, a binder, and an inorganic oxidizing agent such as ammonium perchlorate.[96]

While the principal components of a specific propellant are consistent, there is a wide range of substitutes and additives used in propellant composition. For example, ethyl centralite, dinitrotoluene, or potassium perchlorate may be added to control the burning rate. Nitroguanidine, barium nitrate, dibutylphthalate, or potassium perchlorate may be added to reduce flash. TNT (trinitrotoluene), while not thought of as a propellant, is often used as an additive to control the burning rate.[97] Conversely, potassium perchlorate may be listed as a component rather than an additive, as in propellant M7.[98]

Many materials are added to propellants for the purpose of controlling burning rates, moisture content, rate of decomposition, plasticity, sensitivity, stability, and molding. A list of additives to propellants may contain 50 compounds and this is by no means a list of all additives.[99] These additives may include such components as sugars, pesticides, glues, inorganic metal salts, and plastics.[100] According to the U.S. Army Defense Ammunition Center, chances are good that stored excess propellant will have an "absolutely unknown" stabilizer content. [101]

Badger was the only military propellant production facility that had the capability to use nitrocellulose recovered from excess or surplus propellant.[102] If a single base propellant was no longer needed by the Department of Defense because of a change in weapon system or replacement of a weapon system or because of age of the propellant,

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[94] Robert J. Egan, USEPA Region V, Public Meeting, Badger Army Ammunition Plant, June 21, 2007.
[95] S.Y. Tsai et al, Master Environmental Plan for Badger Army Ammunition Plant, Volume 2: Appendix B (U), September 1987, pages 160-161.
[96] U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Technical Guide 140, *Water Pollution Aspects of Explosive Manufacturing*, page 34.
[97] U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Technical Guide 140, *Water Pollution Aspects of Explosive Manufacturing*, page 37.
[98] U.S. Army Defense Ammunition Center, *Propellant Management Guide*, Appendix D, 1998.
[99] U.S. Army Defense Ammunition Center, *Propellant Management Guide*, Appendix D, 1998, page 6-2.
[100] U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Technical Guide 140, *Water Pollution Aspects of Explosive Manufacturing*, page 3.
[101] U.S. Army Defense Ammunition Center, *Propellant Management Guide*, Appendix D, 1998, page 6-2.
[102] D. Thurow, Olin Corporation, operating contractor at Badger Army Ammunition Plant, email communication to L. Olah, CSWAB, 8/22/01.

this propellant was shipped to Badger. This single-base propellant would have the nitrocellulose recovered and reused at Badger for the manufacture of new double-base propellant.[103]

While Badger's principal mission was the production of propellants[104], evidence of high explosives contamination is reported as early as 1987. Boreholes drilled in Burning Pad #1 had levels of TNT (trinitrotoluene), 2,4-DNT (dinitrotoluene), and/or 2,6-DNT between 1 and 10 ppm (parts per million) at various depths down to 20 feet.[105] One sample beneath Pad #1 contained 2.5 ppm of the explosive HMX (1,3,5,7-tetranitro-1,3,5,7-tetraazacyclo-octane).

Samples from the burning ground that had detectable levels of TNT, 2,4-DNT, and 2,6-DNT were located within the first 20 feet. The explosive RDX (1,3,5-Trinitro-1,3,5-triazacyclohexane) was discovered in several borehole soil samples from 10-40 feet.[106]

A 1989 Health and Safety Plan prepared for the U.S. Army Toxic and Hazardous Material Agency identified 2,4,6 -TNT and RDX as hazardous compounds detected at Badger.[107] High explosives are cited as a contaminant in soils at the Propellant Burning Ground and Landfill #1. Reported maximum concentrations of HMX, RDX, and TNT were 2,100 micrograms per kilogram (ug/kg), 1,400 ug/kg, and 4,200 ug/kg respectively.[108] Other historical references to TNT disposal at Badger include correspondence to the Wisconsin State Board of Health.[109]

- **The Proposed Remedy and Modification must require the Army to research and identify all potential degradation products of DNT and other explosives in soils and groundwater.**

  The public, regulators, and health officials have not been provided with a comprehensive list of potential degradation products associated with DNT and other

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[103] D. Thurow, Olin Corporation, operating contractor at Badger Army Ammunition Plant, email communication to L. Olah, CSWAB, 8/22/01.
[104] U.S. Army Toxic and Hazardous Materials Agency. *Installation Assessment of Badger Army Ammunition Plant*, May 1977, Page II-1.
[105] A.T. Kearney, *Revised Preliminary Review Badger Army Ammunition Plant*, April 13, 1987, page 16 (Investigation of Soil Contamination at the Open-Burning Ground, Badger Army Ammunition Plant, May 8-15, 1984, US Army Environmental Hygiene Agency).
[106] A.T. Kearney, *Revised Preliminary Review Badger Army Ammunition Plant*, April 13, 1987, page 16 (Investigation of Soil Contamination at the Open-Burning Ground, Badger Army Ammunition Plant, May 8-15, 1984, US Army Environmental Hygiene Agency).
[107] E.C. Jordan, U.S. Army Toxic and Hazardous Material Agency, *Phase I Remedial Investigation*, Badger Army Ammunition Plant, *Final Health and Safety Plan*, page 2-3 & Appendix B, January 1989.
[108] E.C. Jordan, U.S. Army Toxic and Hazardous Material Agency, *Phase I Remedial Investigation, Badger Army Ammunition Plant*, *Final Health and Safety Plan*, Table 2-1, January 1989.
[109] Badger Army Ammunition Plant, June 15, 1942 and July 3, 1942 letters to State Board of Health regarding disposal of TNT wastes. (Also referenced in A.T. Kearney, *Revised Preliminary Review Badger Army Ammunition Plant,* April 13, 1987, Reference 110, page 67.)

explosives. Lists provided by the RAB TAPP Consultant, Dr. Jerry Eykholt, the Wisconsin Division of Health, and Army consultants vary significantly**:**

Potential degradation compounds of dinitrotoluene identified by the Wisconsin Division of Public Health include 2-nitroaniline, 3-nitroaniline, 4-nitroaniline, 1,3-dinitrobenzene, *p*-nitrotoluene, *m*-nitrotoluene, *o*-nitrotoluene, and nitrobenzene.[110]

In addition to these, U.S. Army contractors[111] have identified the following as DNT degradation compounds:

- 5-Nitro-o-toluidine
- 2-Methyl-3-Nitroaniline
- 2-Methyl-5-Nitroaniline
- 2-Methyl-6-Nitroaniline
- 4-Methyl-2-Nitroaniline
- 4-Methyl-3-Nitroaniline
- 5-Methyl-2-Nitroaniline
- Bis(2-chloroethyl)ether
- 1,3-Dinitrobenzene

One scientific study found that intermediates formed during degradation of 2,4-DNT include 1,3-dinitrobenzene, hydroxynitrobenzene derivatives, and carboxylic acids.[112] Multiple studies show that the breakdown/intermediate products of 2,4-DNT include 4-amino-2-nitrotoluene, 2-amino-4-nitrotoluene, and/or 2,4-diaminotoluene.[113]

These varying lists demonstrate the inconsistencies in information currently available to regulators, health officials, and the community.

- **The Proposed Remedy and Modification must provide the public with Drinking Water Health Advisory Levels for degradation products of DNT and other explosives that do not have an Enforcement Standard pursuant to NR 140.**

The WDNR is required to notify the Department of' Health and Social Services when monitoring data indicate that a substance is detected in groundwater and to coordinate the collection of groundwater monitoring data and the exchange of these data among

[110] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells,* Badger Army Ammunition Plant, page 15, September 30, 2006.
[111] Badger Restoration Advisory Board, Minutes, Attachment 1, *Dinitrotoluene Degradation Compounds Analyzed in September 2006 Round*, June 7, 2007
[112] Ho, P.C. 1986. Photooxidation of 2,4-dinitrotoluene in aqueous solution in the presence of hydrogen peroxide. Environ Sci Technol 20(3):260-267 (as cited in ATSDR, *Toxicological Profile for 2,4 and 2,-6 Dinitrotoluene,* 1988).
[113] Bradley et al., 1997; Cheng et al., 1996; Freedman et al., 1996; Liu et al., 1984; Noguera and Freedman, 1996, 1997 (as cited in U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene,* Proposal Draft, page 14, August 2006.)

agencies**.**[114] A number of contaminants detected in groundwater monitoring wells and private drinking water wells located in neighborhoods near Badger are not regulated under NR 140 and do not have drinking water standards. As a result, community members do not know if groundwater in their neighborhood is safe to use and consume. Health Advisory Levels help residents to make informed decisions about their drinking water, their health, and the health of their children.

- **The Proposed Remedy and Modification must require regular monitoring of groundwater and residential wells for all potential degradation products of DNT, explosives, and other site contaminants.**

  The applicant must also demonstrate that naturally occurring biodegradation processes are reducing the **total mass** of contaminants in an effective and timely manner. This is demonstrated with historical site monitoring data which indicates an overall decreasing trend in contaminant concentrations over time and distance. This includes a <u>decreasing trend in contaminant breakdown products</u> and demonstrating a stable or receding plume.[115]

  Natural attenuation is defined in s. NR 140.05(14m) and s. NR 700.03(38m) as the "reduction in the concentration and mass of a substance and its <u>breakdown products</u> in groundwater, due to naturally occurring physical, chemical, and biological processes without human intervention or enhancement. These processes include, but are not limited to, dispersion, diffusion, sorption and retardation, and degradation.

  Biodegradation of DNT in subsurface soils may result in either mineralization or transformation of DNT. The latter produces organic derivatives of DNT whose toxicity may vary from the parent molecule. Transformation also leads to partial reduction of and the formation of amines.[116] Once conditions become anaerobic, DNT degradation is negligible. [117]

  Based on hepatic tumor initiation-promotion experiments, several animal studies demonstrated that technical grade (Tg) DNT has tumor-promoting and tumor-initiating activity. These studies further concluded that 2,6 DNT is a complete hepatocarcinogen and has the primary role in Tg-DNT's carcinogenic activity. [118]

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[114] Wis. Stats. § 160.27.
[115] WDNR Bureau for Remediation and Redevelopment, Interim Guidance for Selection of Natural Attenuation for Groundwater Restoration and Case Closure under Section NR 726.05(2)(b), PUBL RR-530-97, page 10, March 1997.
[116] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 2, February 2001.
[117] Shirley F. Nishino and Jim C. Spain, Air Force Research Laboratory, Tyndall AFB, Florida *Technology Status Review: Bioremediation of Dinitrotoluene (DNT)*, page 2, February 2001.
[118] U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene*, Proposal Draft, page 38, August 2006.

The U.S. Environmental Protection Agency classifies the 2,4-DNT/2,6-DNT mixture as "likely to be carcinogenic to humans". [119]

Studies suggests that when these two DNT isomers are present, their combined ability to increase cancer risk is more than just additive, and may be synergistic or multiplicative (ATSDR 1998).[120]

IV. THE PROPOSED REMEDY AND MODIFICATIONS MUST ENSURE THAT THE SENSITIVE POPULATIONS AT RISK ARE NOT EXPOSED TO ANY LEVEL OF GROUNDWATER CONTAMINATION FROM BADGER ARMY AMMUNITION PLANT.

Populations at risk are a population subgroup that is more likely to be exposed to a chemical, or is more sensitive to the chemical, than is the general population.[121] The Agency for Toxic Substances and Disease Registry (ATSDR) as well as the U.S. EPA recognize that certain subpopulations, such as children, may be more sensitive to environment contaminants and having a higher probability of developing a condition, illness, or other abnormal status.[122]

For example, elderly persons may not be particularly sensitive to the effects of sulfur dioxide pollution but are considered to be at risk because lowered respiratory function may reduce their ability to withstand the additional reduction in respiratory function caused by exposure to sulfur dioxide.

At sites or facilities where there may be synergistic effects of contamination, multiple pathways of exposure or both that pose an unacceptable threat to public health, safety or welfare or the environment, responsible parties shall attain more stringent, facility or site–specific numeric standards to ensure that public health, safety and welfare and the environment are protected. In such a situation, the department may require that the responsible parties develop a site–specific numeric or performance standard, or both, that is protective of public health, safety and welfare and the environment for the specific media, migration or exposure pathways and contamination.[123]

As stated in the introduction, people who have heart or lung disease, certain inherited enzyme defects, or cancer may be more sensitive to the toxic effects of nitrate than others. In addition, some experts believe that long-term ingestion of water high in nitrate may increase the risk of certain types of cancer. [124]

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[119] U.S. Environmental Protection Agency, *Drinking Water Health Advisory for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene*, Proposal Draft, page 46, August 2006.
[120] U.S. Department of Health and Human Services, Public Health Service, *Health Consultation: Dinitrotoluene in Private Wells*, Badger Army Ammunition Plant, page 9, September 30, 2006.
[121] USEPA, Terminology Reference System, *population at risk.*
[122] US Environmental Protection Agency. Air quality criteria document for lead. Washington, DC: US Environmental Protection Agency, 1977 (as cited in CDC MMRW, Populations at Risk from Air Pollution -- United States 1991, published April 30, 1993 ref. 42(16);301-304).
[123] Wis. Admin. Code NR § 722.09 (3)
[124] Wisconsin Department of Natural Resources, *Nitrate in Drinking Water*, Publication WS-001, undated.

- **The Proposed Remedy and Modifications must ensure that the expectant mothers, infants, and children are not exposed to contamination from Badger Army Ammunition Plant.**

  Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume.[125]

  There are very limited data on the effects of carbon tetrachloride exposure on children. Adult data cannot simply be extrapolated to children for a variety of different reasons.[126] Exposures of the embryo or fetus to volatile organic compounds such as carbon tetrachloride may occur if the expectant mother is exposed. A newborn infant may be exposed by breathing contaminated air and by ingestion of mother's milk, which can contain small amounts of carbon tetrachloride.[127]

  Several studies suggest that maternal drinking water exposure to carbon tetrachloride might possibly be related to certain birth defects. Studies in animals showed that carbon tetrachloride can cause early fetal deaths, but did not cause birth defects. A study with human breast milk in a test tube suggested that it would be possible for carbon tetrachloride to pass from the maternal circulation to breast milk, but there is no direct demonstration of this occurring.[128]

- **The Proposed Remedy and Modifications must assure that residents and workers that have already been exposed to contaminants from Badger Army Ammunition Plant are not exposed to any additional contamination from Badger.**

  Both families at Private Well #879 and #843 were exposed to high levels of solvents from Badger Army Ammunition Plant in their drinking water for more than 15 years. In March 2007, low levels of explosives have been detected in their replacement wells. Any additional exposure to toxins from Badger places these families at excessive and unacceptable health risk.

  Still other community members that lived and played at Gruber's Grove Bay were exposed to toxins in the water and sediments. Many of these same residents live in areas that are threatened by groundwater toxins from Badger. Again, any additional exposure to contaminants from Badger places these individuals at excessive and unacceptable health risk.

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[125] ATSDR, *Toxicological Profile for Carbon Tetrachloride*, page 192, August 2005.
[126] ATSDR, *Toxicological Profile for Carbon Tetrachloride*, page 197, August 2005.
[127] ATSDR, *Toxicological Profile for Carbon Tetrachloride*, page 197, August 2005.
[128] ATSDR, *ToxFAQs for Carbon Tetrachloride*, August 2005.

Other community members that live downgradient from the Propellant Burning Grounds are former workers that were exposed to many of these same environmental contaminants while working at Badger. Any additional exposure to toxins from Badger places these residents at excessive and unacceptable health risk.

- **The Proposed Remedy and Modifications must assure that residents that have been diagnosed with cancer, with compromised immune systems, or are otherwise considered a population at risk, are not exposed to additional contamination from Badger.**

  Community member have testified at a number of public meetings that they or someone in their family has suffered from cancer or other debilitating illness. Any additional exposure to toxins from Badger places these residents at excessive and unacceptable health risk.

V. DISCHARGE OF THE GROUNDWATER CONTAMINANT PLUME AND STORMWATER RUNOFF TO THE WISCONSIN RIVER MUST NOT HARM THE AQUATIC LIFE OR WATER QUALITY CONDITIONS OF THE RIVER.

- **The Proposed Remedy and Modification must require an antidegradation analysis consistent with the provisions set forth in NR 207 and Title 40 section 131.12 of the Code of Federal Regulations.**

  At sites or facilities in, or in close proximity to, surface water bodies or wetlands, active remedial actions shall be taken to prevent or minimize, to the extent practicable, potential and actual hazardous substance discharges and environmental pollution that may attain or exceed surface water or wetland criteria established in accordance with chs. NR 102 to 106.[129]

  Where a discharge to surface water exists, impacts to surface water quality must be evaluated as required under NR 722.09(2)(c). Receptors in surface waters include aquatic organisms living in the soils and sediments of the seepage zone, waterborne aquatic life, and humans indirectly through recreation and consumption of fish containing the bioaccumulated contaminant.[130]

  The 3**,** 4-DNT isomer is designated as a hazardous substance under section 311(b)(2)(A) of the Federal Water Pollution Control Act and is further regulated by the Clean Water Act Amendments of 1977 and 1978.[131] Moreover, the National Institute

[129] Wis. Admin. Code NR § NR 722.09 (2)(c)3.
[130] WDNR Bureau for Remediation and Redevelopment, Interim Guidance for Selection of Natural Attenuation for Groundwater Restoration and Case Closure under Section NR 726.05(2)(b), PUBL RR-530-97, page 8, March 1997.
[131] Clean Water Act, § 311(b)(2)(A) (2007).

for Operational Health and Safety has listed 3, 4 DNT as a significant health threat to humans and extremely toxic to aquatic organisms.[132]

The 2,4-Dinitotoluene isomer is toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment.[133] Acute toxicity data available for the single isomers of the technical mixture show that the toxicity of 2,4- and 2,6-DNT is in the same order of the toxicity found for the technical mixture. However, the other isomers are about an order of magnitude more toxic to fish than the main isomers.[134]

The 2,3- and 3,4-DNT isomers are considered very toxic to aquatic organisms.[135,136] The 2,5-DNT isomer is considered toxic to aquatic organisms.[137]

- **The Proposed Remedy and Modification should incorporate a general stormwater permit and its accompanying SWPPP in an effort to eliminating, to the extent possible, soil and groundwater contamination from stormwater runoff.**

As recent as 1996, Badger's WPDES permit contained a stormwater discharge permit pursuant to NR 216, Wis. Admin. Code.[138] This condition was due largely to Badger's industrial classification (i.e. likelihood that its industrial activities would affect or contaminate stormwater runoff). The incorporation of the stormwater permit was necessary to coordinate storm water monitoring and the implementation of the Storm Water Pollution Prevention Plan (SWPPP), as it relates to the industrial activity of the facility.

Although Badger's status as an industrial facility has changed from "standby" to "decommission," the facility still maintains its industrial character. Soil and groundwater contamination are, unfortunately, the remnants of this industry activity, acting as an able substitute to industrial operations. The chief concern is that contact between stormwater and the contaminated soil is resulting in both onsite and offsite groundwater contamination.

The land along the southern boundary of the plant is of particular concern. As previously mentioned, this large elongated section of land known as Final Creek and Absorption ponds 1, 2, 3, 4 has been designated as a solid waste management unit under RCRA due to the contamination of soils and subsurface soils with lead, sulfates,

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[132] Centers for Disease Control and Prevention, International Chemical Safety Cards (developed by the National Institute for Occupational Safety and Health), http://www.cdc.gov/niosh/ipcsneng/neng0729.html.
[133]ScienceLab.com, Material Safety Data Sheet, 2,4-Dinitrotoluene, Dangerous Substances Classification and Labeling /European Economic Community (DSCL/EEC), 06/10/99.
[134]Organisation for Economic Co-operation and Development Screening Information DataSet (OECD SIDS) DINITROTOLUENE (ISOMERS MIXTURE) Initial Assessment Report for SIAM 18, Paris, France, April 20-24, pages 38-39.
[135] International Labor Union, 2,3-Dinitrotoluene Material Safety Data Sheet, April 2005.
[136] International Labor Union, 3,4-Dinitrotoluene Material Safety Data Sheet, April 2005.
[137] International Labor Union, 2,5-Dinitrotoluene Material Safety Data Sheet, June, 2006.
[138] WPDES Permit Fact Sheet for Badger Plant, p. 7 (July 19, 2001).

tin, 2, 4 DNT, 2, 6 DNT, diphenylamine, zinc, and nitrocellulose.[139] This interconnected series of ditches and depressions drains 40% of stormwater that falls on the 7,350 acre plant, in addition to the 0.054 mgd discharge from Outfall 002. Considering that none of this water is discharged to Gruber's Grove Bay,[140] the polluted soil interacting with an immense amount of rainfall is likely resulting in the leaching of contaminants into groundwater as it permeates the soil.

NR 216.27 Wis. Admin. Code requires a SWPPP include a short summary of major activities conducted throughout the facility, a drainage map containing the location of outfalls and of activities and materials that have the potential to contaminate stormwater.[141] Moreover, the SWPPP must specifically "identify all potential source areas of storm water contamination including…areas containing residual pollutants from past industrial activity."[142]

Lastly, any time an onsite activity affects the stormwater flow or exposure of stormwater to pollutants the facility is required to reexamine the SWPPP, and, if necessary, amend it.[143]

The amount of contaminated soil still found on the Badger facility, coupled with the long and intense task of future remedial efforts will trigger the constant re-examination of the SWPPP. The incorporation of this plan into the WPDES permit will promote a comprehensive understanding of the facility's soil and groundwater contamination, Badger's cleanup efforts, and the stormwater issues affecting the Badger plant.

VI. THE PROPOSED REMEDY AND MODIFICATION MUST PROMOTE REUSE AND RECYCLING.

- **The Proposed Remedy and Modification must require re-use and recycling of materials and equipment wherever possible rather than burial in place or off-site disposal.**

Sincerely,

Signature on original

Laura Olah
Executive Director

[139] RCRA finding
[140] Badger Stormwater Pollution and Prevention Plan (SWPPP as amended 1999).
[141] Wis. Admin. Code NR § 216.27(3)(c)1-10 (2007).
[142] Wis. Admin. Code NR § 216.27(3)(d) (2007).
[143] Wis. Admin. Code NR § 216.27(4) (2007).

FINAL

PROPOSED PLAN
FOR SITE-WIDE GROUNDWATER
FORMER BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

Prepared for:

U.S. Army Environmental Command
2455 Reynolds Road
JBSA – Fort Sam Houston, TX 78234

DECEMBER 2024

Prepared by:
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ACRONYMS

1,1,2-TCA	1,1,2-Trichloroethane
2,4-DNT	2,4-Dinitrotoluene
2,6-DNT	2,6-Dinitrotoluene
Army	Department of the Army
ARAR	Applicable or relevant and appropriate requirement
BAAP	Former Badger Army Ammunition Plant
BEST	Biologically Enhanced Subsurface Treatment
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).
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
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
FFA	Federal Facility Agreement
FS	Feasibility Study
gpm	Gallons per minute
HHRA	Human Health Risk Assessment
HWTTU	Hazardous Waste Thermal Treatment Unit
IRM	Interim Remedial Measures
LUC	Land Use Control
MCL	Maximum Contaminant Level
MIRM	Modified Interim Remedial Measures
µg/l	Micrograms per liter
mg/l	Milligrams per liter
MNA	Monitored Natural Attenuation
NC	Nitrocellulose

NC Area	Nitrocellulose Production Area
NCP	National Oil and Hazardous Substances Contingency Plan
NG	Nitroglycerin
NR	Natural Resources
NPDWRs	National Primary Drinking Water Regulations
O&M	Operation and Maintenance
PAL	Preventive Action Limit
PBG	Propellant Burning Ground
PP	Proposed Plan
PSTS	Pilot-Scale Treatability Study
RA	Remedial Action
RAB	Restoration Advisory Board
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RSL	Regional Screening Level
SPS	SpecPro Professional Services, LLC
SVE	Soil Vapor Extraction
SVOCs	Semi-volatile Organic Compounds
TCE	Trichloroethene or Trichloroethylene
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WDNR	Wisconsin Department of Natural Resources
WAC	Wisconsin Administrative Code
WP&L	Wisconsin Power and Light
WWTP	Wastewater Treatment Plant

PROPOSED PLAN
for Site-Wide Groundwater

Former Badger Army Ammunition Plant
Baraboo, Wisconsin

DATES TO REMEMBER

Public Comment Period: December 16, 2024 through February 28, 2025.
The Army will accept written comments on this Proposed Plan by letter or email during the public comment period. See pages 44 and 45 of this Proposed Plan for contact information and the location of the Administrative Record file.

Public Meeting: January 16, 2025
The Army will hold a public meeting to explain this Proposed Plan and the remedial alternatives evaluated in the Remedial Investigation/Feasibility Study (RI/FS) and to receive input from the community. Oral and written comments will be accepted at the meeting. An open house will be held from 3 p.m. - 5 p.m. The meeting will be held in conjunction with a Restoration Advisory Board (RAB) meeting will begin at 6 p.m. See page 45 of this Proposed Plan for more information.

1.0 INTRODUCTION

This ***Proposed Plan,*** part of the ***Comprehensive Environmental Response, Compensation, and Liability Act*** (CERCLA) process (Figure 1), identifies the U.S. Army's proposed remedy for Site-Wide Groundwater at the Former Badger Army Ammunition Plant (BAAP). The BAAP is located in Sauk County, Baraboo, Wisconsin (Figure 2).

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

This Proposed Plan identifies the Army's ***preferred alternative*** for achieving the ***remedial action objectives*** (RAOs) to address contaminated groundwater in the Central Plume, DBG Plume, and the PBG Plume and provides the rationale for this preference. Due to lack of risk, an evaluation of remedial alternatives was not conducted for the NC Area Plume.

Figure 1. Progression of the CERCLA Process

The Army's preferred alternative for the Central Plume, DBG Plume, and PBG Plume is Alternative 4: Active Groundwater Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling). Alternative 4 would target remediating the impacted groundwater with elevated dinitrotoluene (DNT) concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Alternative 4 is also expected to reduce the concentrations of volatile organic compounds (VOCs) that coexist within the targeted treatment areas for DNT. Alternative 4 would include in-situ bioremediation treatment utilizing a mix of permanent injection wells and temporary vertical injection wells to administer the nutrient-enriched emulsified vegetable oil (treatment product) into the contaminant plumes. The vertical injection locations would be located both within the BAAP property boundaries (on-site) and beyond the BAAP property boundaries (off-site). Alternative 4 would also include continued groundwater monitoring, on-site groundwater access restrictions, and a provision for an alternate water supply, where necessary.

This Proposed Plan summarizes the results of investigation activities, scope and role of the response action, and site risks. This Proposed Plan also provides a presentation of the RAOs and a summary of remedial alternatives found in the Remedial Investigation/Feasibility Study (RI/FS) for Site-Wide Groundwater at the Former Badger Army Ammunition Plant (June 2021), and other documents contained in the ***Administrative Record***.

Site documents are available for public review in the Administrative Record File and Information Repositories at two local libraries: Ruth Culver Community Library, 540 Water Street, Prairie du Sac, Wisconsin, and George Culver Community Library, 615 Phillips Blvd, Sauk City, Wisconsin. Some of the documents from the Administrative Record are also available online at: https://aec.army.mil/index.php/baap.

The Army is issuing this Proposed Plan (PP) for public review, comment, and participation to fulfill part of its public participation responsibilities under Section 117(a) of the CERCLA of 1980 (42 U.S.C. §9601 et seq.) and under Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)(40CFR Part 300).

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 Army is the lead agency responsible for environmental cleanup of BAAP, under the oversight of the Wisconsin Department of Natural Resources (WDNR). This Proposed Plan was prepared in consultation with the WDNR. The WDNR is the lead oversight agency assisting the Army by providing technical support, project review, project comments, and oversight in accordance with CERCLA and the NCP.

After reviewing and considering input submitted during the 30-day public comment period, the Army, in consultation with the WDNR, will select the final remedy and document the decision through a Decision Document (DD). The public is encouraged to review and comment on the preferred alternative and the rationale provided for this preference, and all other presented remedial alternatives summarized in this Proposed Plan and presented in detail in the RI/FS. The Army, in consultation with the WDNR, may modify the proposed cleanup plan or may select another remedial alternative, based on new information or public comments received during the public comment period.

2.0 SITE BACKGROUND

The BAAP is located in south-central Wisconsin and the southeastern section of Sauk County, see Figure 2. The BAAP is located just south of Devil's Lake State Park and the Baraboo Range and approximately ¼ mile northwest of the Wisconsin River and Lake Wisconsin. The nearest cities are the Village of Prairie du Sac, approximately 2 miles to the south, and the City of Baraboo, approximately 4 miles to the north. The BAAP occupied 7,275 acres between State Highway 78 and US Highway 12. The Army has transferred most of the BAAP land to the following entities: Bluffview Sanitary District, Ho-Chunk Nation, United States Department of Agriculture, WDNR, and Wisconsin Department of Transportation. The land retained by the Army is comprised of two cemeteries and totals less than four acres. Currently, land uses at the BAAP are agriculture, grazing cows, industrial, and recreation.

The Army constructed BAAP in 1942 to produce smokeless gunpowder and solid rocket propellant as munition components for World War II (1942 to 1945). Production also occurred during the Korean War (1951 to 1958) and Vietnam Conflict (1966 to 1975). Production of nitric acid, sulfuric acid, oleum, nitrocellulose (NC), and nitroglycerin (NG) occurred in support of munitions components production. 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 (landfills), and this impacted the groundwater beneath BAAP with multiple contaminants. The main groundwater contaminants are DNT and solvent-related VOCs.

The Army has conducted numerous site investigations and remedial actions at BAAP. Groundwater investigation activities at BAAP began in 1980. Site-wide groundwater investigations identified four groundwater plumes: Propellant Burning Ground (PBG) Plume, Deterrent Burning Ground (DBG) Plume, Central Plume, and Nitrocellulose Production Area (NC Area) Plume. Figure 2 displays the four groundwater plumes in relation to BAAP and the surrounding area.

2.1 Geology

The land surface features at BAAP are the result of glaciation. The terminal moraine, deposited by the leading edge of the last glacier, extends from north to south across the central portion of BAAP. The terminal moraine is visible from the western BAAP boundary as a 40-foot ridge. The Baraboo Range (ancient mountains) rises 500 feet above BAAP to the north. The Wisconsin River and Lake Wisconsin run along the eastern side of BAAP.

Underlying BAAP is approximately 200 feet of glacially deposited sediments. The upper 10 to 90 feet consists of a mixture of sand, silt, clay, and rock fragments (glacial till). Outwash sand and gravel or stream sediment (gravel, sand, or silt) lie beneath the till. Beneath the glacially deposited sediments is a mixture of sedimentary bedrock formations that contain sandstone, shale, siltstone, and dolomite. The Baraboo quartzite underlies the sedimentary formations throughout the BAAP area. Figures 3 and 4 are generalized geologic cross sections that show the thicknesses of the glacial sediments, bedrock layers, and groundwater depth.

2.2 Hydrogeology

Two major groundwater aquifers and one minor aquifer are present beneath BAAP: the surficial sand and gravel aquifer, the sedimentary bedrock (Eau Claire Formation), and the deeper sandstone aquifer (Mt. Simon Formation), respectively. The sand and gravel aquifer and the Eau Claire Formation are un-confined to semi-confined. A shale layer within the Eau Claire Formation acts as an aquitard beneath BAAP. An aquitard is a dense layer of bedrock that restricts groundwater from moving downward into bedrock that is more permeable.

The groundwater surface (water table), beneath BAAP, intersects the sand and gravel aquifer. Groundwater in the sand and gravel aquifer is highly conductive, meaning water flows faster between the soil particles. The high conductivity has created long and narrow groundwater contaminant plumes (see Figure 2). The general direction of groundwater flow is south to southeast, towards the Wisconsin River and Lake Wisconsin. Figure 5 depicts the groundwater contours at BAAP, both on-site and off-site. Lake Wisconsin is located north of the WP&L hydroelectric dam. The dam artificially raises the groundwater surface and influences groundwater flow across BAAP. Groundwater in the northeastern portion of BAAP discharges to Lake Wisconsin. Approximately three miles north of the dam, water from Lake Wisconsin can discharge back to groundwater. The height of water in Lake Wisconsin (774 feet) determines if groundwater recharges the lake. Below the dam, groundwater naturally discharges into the Wisconsin River. The dam has affected the paths of the groundwater contaminant plumes and their proximity to Lake Wisconsin.

3.0 PROPELLANT BURNING GROUND PLUME

3.1 Site Background

The PBG is located in the southwestern portion of BAAP. The PBG source areas are comprised of the following areas: PBG Waste Pits, 1949 Pit, Racetrack Area, and Landfill #1 (see Figure 2). The following sections describe the PBG sources in more detail.

3.1.1 PBG Waste Pits & 1949 Pit

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 12-15 feet deep. The Army used the PBG Waste Pits from approximately 1949 to 1983. DNT and organic solvent-containing materials were disposed of at the PBG through open burning and burial during production periods. Impacted soil contained DNT, polycyclic aromatic hydrocarbons, benzene, carbon tetrachloride (CTET), and trichloroethylene (TCE). The 1949 Pit was a waste disposal area, active between 1949 and 1962, that contains approximately 58,080 cubic yards of construction materials, general waste, and propellant waste. The 1949 Pit was located directly west of the PBG Waste Pits (see Figure 2).

A soil vapor extraction (SVE) system operated at the PBG Waste Pits from 1997 to 1999 to remove solvent-related VOCs from the soil. After achieving satisfactory removal of VOCs, the SVE system was shut down. In 1998, a clay and geomembrane barrier cap was installed above the 1949 Pit. In

1999, approximately 2,280 cubic yards of soil were removed from the Waste Pits. The contaminated soil was incinerated off-site. From 2001 to 2005, the Biologically Enhanced Subsurface Treatment (BEST) system operated at the PBG Waste Pits. The BEST system was an in-situ remedial method that enhanced bacterial degradation of DNT by modifying soil conditions for naturally occurring bacteria. This increased the rate at which the bacteria consumed the DNT compounds. The BEST system extracted contaminated groundwater at each waste pit, treated the water with phosphate, and reinjected it into the soil column above each waste pit. Air injection wells added oxygen to the soil column. After sufficient DNT reductions in the soil and groundwater were observed, the BEST system was removed in 2008. In 2009, the PBG Waste Pits were capped with clay and a geomembrane barrier. This cap was horizontally tied into the cap over the 1949 Pit.

The WDNR requires the Army to maintain and annually inspect the caps over the PBG Waste Pits and 1949 Pit. Cap areas are inspected for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR.

3.1.2 Racetrack Area

The Racetrack Area includes the former Hazardous Waste Thermal Treatment Unit (HWTTU) and consisted of an oval gravel road, three refuse pits, and burning plates. Waste propellants and organic solvent-containing materials were disposed at the Racetrack/HWTTU Area through open burning. In 1995, three-fourths of the Racetrack/HWTTU Area were covered with soil to prevent contact with residual lead in the soil. In 1998, contaminated soil from the remaining portion of the Racetrack Area was excavated and transported to an off-site disposal facility.

The WDNR requires the Army to maintain and annually inspect the soil cover over the Racetrack/HWTTU Area. The cover area is inspected for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR.

3.1.3 Landfill #1

Landfill #1 is a closed demolition debris disposal facility located east of the PBG that was used between 1942 and 1959. Landfill #1 contains approximately 19,500 cubic yards of ash, slag, asphalt, concrete, wood, and other metallic and nonmetallic wastes. In 1997, a composite cap including two feet of clay and a geomembrane barrier was installed over Landfill #1.

The WDNR requires the Army to maintain and annually inspect the cap over Landfill #1. The cap area is inspected for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR.

3.1.4 Groundwater Remediation

Between 1990 and 2015, groundwater remediation was performed in the PBG Plume. Groundwater was pumped from extraction wells in the sand and gravel aquifer, conveyed through underground pipes to treatment buildings, and then treated with granular activated carbon and air stripping. The treated groundwater was pumped through underground piping and then discharged to Lake Wisconsin/Wisconsin River. The extraction wells were located throughout the PBG Plume and within the BAAP boundary. Currently, groundwater contamination is being monitored through recurring sampling as directed by the WDNR.

IRM

The Interim Remedial Measures (IRM) groundwater pump and treat system operated between 1990 and 2012. The IRM pumped between 310 to 350 gallons per minute (gpm) of contaminated groundwater from the PBG Plume. Six extraction wells were located near the PBG Waste Pits and approximately ¾ mile to the south. From 1998 to 2012, only the two extraction wells near the PBG Waste Pits were in operation. In 2012, the WDNR authorized shut down of the IRM due to diminishing returns in groundwater contaminant removal and that further operation would not be cost-effective. In 2014, the IRM extraction wells were abandoned and the IRM building demolished.

MIRM

A second system, the Modified Interim Remedial Measures (MIRM) groundwater pump and treat system, operated between 1996 and 2015. The MIRM pumped between 2,400 to 3,000 gpm of contaminated groundwater from the PBG Plume. From 1996 to 2005, six extraction wells were located along the southern BAAP boundary. These six extraction wells were placed to capture groundwater before it crossed the BAAP boundary to the south. In 2005, optimization of the MIRM extraction well network was performed to remove groundwater contaminants between the PBG Waste Pits and the BAAP boundary. This optimization was intended to reduce the concentration of contaminants in the groundwater. From 2005 to 2015, the MIRM utilized five extraction wells along the middle of the PBG Plume. In 2015, the WDNR authorized shut down of the MIRM citing diminishing returns in groundwater contaminant removal and that further operation would not be cost-effective. In 2016, the MIRM extraction wells were abandoned and the groundwater treatment equipment removed from the MIRM building.

3.2 Groundwater Quality Regulations

Both the USEPA and State of Wisconsin have published groundwater quality regulations related to groundwater. The USEPA has established National Primary Drinking Water Regulations (NPDWRs) that set mandatory water quality standards 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.

Wisconsin Statute Ch. 160, Groundwater Protection Standards, was adopted to minimize the concentration of polluting substances in groundwater through the use of numerical standards in all groundwater regulatory programs. Under Ch. 160, the WDNR must establish state groundwater quality standards based on recommendations from the Wisconsin Department of Health Services. The Wisconsin groundwater standards are published in Chapter NR 140, Wisconsin Administrative Code. Chapter NR 140 references enforceable standards called Enforcement Standards (ESs) and Preventive Action Limits (PALs) for groundwater in Wisconsin. The NR 140 ESs are used to define contaminants of potential concern and areas warranting remedial action. The 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 NR 140 ES concentrations are equal to or more stringent than the USEPA MCLs. Further references to groundwater standard exceedances will reference the NR 140 ES.

3.3 Groundwater Contamination

As described above, the sources of groundwater contamination are the former PBG Waste Pits, 1949 Pit, Racetrack Area, and Landfill #1. The PBG Plume is approximately 3½ miles long and ½ mile wide 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. The Army has collected groundwater samples within and surrounding the PBG Plume from 1982 to present, characterizing the nature and extent of groundwater contamination. Groundwater contamination resides mainly in the surficial sand and gravel aquifer. There have been VOCs detected in off-site monitoring wells screened at the top of the bedrock.

Groundwater data collected during and prior to 2018 is summarized in the RI/FS. Detected concentrations from groundwater samples collected from 2019 to 2023 were compared to the Wisconsin Chapter NR 140 ES and PAL and the USEPA cancer-based and noncancer-based tapwater regional screening levels (screening levels). The following chemicals exceeded the screening levels and were identified as contaminants of potential concern (COPCs) for the PBG Plume:

Table 3.1
Groundwater COPCs
Propellant Burning Ground Plume

Contaminants of Potential Concern (COPCs)	Maximum Concentration 2019 - 2023	Chapter NR 140 Wisconsin Groundwater Quality Standards		Well & Date of Maximum Concentration
		Preventive Action Limit (PAL)	Enforcement Standard (ES)	
Benzene	41	0.5	5	PBN-8202C (6/8/20)
Bromodichloromethane	0.23	0.06	0.6	PBN-1404C (9/28/21)
Carbon Tetrachloride	38	0.5	5	PBN-9101C (9/22/21)
Chloroform	3.6	0.6	6	PBN-9101C (10/8/19)
Ethyl Ether	2,000	100	1,000	SPN-9104D (9/23/19)
1,2-Dichloroethane	2.2	0.5	5	PBN-8202C (4/30/20)
Total Dinitrotoluene (2)	1286.9	0.005	0.05	PBN-8202A (4/30/20)
2,4-Dinitrotoluene (1)	670	0.005	0.05	PBN-8202A (4/30/20)
2,6-Dinitrotoluene (1)	500	0.005	0.05	PBN-8202A (4/30/20)
Naphthalene	0.23	10	100	PBN-8202C (6/8/20)
Nitrate	4.4	2	10	PBM-9801 (9/20/23)
Trichloroethene	15	0.5	5	PBN-9101C (10/8/19)

Notes:

(1) The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (Total DNT).

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

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

The PBG Plume shown in Figure 6 represents the area where the groundwater COPCs have been identified above the NR 140 ES or PAL (2019-2023). Figure 6 also displays the current monitoring well and residential well sampling frequencies associated with the PBG Plume.

Historically, CTET, ethyl ether, and TCE have defined the boundaries of VOC contamination. These three VOCs help monitor VOCs migrating from the PBG. 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. Total DNT concentrations help monitor DNT migrating from the PBG. Figures 7, 8, 9, and 10 are isoconcentration maps for CTET, ethyl ether, TCE, and total DNT, respectively. The isoconcentration maps were prepared using all groundwater data collected during 2023 and supplemented with an additional 107 monitoring wells sampled in 2020. The additional 107 monitoring wells sampled in the PBG area were not part of the WDNR required sampling program in 2023. The additional 2020 groundwater data was to supplement the 2023 data and fill in gaps to generate the isoconcentration boundaries. The green shaded areas indicate where the COPC is above the NR 140 PAL. The blue shaded areas indicate where the COPC is above the NR 140 ES.

The extent of CTET contamination shown on Figure 7 covers the largest area compared to ethyl ether, total DNT, or TCE. CTET concentrations near the PBG sources are lower than areas farther south (downgradient). The highest concentration of CTET (38 µg/l), detected in September 2021, was in monitoring well PBN-9101C located off-site and near the Wisconsin River. The NR 140 ES for CTET is 5 µg/l.

The extent of ethyl ether contamination shown on Figure 8 is narrow and extends approximately one mile downgradient from the BAAP boundary towards the Wisconsin River. Ethyl ether is not present near the PBG sources. The highest concentration of ethyl ether (2,000 µg/l), detected in September 2019, was in monitoring well SPN-9104D located at the BAAP boundary. Ethyl ether concentrations in monitoring well SWN-9103D, located one mile south of the BAAP boundary, have steadily increased since first detected in 2021. The ethyl ether concentration in SWN-9103D was 1,300 µg/l during September 2023. The NR 140 ES for ethyl ether is 1,000 µg/l.

The extent of TCE contamination shown on Figure 9 is narrow but still extends from the PBG sources down to the Wisconsin River. TCE concentrations near the PBG sources are much lower than areas farther south (downgradient). The highest concentration of TCE (15 µg/l), detected in October 2019, was in monitoring well PBN-9101C located off-site and near the Wisconsin River. Since September 2020, TCE concentrations in the PBG (on-site and off-site) have been below the NR 140 ES (5 µg/l).

The extent of total DNT contamination shown on Figure 10 is broken into three separate areas, near the PBG sources (PBG Waste Pits, 1949 Pit, and Racetrack Area), near the BAAP boundary, and near the Wisconsin River. The extensive groundwater pumping may have caused the separation of the total DNT contamination. The total DNT isoconcentrations shown on Figure 10 are broken into four-color designations. The green shaded areas indicate where total DNT is above the NR 140 PAL (0.005 µg/l). The blue shaded areas indicate where total DNT is above the NR 140 ES (0.05 µg/l) but below 0.5 µg/l. The orange shaded areas indicate where total DNT is between 0.5 and 5 µg/l. The purple shaded area displays where total DNT is above 5 µg/l. The area closest to the PBG sources contains the highest concentrations of total DNT. The highest concentration of total DNT (1286.9 µg/l), detected during April 2020, was in monitoring well PBN-8202A located immediately downgradient of the PBG Waste Pits. Total DNT concentrations near the PBG sources have increased from 2017 to 2023. A rise in the groundwater table seemed to cause the increased DNT concentrations. Between 2016 and 2020, the groundwater table near the PBG Waste Pits rose approximately nine feet. Since 2020, the groundwater table has dropped approximately seven feet.

3.4 Scope and Role of the Proposed Action

The scope and role of the action discussed in this PP includes all the groundwater remedial actions planned for the PBG Plume. The preferred groundwater remedial action will reduce potential risks associated with exposure to contaminated groundwater in the sand and gravel aquifer. Using treatment technologies, this response will reduce the toxicity, mobility, and volume of source materials that constitute the principal threat.

Local residents have historically used groundwater outside the BAAP boundary as a drinking water source. The Army has replaced three residential wells in the PBG Plume due to VOC impacts. Two residential wells were installed in 1990 and one well in 1996. The use of groundwater for human consumption will continue in the future. When establishing the RAOs for this response action, the Army has considered the NCP's expectation to return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The Army intends to return the contaminated sand and gravel aquifer at BAAP to its potential beneficial uses, which is considered to be total DNT concentrations below the NR 140 ES, to the extent practicable. If a return to potential beneficial use is not practicable, the expectation is to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction.

3.5 Summary of Site Risks

The Army performed a risk assessment to determine and document whether groundwater contamination in the PBG Plume poses a risk to human health. CERCLA requires the completion of a Human Health Risk Assessment (HHRA) prior to selecting a remedial alternative. The HHRA must evaluate the potential human health risks associated with chemical exposure to environmental media (e.g., groundwater, vapor). The HHRA was conducted using standard USEPA risk assessment guidance, exposure assumptions, and toxicity factors. The USEPA risk assessment process uses conservative assumptions about exposure to chemicals and their toxicity so that risks reported are not underestimated. In all circumstances, priority was given to evaluating the potential human health risk regardless of the impact. The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion.

Domestic Groundwater Risk

Groundwater located in the PBG Plume and within the BAAP boundary is not used for human consumption. BAAP land was transferred from the Army to other property owners and includes a deed restriction on the use of groundwater. This 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."

Beyond the boundary of BAAP, the Army cannot control groundwater use. Residential wells located outside of BAAP use groundwater for potable water and domestic purposes. There is a potential for the installation and use of additional residential wells outside of the BAAP boundary. Current and future 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.

The human health risks were evaluated using groundwater data from residential wells and monitoring wells. The maximum groundwater concentration of each COPC during 2019, 2020, 2021, 2022, and 2023 were used to estimate the risk. The groundwater risk estimates were calculated for each COPC using the maximum groundwater concentrations and a simple scaling method described in Section 2.6.1 of the USEPA's Regional Screening Levels (RSLs) – User's Guide (November 2023). These calculations use the USEPA's RSL Resident Tapwater Generic Table (November 2023). The calculated cancer and non-cancer risks for each COPC and the cumulative cancer and non-cancer risks for the PBG Plume are summarized in Appendix A - 2019-2023 Screening Level Groundwater Risk Evaluation Summary Tables.

The results of the HHRA determined that contaminated groundwater in the PBG Plume poses an unacceptable risk to groundwater usage by humans. Provided below is a summary of exposure risks for the PBG Plume.

PBG Plume Risk Summary

Based on the groundwater monitoring data from 2019 to 2023, the risk-based contaminants of concern (COCs) identified in the PBG Plume were benzene, CTET, chloroform, ethyl ether, total DNT, 2,4-DNT, 2,6-DNT, and TCE.

- Benzene had a non-cancer risk above the risk management criteria. Benzene concentrations were above the NR 140 ES.
- CTET had a cancer risk above the risk management criteria. CTET concentrations were above the NR 140 ES.
- Chloroform had a cancer risk above the risk management criteria. Chloroform concentrations were below the NR 140 ES. Therefore, remedial alternatives were not evaluated for chloroform.
- Ethyl ether had a non-cancer risk above the risk management criteria. Ethyl ether concentrations were above the NR 140 ES.

- Total DNT had both a cancer risk and a non-cancer risk above the risk management criteria. Total DNT concentrations were above the NR 140 ES.
- 2,4-DNT had both a cancer risk and a non-cancer risk above the risk management criteria. 2,4-DNT concentrations were above the NR 140 ES.
- 2,6-DNT had both a cancer risk and a non-cancer risk above the risk management criteria. 2,6-DNT concentrations were above the NR 140 ES.
- TCE had both a cancer risk and a non-cancer risk above the risk management criteria. TCE concentrations were above the NR 140 ES.

Benzene, CTET, ethyl ether, total DNT, 2,4-DNT, 2,6-DNT, and TCE were 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 3.2
Groundwater COCs & Cleanup Levels
Propellant Burning Ground Plume

COC (1)	Cancer Risk	Non-Cancer Risk	Groundwater Cleanup Level (2)
Benzene	none	X	5
Carbon Tetrachloride	X	none	5
Chloroform	X	none	6
Ethyl Ether	none	X	1,000
Total Dinitrotoluene	X	X	0.05
2,4-Dinitrotoluene	X	X	0.05
2,6-Dinitrotoluene	X	X	0.05
Trichloroethene	X	X	5

Notes:
(1) COC (Contaminant of Concern)
(2) The Groundwater Cleanup Level is the NR 140 Enforcement Standard (ES)
Based on analytical lab results from residential and groundwater monitoring well samples from 2019, 2020, 2021, 2022, and 2023.
All concentration values are expressed in micrograms-per-liter (µg/l)

Vapor Intrusion Risk

The vapor intrusion pathway was considered in the HHRA. An evaluation was conducted to determine whether vapors from the PBG Plume 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 (e.g., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air. The HHRA did not identify vapor intrusion risks from groundwater contamination.

3.6 Remedial Action Objectives

The following remedial action objectives (RAOs) were developed for the PBG Plume:

- Protect human health by preventing human exposure to contaminated groundwater.
- Restore the groundwater aquifer to beneficial use (i.e., for potable purposes) within a reasonable time frame wherever practicable, based upon site conditions, by reducing contaminant concentrations in groundwater to levels that comply with chemical-specific applicable or relevant and appropriate requirements (ARARs).
- Minimize the impact of contaminated groundwater on the environment.

The RAOs for the PBG Plume will be achieved when the risk-based groundwater COCs are below the groundwater cleanup levels (NR 140 ES) shown above in Table 3.2.

3.7 Summary of Remedial Alternatives

The FS identified and screened remedial technologies and associated process options that may be appropriate for satisfying the RAOs with respect to effectiveness, implementability, and cost. All remediation costs utilize 30 years of implementation (including groundwater monitoring). For alternatives taking longer than 30 years to achieve RAOs, costs would be considerably higher. The Army developed the following remedial alternatives from the retained remedial technologies carried forward after the initial screening. Remedial alternatives were based on achieving the NR 140 ES groundwater standard.

- **Alternative 1 – No Action (Groundwater LUCs)**, as required by the NCP. Alternative 1 would have no impact on the PBG Plume 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, land use controls (LUCs) will restrict groundwater use within the property boundaries of the former BAAP boundary.

- **Alternative 2 – Monitored Natural Attenuation (MNA) and Alternate Water Supply (Groundwater LUCs and Sampling).** Alternative 2 would include MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 2 would also continue residential and monitoring well sampling.

- **Alternative 3 – Active Groundwater Remediation – Pump and Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 3 would include groundwater extraction and treatment with mobile treatment units, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 3 would also continue residential and monitoring well sampling.

- **Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 4 would include in-situ anaerobic biodegradation of groundwater contaminants, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 4 would also continue residential and monitoring well sampling. MNA will reduce the concentrations of the following VOCs by natural processes: benzene, CTET, chloroform, ethyl ether, and TCE. The *Draft Technical Report Natural Attenuation Screening Study for the Propellant Burning Ground* (Stone & Webster, August 1999) supports MNA as an effective alternative to remediate VOCs in the PBG Plume. Alternative 4 would target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts will be inclusive of all six DNT isomers (total DNT). Alternative 4 would include in-situ bioremediation (biochemical) treatment utilizing permanent and temporary vertical injection wells to administer the biochemical product into the PBG Plume. The biochemical product would consist of a nutrient-enriched emulsified vegetable oil (EVO). The EVO would be distributed in the groundwater as an oil-in-water emulsion (mixture). The oil-in-water emulsion would be prepared using a food-grade oil, food-grade surfactants, and clean water. Once injected into the groundwater, the EVO mixture would stimulate anaerobic biodegradation of the DNT. The vertical injection locations would be located both on-site and off-site. At each injection location, the EVO mixture would be pumped into various depths within the PBG Plume. This method would treat both the horizontal and vertical extent of DNT contaminated groundwater. Alternative 4 is expected to also reduce the concentrations of VOCs that coexist within the targeted treatment areas for DNT.

- **Alternative 5 – Well Replacement – Plume Area (MNA, Groundwater LUCs and Sampling).** Alternative 5 would involve replacing shallow aquifer residential wells (meeting replacement criteria) within the PBG Plume area with deeper aquifer wells, MNA and LUCs consisting of on-site groundwater access restrictions. Alternative 5 would also continue residential and monitoring well sampling.

- **Alternative 6 – Source Area Treatment (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 6 would involve in-situ anaerobic biodegradation of groundwater contaminants (elevated DNT concentrations) directly downgradient of the source area, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 6 would also continue residential and monitoring well sampling.

The Army expects MNA to reduce the concentrations of the following VOCs by natural processes: benzene, CTET, chloroform, ethyl ether, and TCE. The Army developed active remedial alternatives specifically for elevated concentrations of 2,6-DNT in the PBG Plume. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

3.8 Evaluation of Alternatives for PBG Plume

This section compares the remedial alternatives summarized above to each other using the nine criteria set forth in 40 CFR 300.430(e)(9)(iii) and listed in Table 3.3 below. In the remedial decision-making process, USEPA describes the relative performance of each alternative against the evaluation criteria and notes how each alternative compares to the other alternatives under consideration. The FS contains a detailed analysis of the alternatives. The nine evaluation criteria fall into three groups described as follows:

> ***Threshold criteria*** are requirements that each alternative must meet to be eligible for selection.
>
> ***Primary balancing criteria*** are used to weigh major trade-offs between alternatives.
>
> ***Modifying criteria*** are considered after public comments are received on the PP.

Table 3.3: Evaluation Criteria for CERCLA Remedial Alternatives	
Threshold Criteria	**1. Overall Protection of Human Health and the Environment** determines whether an alternative can adequately protect human health and the environment by eliminating, reducing, or controlling exposures to hazardous substances, pollutants or contaminants to levels that do not pose an unacceptable risk.
	2. Compliance with ARARs evaluates whether the remedial alternative meets Federal and State environmental statutes, regulations, and other requirements that pertain to the site, or whether a waiver is required and justified.
Primary Balancing Criteria	**3. Long-term Effectiveness and Permanence** considers the ability of an alternative to maintain protection of human health and the environment over time.
	4. Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present.
	5. Short-term Effectiveness considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation.
	6. Implementability considers the technical and administrative feasibility of implementing an alternative, including factors such as the relative availability of goods and services.
	7. Cost includes the estimated capital and annual operation and maintenance costs, as well as present worth cost of an alternative. Present worth cost is the total cost of an alternative over time in today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent. 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.

Modifying Criteria	**8. State Agency Acceptance** considers whether the State agrees with the Army's analyses and recommendations, as described in the RI/FS and PP.
	9. Community Acceptance considers whether the local community agrees with State's analyses and preferred alternative. Comments received on the PP are an important indicator of community acceptance.

3.8.1 Overall Protection of Human Health and the Environment

The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion. The HHRA did not identify risks to groundwater through vapor intrusion. The results of the HHRA indicated that domestic groundwater use poses both a current (off-site) and hypothetical future (on-site) risk to human health.

The six alternatives provide varying levels of human health protection and the environmental protection.

Alternative 1 (No Action) would not be protective of human health or the environment. This alternative would still restrict groundwater usage within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program. Alternative 1 fails this threshold criterion.

Alternative 2 (MNA and Alternate Water Supply) 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.

Alternatives 3 (Pump and Treat), 4 (In-Situ Anaerobic Bioremediation), and 6 (Source Area Treatment) would provide protection of human health and the environment by reducing the groundwater contaminants. They would also restrict groundwater usage within the BAAP boundary. The provision of the alternate water supply condition would address concerns associated with residential well impacts. The groundwater sampling program would monitor the groundwater concentrations for compliance and contaminant reduction.

Alternative 5 (Well Replacement) would be protective of human health but not the environment. The Army would provide clean potable water to potential domestic groundwater users. There would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. There would be no active groundwater remediation performed. Alternative 5 fails this threshold criterion.

3.8.2 Compliance with ARARs

CERCLA and the NCP require that remedial actions at least attain legally applicable or relevant and appropriate Federal and State requirements, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law, which are collectively referred to as "ARARs," unless such ARARs can be waived. The USEPA defines three types of ARARs: action-specific, chemical-specific, and location-specific.

Alternative 1 (No Action) would not comply with ARARs and provide no groundwater monitoring.

Alternatives 2, 3, 4, 5, and 6 would comply with ARARs. The evaluation did not identify any location-specific ARARs. Listed below are the ARARs that apply.

- National Primary Drinking Water Regulations: 40 CFR Part 141 Subpart G (chemical-specific).
- Wisconsin Groundwater Standards: Chapter NR 140 Groundwater Quality (chemical-specific).
- Residential Well Construction Standards: Chapter NR 812 Well Construction and Pump Installation (action-specific). Requirements for installing water supply wells and extracting groundwater.

3.8.3 Long-term Effectiveness and Permanence

Alternative 1 (No Action) would not be effective in reducing the risk associated with contaminated groundwater and provides no controls to prevent exposure over time.

Alternative 2 (MNA and Alternate Water Supply) offers a long-term solution as groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. Alternative 2 would be the least effective alternative.

Alternative 3 (Pump and Treat) would reduce DNT concentrations through groundwater removal and treatment. Maintaining hydraulic control of groundwater must occur throughout the treatment process to be effective.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would reduce DNT concentrations through in-situ anaerobic biodegradation. The bioremediation process permanently destroys the groundwater contaminants. Both alternatives would be an effective long-term solution. Alternative 6 would only reduce DNT concentrations near the source areas of the DBG and PBG. Alternative 4 would be the most effective long-term alternative and the most permanent for treatment of DNT contaminated groundwater.

Alternative 5 (Well Replacement) would provide receptors with long-term access to clean potable water. Groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. This alternative would be an effective long-term and permanent solution.

3.8.4 Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment

Alternative 1 (No Action) would not reduce the toxicity, mobility, and volume of contaminants because it does not include a treatment component. This alternative does not meet the statutory preference for the use of treatment as a principal element for the reduction of toxicity, mobility, and volume of hazardous substances.

All other alternatives, except Alternative 2 (MNA and Alternate Water Supply) and Alternative 5 (Well Replacement), have the potential to be effective at reducing the toxicity, mobility, and volume of the COCs through treatment. Alternatives 2 and 5 would have limited reductions in toxicity, mobility, and volume as the contaminants would only naturally degrade.

Alternative 3 (Pump and Treat) would use groundwater extraction and treatment to decrease the toxicity and volume of impacted groundwater and decrease the mobility of groundwater impacts through hydraulic control.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would achieve the greatest overall decrease in toxicity and volume of the DNT in groundwater through in-situ anaerobic biodegradation.

3.8.5 Short-Term Effectiveness

Alternative 1 (No Action) would have no short-term impacts and not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) would have no short-term impacts and no additional work associated with implementation.

Alternative 3 (Pump and Treat) would have moderate short-term impacts to workers, residents and the environment during implementation. Construction of extraction wells, mobile treatment units, and underground discharge piping would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would have moderate short-term impacts to workers, residents and the environment during implementation. Installation of the permanent and temporary vertical injection wells would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternative 5 (Well Replacement) would have moderate short-term impacts to workers, residents and the environment during implementation. Installation of new homeowner wells would cause impacts to private property.

3.8.6 Implementability

Alternative 1 (No Action) would be easy to implement as it would not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) is the most implementable as it is currently being applied.

Alternatives 3 (Pump and Treat), 4 (In-Situ Anaerobic Bioremediation), and 6 (Source Area Treatment) require drilling and construction activities and would be readily implementable using standard construction equipment. The in-situ injection of the biochemical product under Alternatives 4 and 6 would be more challenging due to varying soil conditions at depth.

3.8.7 Cost

The FS developed the estimated 30-year costs for each alternative. These preliminary cost estimates should be within -30 percent to +50 percent of the actual implementation costs. Table 3.4 shows a summary of the capital costs, operation and maintenance (O&M) costs and total costs.

3.8.8 State Acceptance

Alternatives 1, 2, and 5 may not be acceptable to the WDNR because they would not perform any active groundwater remediation and would not achieve the RAOs. Alternative 6 may not be acceptable to the WDNR because it would only treat groundwater near the source areas and would not prevent potential human exposure to the groundwater contamination migrating off-site. Alternatives 3 and 4 may be acceptable to the WDNR based on permanence, long-term protectiveness, and effectiveness. Ultimate WDNR acceptance will be determined during the remedial design phase.

3.8.9 Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends. The community's comments will be described and addressed in the Record of Decision (ROD).

Table 3.4
Cost Estimates for Alternatives
Propellant Burning Ground Plume

	Alternative	Capital Cost	Long-Term Operating Cost	Contingency	Total Cost
1	No Action (Groundwater LUCs)	$0	$0	$0	$0
2	MNA & Alternate Water Supply (Groundwater LUCs and Sampling)	$0	$4,913,113	$0	$4,913,113
3	Active GW Remediation – Pump & Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$4,541,967	$7,433,131	$726,715	$12,701,812
4	Active GW Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$4,068,412	$4,913,113	$650,946	$9,632,470
5	Well Replacement – Plume Area (MNA, Groundwater LUCs and Sampling)	$2,937,500	$4,511,746	$470,000	$7,919,246
6	Source Area Treatment – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$251,791	$4,913,113	$40,287	$5,205,190

3.9 Summary of the Preferred Alternative for PBG Plume

The Army's preferred remedial alternative is Active Groundwater Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling) – Alternative 4. Alternative 4 will target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Alternative 4 will include in-situ bioremediation (biochemical) treatment utilizing permanent and temporary vertical injection wells to administer the biochemical product into the contaminant plume. The vertical injection locations would be located both on-site and off-site. Shown on Figure 11 is a conceptual plan for in-situ bioremediation treatment (Alternative 4) with the anticipated treatment lines of vertical injection wells. The locations of the vertical injection wells and the horizontal and vertical extent of in-situ treatment will be determined during the remedial design phase.

The preferred remedial action for the PBG Plume will reduce potential exposure risks associated with the contaminated groundwater. The in-situ treatment of DNT in the PBG Plume will positively affect groundwater by reducing the potential for DNT impacted groundwater to migrate downgradient towards residential properties. Groundwater monitoring and MNA will verify contaminant level reduction and provide protection to residential drinking water supplies. LUCs will restrict groundwater use within the property boundaries of the BAAP. These LUCs will continue until COC levels in groundwater allow for unrestricted use and unlimited exposure. If needed, the remedial action will also include a provision for an alternate water supply condition including bottled water or well replacement.

4.0 DETERRENT BURNING GROUND PLUME

4.1 Site Background

The seven-acre DBG area is located in the northeastern portion of BAAP (see Figure 2). The Army used the DBG area as a waste disposal site from the 1940s to 1970s. The east side of the DBG consisted of three burn pits and metal tanks within a former sand borrow pit. Open burning of the deterrent caused soil and groundwater contamination. Deterrent is 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 NC. Coal ash from the power plant, construction rubble, trash, and burned garbage were deposited in Landfill #3, located on the west side of the DBG.

In 1999 and 2000, approximately 4,260 cubic yards of impacted soil (DNT and metals) were removed from the three burn pits and incinerated off-site. During 2003, a geosynthetic clay and geomembrane barrier cap was installed over the DBG burn pits and Landfill #3. Between 2003 and 2008, an Enhanced Biodegradation System (EBS) operated beneath the DBG cap and near the former burn 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. Due to lack of evidence showing that the EBS was enhancing degradation beyond natural processes, the system was decommissioned. The Army has not conducted any active groundwater remediation in the DBG area.

Landfill #5 is located to the northeast of the DBG. Landfill #5 reportedly received solid waste, including office waste, demolition debris, laboratory waste, and coal ash from the power plant. Records indicate that no hazardous materials were disposed in Landfill #5. In 1988, a clay barrier cap was constructed over Landfill #5. The cap received regulatory approval from the WDNR on September 20, 1989.

The WDNR requires the Army to maintain and annually inspect the DBG and Landfill #5 caps. The caps are inspected for erosion, settlement, undesirable vegetation, and other deficiencies. Annual cap and cover maintenance reports are submitted to the WDNR.

4.2 Groundwater Contamination

As described above, the sources of groundwater contamination are the former burn pits at the DBG and Landfill #3. The DBG Plume is approximately 1½ miles long and 800 feet wide and extends southeast beyond the BAAP boundary. Outside of BAAP, the plume continues southeast towards Weigand's Bay (connected to the Wisconsin River). The DBG Plume shown in Figure 12 represents the area where groundwater concentrations exceed a NR 140 ES or PAL for 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. Figure 12 displays the current monitoring well and residential well sampling frequencies associated with the DBG Plume. Currently, groundwater contamination is being monitored through recurring sampling as directed by the WDNR. Groundwater contamination remains in the surficial sand and gravel aquifer and has not migrated into the bedrock.

Groundwater data collected during and prior to 2018 is summarized in the RI/FS. Detected concentrations from groundwater samples collected from 2019 to 2023 were compared to the Wisconsin Chapter NR 140 ES and PAL and the USEPA cancer-based and noncancer-based tapwater regional screening levels (screening levels). The following chemicals exceeded the screening levels and were identified as COPCs for the DBG Plume:

**Table 4.1
Groundwater COPCs
Deterrent Burning Ground Plume**

Contaminants of Potential Concern (COPCs)	Maximum Concentration 2019 - 2023	Chapter NR 140 Wisconsin Groundwater Quality Standards		Well & Date of Maximum Concentration
		Preventive Action Limit (PAL)	Enforcement Standard (ES)	
Chloroform	0.37	0.6	6	E12653 (8/16/23)
1,2-Dichloropropane	0.66	0.5	5	ELN-8203 (4/6/21)
Total Dinitrotoluene (2)	2.898	0.005	0.05	DBM-8201 (4/24/23)
2,4-Dinitrotoluene (1)	0.088	0.005	0.05	DBM-8201 (4/24/23)
2,6-Dinitrotoluene (1)	0.11	0.005	0.05	DBM-8201 (4/24/23)
Sulfate (3)	1,500	125	250	ELN-8203A (4/1/20)
Tetrahydrofuran	25	10	50	ELN-8203B (5/2/22)
1,1,2-Trichlorethane	1.8	0.5	5	S1134R (4/6/21)

Notes:

(1) The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (Total DNT).

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

(3) The Sulfate Chapter NR 140 ES and PAL are based on a taste threshold and not based on risk to human health.

All concentration values except for Sulfate are expressed in micrograms-per-liter (µg/l)
Sulfate concentration values are expressed in milligrams-per-liter (mg/l)

Figure 13 is a total DNT isoconcentration map for the DBG Plume. The isoconcentration map was prepared using all groundwater data collected during 2023. The total DNT isoconcentrations shown on Figure 13 are broken into three-color designations. The green shaded areas indicate where total DNT is above the NR 140 PAL (0.005 µg/l). The blue shaded areas indicate where total DNT is above the NR 140 ES (0.05 µg/l) but below 1.0 µg/l. The red shaded area displays where total DNT is above 1.0 µg/l. The area closest to the DBG sources (DBG and Landfill #3) contains the highest concentrations of total DNT. The highest concentration of total DNT (2.898 µg/l), detected during April 2023, was in monitoring well DBM-8201 located immediately downgradient of the DBG. Total DNT concentrations near the DBG sources have been decreasing. Total DNT concentrations near the BAAP boundary and the leading edge of the DBG Plume have shown increasing trends. Groundwater monitoring has shown that Landfill #5 is not a source of DNT in the DBG Plume.

The extent of sulfate contamination shown on Figure 14 is adjacent to Landfill #5. The isoconcentration map was prepared using all groundwater data collected during 2023. 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 (1,500 mg/l), detected during April 2020, was in monitoring well ELN-8203A, which is immediately downgradient of Landfill #5. The limits of the sulfate isoconcentrations are approximately 450 by 800 feet and do not intersect with DNT migrating from the DBG. Sulfate concentrations have remained stable. Wisconsin has a "secondary" NR 140 Public Welfare Groundwater Quality Standard for sulfate. The sulfate NR 140 Groundwater Standard is based on a taste threshold and not on the risk to human health.

1,1,2-Trichloroethane (1,1,2-TCA) has only exceeded the NR 140 PAL in four monitoring wells (ELN-8203A, B, C and S1134R) located directly south and downgradient of Landfill #5. 1,1,2-TCA concentrations have remained stable. Due to the limited extent of 1,1,2-TCA detections, an isoconcentration map was not prepared.

Tetrahydrofuran has only exceeded the NR 140 PAL in monitoring well ELN-8203B. Tetrahydrofuran has been detected in other monitoring wells near Landfill #5 but always below the NR 140 PAL. Due to the limited extent of tetrahydrofuran detections, an isoconcentration map was not prepared.

4.3 Scope and Role of the Proposed Action

The scope and role of the action discussed in this PP includes all the groundwater remedial actions planned for the DBG Plume. The preferred groundwater remedial action will reduce potential risks associated with exposure to contaminated groundwater in the sand and gravel aquifer. Using treatment technologies, this response will reduce the toxicity, mobility, and volume of source materials that constitute the principal threat.

Local residents have historically used groundwater outside the BAAP boundary as a drinking water source. The Army replaced one residential well within the DBG Plume, due to DNT impacts. The replacement well was installed in 2019. The use of groundwater for human consumption will continue in the future. When establishing the RAOs for this response action, the Army has considered the NCP's expectation to return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The Army intends to return the contaminated sand and gravel aquifer at BAAP to its potential beneficial uses, which is considered to be total DNT concentrations below the NR 140 ES, to the extent practicable. If a return to potential beneficial use is not practicable, the expectation is to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction.

4.4 Summary of Site Risks

The Army performed a risk assessment to determine and document whether groundwater contamination in the DBG Plume poses a risk to human health. CERCLA requires the completion of a HHRA prior to selecting a remedial alternative. The HHRA must evaluate the potential human health risks associated with chemical exposure to environmental media (e.g., groundwater, vapor). The HHRA was conducted using standard USEPA risk assessment guidance, exposure assumptions, and toxicity factors. The USEPA risk assessment process uses conservative assumptions about exposure to chemicals and their toxicity so that risks reported are not underestimated. In all circumstances, priority was given to evaluating the potential human health risk regardless of the impact. The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion.

Domestic Groundwater Risk

Groundwater located in the DBG Plume and within the BAAP boundary is not used for human consumption. The former BAAP land was transferred from the Army to other property owners and includes a deed restriction on the use of groundwater. This 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."

Beyond the boundary of BAAP, the Army cannot control groundwater use. Residential wells located outside of BAAP use groundwater for potable water and domestic purposes. There is potential for the installation and use of additional residential wells outside of BAAP. Current and future 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.

The human health risks were evaluated using groundwater data from residential wells and monitoring wells. The maximum groundwater concentration of each COPC during 2019, 2020, 2021, 2022, and 2023 were used to estimate the risk. The groundwater risk estimates were calculated for each COPC using the maximum groundwater concentrations and a simple scaling method described in Section 2.6.1 of the USEPA's RSLs – User's Guide (November 2023). These calculations use the USEPA's RSL Resident Tapwater Generic Table (November 2023). The calculated cancer and non-cancer risks for each COPC and the cumulative cancer and non-cancer risks for the DBG Plume are summarized in Appendix A - 2019-2023 Screening Level Groundwater Risk Evaluation Summary Tables.

The results of the HHRA determined that contaminated groundwater in the DBG Plume poses an unacceptable risk to groundwater usage by humans. Provided below is a summary of exposure risks for the DBG Plume.

DBG Plume Risk Summary

Based on the groundwater monitoring data from 2019 to 2023, the risk-based COCs identified in the DBG Plume were chloroform, total DNT, and 1,1,2-TCA.

- Chloroform had a cancer risk above the risk management criteria. Chloroform concentrations were below the NR 140 ES. Therefore, remedial alternatives were not evaluated for chloroform.
- Total DNT had a cancer risk above the risk management criteria. Total DNT concentrations were above the NR 140 ES.
- 1,1,2-TCA had both a cancer and a non-cancer risk above the risk management criteria. 1,1,2-TCA concentrations were below the NR 140 ES. Therefore, remedial alternatives were not evaluated for 1,1,2-TCA.

Total DNT (all six DNT isomers) was the only COC considered in the FS for the development of remedial alternatives in the DBG Plume. However, the Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

Table 4.2
Groundwater COCs & Cleanup Levels
Deterrent Burning Ground Plume

COC [(1)]	Cancer Risk	Non-Cancer Risk	Groundwater Cleanup Level [(2)]
Chloroform	X	none	6
Total Dinitrotoluene	X	none	0.05
1,1,2-Trichloroethane	X	X	5

Notes:
(1) COC (Contaminant of Concern)
(2) The Groundwater Cleanup Level is the NR 140 Enforcement Standard (ES)
Based on analytical lab results from residential and groundwater monitoring well samples from 2019, 2020, 2021, 2022, and 2023.
All concentration values are expressed in micrograms-per-liter (µg/l)

Vapor Intrusion Risk

The vapor intrusion pathway was considered in the HHRA. An evaluation was conducted to determine whether vapors from the DBG Plume 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 (e.g., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air. The HHRA did not identify vapor intrusion risks from groundwater contamination.

4.5 Remedial Action Objectives

The following RAOs were developed for the DBG Plume:

- Protect human health by preventing human exposure to contaminated groundwater.
- Restore the groundwater aquifer to beneficial use (i.e., for potable purposes) within a reasonable time frame wherever practicable, based upon site conditions, by reducing contaminant concentrations in groundwater to levels that comply with chemical-specific ARARs.
- Minimize the impact of contaminated groundwater on the environment.

The RAOs for the DBG Plume will be achieved when the risk-based groundwater COCs are below the groundwater cleanup levels (NR 140 ES) shown above in Table 4.2.

4.6 Summary of Remedial Alternatives

The FS identified and screened remedial technologies and associated process options that may be appropriate for satisfying the RAOs with respect to effectiveness, implementability, and cost. All remediation costs utilize 30 years of implementation (including groundwater monitoring). For alternatives taking longer than 30 years to achieve RAOs, costs would be considerably higher. The Army developed the following remedial alternatives from the retained remedial technologies carried forward after the initial screening. Remedial alternatives were based on achieving the NR 140 ES groundwater standard.

- **Alternative 1 – No Action (Groundwater LUCs)**, as required by the NCP. Alternative 1 would have no impact on the DBG Plume 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, LUCs will restrict groundwater use within the property boundaries of the former BAAP boundary.

- **Alternative 2 – Monitored Natural Attenuation (MNA) and Alternate Water Supply (Groundwater LUCs and Sampling).** Alternative 2 would include MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 2 would also continue residential and monitoring well sampling.

- **Alternative 3 – Active Groundwater Remediation – Pump and Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 3 would include groundwater extraction and treatment with mobile treatment units, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 3 would also continue residential and monitoring well sampling.

- **Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 4 would include in-situ anaerobic biodegradation of groundwater contaminants, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 4 would also continue residential and monitoring well sampling. Alternative 4 would target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts will be inclusive of all six DNT isomers (total DNT). Alternative 4 would include in-situ bioremediation (biochemical) treatment utilizing temporary vertical injection wells to administer the biochemical product into the DBG Plume. The biochemical product would consist of a nutrient-enriched emulsified vegetable oil (EVO). The EVO would be distributed in the groundwater as an oil-in-water emulsion (mixture). The oil-in-water emulsion would be prepared using a food-grade oil, food-grade surfactants, and clean water. Once injected into the groundwater, the EVO mixture would stimulate anaerobic biodegradation of the DNT. The vertical injection locations would be located both on-site and off-site. At each injection location, the EVO mixture would be pumped into various depths within the DBG Plume. This method would treat both the horizontal and vertical extent of DNT contaminated groundwater.

- **Alternative 5 – Well Replacement – Plume Area (MNA, Groundwater LUCs and Sampling).** Alternative 5 would involve replacing shallow aquifer residential wells (meeting replacement criteria) within the DBG Plume area with deeper aquifer wells, MNA and LUCs consisting of on-site groundwater access restrictions. Alternative 5 would also continue residential and monitoring well sampling.

- **Alternative 6 – Source Area Treatment (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 6 would involve in-situ anaerobic biodegradation of groundwater contaminants (elevated DNT concentrations) directly downgradient of the source area, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 6 would also continue residential and monitoring well sampling.

The Army developed active remedial alternatives specifically for elevated concentrations of total DNT in the DBG Plume. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

4.7 Evaluation of Alternatives for DBG Plume

This section compares the remedial alternatives summarized above to each other using the nine criteria set forth in 40 CFR 300.430(e)(9)(iii). The nine criteria were presented above in Section 3.8. In the remedial decision-making process, USEPA describes the relative performance of each alternative against the evaluation criteria and notes how each alternative compares to the other alternatives under consideration. The FS contains a detailed analysis of the alternatives.

4.7.1 Overall Protection of Human Health and the Environment

The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion. The HHRA did not identify risks to groundwater through vapor intrusion. The results of the HHRA indicated that domestic groundwater use poses both a current (off-site) and hypothetical future (on-site) risk to human health.

The six alternatives provide varying levels of human health protection and the environmental protection.

Alternative 1 (No Action) would not be protective of human health or the environment. This alternative would still restrict groundwater usage within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program. Alternative 1 fails this threshold criterion.

Alternative 2 (MNA and Alternate Water Supply) 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.

Alternatives 3 (Pump and Treat), 4 (In-Situ Anaerobic Bioremediation), and 6 (Source Area Treatment) would provide protection of human health and the environment by reducing the groundwater contaminants. They would also restrict groundwater usage within the BAAP boundary. The provision of the alternate water supply condition would address concerns associated with residential well impacts. The groundwater sampling program would monitor the groundwater concentrations for compliance and contaminant reduction.

Alternative 5 (Well Replacement) would be protective of human health but not the environment. The Army would provide clean potable water to potential domestic groundwater users. There would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. There would be no active groundwater remediation performed. Alternative 5 fails this threshold criterion.

4.7.2 Compliance with ARARs

CERCLA and the NCP require that remedial actions at least attain legally applicable or relevant and appropriate Federal and State requirements, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law, which are collectively referred to as "ARARs," unless such ARARs can be waived. The USEPA defines three types of ARARs: action-specific, chemical-specific, and location-specific.

Alternative 1 (No Action) would not comply with ARARs and provide no groundwater monitoring.

Alternatives 2, 3, 4, 5, and 6 would comply with ARARs. The evaluation did not identify any location-specific ARARs. Listed below are the ARARs that apply.

- National Primary Drinking Water Regulations: 40 CFR Part 141 Subpart G (chemical-specific).
- Wisconsin Groundwater Standards: Chapter NR 140 Groundwater Quality (chemical-specific).
- Residential Well Construction Standards: Chapter NR 812 Well Construction and Pump Installation (action-specific). Requirements for installing water supply wells and extracting groundwater.

4.7.3 Long-term Effectiveness and Permanence

Alternative 1 (No Action) would not be effective in reducing the risk associated with contaminated groundwater and provides no controls to prevent exposure over time.

Alternative 2 (MNA and Alternate Water Supply) offers a long-term solution as groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. Alternative 2 would be the least effective alternative.

Alternative 3 (Pump and Treat) would reduce DNT concentrations through groundwater removal and treatment. Maintaining hydraulic control of groundwater must occur throughout the treatment process to be effective.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would reduce DNT concentrations through in-situ anaerobic biodegradation. The bioremediation process permanently destroys the groundwater contaminants. Both alternatives would be an effective long-term solution. Alternative 6 would only reduce DNT concentrations near the source areas of the DBG and PBG. Alternative 4 would be the most effective long-term alternative and the most permanent for treatment of DNT contaminated groundwater.

Alternative 5 (Well Replacement) would provide receptors with long-term access to clean potable water. Groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. This alternative would be an effective long-term and permanent solution.

4.7.4 Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment

Alternative 1 (No Action) would not reduce the toxicity, mobility, and volume of contaminants because it does not include a treatment component. This alternative does not meet the statutory preference for the use of treatment as a principal element for the reduction of toxicity, mobility, and volume of hazardous substances.

All other alternatives, except Alternative 2 (MNA and Alternate Water Supply) and Alternative 5 (Well Replacement), have the potential to be effective at reducing the toxicity, mobility, and volume of the COCs through treatment. Alternatives 2 and 5 would have limited reductions in toxicity, mobility, and volume as the contaminants would only naturally degrade.

Alternative 3 (Pump and Treat) would use groundwater extraction and treatment to decrease the toxicity and volume of impacted groundwater and decrease the mobility of groundwater impacts through hydraulic control.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would achieve the greatest overall decrease in toxicity and volume of the DNT in groundwater through in-situ anaerobic biodegradation.

4.7.5 Short-Term Effectiveness

Alternative 1 (No Action) would have no short-term impacts and not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) would have no short-term impacts and no additional work associated with implementation.

Alternative 3 (Pump and Treat) would have moderate short-term impacts to workers, residents and the environment during implementation. Construction of extraction wells, mobile treatment units, and underground discharge piping would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternatives 4 (In-Situ Anaerobic Bioremediation) and 6 (Source Area Treatment) would have moderate short-term impacts to workers, residents, and the environment during implementation.

Installation of the temporary vertical injection wells would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternative 5 (Well Replacement) would have moderate short-term impacts to workers, residents and the environment during implementation. Installation of new homeowner wells would cause impacts to private property.

4.7.6 Implementability

Alternative 1 (No Action) would be easy to implement as it would not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) is the most implementable as it is currently being applied.

Alternatives 3 (Pump and Treat), 4 (In-Situ Anaerobic Bioremediation), and 6 (Source Area Treatment) require drilling and construction activities and would be readily implementable using standard construction equipment. The in-situ injection of the biochemical product under Alternatives 4 and 6 would be more challenging due to varying soil conditions at depth.

4.7.7 Cost

The FS developed the estimated 30-year costs for each alternative. These preliminary cost estimates should be within -30 percent to +50 percent of the actual implementation costs. Table 4.3 shows a summary of the capital costs, O&M costs and total costs.

4.7.8 State Acceptance

Alternatives 1, 2, and 5 may not be acceptable to the WDNR because they would not perform any active groundwater remediation and would not achieve the RAOs. Alternative 6 may not be acceptable to the WDNR because it would only treat groundwater near the source areas and would not prevent potential human exposure to the groundwater contamination migrating off-site. Alternatives 3 and 4 may be acceptable to the WDNR based on permanence, long-term protectiveness, and effectiveness. Ultimate WDNR acceptance will be determined during the remedial design phase.

4.7.9 Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends. The community's comments will be described and addressed in the ROD.

Table 4.3
Cost Estimates for Alternatives
Deterrent Burning Ground Plume

	Alternative	Capital Cost	Long-Term Operating Cost	Contingency	Total Cost
1	No Action (Groundwater LUCs)	$0	$0	$0	$0
2	MNA & Alternate Water Supply (Groundwater LUCs and Sampling)	$0	$4,240,490	$0	$4,240,490
3	Active GW Remediation - Pump & Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$3,470,038	$8,522,395	$555,206	$12,547,639
4	Active GW Remediation - Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$10,134,835	$706,748	$1,621,574	$12,463,156
5	Well Replacement - Plume Area (MNA, Groundwater LUCs and Sampling)	$2,850,000	$3,839,123	$456,000	$7,145,123
6	Source Area Treatment - Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$807,038	$4,240,490	$129,126	$5,176,654

4.8 Summary of the Preferred Alternative for DBG Plume

The Army's preferred remedial alternative is Active Groundwater Remediation - Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling) - Alternative 4. Alternative 4 will target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Alternative 4 will include in-situ bioremediation (biochemical) treatment utilizing temporary vertical injection wells to administer the biochemical product into the contaminant plume. The vertical injection locations will be located both on-site and off-site. Shown on Figure 15 is a conceptual plan for in-situ bioremediation treatment (Alternative 4) with the anticipated treatment lines of vertical injection wells. The locations of the vertical injection wells and the horizontal and vertical extent of in-situ treatment will be determined during the remedial design phase.

The preferred remedial action for the DBG Plume will reduce potential exposure risks associated with the contaminated groundwater. The in-situ treatment of DNT in the DBG Plume will positively affect groundwater by reducing the potential for DNT impacted groundwater to migrate downgradient towards residential properties. Groundwater monitoring and MNA will verify contaminant level reduction and provide protection to residential drinking water supplies. LUCs will restrict groundwater use within the property boundaries of the BAAP. These LUCs will continue until COC levels in groundwater allow for unrestricted use and unlimited exposure. If needed, the remedial action will also include a provision for an alternate water supply condition including bottled water or well replacement.

5.0 CENTRAL PLUME

5.1 Site Background

The source of DNT contaminated groundwater in the Central Plume is located in the north-central portion of BAAP (see Figure 2). The production of NG, rocket paste, and rocket propellant occurred there. These production areas were not connected to the main industrial sewer network. The production related wash waters were discharged to open ditches and may have contributed to groundwater contamination.

Soil removal activities were conducted around production buildings and along ditches and drainage pathways leading from the Nitroglycerin, Rocket Paste, and Rocket Propellant production areas. In addition, sewer removal and adjacent soil excavations were completed. The Army has not conducted any active groundwater remediation in the Central Plume.

5.2 Groundwater Contamination

As described above, the source of groundwater contamination was the discharge of production related water to open ditches and ponds. The Central Plume is approximately 3.5 miles long and extends south beyond the BAAP boundary. Outside of BAAP, the plume continues south towards Gruber's Grove Bay (connected to the Wisconsin River). Figure 16 displays the current monitoring well and residential well sampling frequencies associated with the Central Plume. Currently, groundwater contamination is being monitored through recurring sampling as directed by the WDNR. Groundwater contamination remains in the surficial sand and gravel aquifer and has not migrated into the bedrock.

Groundwater data collected during and prior to 2018 is summarized in the RI/FS. Detected concentrations from groundwater samples collected from 2019 to 2023 were compared to the Wisconsin Chapter NR 140 ES and PAL and the USEPA cancer-based and noncancer-based tapwater regional screening levels (screening levels). The following chemicals exceeded the screening levels and were identified as COPCs for the Central Plume:

Table 5.1
Groundwater COPCs
Central Plume

Contaminants of Potential Concern (COPCs)	Maximum Concentration 2019 - 2023	Chapter NR 140 Wisconsin Groundwater Quality Standards		Well & Date of Maximum Concentration
		Preventive Action Limit (PAL)	Enforcement Standard (ES)	
Chloroform	2.1	0.6	6	WE-SQ001 (8/14/19)
Total Dinitrotoluene (2)	0.336	0.005	0.05	NLN-1001C (7/5/22)
2,4-Dinitrotoluene (1)	0.073	0.005	0.05	NLN-1001C (6/10/20)
2,6-Dinitrotoluene (1)	0.064	0.005	0.05	NLN-1001C (6/10/20)

Notes:

(1) The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (Total DNT).

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

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

Figure 17 is a total DNT isoconcentration map for the Central Plume. The isoconcentration map was prepared using all groundwater data collected during 2023. The total DNT isoconcentrations shown on Figure 17 are broken into two-color designations. The green shaded areas indicate where total DNT is above the NR 140 PAL (0.005 µg/l). The blue shaded areas indicate where total DNT is above the NR 140 ES (0.05 µg/l). The northern section of the Central Plume contains the highest concentrations of total DNT. The highest concentration of total DNT (0.336 µg/l), detected during July 2022, was in monitoring well NLN-1001C. Total DNT concentrations in the northern section of the Central Plume have been increasing. Total DNT concentrations near the BAAP boundary and the leading edge of the Central Plume have been decreasing.

Chloroform has exceeded the NR 140 PAL in monitoring wells and residential wells south of the BAAP boundary. Upgradient monitoring wells have not seen chloroform exceedances. There has been no source of chloroform identified in the Central Plume. Chloroform concentrations have remained stable. Due to the limited extent of chloroform detections, an isoconcentration map was not prepared.

5.3 Scope and Role of the Proposed Action

The scope and role of the action discussed in this PP includes all the groundwater remedial actions planned for the Central Plume. The preferred groundwater remedial action will reduce potential risks associated with exposure to contaminated groundwater in the sand and gravel aquifer. Using treatment technologies, this response will reduce the toxicity, mobility, and volume of source materials that constitute the principal threat.

Local residents have historically used groundwater outside the BAAP boundary as a drinking water source. The Army has replaced three residential wells, due to DNT impacts, in the Central Plume. Two residential wells were installed in 2005 and one well in 2018. The use of groundwater for human consumption will continue in the future. When establishing the RAOs for this response action, the Army has considered the NCP's expectation to return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The Army intends to return the contaminated sand and gravel aquifer at BAAP to its potential beneficial uses, which is considered to be total DNT concentrations below the NR 140 ES, to the extent practicable. If a return to potential beneficial use is not practicable, the expectation is to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction.

5.4 Summary of Site Risks

The Army performed a risk assessment to determine and document whether groundwater contamination in the Central Plume poses a risk to human health. CERCLA requires the completion of a HHRA prior to selecting a remedial alternative. The HHRA must evaluate the potential human health risks associated with chemical exposure to environmental media (e.g., groundwater, vapor). The HHRA was conducted using standard USEPA risk assessment guidance, exposure assumptions, and toxicity factors. The USEPA risk assessment process uses conservative assumptions about exposure to chemicals and their toxicity so that risks reported are not underestimated. In all circumstances, priority was given to evaluating the potential human health risk regardless of the impact. The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion.

Domestic Groundwater Risk

Groundwater located in the Central Plume and within the BAAP boundary is not used for human consumption. The former BAAP land was transferred from the Army to other property owners and includes a deed restriction on the use of groundwater. This 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."

Beyond the boundary of BAAP, the Army cannot control groundwater use. Residential wells located outside of BAAP use groundwater for potable water and domestic purposes. There is potential for the installation and use of additional residential wells outside of BAAP. Current and future 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.

The human health risks were evaluated using groundwater data from residential wells and monitoring wells. The maximum groundwater concentration of each COPC during 2019, 2020, 2021, 2022, and 2023 were used to estimate the risk. The groundwater risk estimates were calculated for each COPC using the maximum groundwater concentrations and a simple scaling method described in Section 2.6.1 of the USEPA's RSLs – User's Guide (November 2023). These calculations use the USEPA's RSL Resident Tapwater Generic Table (November 2023). The calculated cancer and non-cancer risks for each COPC and the cumulative cancer and non-cancer risks for the Central Plume are summarized in Appendix A - 2019-2023 Screening Level Groundwater Risk Evaluation Summary Tables.

The results of the HHRA determined that contaminated groundwater in the Central Plume poses an unacceptable risk to groundwater usage by humans. Provided below is a summary of exposure risks for the Central Plume.

Central Plume Risk Summary

Based on the groundwater monitoring data from 2019 to 2023, the risk-based COCs identified in the Central Plume were chloroform and total DNT.

- Chloroform had a cancer risk above the risk management criteria. Chloroform concentrations were below the NR 140 ES. Therefore, remedial alternatives were not evaluated for chloroform.
- Total DNT had a cancer risk above the risk management criteria. Total DNT concentrations were above the NR 140 ES.

Total DNT (all six DNT isomers) was 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).

Table 5.2
Groundwater COCs & Cleanup Levels
Central Plume

COC (1)	Cancer Risk	Non-Cancer Risk	Groundwater Cleanup Level (2)
Chloroform	X	none	6
Total Dinitrotoluene	X	none	0.05

Notes:
(1) COC (Contaminant of Concern)
(2) The Groundwater Cleanup Level is the NR 140 Enforcement Standard (ES)
Based on analytical lab results from residential and groundwater monitoring well samples from 2019, 2020, 2021, 2022, and 2023.
All concentration values are expressed in micrograms-per-liter (µg/l)

Vapor Intrusion Risk

The vapor intrusion pathway was considered in the HHRA. An evaluation was conducted to determine whether vapors from the Central Plume 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 (e.g., contaminated groundwater) into an overlying building. The exposure route evaluated was the inhalation of contaminants from indoor air. The HHRA did not identify vapor intrusion risks from groundwater contamination.

5.5 Remedial Action Objectives

The following RAOs were developed for the Central Plume:

- Protect human health by preventing human exposure to contaminated groundwater.
- Restore the groundwater aquifer to beneficial use (i.e., for potable purposes) within a reasonable time frame wherever practicable, based upon site conditions, by reducing contaminant concentrations in groundwater to levels that comply with chemical-specific ARARs.
- Minimize the impact of contaminated groundwater on the environment.

The RAOs for the Central Plume will be achieved when the risk-based groundwater COCs are below the groundwater cleanup levels (NR 140 ES) shown in Table 5.2.

5.6 Summary of Remedial Alternatives

The FS identified and screened remedial technologies and associated process options that may be appropriate for satisfying the RAOs with respect to effectiveness, implementability, and cost. A source area alternative was not developed for the Central Plume because there are no known remaining source areas. All remediation costs utilize 30 years of implementation (including groundwater monitoring). For alternatives taking longer than 30 years to achieve RAOs, costs would be considerably higher. The Army developed the following remedial alternatives from the retained remedial technologies carried forward after the initial screening. Remedial alternatives were based on achieving the NR 140 ES groundwater standard.

- **Alternative 1 – No Action (Groundwater LUCs)**, as required by the NCP. Alternative 1 would have no impact on the Central Plume 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, LUCs will restrict groundwater use within the property boundaries of the former BAAP boundary.

- **Alternative 2 – Monitored Natural Attenuation (MNA) and Alternate Water Supply (Groundwater LUCs and Sampling).** Alternative 2 would include MNA, LUCs consisting of on-site groundwater access restrictions and a provision for an alternate water supply condition for residential wells. Alternative 2 would also continue residential and monitoring well sampling.

- **Alternative 3 – Active Groundwater Remediation – Pump and Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 3 would include groundwater extraction and treatment with mobile treatment units, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 3 would also continue residential and monitoring well sampling.

- **Alternative 4 – Active Groundwater Remediation – Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling).** Alternative 4 would include in-situ anaerobic biodegradation of groundwater contaminants, MNA, LUCs consisting of on-site groundwater access restrictions, and a provision for an alternate water supply condition for residential wells. Alternative 4 would also continue residential and monitoring well sampling. Alternative 4 would target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts will be inclusive of all six DNT isomers (total DNT). Alternative 4 would include in-situ bioremediation (biochemical) treatment utilizing temporary vertical injection wells to administer the biochemical product into the Central Plume. The biochemical product would consist of a nutrient-enriched emulsified vegetable oil (EVO). The EVO would be distributed in the groundwater as an oil-in-water emulsion (mixture). The oil-in-water emulsion would be prepared using a food-grade oil, food-grade surfactants, and clean water. Once injected into the groundwater, the EVO mixture would stimulate anaerobic biodegradation of the DNT. The vertical injection locations would be located both on-site and off-site. At each injection location, the EVO mixture would be pumped into various depths within the Central Plume. This method would treat both the horizontal and vertical extent of DNT contaminated groundwater.

- **Alternative 5 – Well Replacement – Plume Area (MNA, Groundwater LUCs and Sampling).** Alternative 5 would involve replacing shallow aquifer residential wells (meeting replacement criteria) within the Central Plume area with deeper aquifer wells, MNA and LUCs consisting of on-site groundwater access restrictions. Alternative 5 would also continue residential and monitoring well sampling.

The Army developed active remedial alternatives specifically for elevated concentrations of 2,6-DNT in the Central Plume. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT).

5.7 Evaluation of Alternatives for Central Plume

This section compares the remedial alternatives summarized above to each other using the nine criteria set forth in 40 CFR 300.430(e)(9)(iii). The nine criteria were presented above in Section 3.8. In the remedial decision-making process, USEPA describes the relative performance of each alternative against the evaluation criteria and notes how each alternative compares to the other alternatives under consideration. The FS contains a detailed analysis of the alternatives.

5.7.1 Overall Protection of Human Health and the Environment

The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion. The HHRA did not identify risks to groundwater through vapor intrusion. The results of the HHRA indicated that domestic groundwater use poses a current (off-site) risk to human health.

The five alternatives provide varying levels of human health protection and the environmental protection.

Alternative 1 (No Action) would not be protective of human health or the environment. This alternative would still restrict groundwater usage within the BAAP boundary. This alternative would result in the Army terminating the residential and monitoring well sampling program. Alternative 1 fails this threshold criterion.

Alternative 2 (MNA and Alternate Water Supply) 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.

Alternatives 3 (Pump and Treat) and 4 (In-Situ Anaerobic Bioremediation would provide protection of human health and the environment by reducing the groundwater contaminants. They would also restrict groundwater usage within the BAAP boundary. The provision of the alternate water supply condition would address concerns associated with residential well impacts. The groundwater sampling program would monitor the groundwater concentrations for compliance and contaminant reduction.

Alternative 5 (Well Replacement) would be protective of human health but not the environment. The Army would provide clean potable water to potential domestic groundwater users. There would be no route of entry through groundwater consumption, eliminating the risk of exposure through groundwater. There would be no active groundwater remediation performed. Alternative 5 fails this threshold criterion.

5.7.2 Compliance with ARARs

CERCLA and the NCP require that remedial actions at least attain legally applicable or relevant and appropriate Federal and State requirements, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law, which are collectively referred to as "ARARs," unless such ARARs can be waived. The USEPA defines three types of ARARs: action-specific, chemical-specific, and location-specific.

Alternative 1 (No Action) would not comply with ARARs and provide no groundwater monitoring.

Alternatives 2, 3, 4, and 5 would comply with ARARs. The evaluation did not identify any location-specific ARARs. Listed below are the ARARs that apply.

- National Primary Drinking Water Regulations: 40 CFR Part 141 Subpart G (chemical-specific).
- Wisconsin Groundwater Standards: Chapter NR 140 Groundwater Quality (chemical-specific).
- Residential Well Construction Standards: Chapter NR 812 Well Construction and Pump Installation (action-specific). Requirements for installing water supply wells and extracting groundwater.

5.7.3 Long-term Effectiveness and Permanence

Alternative 1 (No Action) would not be effective in reducing the risk associated with contaminated groundwater and provides no controls to prevent exposure over time.

Alternative 2 (MNA and Alternate Water Supply) offers a long-term solution as groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. Alternative 2 would be the least effective alternative.

Alternative 3 (Pump and Treat) would reduce DNT concentrations through groundwater removal and treatment. Maintaining hydraulic control of groundwater must occur throughout the treatment process to be effective.

Alternative 4 (In-Situ Anaerobic Bioremediation) would reduce DNT concentrations through in-situ anaerobic biodegradation. The bioremediation process permanently destroys the groundwater contaminants. Alternative 4 would be an effective long-term solution. Alternative 4 would be the most effective long-term alternative and the most permanent for treatment of DNT contaminated groundwater.

Alternative 5 (Well Replacement) would provide receptors with long-term access to clean potable water. Groundwater concentrations are expected to decrease as the chemicals would undergo a slow natural degradation process. This alternative would be an effective long-term and permanent solution.

5.7.4 Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment

Alternative 1 (No Action) would not reduce the toxicity, mobility, and volume of contaminants because it does not include a treatment component. This alternative does not meet the statutory preference for the use of treatment as a principal element for the reduction of toxicity, mobility, and volume of hazardous substances.

All other alternatives, except Alternative 2 (MNA and Alternate Water Supply) and Alternative 5 (Well Replacement), have the potential to be effective at reducing the toxicity, mobility, and volume of the COCs through treatment. Alternatives 2 and 5 would have limited reductions in toxicity, mobility, and volume as the contaminants would only naturally degrade.

Alternative 3 (Pump and Treat) would use groundwater extraction and treatment to decrease the toxicity and volume of impacted groundwater and decrease the mobility of groundwater impacts through hydraulic control.

Alternative 4 (In-Situ Anaerobic Bioremediation) would achieve the greatest overall decrease in toxicity and volume of the DNT in groundwater through in-situ anaerobic biodegradation.

5.7.5 Short-Term Effectiveness

Alternative 1 (No Action) would have no short-term impacts and not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) would have no short-term impacts and no additional work associated with implementation.

Alternative 3 (Pump and Treat) would have moderate short-term impacts to workers, residents and the environment during implementation. Construction of extraction wells, mobile treatment units, and underground discharge piping would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternative 4 (In-Situ Anaerobic Bioremediation) would have moderate short-term impacts to workers, residents, and the environment during implementation. Installation of the temporary vertical injection wells would cause the impacts. Both on-site and off-site construction would occur. Once construction was completed, short-term impacts would be limited to vehicle activity.

Alternative 5 (Well Replacement) would have moderate short-term impacts to workers, residents and the environment during implementation. Installation of new homeowner wells would cause impacts to private property.

5.7.6 Implementability

Alternative 1 (No Action) would be easy to implement as it would not involve site activities.

Alternative 2 (MNA and Alternate Water Supply) is the most implementable as it is currently being applied.

Alternatives 3 (Pump and Treat), 4 (In-Situ Anaerobic Bioremediation), and 6 (Source Area Treatment) require drilling and construction activities and would be readily implementable using standard construction equipment. The in-situ injection of the biochemical product under Alternative 4 would be more challenging due to varying soil conditions at depth.

5.7.7 Cost

The FS developed the estimated 30-year costs for each alternative. These preliminary cost estimates should be within -30 percent to +50 percent of the actual implementation costs. Table 5.3 shows a summary of the capital costs, O&M costs and total costs.

5.7.8 State Acceptance

Alternatives 1, 2, and 5 may not be acceptable to the WDNR because they would not perform any active groundwater remediation and would not achieve the RAOs. Alternatives 3 and 4 may be acceptable to the WDNR based on permanence, long-term protectiveness, and effectiveness. Ultimate WDNR acceptance will be determined during the remedial design phase.

5.7.9 Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends. The community's comments will be described and addressed in the ROD.

Table 5.3
Cost Estimates for Alternatives
Central Plume

	Alternative	Capital Cost	Long-Term Operating Cost	Contingency	Total Cost
1	No Action (Groundwater LUCs)	$0	$0	$0	$0
2	MNA & Alternate Water Supply (Groundwater LUCs and Sampling)	$0	$2,398,538	$0	$2,398,538
3	Active GW Remediation - Pump & Treat (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$8,674,059	$7,953,709	$1,387,849	$18,015,617
4	Active GW Remediation - Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling)	$20,103,428	$399,756	$3,216,548	$23,719,733
5	Well Replacement - Plume Area (MNA, Groundwater LUCs and Sampling)	$1,150,000	$1,997,172	$184,000	$3,331,172

5.8 Summary of the Preferred Alternative for Central Plume

The Army's preferred remedial alternative is Active Groundwater Remediation - Anaerobic Bioremediation (Alternate Water Supply, MNA, Groundwater LUCs and Sampling) - Alternative 4. Alternative 4 will target remediating the impacted groundwater with elevated DNT concentrations. The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (total DNT). Alternative 4 will include in-situ bioremediation (biochemical) treatment utilizing temporary vertical injection wells to administer the biochemical product into the contaminant plume. The vertical injection locations will be located both on-site and off-site. Shown on Figure 18 is a conceptual plan for in-situ bioremediation treatment (Alternative 4) with the anticipated treatment lines of vertical injection wells. The locations of the vertical injection wells and the horizontal and vertical extent of in-situ treatment will be determined during the remedial design phase.

The preferred remedial action for the Central Plume will reduce potential exposure risks associated with the contaminated groundwater. The in-situ treatment of DNT in the Central Plume will positively affect groundwater by reducing the potential for DNT impacted groundwater to migrate downgradient towards residential properties. Groundwater monitoring and MNA will verify contaminant level reduction and provide protection to residential drinking water supplies. LUCs will restrict groundwater use within the property boundaries of the BAAP. These LUCs will continue until COC levels in groundwater allow for unrestricted use and unlimited exposure. If needed, the remedial action will also include a provision for an alternate water supply condition including bottled water or well replacement.

6.0 NITROCELLULOSE PRODUCTION AREA PLUME

6.1 Site Background

The northwest portion of BAAP is the source of DNT contaminated groundwater in the Nitrocellulose Production Area (NC Area) Plume (see Figure 2). The production of smokeless gunpowder and NC occurred in this area. DNT was a component of the manufacturing process. These production areas were connected to the main industrial sewer network. The production related wastewater may have leaked into the soil beneath the piping network or beneath the production buildings.

Soil investigation and subsequent contaminated soil excavation activities were conducted around and beneath production buildings. The former DNT Screen House (located in the middle of the NC Area Plume) was identified as a specific source of DNT contamination. Containers of solid DNT were brought to the DNT Screen House. The solid DNT was ground up and screened to remove foreign material. The screened DNT was then distributed to mixing operations within the NC Production Area. DNT contaminated soil was excavated from around a sewer sump, around and beneath the DNT Screen House. Beneath some building basements, DNT contaminated soil was identified and then excavated. In addition, the industrial sewers were removed and the surrounding soil excavated. The Army has not conducted any active groundwater remediation in the NC Area Plume.

6.2 Groundwater Contamination

As described above, the source of groundwater contamination was the discharge of production related wastewater and production activities. Figure 19 displays the current monitoring well sampling frequency associated with the NC Area Plume. The NC Area Plume is approximately ¾ mile long and ¼ mile wide. The extent of the NC Area Plume remains within the BAAP boundary. In the future, the NC Area Plume could comingle with the PBG Plume. There are no residential wells located within 2 miles downgradient (south) of the NC Area Plume. Currently, groundwater contamination is being monitored through recurring sampling as directed by the WDNR. Groundwater contamination remains in the surficial sand and gravel aquifer and has not migrated into the bedrock.

Groundwater data collected during and prior to 2018 is summarized in the RI/FS. Detected concentrations from groundwater samples collected from 2019 to 2023 were compared to the Wisconsin Chapter NR 140 ES and PAL and the USEPA cancer-based and noncancer-based tapwater regional screening levels (screening levels). The following chemicals exceeded the screening levels and were identified as COPCs for the NC Area Plume:

Table 6.1
Groundwater COPCs
Nitrocellulose Production Area Plume

Contaminants of Potential Concern (COPCs)	Maximum Concentration 2019-2023	Chapter NR 140 Wisconsin Groundwater Quality Standards		Well & Date of Maximum Concentration
		Preventive Action Limit (PAL)	Enforcement Standard (ES)	
Total Dinitrotoluene (2)	0.144	0.005	0.05	RIM-0705 (9/13/22)
2,4-Dinitrotoluene (1)	0.062	0.005	0.05	RIM-1002 (4/23/19)
2,6-Dinitrotoluene (1)	0.097	0.005	0.05	RIM-0705 (9/13/22)

Notes:
(1) The Army's groundwater remediation efforts at BAAP will be inclusive of all six DNT isomers (Total DNT).
(2) Total DNT consists of isomers (2,3-DNT; 2,4-DNT; 2,5-DNT; 2,6-DNT; 3,4-DNT; 3,5-DNT)
All concentration values are expressed in micrograms-per-liter (µg/l)

Figure 20 is a total DNT isoconcentration map for the NC Area Plume. The isoconcentration map was prepared using all groundwater data collected during 2023. The total DNT isoconcentrations shown on Figure 20 are broken into two-color designations. The green shaded areas indicate where total DNT is above the NR 140 PAL (0.005 µg/l). The blue shaded areas indicate where total DNT is above the NR 140 ES (0.05 µg/l). The highest concentration of total DNT (0.144 µg/l), detected during September 2022, was in monitoring well RIM-0705. RIM-0705 is located in the north central portion of the NC Area Plume. Total DNT concentrations in the NC Area Plume have been stable.

6.3 Scope and Role of the Proposed Action

The scope and role of the action discussed in this PP includes all the groundwater remedial actions planned for the NC Area Plume. The preferred groundwater remedial action will reduce potential risks associated with exposure to contaminated groundwater in the sand and gravel aquifer.

Local residents have historically used groundwater outside the BAAP boundary as a drinking water source. The NC Area Plume is expected to remain within the BAAP boundary and not impact off-site drinking water. When establishing the RAOs for this response action, the Army has considered the NCP's expectation to return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The Army intends to return the contaminated sand and gravel aquifer at BAAP to its potential beneficial uses, which is considered to be total DNT concentrations below the NR 140 ES, to the extent practicable.

6.4 Summary of Site Risks

The Army performed a risk assessment to determine and document whether groundwater contamination in the NC Area Plume poses a potential current or hypothetical future risk to human health. CERCLA requires the completion of a HHRA prior to selecting a remedial alternative. The HHRA must evaluate the potential human health risks associated with chemical exposure to environmental media (e.g., groundwater, vapor). The HHRA was conducted using standard USEPA risk assessment guidance, exposure assumptions, and toxicity factors. The USEPA risk assessment process uses conservative assumptions about exposure to chemicals and their toxicity so that risks reported are not underestimated. In all circumstances, priority was given to evaluating the potential human health risk regardless of the impact.

The HHRA evaluated two potential human exposure pathways to contaminated groundwater; domestic groundwater uses and vapor intrusion.

Domestic Groundwater Risk

Groundwater located in the NC Area Plume is not used for human consumption. The extent of the NC Area Plume remains within the BAAP boundary, where the Army controls the use of groundwater. The former BAAP land was transferred from the Army to other property owners and includes a deed restriction on the use of groundwater. This 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". There are no residential wells located within two miles downgradient (south) of the NC Area Plume.

The human health risks were evaluated using groundwater data from residential wells and monitoring wells. The maximum groundwater concentration of each COPC during 2019, 2020, 2021, 2022, and 2023 were used to estimate the risk. The groundwater risk estimates were calculated for each COPC using the maximum groundwater concentrations and a simple scaling method described in Section 2.6.1 of the USEPA's RSLs – User's Guide (November 2023). These calculations use the USEPA's RSL Resident Tapwater Generic Table (November 2023). The calculated cancer and non-cancer risks for each COPC and the cumulative cancer and non-cancer risks for the NC Plume are summarized in Appendix A - 2019-2023 Screening Level Groundwater Risk Evaluation Summary Tables.

Both the cancer and non-cancer risk calculations were below the risk management criteria. 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 COCs were identified. The HHRA determined that contaminated groundwater in the NC Area Plume does not pose a risk to groundwater usage by humans.

Table 6.2
Groundwater COCs & Cleanup Levels
Nitrocellulose Production Area Plume

COC (1)	Cancer Risk	Non-Cancer Risk	Groundwater Cleanup Level (2)
Total Dinitrotoluene	none	none	0.05
2,4-Dinitrotoluene	none	none	0.05
2,6-Dinitrotoluene	none	none	0.05

Notes:
(1) COC (Contaminant of Concern)
(2) The Groundwater Cleanup Level is the NR 140 Enforcement Standard (ES)
Based on analytical lab results from residential and groundwater monitoring well samples from 2019, 2020, 2021, 2022, and 2023.
All concentration values are expressed in micrograms-per-liter (μg/l)

Vapor Intrusion Risk

The vapor intrusion pathway was considered in the HHRA. An evaluation was conducted to determine whether vapors from the NC Area Plume 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 (e.g., contaminated groundwater) into an overlying building. There are no on-site buildings located over the NC Area Plume. The HHRA did not identify vapor intrusion risks from groundwater contamination.

6.5 Remedial Alternative Selection

The HHRA did not identify any unacceptable risk to human health or the environment for the NC Area Plume; therefore, the FS did not develop remedial alternatives. Under CERCLA, remedial decisions must be based on risk. If the risk assessment determines there is no risk, then a no-action decision can be made.

Groundwater monitoring will verify contaminant level reduction within the NC Area Plume. The Army will continue to perform groundwater monitoring until the WDNR deems it unnecessary. LUCs will restrict groundwater use within the property boundaries of the BAAP. These LUCs will continue until COPC levels in groundwater allow for unrestricted use and unlimited exposure.

7.0 COMMUNITY PARTICIPATION

The Army will provide information about the BAAP groundwater remediation through public meetings, the Administrative Record File, fact sheets, and announcements in the local newspapers: Baraboo News Republic and Star News. Site documents are available for public review in the Administrative Record File and Information Repository at the Ruth Culver Community Library, 540 Water Street, Prairie du Sac, Wisconsin, and the George Culver Community Library, 615 Phillips Blvd, Sauk City, Wisconsin. The Information Repository includes the various documents containing findings and recommendations pertaining to the remedy, in addition to what are identified in this PP.

The Army routinely holds RAB meetings to inform the public about environmental cleanup activities performed at BAAP. The Army presented information on the RI/FS at the December 5, 2019 RAB meeting. The public meeting about the PP will coincide with the January 16, 2025 RAB meeting.

The Army will review all comments submitted during the comment period. Once reviewed, the Army will make a final decision on a remedial alternative. The public comment period begins on December 16, 2024 and ends on February 28, 2025. Comments must be postmarked or emailed no later than February 28, 2025 to be considered.

The Army, in consultation with the WDNR, will make a final decision on the remedy for BAAP groundwater remediation after the public has had an opportunity to comment. Public comment may lead the Army to modify the proposed remedy. Therefore, the public is encouraged to gain a more comprehensive understanding of the site and comment on this PP, the rationale for the preference for the preferred remedial alternative, and all other remedial alternatives presented during the public comment period. All written comments received during the public comment period will be considered in making a final decision.

The Army will respond to comments received during the public comment period. These responses will be documented in the Responsiveness Summary section of the Record of Decision (ROD). The responses will become part of the site's Administrative Record, in accordance with Section 300.825(a)(2) of the NCP, after the ROD is signed.

HOW TO SUBMIT COMMENTS

There are several ways to comment during the public comment period that runs from December 16, 2024 to February 28, 2025:

Mail comment to:
U.S. Army Environmental Command
ATTN: AMIM-AEC-M/Nguyen
2455 Reynolds Road, Mailstop 112
JBSA Fort Sam Houston, TX 78234-7588

Email comment to:
usarmy.jbsa.imcom-aec.mbx.public-mailbox@army.mil
Please add "BAAP Groundwater Proposed Plan" to the subject line of emails.

The public meeting will be held on January 16, 2025 in Leola Hall at the Sauk Prairie River Arts Center, 105 9th Street, Prairie Du Sac, Wisconsin. An open house will be held from 3:00 – 5:00 p.m. Central Time. The public meeting in conjunction with a RAB meeting will begin at 6:00 p.m. Immediately following the RAB meeting, the public is invited to provide oral comments on the Proposed Plan (for the record). The public meeting can be attended virtually via Microsoft Teams. Virtual public meeting information will be provided to all RAB members and community members on the mailing list, as well as anyone who calls or emails to request the information. Please email usarmy.jbsa.imcom-aec.mbx.public-mailbox@army.mil or call 520-674-2716 to request access to the public meeting.

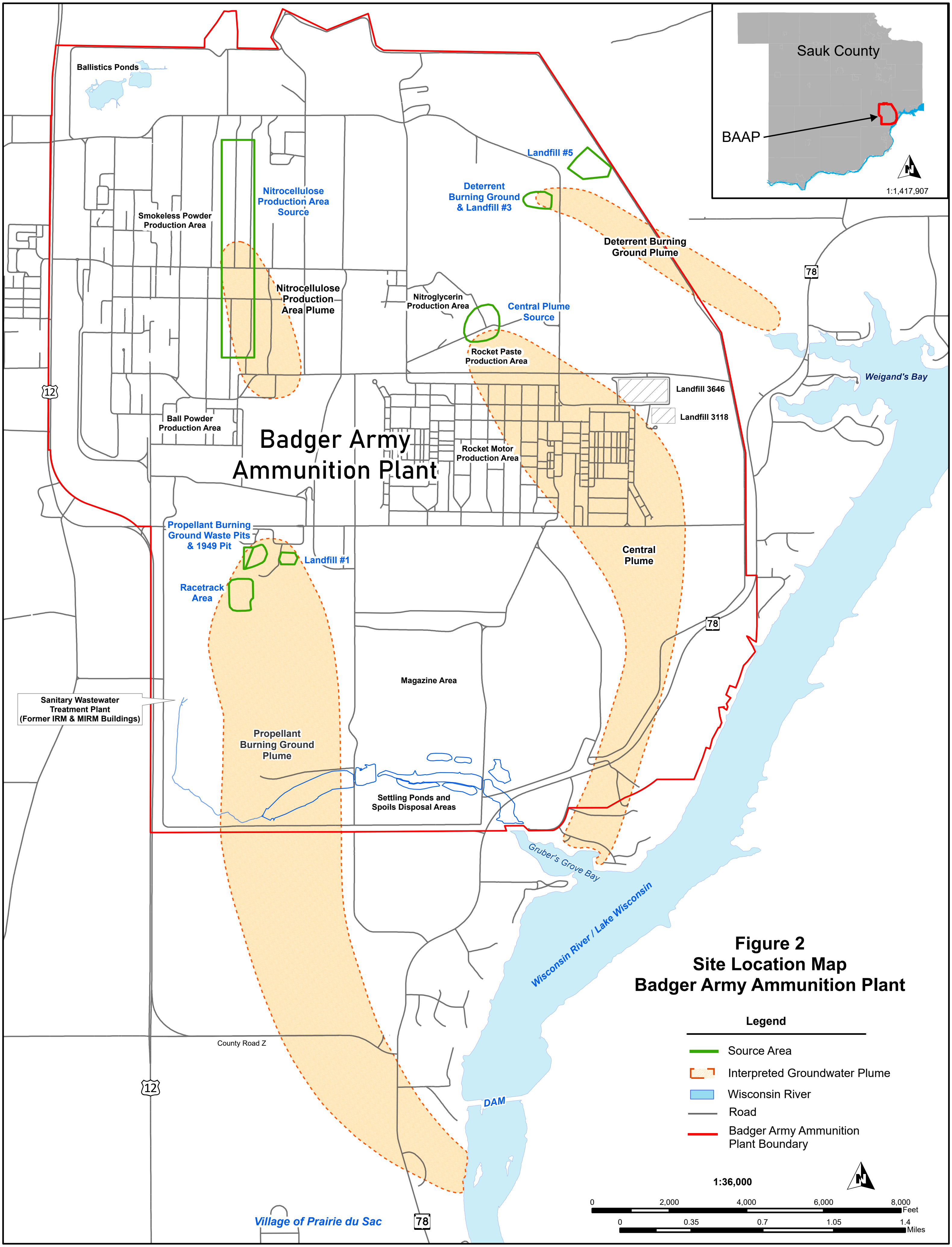
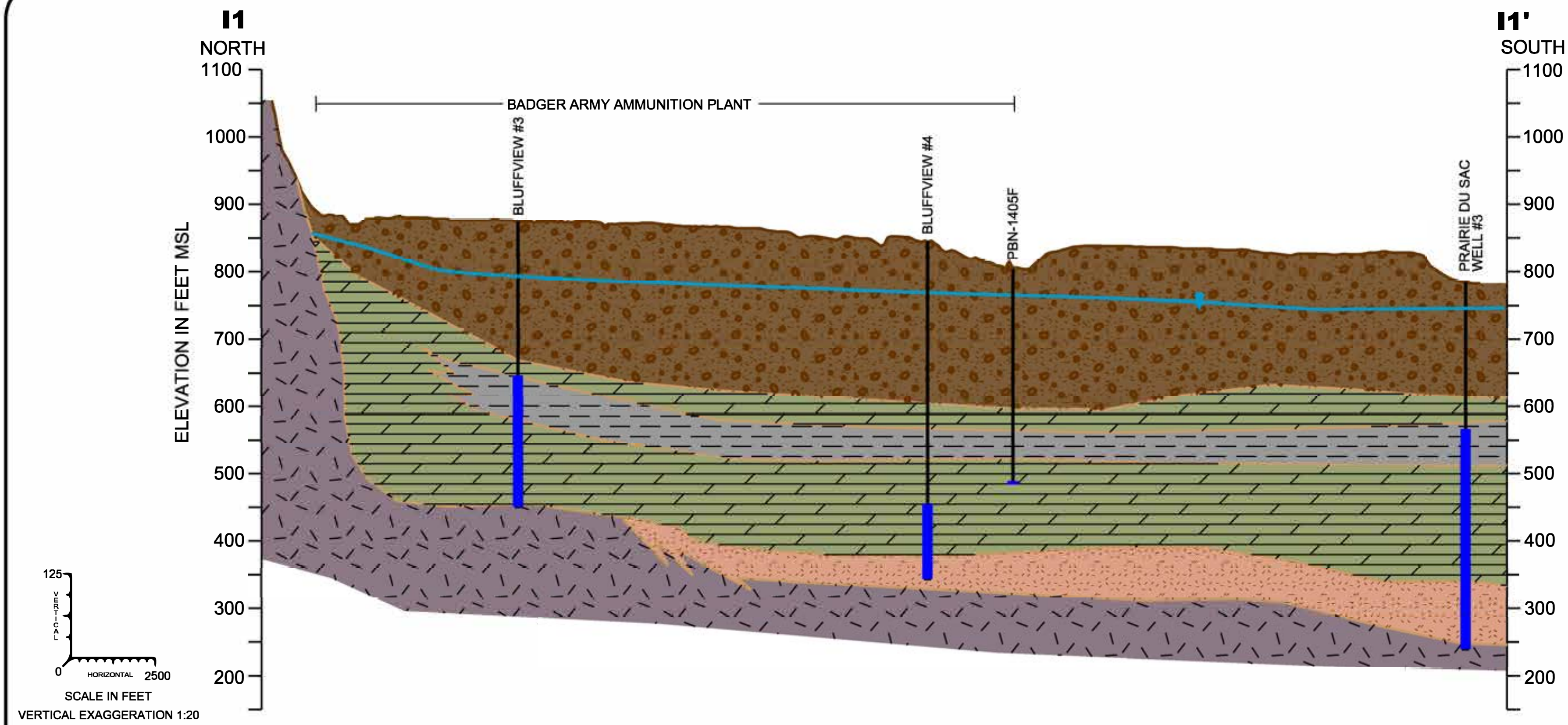


Figure 2
Site Location Map
Badger Army Ammunition Plant



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

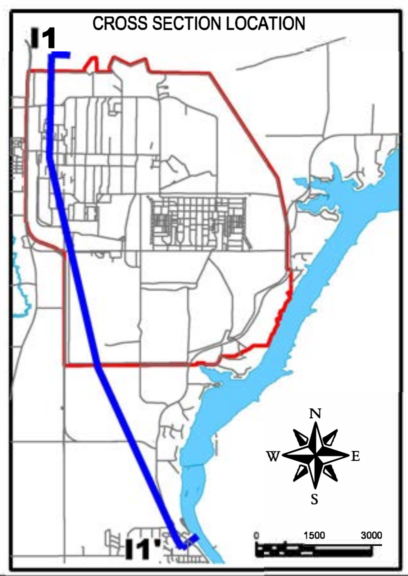
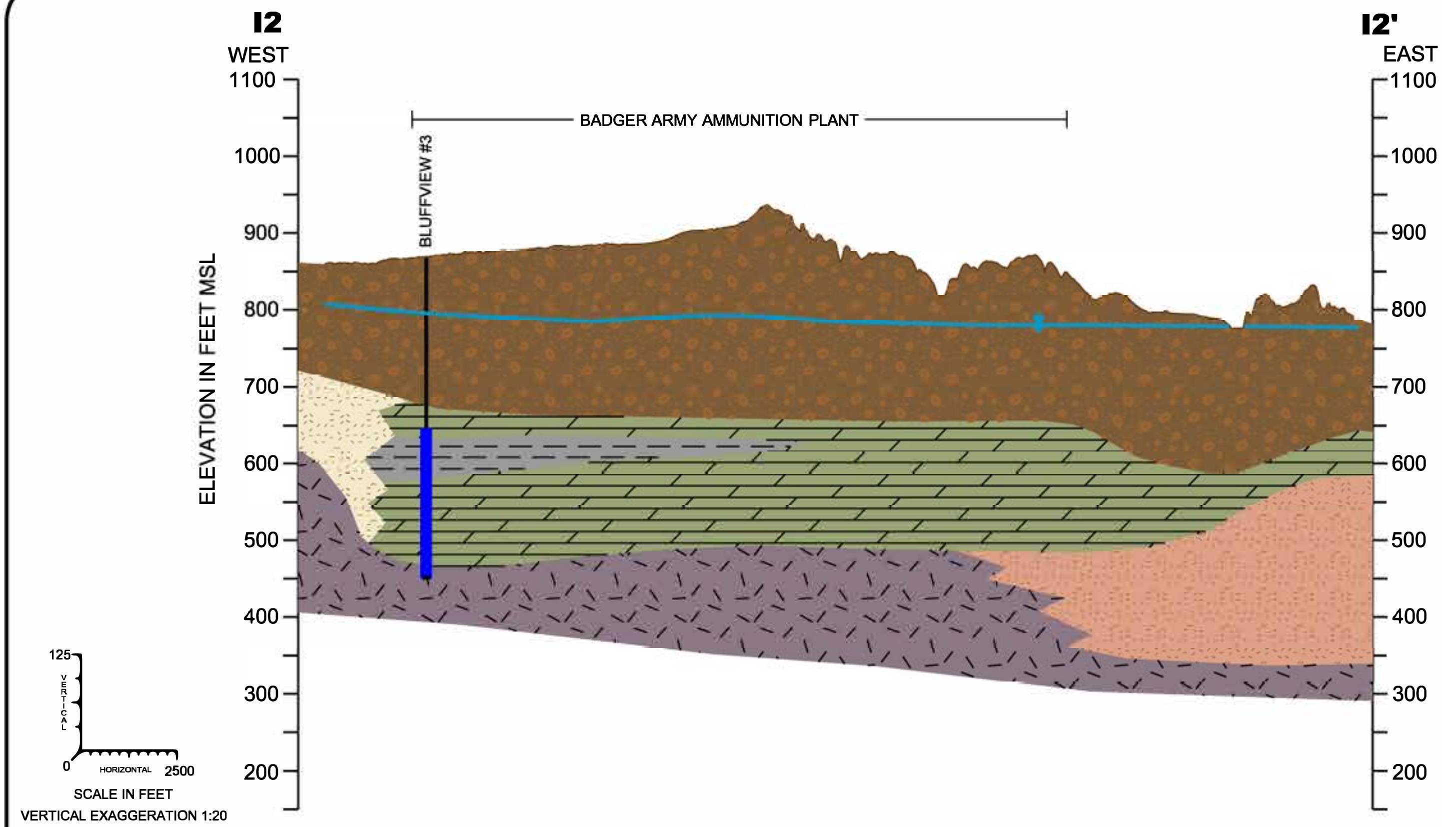


FIGURE 3

GENERALIZED GEOLOGIC CROSS SECTION NORTH-SOUTH BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES



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

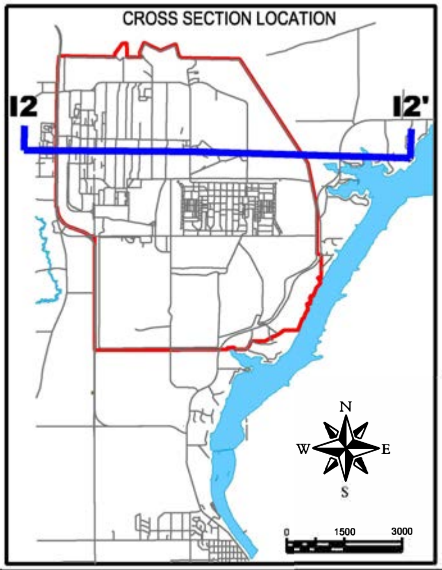
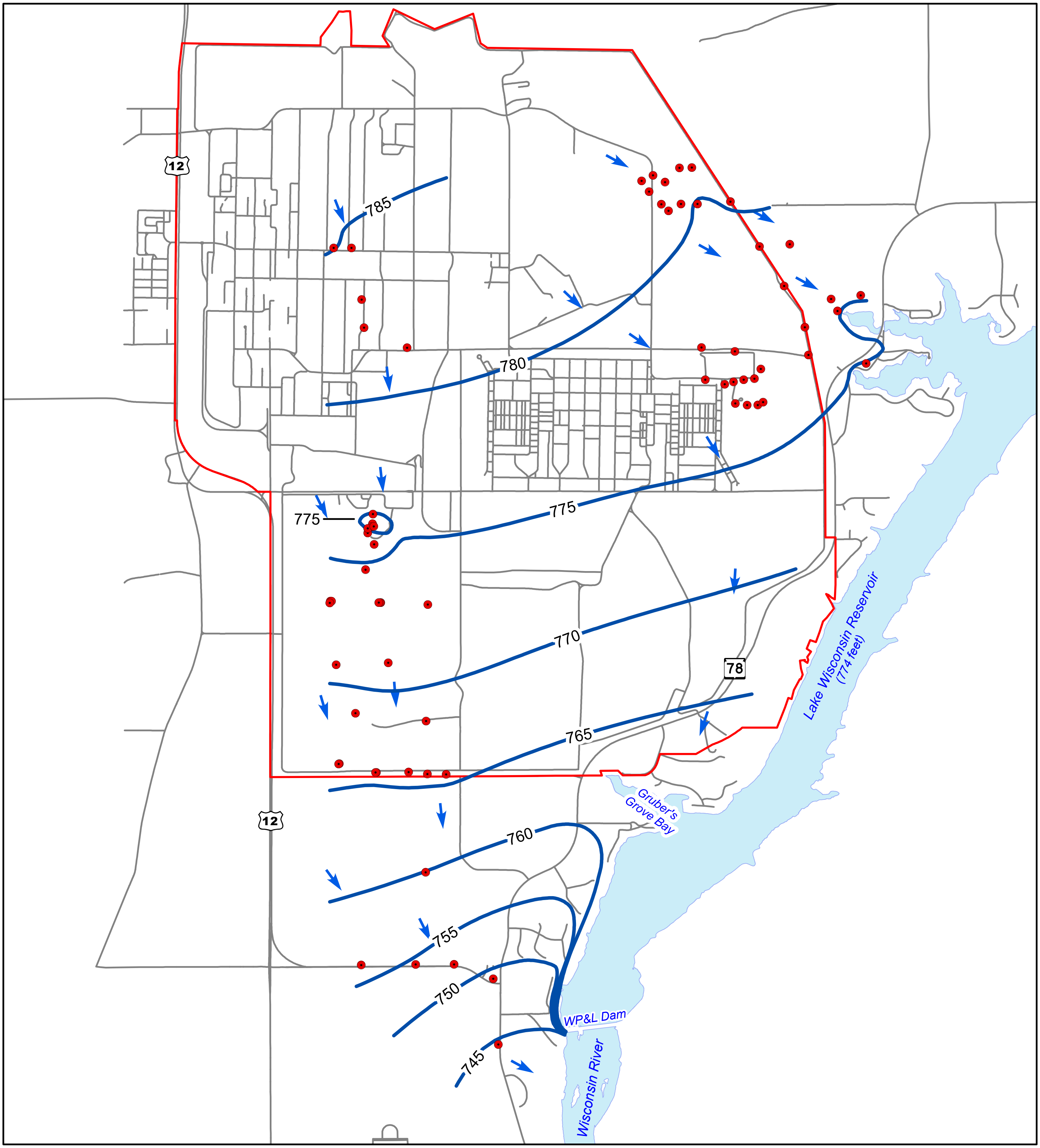


FIGURE 4

GENERALIZED GEOLOGIC CROSS SECTION WEST-EAST BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES



Legend

- Badger Army Ammunition Plant Boundary
- Monitoring Well (used to draw contours)
- Groundwater Contour (2023)
- Contour Interval = 5 feet
- Groundwater Flow Direction
- Road

Figure 5

September 2023 Groundwater Contours
Badger Army Ammunition Plant

1:41,700

0 5,000 10,000 Feet

SPS
SPECPRO PROFESSIONAL SERVICES

N

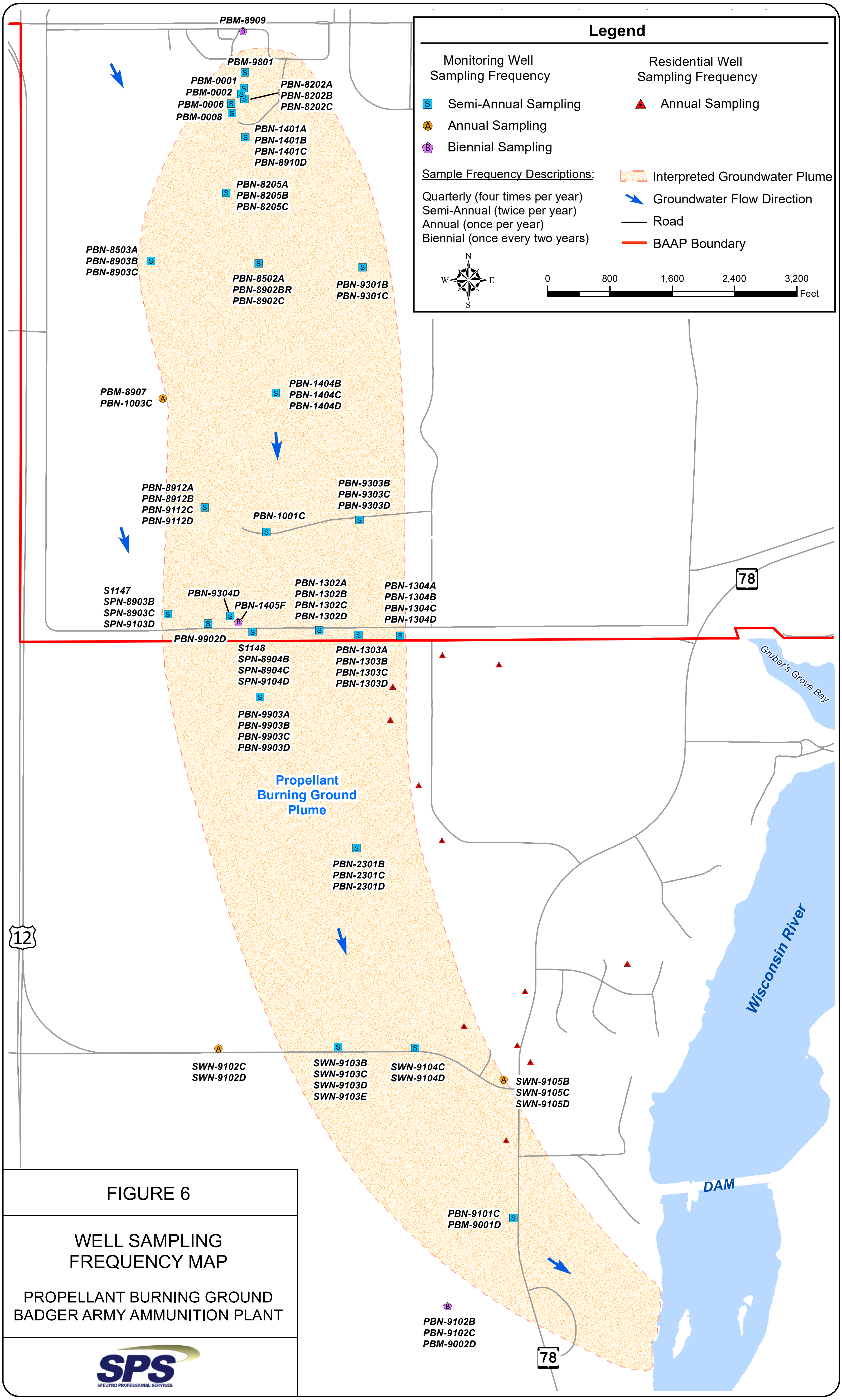


FIGURE 6

WELL SAMPLING FREQUENCY MAP

PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

SPS
SPECPRO PROFESSIONAL SERVICES

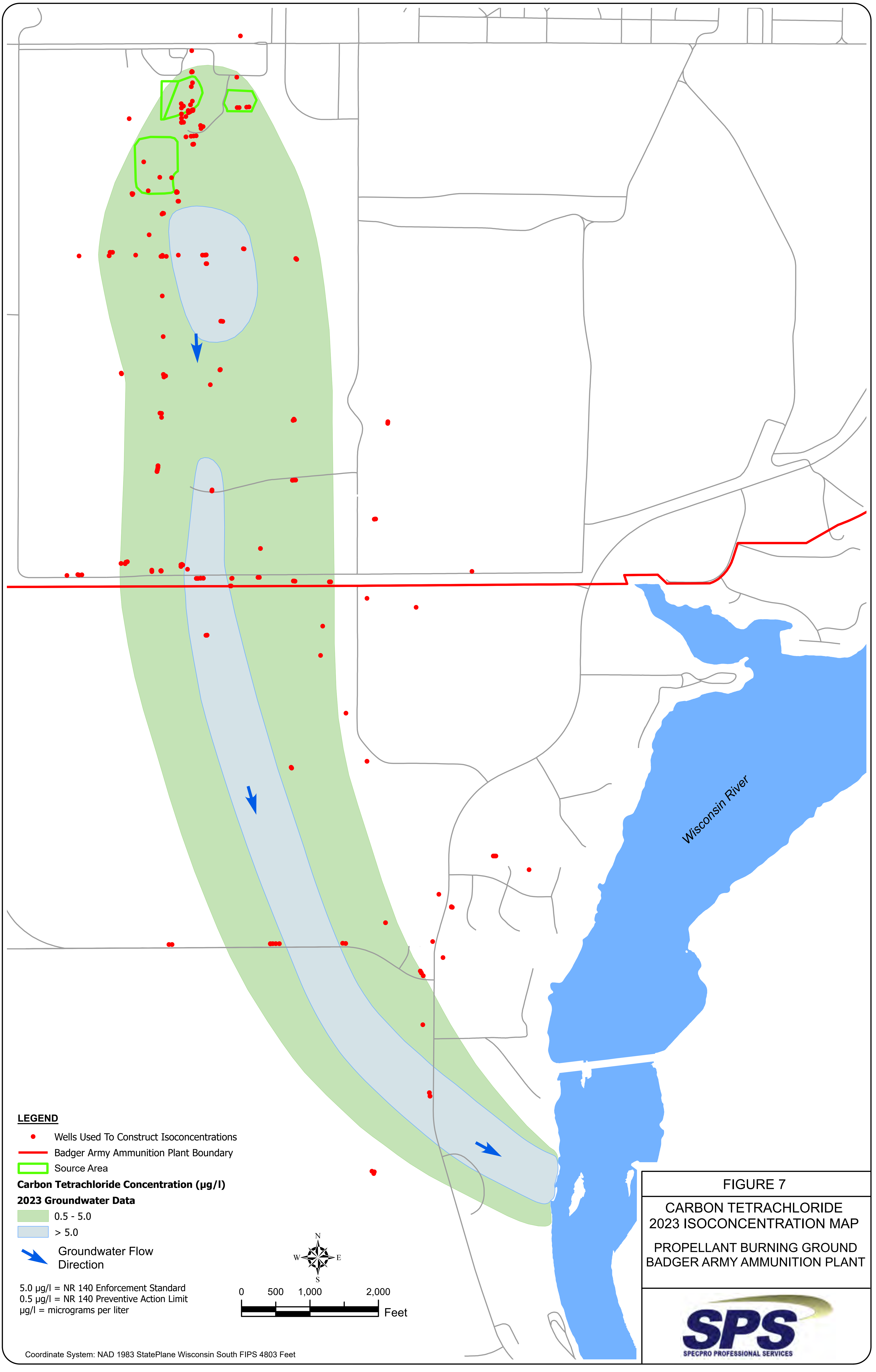
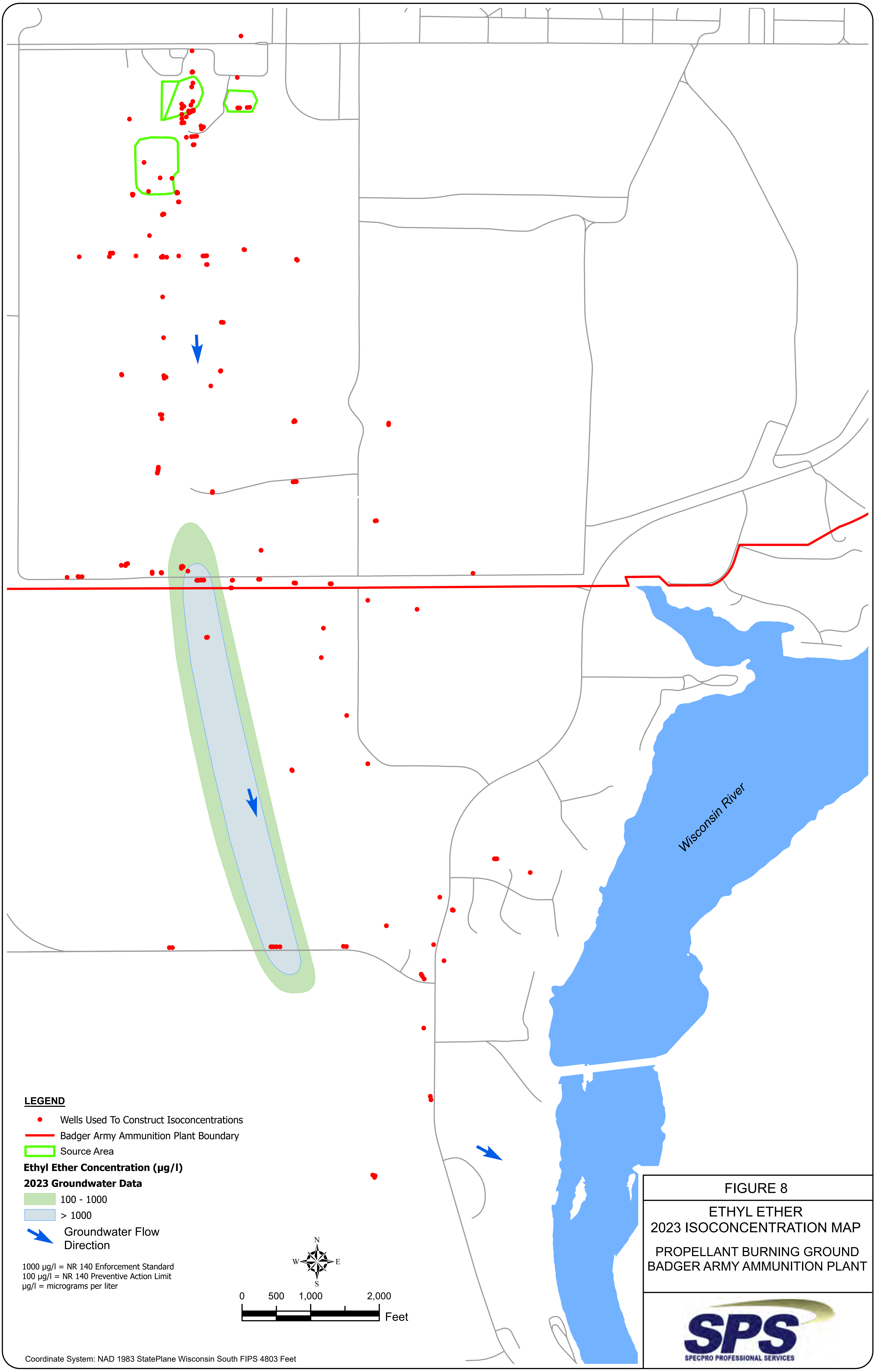
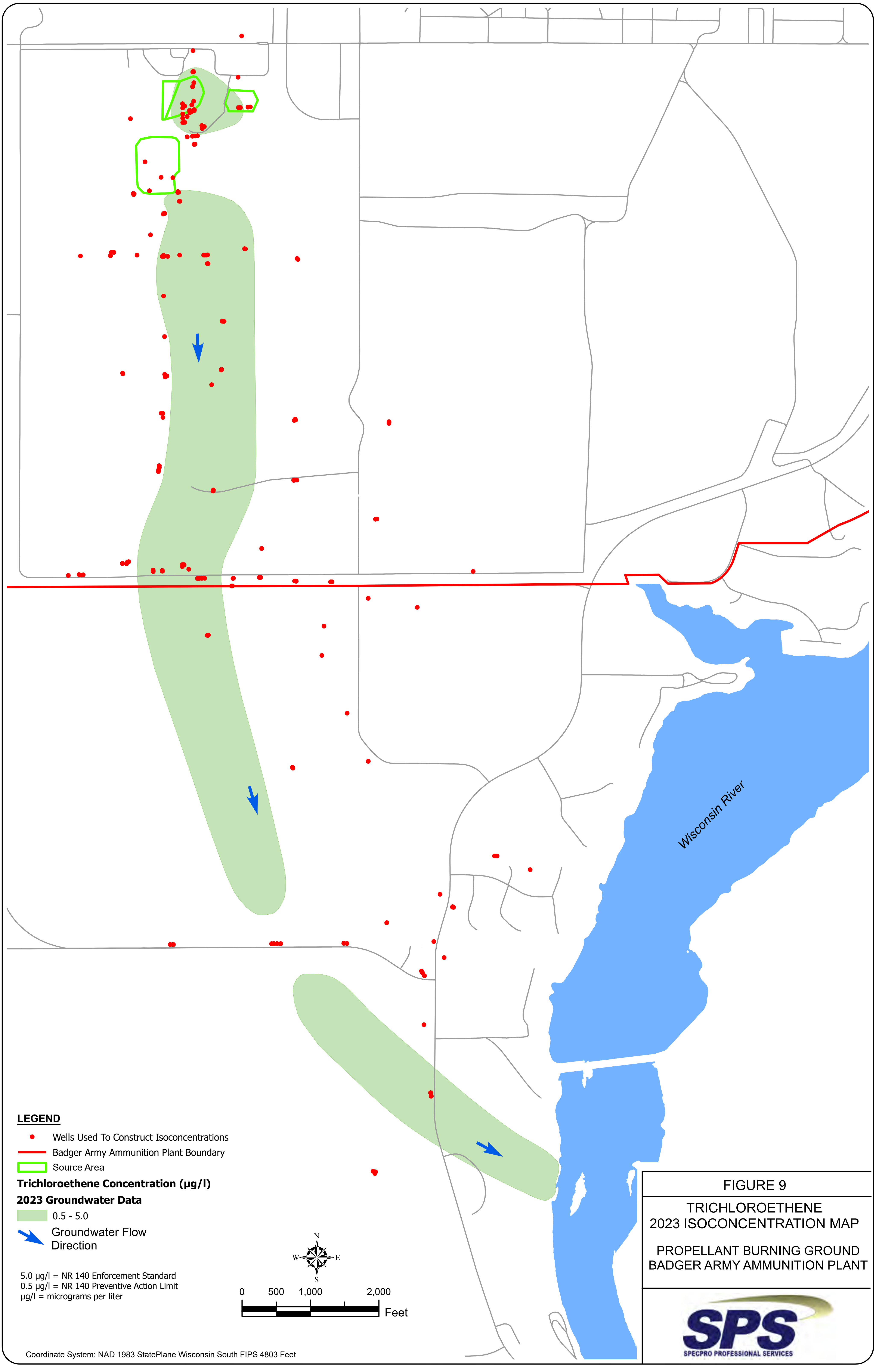


FIGURE 7

CARBON TETRACHLORIDE
2023 ISOCONCENTRATION MAP

PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Badger Army Ammunition Plant Boundary
Source Area
Ethyl Ether Concentration (µg/l)
2023 Groundwater Data
100 - 1000
> 1000
Groundwater Flow Direction
1000 µg/l = NR 140 Enforcement Standard
100 µg/l = NR 140 Preventive Action Limit
µg/l = micrograms per liter
N
W
E
S
0
500
1,000
2,000
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 8
ETHYL ETHER
2023 ISOCONCENTRATION MAP
PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Badger Army Ammunition Plant Boundary
Source Area
Trichloroethene Concentration (µg/l)
2023 Groundwater Data
0.5 - 5.0
Groundwater Flow Direction
5.0 µg/l = NR 140 Enforcement Standard
0.5 µg/l = NR 140 Preventive Action Limit
µg/l = micrograms per liter
N
W
E
S
0
500
1,000
2,000
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 9
TRICHLOROETHENE
2023 ISOCONCENTRATION MAP
PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES

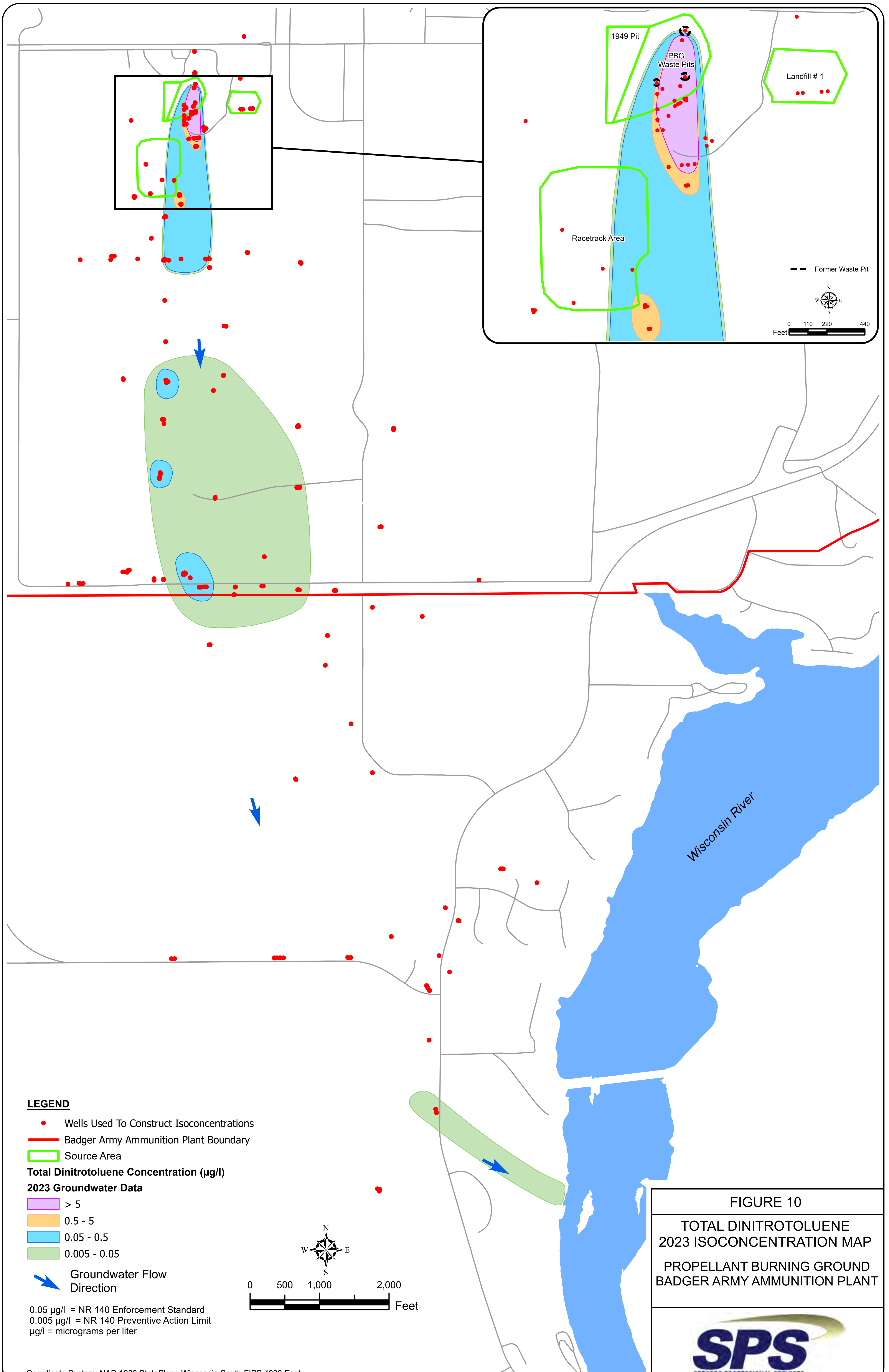


FIGURE 10

TOTAL DINITROTOLUENE
2023 ISOCONCENTRATION MAP

PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

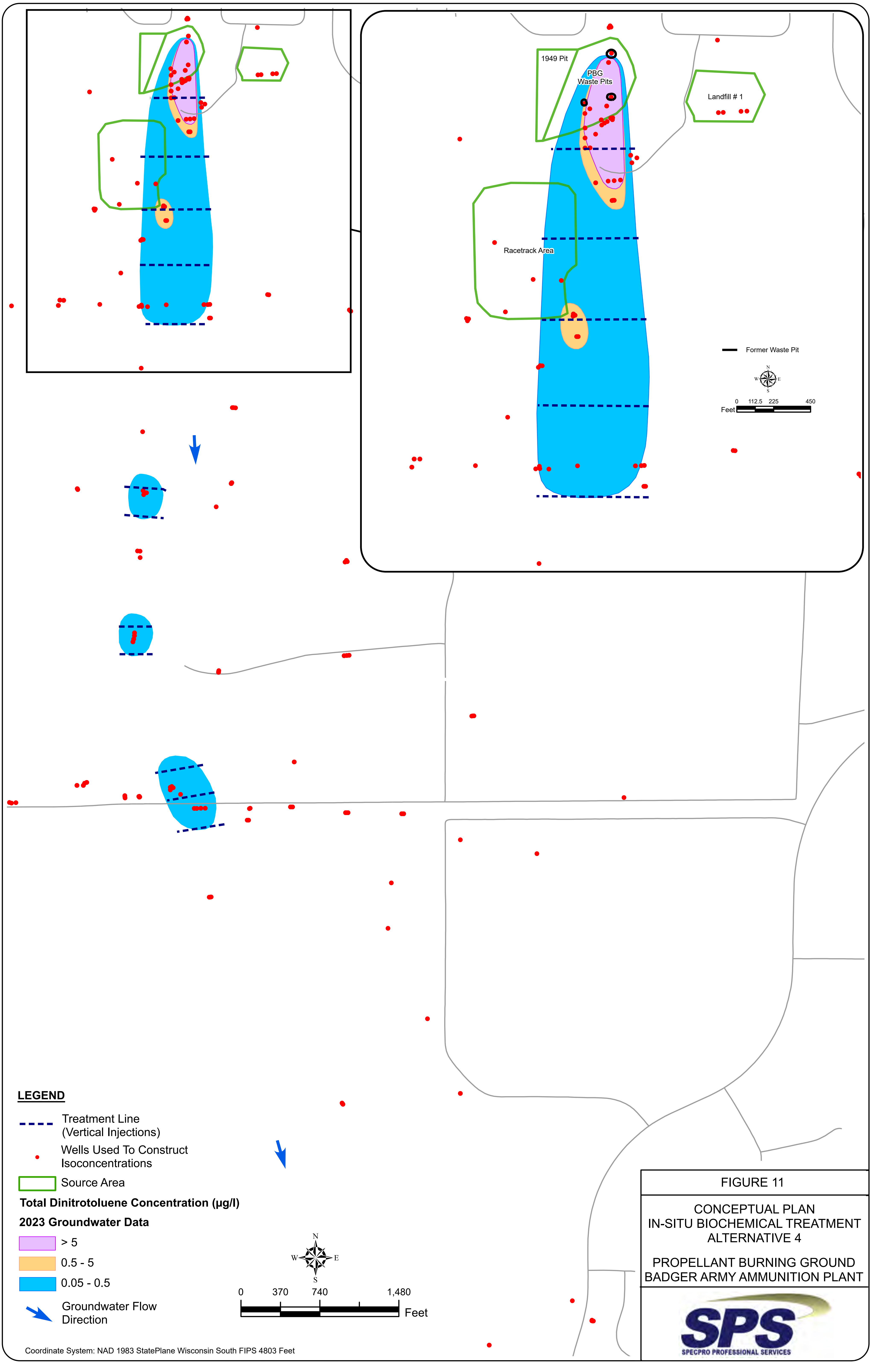
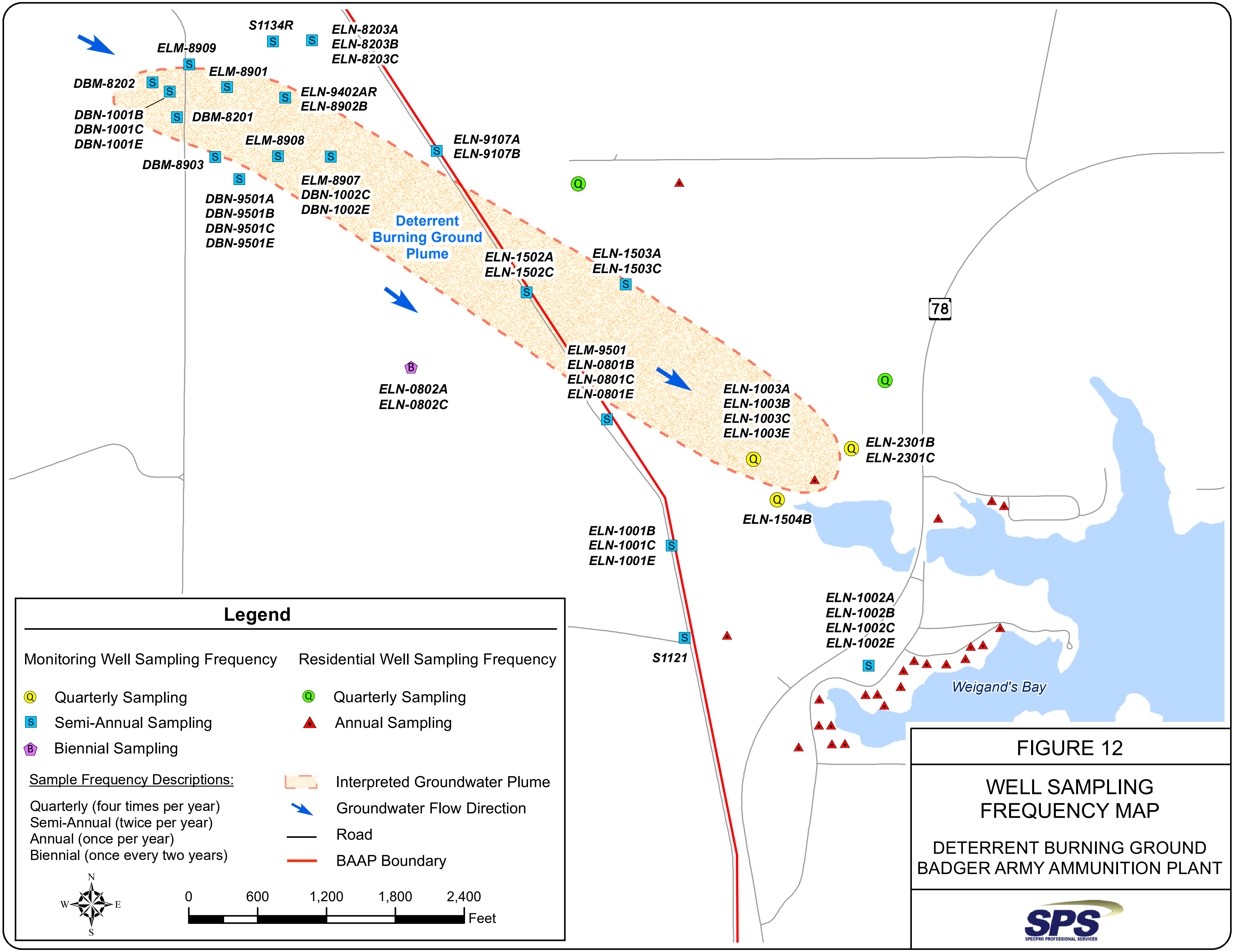


FIGURE 11

CONCEPTUAL PLAN
IN-SITU BIOCHEMICAL TREATMENT
ALTERNATIVE 4

PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT


S1134R
ELN-8203A
ELN-8203B
ELN-8203C
ELM-8909
ELM-8901
DBM-8202
ELN-9402AR
ELN-8902B
DBN-1001B
DBN-1001C
DBN-1001E
DBM-8201
ELM-8908
DBM-8903
ELN-9107A
ELN-9107B
ELM-8907
DBN-1002C
DBN-1002E
DBN-9501A
DBN-9501B
DBN-9501C
DBN-9501E
Deterrent
Burning Ground
Plume
ELN-1502A
ELN-1502C
ELN-1503A
ELN-1503C
78
ELM-9501
ELN-0801B
ELN-0801C
ELN-0801E
ELN-0802A
ELN-0802C
ELN-1003A
ELN-1003B
ELN-1003C
ELN-1003E
ELN-2301B
ELN-2301C
ELN-1504B
ELN-1001B
ELN-1001C
ELN-1001E
ELN-1002A
ELN-1002B
ELN-1002C
ELN-1002E
S1121
Weigand's Bay
Legend
Monitoring Well Sampling Frequency
Quarterly Sampling
Semi-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)
Interpreted Groundwater Plume
Groundwater Flow Direction
Road
BAAP Boundary
N
W
E
S
0
600
1,200
1,800
2,400
Feet
FIGURE 12
WELL SAMPLING
FREQUENCY MAP
DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
SPS

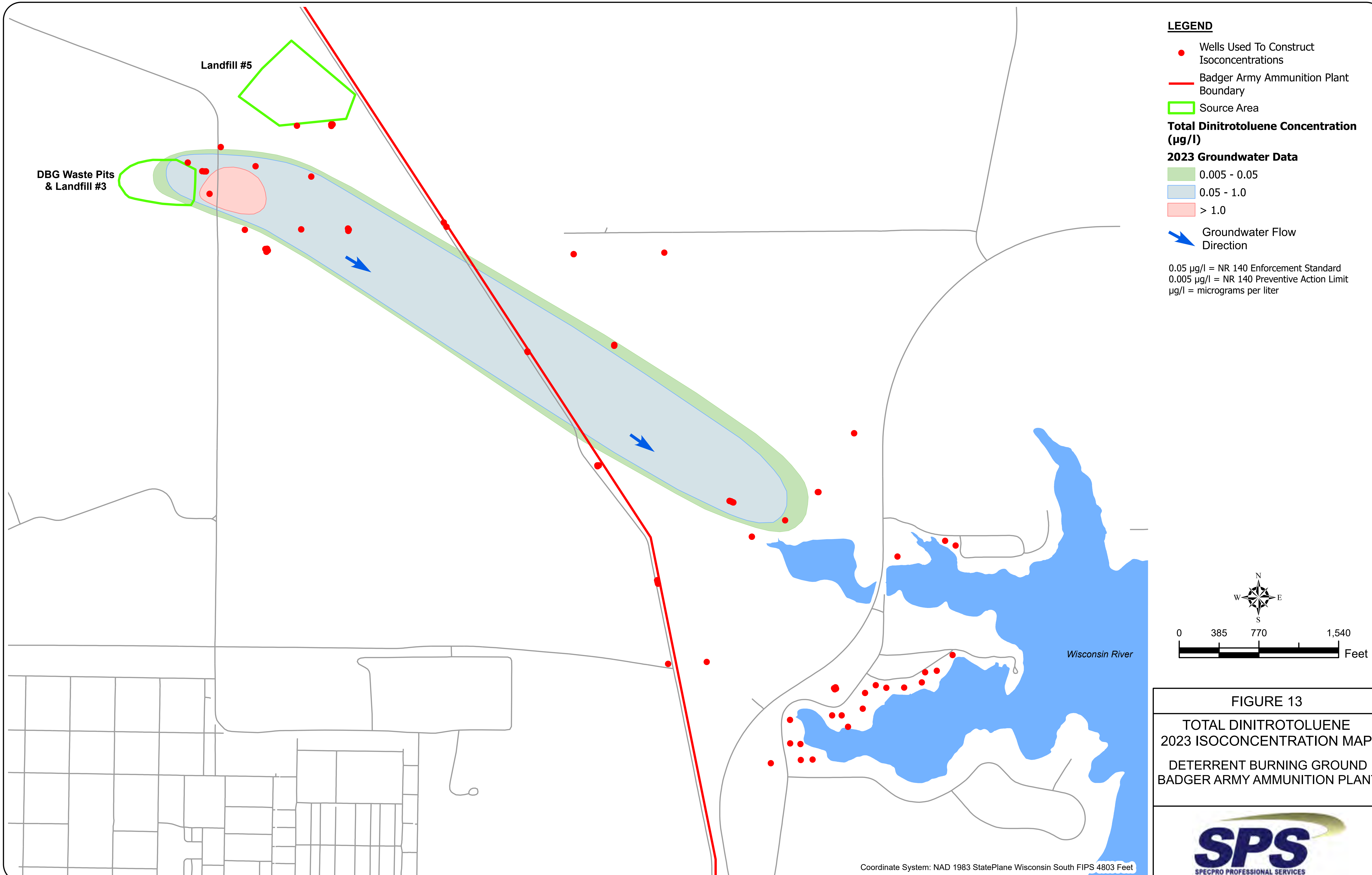
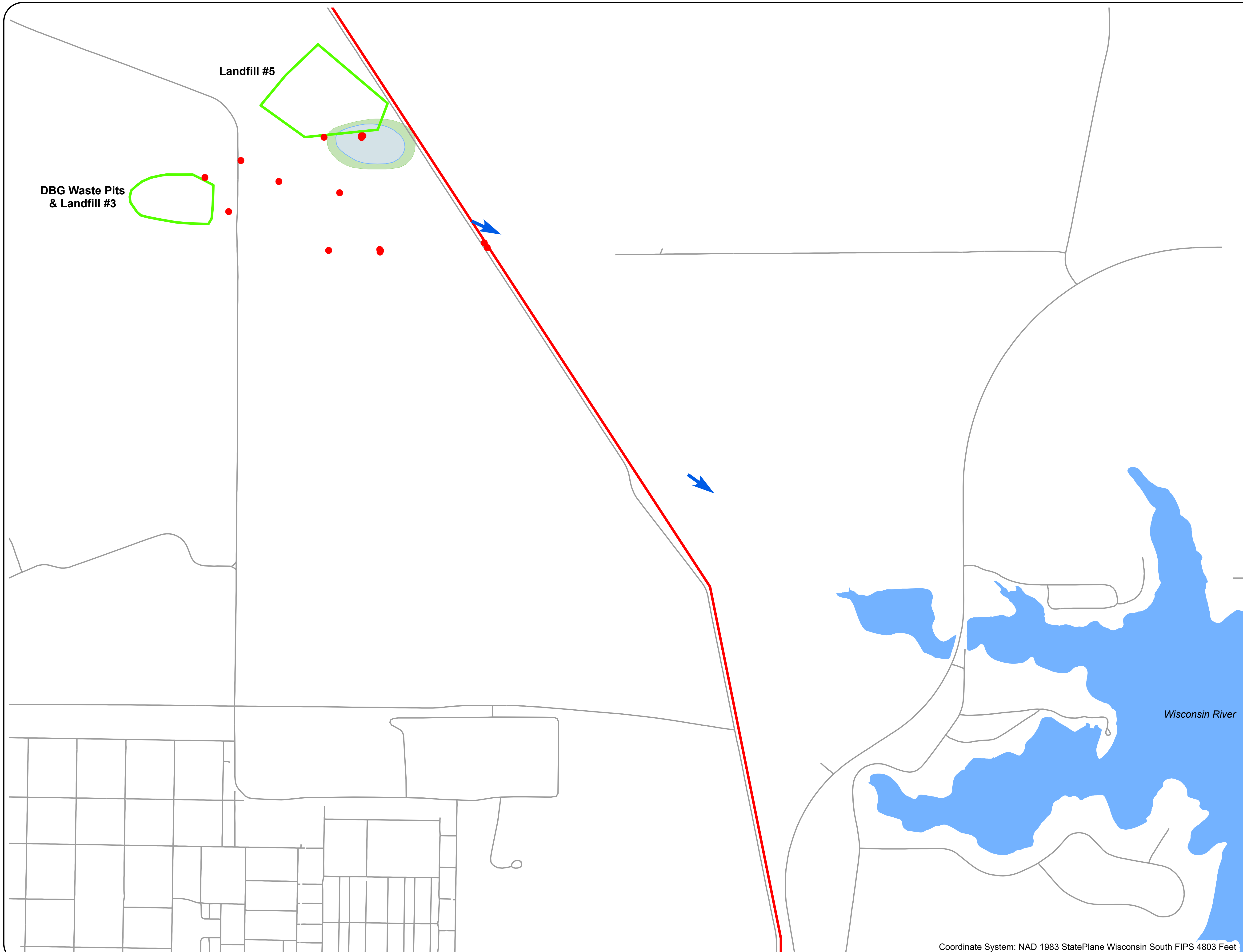


FIGURE 13

TOTAL DINITROTOLUENE 2023 ISOCONCENTRATION MAP

DETERRENT BURNING GROUND BADGER ARMY AMMUNITION PLANT



LEGEND

- Wells Used To Construct Isoconcentrations
- Badger Army Ammunition Plant Boundary
- Source Area

Sulfate Concentration (mg/l)

2023 Groundwater Data

- 125 - 250
- > 250
- Groundwater Flow Direction

Notes: The sulfate isoconcentrations in milligrams per liter (mg/l) are interpreted from groundwater data collected during 2023. 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

0 385 770 1,540 Feet

FIGURE 14

SULFATE
2023 ISOCONCENTRATION MAP

DETERRENT BURNING GROUND
& LANDFILL #5
BADGER ARMY AMMUNITION PLANT

SPECPRO PROFESSIONAL SERVICES

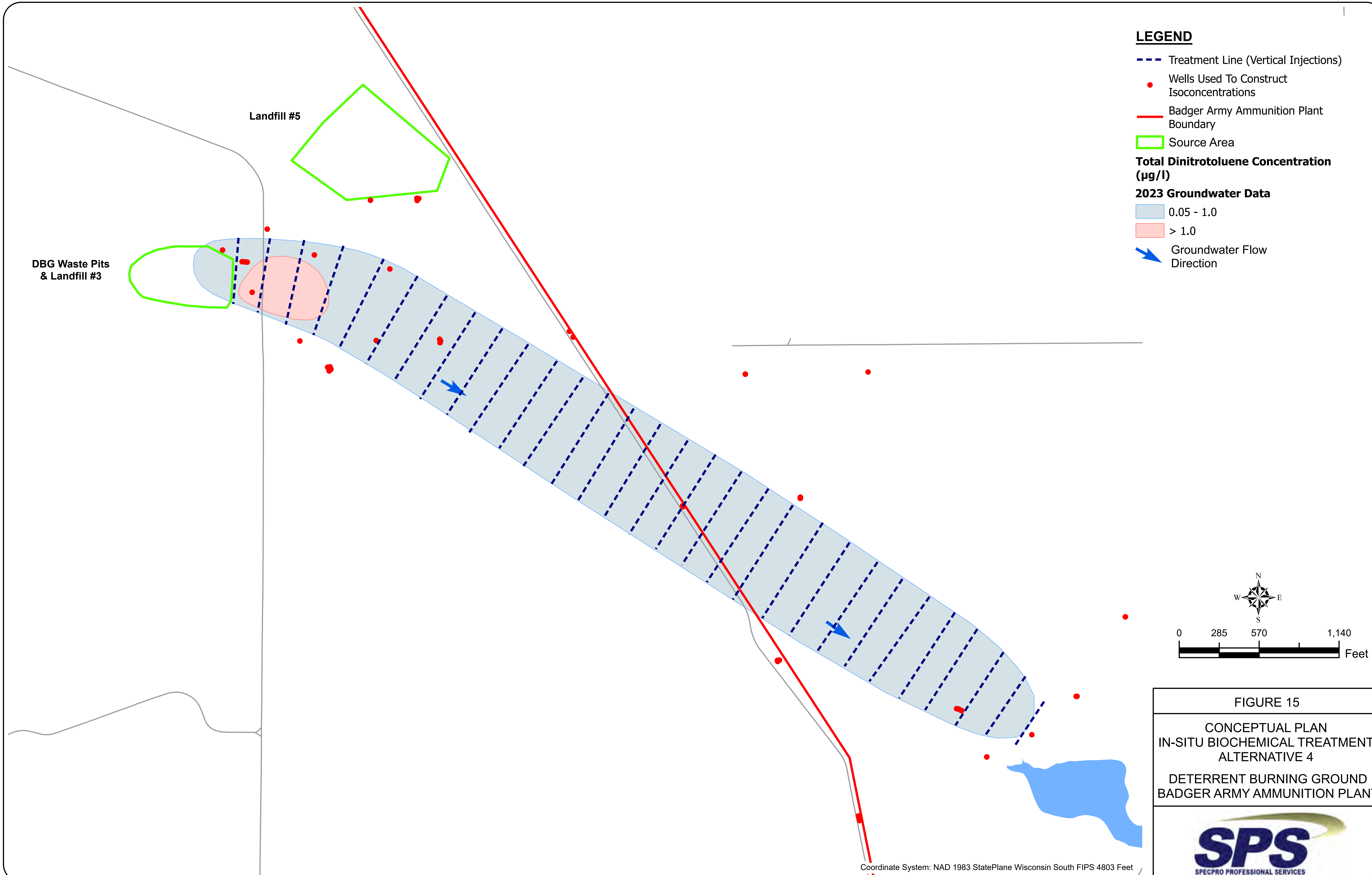


FIGURE 15

CONCEPTUAL PLAN
IN-SITU BIOCHEMICAL TREATMENT
ALTERNATIVE 4

DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

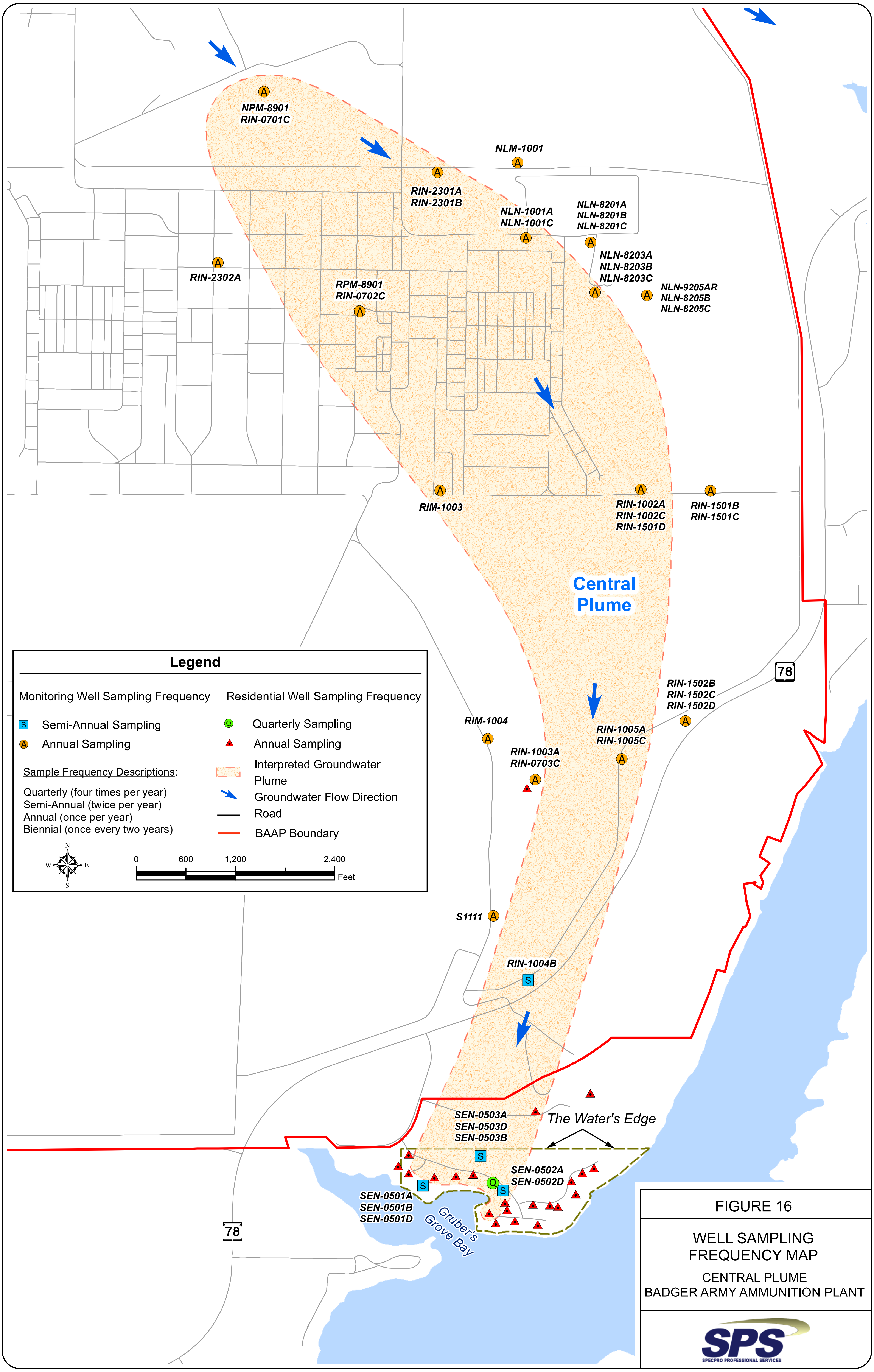
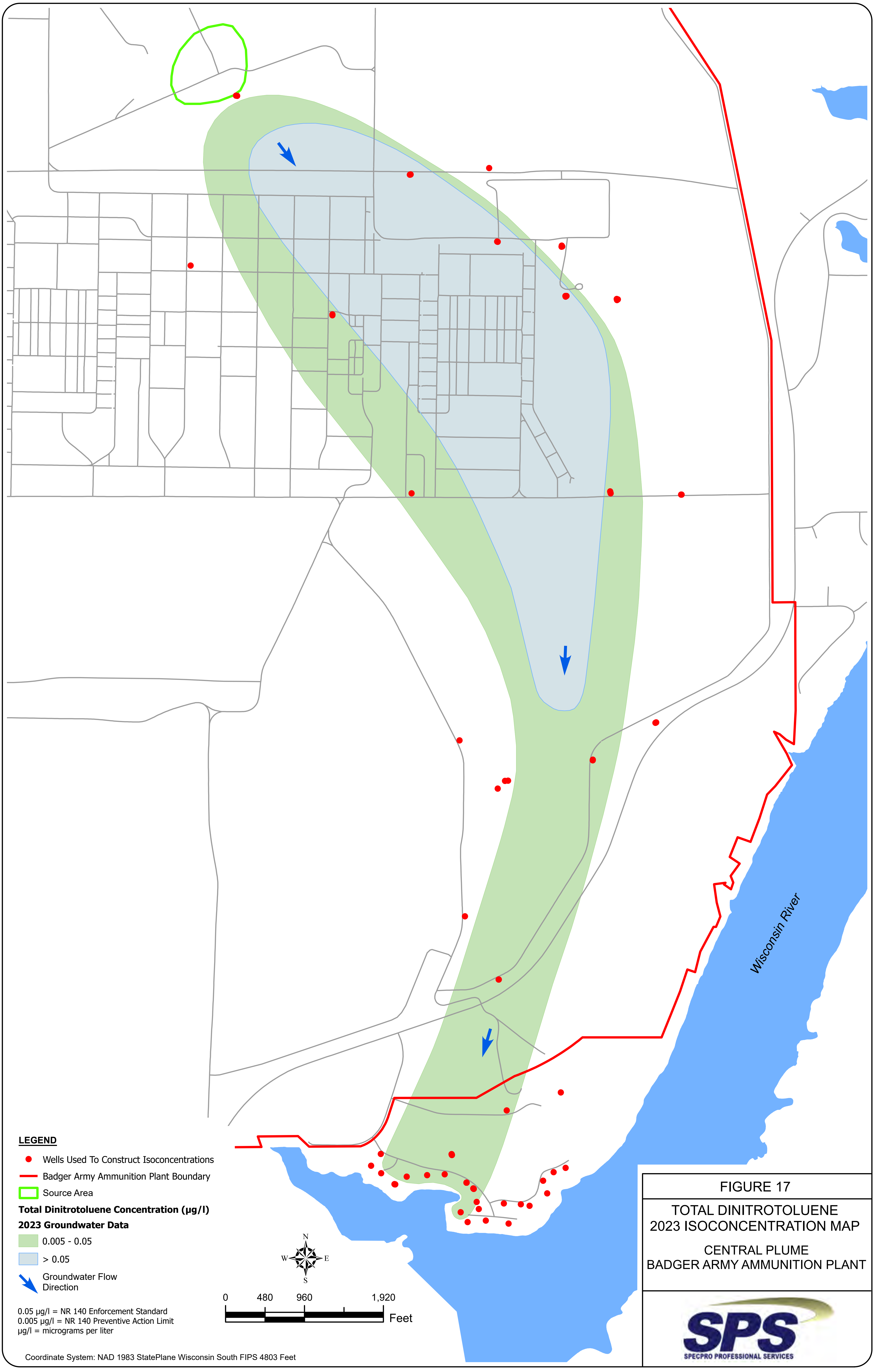


FIGURE 16

WELL SAMPLING FREQUENCY MAP

CENTRAL PLUME
BADGER ARMY AMMUNITION PLANT


Wisconsin River
LEGEND
Wells Used To Construct Isoconcentrations
Badger Army Ammunition Plant Boundary
Source Area
Total Dinitrotoluene Concentration (µg/l)
2023 Groundwater Data
0.005 - 0.05
> 0.05
Groundwater Flow Direction
0.05 µg/l = NR 140 Enforcement Standard
0.005 µg/l = NR 140 Preventive Action Limit
µg/l = micrograms per liter
N
W
E
S
0
480
960
1,920
Feet
Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet
FIGURE 17
TOTAL DINITROTOLUENE
2023 ISOCONCENTRATION MAP
CENTRAL PLUME
BADGER ARMY AMMUNITION PLANT
SPS
SPECPRO PROFESSIONAL SERVICES

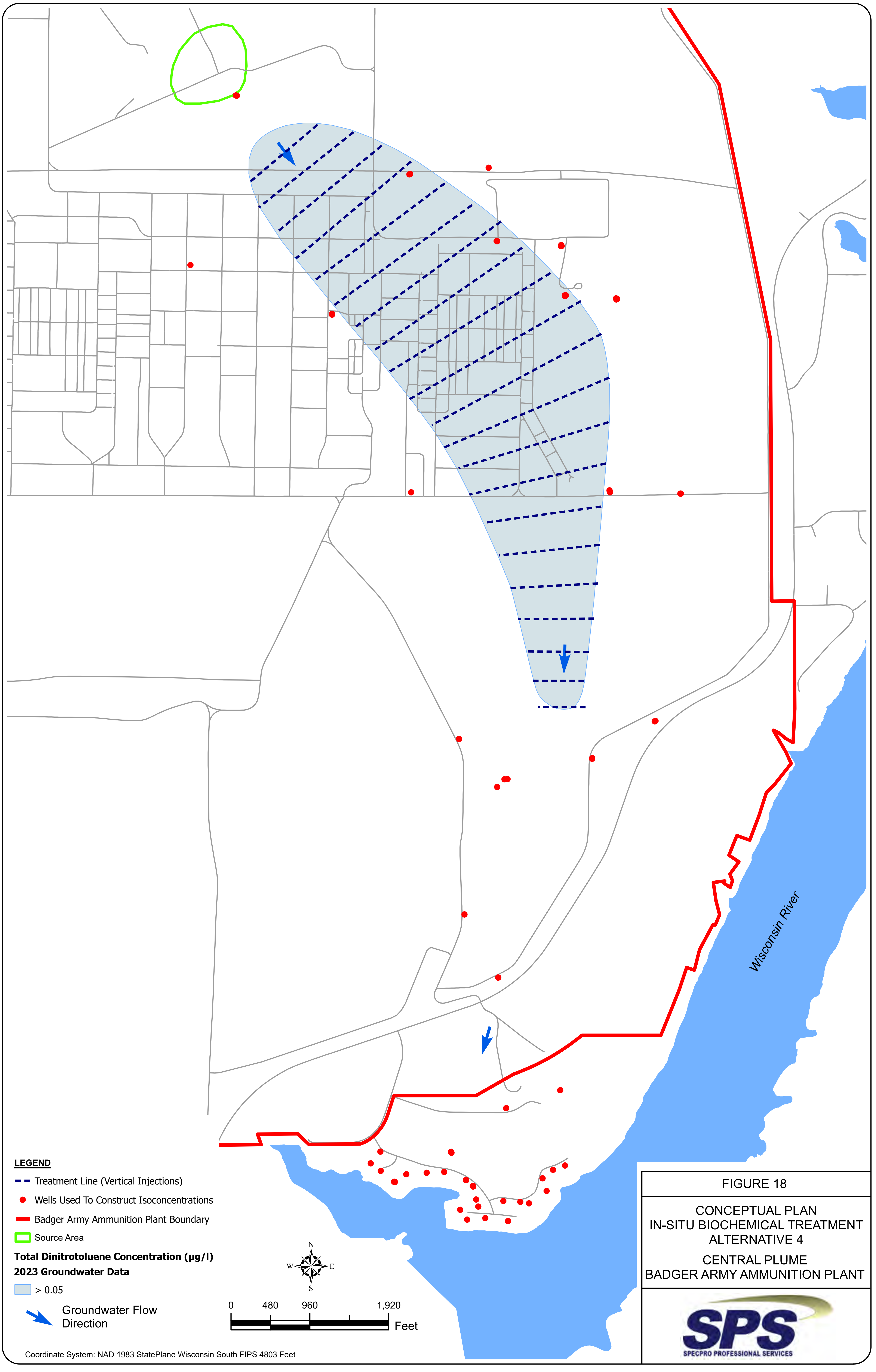
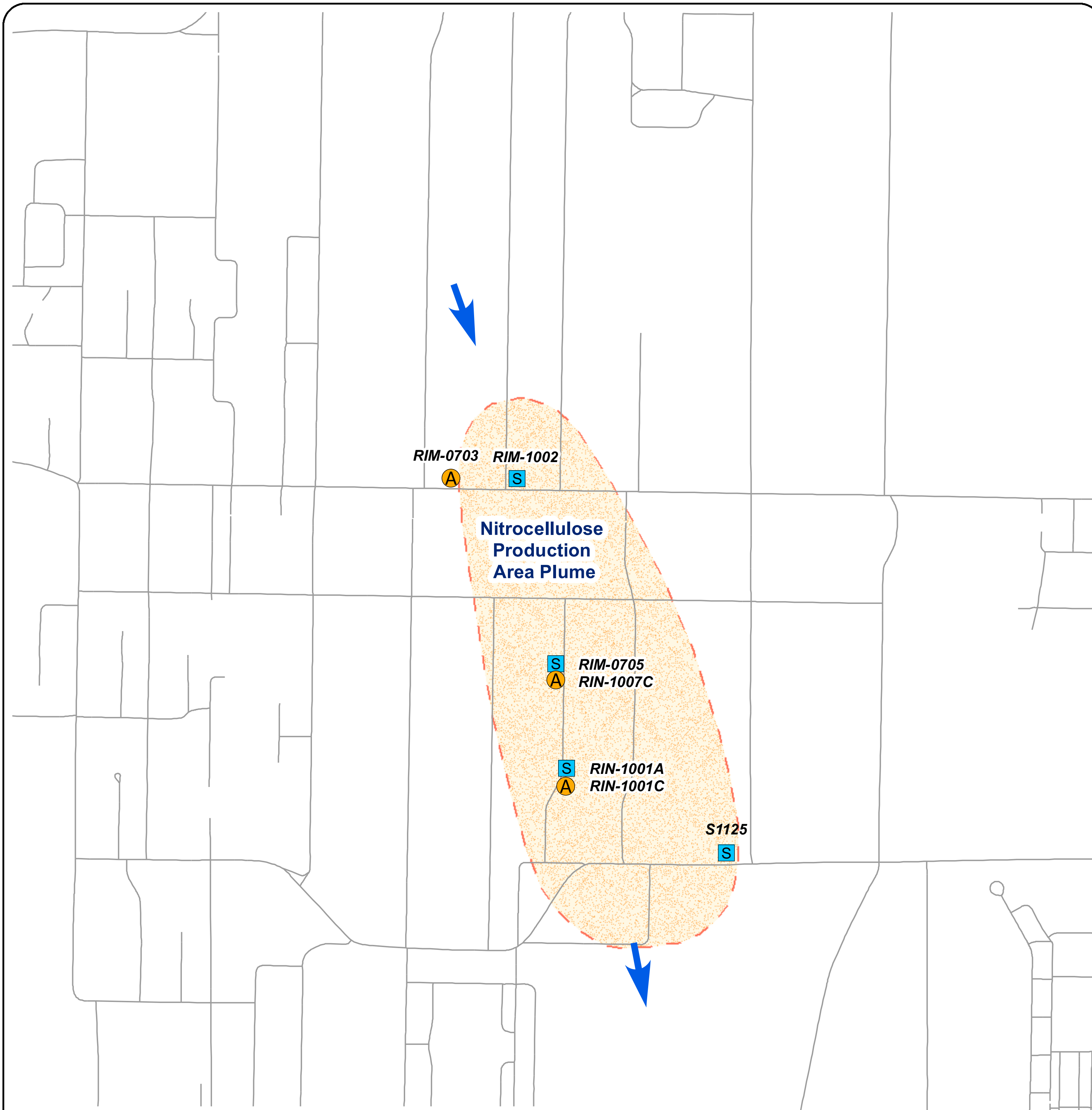


FIGURE 18

CONCEPTUAL PLAN
IN-SITU BIOCHEMICAL TREATMENT
ALTERNATIVE 4

CENTRAL PLUME
BADGER ARMY AMMUNITION PLANT



Legend

Monitoring Well Sampling Frequency

- S Semi-Annual Sampling
- A Annual Sampling

Interpreted Groundwater Plume
Groundwater Flow Direction
Road
BAAP Boundary

Sample Frequency Descriptions:

Semi-Annual (twice per year)
Annual (once per year)

N W E S

0 700 1,400 2,800 Feet

FIGURE 19

WELL SAMPLING FREQUENCY MAP

NITROCELLULOSE PRODUCTION AREA
BADGER ARMY AMMUNITION PLANT

SPS SPECPRO PROFESSIONAL SERVICES

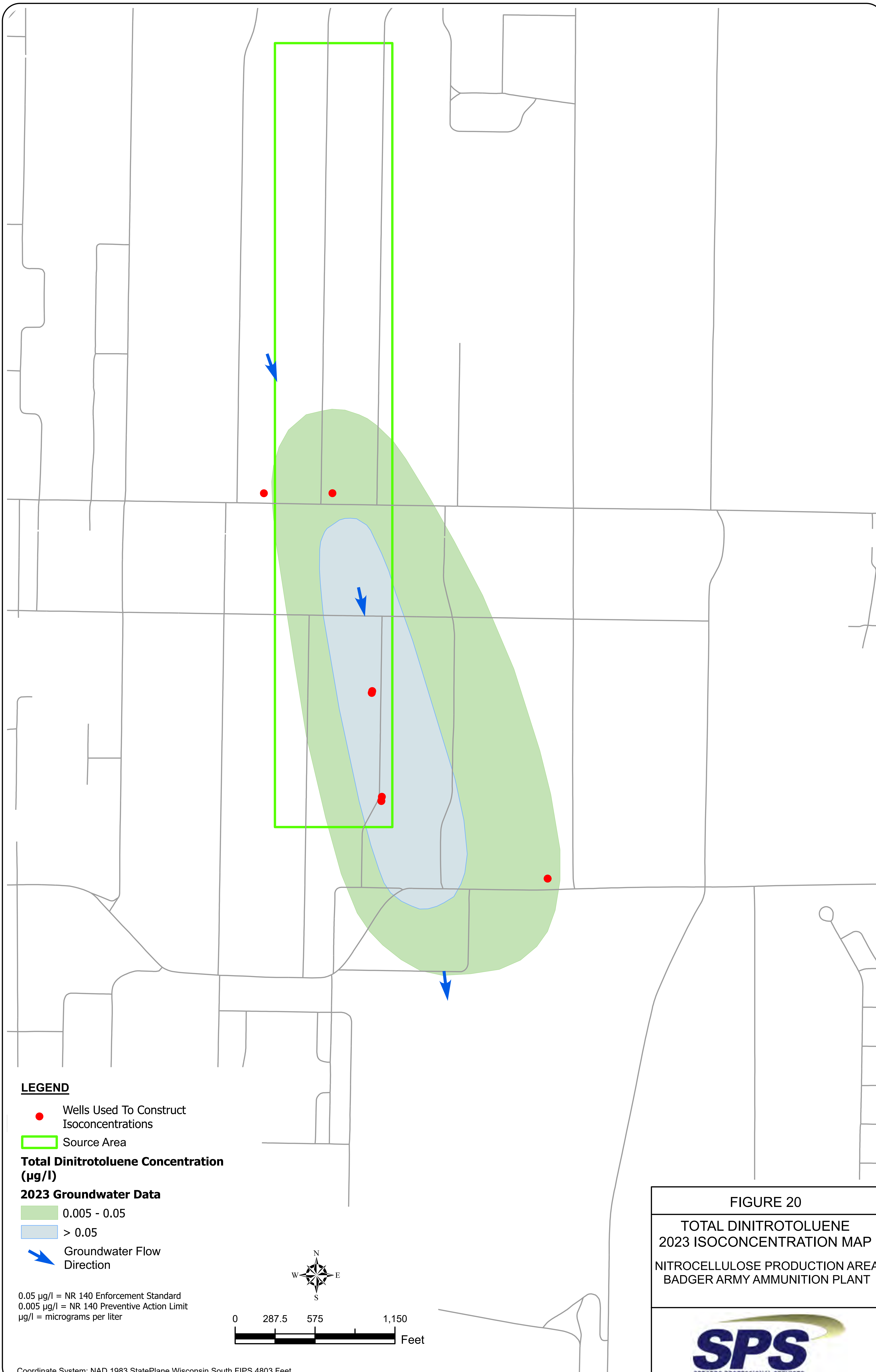


FIGURE 20

TOTAL DINITROTOLUENE
2023 ISOCONCENTRATION MAP

NITROCELLULOSE PRODUCTION AREA
BADGER ARMY AMMUNITION PLANT

Appendix A

2019-2023 Screening Level Groundwater Risk Evaluation

Summary Tables

Table 1. Summary of Groundwater Screening Levels Used for the Screening Level Groundwater Risk Evaluation
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Minimum Value	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)[1]	NR 140 ES	NR 140 PAL	Units
71-55-6	1,1,1-Trichloroethane	40	NA	800	200	40	µg/L
79-00-5	1,1,2-Trichloroethane	0.041	0.28	0.041	5	0.5	µg/L
75-34-3	1,1-Dichloroethane	2.8	2.8	380	850	85	µg/L
75-35-4	1,1-Dichloroethene	0.7	NA	28	7	0.7	µg/L
95-63-6	1,2,4-Trimethylbenzene	5.6	NA	5.6	480	96	µg/L
95-50-1	1,2-Dichlorobenzene	30	NA	30	600	60	µg/L
107-06-2	1,2-Dichloroethane	0.17	0.17	1.3	5	0.5	µg/L
78-87-5	1,2-Dichloropropane	0.5	0.85	0.82	5	0.5	µg/L
108-67-8	1,3,5-Trimethylbenzene	6	NA	6	480	96	µg/L
602-01-7	2,3-Dinitrotoluene	NA	NA	NA	NA	NA	µg/L
121-14-2	2,4-Dinitrotoluene	0.005	0.24	3.8	0.05	0.005	µg/L
619-15-8	2,5-Dinitrotoluene	NA	NA	NA	NA	NA	µg/L
606-20-2	2,6-Dinitrotoluene	0.005	0.049	0.57	0.05	0.005	µg/L
78-93-3	2-Butanone	560	NA	560	4000	800	µg/L
610-39-9	3,4-Dinitrotoluene	NA	NA	NA	NA	NA	µg/L
618-85-9	3,5-Dinitrotoluene	NA	NA	NA	NA	NA	µg/L
67-64-1	Acetone	1800	NA	1800	9000	1800	µg/L
71-43-2	Benzene	0.46	0.46	3.3	5	0.5	µg/L
75-27-4	Bromodichloromethane	0.06	0.13	15	0.6	0.06	µg/L
74-83-9	Bromomethane	1	NA	75	10	1	µg/L
75-15-0	Carbon disulfide	81	NA	81	1000	200	µg/L
56-23-5	Carbon tetrachloride	0.46	0.46	4.9	5	0.5	µg/L
108-90-7	Chlorobenzene	7.8	NA	7.8	100	20	µg/L
75-00-3	Chloroethane	80	NA	830	400	80	µg/L
67-66-3	Chloroform	0.22	0.22	9.7	6	0.6	µg/L
74-87-3	Chloromethane	3	NA	19	30	3	µg/L
156-59-2	cis-1,2-Dichloroethene	2.5	NA	2.5	70	7	µg/L
124-48-1	Dibromochloromethane	0.87	0.87	38	60	6	µg/L
75-71-8	Dichlorodifluoromethane	20	NA	20	1000	200	µg/L
75-43-4	Dichlorofluoromethane	NA	NA	NA	NA	NA	µg/L
60-29-7	Ethyl ether	100	NA	390	1000	100	µg/L
100-41-4	Ethylbenzene	1.5	1.5	50	700	140	µg/L
98-82-8	Isopropylbenzene	45	NA	45	NA	NA	µg/L
179601-23-1	m & p-Xylene	19	NA	19	2000	400	µg/L
1634-04-4	Methyl tert-Butyl Ether	12	14	630	60	12	µg/L
91-20-3	Naphthalene	0.12	0.12	0.61	100	10	µg/L
14797-55-8	Nitrate	2	NA	3.2	10	2	mg/L
103-65-1	n-Propylbenzene	66	NA	66	NA	NA	µg/L
95-47-6	o-Xylene	19	NA	19	2000	400	µg/L
100-42-5	Styrene	10	NA	120	100	10	µg/L
14808-79-8	Sulfate	125	NA	NA	250	125	mg/L
98-06-6	tert-Butylbenzene	69	NA	69	NA	NA	µg/L
127-18-4	Tetrachloroethene	0.5	11	4.1	5	0.5	µg/L
109-99-9	Tetrahydrofuran	10	NA	340	50	10	µg/L
108-88-3	Toluene	110	NA	110	800	160	µg/L
25321-14-6	Total Dinitrotoluene	0.005	0.1	1.1	0.05	0.005	µg/L
156-60-5	trans-1,2-Dichloroethene	6.8	NA	6.8	100	20	µg/L
79-01-6	Trichloroethene	0.28	0.49	0.28	5	0.5	µg/L
75-69-4	Trichlorofluoromethane	520	NA	520	3490	698	µg/L

Footnote 1. The U.S. Environmental Protection Agency (EPA) noncancer-based tapwater regional screening levels (RSLs) presented in this table are based on a target hazard quotient (THQ) of 0.1. A THQ of 0.1 is used at the screening step in the risk assessment as a conservative means to select chemicals of potential concern (COPCs).

Table 2a. Summary of Screening Assessment - Propellant Burning Ground Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
71-55-6	1,1,1-Trichloroethane	40	µg/L	Monitoring	674	PBN-9303C	8/20/2020	1.9
75-34-3	1,1-Dichloroethane	2.8	µg/L	Monitoring	675	PBN-9303D	9/20/2022	1.1
75-35-4	1,1-Dichloroethene	0.7	µg/L	Monitoring	724	SPN-9102D	8/24/2020	0.37
95-63-6	1,2,4-Trimethylbenzene	5.6	µg/L	Monitoring	655	PBN-8912B	4/26/2022	0.19
107-06-2	1,2-Dichloroethane	0.17	µg/L	Monitoring	615	PBN-8202C	4/30/2020	2.2
71-43-2	Benzene	0.46	µg/L	Monitoring	615	PBN-8202C	6/8/2020	41
75-27-4	Bromodichloromethane	0.06	µg/L	Monitoring	792	PBN-1404C	9/28/2021	0.23
74-83-9	Bromomethane	1	µg/L	Monitoring	620	PBN-8204B	9/24/2020	0.33
75-15-0	Carbon disulfide	81	µg/L	Monitoring	793	PBN-1404D	10/9/2019	0.97
56-23-5	Carbon tetrachloride	0.46	µg/L	Monitoring	632	PBN-8502A	5/4/2020	13
108-90-7	Chlorobenzene	7.8	µg/L	Monitoring	793	PBN-1404D	4/23/2019	1.5
67-66-3	Chloroform	0.22	µg/L	Monitoring	669	PBN-9301C	4/13/2023	1.7
74-87-3	Chloromethane	3	µg/L	Monitoring	687	PBN-9304D	9/14/2022	0.65
60-29-7	Ethyl ether	100	µg/L	Monitoring	726	SPN-9104D	9/23/2019	2000
100-41-4	Ethylbenzene	1.5	µg/L	Monitoring	655	PBN-8912B	4/26/2022	0.26
179601-23-1	m & p-Xylene	19	µg/L	Monitoring	655	PBN-8912B	9/19/2022	0.87
91-20-3	Naphthalene	0.12	µg/L	Monitoring	615	PBN-8202C	6/8/2020	0.23
14797-55-8	Nitrate	2	mg/L	Monitoring	360	PBM-9801	9/20/2023	4.4
95-47-6	o-Xylene	19	µg/L	Monitoring	655	PBN-8912B	9/19/2022	0.46
14808-79-8	Sulfate	125	µg/L	Monitoring	368	PBM-0002	5/4/2022	22
127-18-4	Tetrachloroethene	0.5	µg/L	Monitoring	655	PBN-8912B	9/19/2022	0.16
109-99-9	Tetrahydrofuran	10	µg/L	Monitoring	782	PBN-1401A	9/24/2020	1.4
108-88-3	Toluene	110	µg/L	Monitoring	655	PBN-8912B	4/26/2022	5.1
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	1286.9
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	613	PBN-8202A	9/25/2019	75
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	670
619-15-8	2,5-Dinitrotoluene	NA	µg/L	Monitoring	367	PBM-0001	4/30/2020	0.18
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	500
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	614	PBN-8202B	4/8/2019	36
618-85-9	3,5-Dinitrotoluene	NA	µg/L	Monitoring	613	PBN-8202A	4/30/2020	9.9
79-01-6	Trichloroethene	0.28	µg/L	Monitoring	615	PBN-8202C	4/30/2020	2.9

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.

NA - A screening value is not available for the analyte.

Table 2b. Summary of Hypothetical Future Risks - Propellant Burning Ground Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
107-06-2	1,2-Dichloroethane	0.17	µg/L	Monitoring	615	PBN-8202C	4/30/2020	2.2	0.17	1.3	1E-05	0.2
71-43-2	Benzene	0.46	µg/L	Monitoring	615	PBN-8202C	6/8/2020	41	0.46	3.3	9E-05	1
75-27-4	Bromodichloromethane	0.06	µg/L	Monitoring	792	PBN-1404C	9/28/2021	0.23	0.13	15	2E-06	0.002
56-23-5	Carbon tetrachloride	0.46	µg/L	Monitoring	632	PBN-8502A	5/4/2020	13	0.46	4.9	3E-05	0.3
67-66-3	Chloroform	0.22	µg/L	Monitoring	669	PBN-9301C	4/13/2023	1.7	0.22	9.7	8E-06	0.02
60-29-7	Ethyl ether	100	µg/L	Monitoring	726	SPN-9104D	9/23/2019	2000	NA	390	NA	1
91-20-3	Naphthalene	0.12	µg/L	Monitoring	615	PBN-8202C	6/8/2020	0.23	0.12	0.61	2E-06	0.04
14797-55-8	Nitrate	2	mg/L	Monitoring	360	PBM-9801	9/20/2023	4.4	NA	3.2	NA	0.1
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	1286.9	0.1	1.1	1E-02	117
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	613	PBN-8202A	9/25/2019	75	NA	NA	NA	NA
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	670	0.24	3.8	3E-03	18
619-15-8	2,5-Dinitrotoluene	NA	µg/L	Monitoring	367	PBM-0001	4/30/2020	0.18	NA	NA	NA	NA
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	613	PBN-8202A	4/30/2020	500	0.049	0.57	1E-02	88
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	614	PBN-8202B	4/8/2019	36	NA	NA	NA	NA
618-85-9	3,5-Dinitrotoluene	NA	µg/L	Monitoring	613	PBN-8202A	4/30/2020	9.9	NA	NA	NA	NA
79-01-6	Trichloroethene	0.28	µg/L	Monitoring	615	PBN-8202C	4/30/2020	2.9	0.49	0.28	6E-06	1
											1E-02	120
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water samples are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 3a. Summary of Screening Assessment - Propellant Burning Ground Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
71-55-6	1,1,1-Trichloroethane	40	µg/L	Monitoring	545	PBN-2301C	9/26/2023	0.42
75-34-3	1,1-Dichloroethane	2.8	µg/L	Monitoring	546	PBN-2301D	9/26/2023	0.2
74-83-9	Bromomethane	1	µg/L	Monitoring	561	PBN-9101C	4/1/2019	0.23
75-15-0	Carbon disulfide	81	µg/L	Monitoring	561	PBN-9101C	4/1/2019	0.26
56-23-5	Carbon tetrachloride	0.46	µg/L	Monitoring	561	PBN-9101C	9/22/2021	38
67-66-3	Chloroform	0.22	µg/L	Monitoring	561	PBN-9101C	10/8/2019	3.6
74-87-3	Chloromethane	3	µg/L	Monitoring	981	PBM-9001D	4/23/2019	0.16
75-71-8	Dichlorodifluoromethane	20	µg/L	Residential	899	S9294	7/10/2019	0.18
60-29-7	Ethyl ether	100	µg/L	Monitoring	573	SWN-9103D	9/26/2023	1300
179601-23-1	m & p-Xlene	19	µg/L	Residential	961	S9270A	7/8/2019	0.22
108-88-3	Toluene	110	µg/L	Monitoring	574	SWN-9103E	9/23/2021	0.71
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.144
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.053
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	561	PBN-9101C	4/12/2022	0.051
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	561	PBN-9101C	4/1/2019	0.09
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.052
79-01-6	Trichloroethene	0.28	µg/L	Monitoring	561	PBN-9101C	10/8/2019	15

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.
4. Analytes highlighted in blue are not attributed to Army sources. Residential well plumbing components are the suspected sources for these analytes. Therefore, these analytes will not be used to evaluate risk in the PBG Plume.

NA - A screening value is not available for the analyte.

Table 3b. Summary of Current Risks - Propellant Burning Ground Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
56-23-5	Carbon tetrachloride	0.46	µg/L	Monitoring	561	PBN-9101C	9/22/2021	38	0.46	4.9	8E-05	0.8
67-66-3	Chloroform	0.22	µg/L	Monitoring	561	PBN-9101C	10/8/2019	3.6	0.22	9.7	2E-05	0.04
60-29-7	Ethyl ether	100	µg/L	Monitoring	573	SWN-9103D	9/26/2023	1300	NA	390	NA	0.3
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.144	0.1	1.1	1E-06	0.01
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.053	NA	NA	NA	NA
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	561	PBN-9101C	4/12/2022	0.051	0.24	3.8	2E-07	0.001
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	561	PBN-9101C	4/1/2019	0.09	0.049	0.57	2E-06	0.02
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	693	PBN-9903B	4/12/2021	0.052	NA	NA	NA	NA
79-01-6	Trichloroethene	0.28	µg/L	Monitoring	561	PBN-9101C	10/8/2019	15	0.49	0.28	3E-05	5
											1E-04	7
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water samples are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 4a. Summary of Screening Assessment - Deterrent Burning Ground Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
71-55-6	1,1,1-Trichloroethane	40	µg/L	Monitoring	302	DBM-8202	4/8/2019	1.5
79-00-5	1,1,2-Trichloroethane	0.041	µg/L	Monitoring	236	S1134R	4/6/2021	1.8
75-35-4	1,1-Dichloroethene	0.7	µg/L	Monitoring	534	ELN-1502C	4/25/2022	0.11
95-50-1	1,2-Dichlorobenzene	30	µg/L	Monitoring	236	S1134R	5/2/2022	0.66
78-87-5	1,2-Dichloropropane	0.5	µg/L	Monitoring	210	ELN-8203A	4/6/2021	0.66
75-00-3	Chloroethane	80	µg/L	Monitoring	474	DBN-1001E	4/7/2020	0.26
156-59-2	cis-1,2-Dichloroethene	2.5	µg/L	Monitoring	210	ELN-8203A	4/6/2021	0.15
75-71-8	Dichlorodifluoromethane	20	µg/L	Monitoring	211	ELN-8203B	4/25/2023	1
60-29-7	Ethyl ether	100	µg/L	Monitoring	210	ELN-8203A	4/6/2021	3.7
14808-79-8	Sulfate	125	mg/L	Monitoring	210	ELN-8203A	4/1/2020	1500
127-18-4	Tetrachloroethene	0.5	µg/L	Monitoring	229	ELM-9110	4/7/2020	0.12
109-99-9	Tetrahydrofuran	10	µg/L	Monitoring	211	ELN-8203B	5/2/2022	25
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	2.898
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	301	DBM-8201	4/24/2023	1.6
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.088
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.11
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	216	ELM-8901	10/9/2019	0.66
618-85-9	3,5-Dinitrotoluene	NA	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.68

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.

NA - A screening value is not available for the analyte.

Table 4b. Summary of Hypothetical Future Risks - Deterrent Burning Ground Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
79-00-5	1,1,2-Trichloroethane	0.041	µg/L	Monitoring	236	S1134R	4/6/2021	1.8	0.28	0.041	6E-06	4
78-87-5	1,2-Dichloropropane	0.5	µg/L	Monitoring	210	ELN-8203A	4/6/2021	0.66	0.85	0.82	8E-07	0.08
14808-79-8	Sulfate	125	mg/L	Monitoring	210	ELN-8203A	4/1/2020	1500	NA	NA	NA	NA
109-99-9	Tetrahydrofuran	10	µg/L	Monitoring	211	ELN-8203B	5/2/2022	25	NA	340	NA	0.01
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	2.898	0.1	1.1	3E-05	0.3
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	301	DBM-8201	4/24/2023	1.6	NA	NA	NA	NA
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.088	0.24	3.8	4E-07	0.002
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.11	0.049	0.57	2E-06	0.02
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	216	ELM-8901	10/9/2019	0.66	NA	NA	NA	NA
618-85-9	3,5-Dinitrotoluene	NA	µg/L	Monitoring	301	DBM-8201	4/24/2023	0.68	NA	NA	NA	NA
											4E-05	5
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 5a. Summary of Screening Assessment - Deterrent Burning Ground Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
71-55-6	1,1,1-Trichloroethane	40	µg/L	Monitoring	469	ELN-1003C	4/23/2019	0.1
79-00-5	1,1,2-Trichloroethane	0.041	µg/L	Residential	803	E12375A	8/10/2020	0.32
74-83-9	Bromomethane	1	µg/L	Residential	953	E12586A	4/23/2019	0.16
67-66-3	Chloroform	0.22	µg/L	Residential	860	E12653	8/16/2023	0.37
75-71-8	Dichlorodifluoromethane	20	µg/L	Monitoring	536	ELN-1503C	4/27/2023	0.68
179601-23-1	m & p-Xylene	19	µg/L	Residential	916	S7655	8/10/2020	0.24
1634-04-4	Methyl tert-butyl ether	12	µg/L	Residential	860	E12653	8/9/2022	0.85
91-20-3	Naphthalene	0.17	µg/L	Residential	429	E12564	7/15/2019	0.46
95-47-6	o-Xylene	19	µg/L	Residential	916	S7655	8/10/2020	0.13
109-99-9	Tetrahydrofuran	10	µg/L	Residential	419	S7832	8/15/2023	1.3
108-88-3	Toluene	110	µg/L	Residential	163	S7703A	8/13/2019	9.6
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	468	ELN-1003B	9/17/2019	0.231
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	469	ELN-1003C	6/8/2021	0.054
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Residential	803	E12375A	8/17/2021	0.076
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Residential	803	E12375A	8/17/2021	0.07
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	468	ELN-1003B	11/20/2019	0.17
156-60-5	trans-1,2-Dichloroethene	20	µg/L	Residential	419	S7832	8/15/2023	0.13
79-01-6	Trichloroethene	0.28	µg/L	Residential	414	E12655	8/17/2021	1.8

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.
4. Analytes highlighted in blue are not attributed to Army sources. Residential well plumbing components are the suspected sources for these analytes. Therefore, these analytes will not be used to evaluate risk in the DBG Plume.

NA - A screening value is not available for the analyte.

Table 5b. Summary of Current Risks - Deterrent Burning Ground Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
79-00-5	1,1,2-Trichloroethane	0.041	µg/L	Residential	803	E12375A	8/10/2020	0.32	0.28	0.041	1E-06	0.8
67-66-3	Chloroform	0.22	µg/L	Residential	860	E12653	8/16/2023	0.37	0.22	9.7	2E-06	0.004
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	468	ELN-1003B	9/17/2019	0.231	0.1	1.1	2E-06	0.02
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	469	ELN-1003C	6/8/2021	0.054	NA	NA	NA	NA
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Residential	803	E12375A	8/17/2021	0.076	0.24	3.8	3E-07	0.002
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Residential	803	E12375A	8/17/2021	0.07	0.049	0.57	1E-06	0.012
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	468	ELN-1003B	11/20/2019	0.17	NA	NA	NA	NA
											5E-06	1
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 6a. Summary of Screening Assessment - Central Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	7/5/2022	0.336
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	332	NLN-1001C	7/5/2022	0.081
619-15-8	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	6/10/2020	0.073
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	6/10/2020	0.064
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	331	NLN-1001A	4/8/2019	0.16

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.

NA - A screening value is not available for the analyte.

Table 6b. Summary of Hypothetical Future Risks - Central Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	7/5/2022	0.336	0.1	1.1	3E-06	0.03
602-01-7	2,3-Dinitrotoluene	NA	µg/L	Monitoring	332	NLN-1001C	7/5/2022	0.081	NA	NA	NA	NA
619-15-8	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	6/10/2020	0.073	0.24	3.8	3E-07	0.002
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	332	NLN-1001C	6/10/2020	0.064	0.049	0.57	1E-06	0.01
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Monitoring	331	NLN-1001A	4/8/2019	0.16	NA	NA	NA	NA
											3E-06	0
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 7a. Summary of Screening Assessment - Central Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
56-23-5	Carbon tetrachloride	0.46	µg/L	Monitoring	582	SEN-0501D	6/13/2019	0.21
67-66-3	Chloroform	0.22	µg/L	Residential	165	WE-SQ001	8/14/2019	2.1
108-88-3	Toluene	110	µg/L	Monitoring	580	SEN-0501A	6/13/2019	0.6
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Residential	435	WE-XK342	4/15/2021	0.131
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Residential	435	WE-XK342	4/15/2021	0.047
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	586	SEN-0503B	11/8/2022	0.046
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Residential	435	WE-XK342	4/15/2021	0.06
79-01-6	Trichloroethene	0.28	µg/L	Residential	172	E12014	7/10/2019	2.3

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022 or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.
4. Analytes highlighted in blue are not attributed to Army sources. Residential well plumbing components are the suspected sources for these analytes. Therefore, these analytes will not be used to evaluate risk in the Central Plume.

NA - A screening value is not available for the analyte.

Table 7b. Summary of Current Risks - Central Plume - Offsite Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
67-66-3	Chloroform	0.22	µg/L	Residential	165	WE-SQ001	8/14/2019	2.1	0.22	9.7	1E-05	0.02
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Residential	435	WE-XK342	4/15/2021	0.131	0.1	1.1	1E-06	0.01
121-14-2	2,4-Dinitrotoluene	0.005	µg/L	Residential	435	WE-XK342	4/15/2021	0.047	0.24	3.8	2E-07	0.001
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	586	SEN-0503B	11/8/2022	0.046	0.049	0.57	9E-07	0.008
610-39-9	3,4-Dinitrotoluene	NA	µg/L	Residential	435	WE-XK342	4/15/2021	0.06	NA	NA	NA	NA
											1E-05	0
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

NA - A screening value and/or tapwater RSL was not available for the analyte. Where a tapwater RSL was not available, risk was not estimated.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

Table 8a. Summary of Screening Assessment - Nitrocellulose Production Area Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	442	RIM-0705	9/13/2022	0.144
619-15-8	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	478	RIM-1002	4/23/2019	0.062
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	442	RIM-0705	9/13/2022	0.097

Notes:

1. Those analytes detected at least once in a well in 2019, 2020, 2021, 2022, or 2023 within this specific plume area are presented in this table.
2. Those analytes that have a maximum concentration greater than the screening level are highlighted in yellow and represent chemicals of potential concern (COPCs) for which further evaluation of risk will be conducted.
3. For the screening assessment, all dinitrotoluene isomers (e.g., 2,4-dinitrotoluene, 3,4-dinitrotoluene, etc.) were summed together to calculate a total dinitrotoluene value for each sample. The total dinitrotoluene value was then compared to the lowest screening value available for the dinitrotoluene isomers. This conservative approach was used because many of the dinitrotoluene isomers did not have screening values. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting for informational purposes.

Table 8b. Summary of Hypothetical Future Risks - Nitrocellulose Production Area Plume - Onsite Monitoring Wells
Screening Level Groundwater Risk Evaluation
Badger Army Ammunition Plant

CAS	Analyte	Screening Level	Units	Well Type	Well ID	Well Name	Date Sampled	Result (maximum)	EPA Cancer-based Tapwater RSL	EPA Noncancer-based Tapwater RSL (Based on THQ=0.1)	Cancer Risk[1]	Noncancer Hazard Quotient (HQ)[1]
25321-14-6	Total Dinitrotoluene	0.005	µg/L	Monitoring	442	RIM-0705	9/13/2022	0.144	0.1	1.1	1E-06	0.01
619-15-8	2,4-Dinitrotoluene	0.005	µg/L	Monitoring	478	RIM-1002	4/23/2019	0.062	0.24	3.8	3E-07	0.002
606-20-2	2,6-Dinitrotoluene	0.005	µg/L	Monitoring	442	RIM-0705	9/13/2022	0.097	0.049	0.57	2E-06	0.02
											2E-06	0
											Cumulative Cancer Risk	Hazard Index (HI)

Notes:

1. For each chemical of potential concern (COPC) identified for the plume area, a cancer risk and noncancer hazard quotient (HQ) were calculated if appropriate U.S. Environmental Protection Agency (EPA) tapwater regional screening levels (RSLs) were available for an analyte.
2. The noncancer HQ for each chemical was calculated using the EPA noncancer-based tapwater RSLs based on a target hazard quotient (THQ) of 0.1.
3. The cumulative cancer risk is calculated by summing the individual cancer risks for each COPC. The total noncancer risk is calculated by summing the analyte-specific HQs to develop a hazard index (HI).
4. The total dinitrotoluene concentration represents the sum of all isomers of dinitrotoluene detected in the water sample. The individual isomers that make up the total dinitrotoluene concentration for the water sample are provided below the total value in gray highlighting. The risks associated with dinitrotoluene are based on the total value and the individual isomers. The highest of the two risk estimates (i.e., based on total or the sum of individual isomers) are used in calculating the total risk for the plume area.

Footnote:

1. All risk values are rounded to one significant figure by convention. In some cases the cumulative cancer risk or hazard index may be different from the sum of the individual cancer risks or HQs as presented because they are summed from the unrounded values.

RESOLUTION by Members of the Badger Restoration Advisory Board (RAB)

Supporting U.S. Army Compliance with WI Groundwater Standards and WDNR Directives at and near Badger Army Ammunition Plant

January 16, 2025

WHEREAS, the U.S. Army Environmental Command has informed the Wisconsin Department of Natural Resources (WDNR) that it will NOT comply with the State's enforceable groundwater standards for certain cancer-causing chemicals that have migrated to groundwater, and

WHEREAS, for decades, contamination from the former 7,400-acre Badger Army Ammunition Plant has been moving offsite and now poses a threat to as many as 300 residential drinking water wells in rural Sauk County, and

WHEREAS, the WDNR has issued at least three formal letters (June 2023, October of 2023 and again in October 2024) to the U.S. Army calling for compliance with state groundwater standards, and

WHEREAS, the Army is pursuing a level of cleanup that is 100 times LESS protective of human health (1x10-4) for the Badger lands, and

WHEREAS, the purpose of the Badger Restoration Advisory Board is to serve as an avenue for communications between the installation, state and federal officials, and the community about the environmental restoration activities at the former Badger Army Ammunition Plant,

THEREFORE we, the undersigned members of the Badger Restoration Advisory Board, call on **Wisconsin Governor Tony Evers** to act to assure that the Department of Defense fully complies with state environmental rules and regulations and act to protect the health and sustainability of Wisconsin's groundwater at Badger Army Ammunition Plant and throughout the state.

SIGNED:

Laura Olah, Citizens for Safe Water Around Badger (CSWAB)

Charlie Wilhelm, At Large member

Kendall Lins, At Large member

Bill Stehling, Sauk City

Mike Gleason, Lake Wisconsin Alliance

Doug Gjertson, Town of Sumpter

Chris Hanson, Member-at-Large

Michele Hopp, Village of Merrimac

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
3911 Fish Hatchery Road
Fitchburg WI 53711-5397

Tony Evers, Governor

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WISCONSIN
DEPT. OF NATURAL RESOURCES

July 17, 2024

Laura Powell
U.S. Army Environmental Command
2455 Reynolds Road
Joint Base San Antonio Fort Sam Houston, TX 78234

SENT BY ELECTRONIC MAIL

Subject: Nitrocellulose Production Area Plume
Former Badger Army Ammunition Plant, Baraboo, WI
DNR BRRTS Activity #02-57-001002

Dear Laura Powell:

The U.S. Army Environmental Command (Army) and the Wisconsin Department of Natural Resources (DNR) have been in correspondence regarding the Draft Final Proposed Plan for Site-Wide Groundwater at the Former Badger Army Ammunition Plant (Draft Proposed Plan). The Draft Proposed Plan identifies the Army's preferred remedial alternative to address contaminated groundwater in the Central Plume, Deterrent Burning Ground Plume, and Propellant Burning Ground Plume. No remedial alternatives were evaluated for the Nitrocellulose Production Area Plume (Nitrocellulose Plume) and no remedial action is proposed to be taken. In the Draft Proposed Plan, the Army stated that, based on its Human Health Risk Assessment, the Nitrocellulose Plume "does not pose a hypothetical future risk to groundwater usage by humans." The DNR does not concur with the Army's determination and in June and October 2023 provided comments on the Draft Proposed Plan requesting that the Army evaluate remedial alternatives to address groundwater contamination in the Nitrocellulose Plume. In a November 2023 response to DNR's comments on the Draft Proposed Plan, the Army indicated that it would update the Draft Proposed Plan to include an evaluation of remedial alternatives and remedy selection for the Nitrocellulose Plume. Subsequently, the Army in March 2024 indicated to the DNR that it does not intend to conduct this evaluation.

The Nitrocellulose Plume is located on land held in trust for the Ho-Chunk Nation and the groundwater plume may be migrating on to land owned by DNR. The Army is addressing this site under CERCLA and is responsible for complying with any applicable requirements or policies regarding tribal consultation. The DNR requests that the Army actively engage with the Ho-Chunk Nation regarding the Draft Proposed Plan and the Army's determination that it is not necessary to evaluate remedial alternatives for the Nitrocellulose Plume. The DNR intends to engage with the Ho-Chunk Nation before issuing any determination on the Draft Proposed Plan. To help inform the DNR's discussion with the Ho-Chunk Nation, the DNR requests a written response from the Army on how the Army has engaged with the Ho-Chunk Nation to date and what additional engagement the Army plans to have with the Ho-Chunk Nation.

The DNR appreciates your efforts to investigate and remediate this site. If you have any questions, please contact me at (414) 750-7140 or Issac.Ross@wisconsin.gov or the DNR Project Manager, Luke Lampo at (608) 206-5809 or luke.lampo@wisconsin.gov.

Sincerely,

Issac A. Ross
Regional Supervisor
South Central Region, Fitchburg, WI
Remediation & Redevelopment Program

cc: Quang Nguyen, Army
Issac Ross, DNR SCR Region
Ben Cornelius, DNR
Shelly Allness, DNR SCR Region

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October 17, 2024

Laura Powell
US Army Environmental Command
2455 Reynolds Road
Joint Base San Antonio Fort Sam Houston, TX 78234

SENT BY ELECTRONIC MAIL

Subject: DNR Comments on Proposed Plan for Site-Wide Groundwater
Former Badger Army Ammunition Plant, Baraboo, WI
DNR BRRTS Activity #02-57-001002, 02-57-562629, and 02-57-526445

Dear Laura Powell:

The Wisconsin Department of Natural Resources (DNR) has received and reviewed the document entitled "Final Proposed Plan for Site-Wide Groundwater Former Badger Army Ammunition Plant Baraboo, Wisconsin" (Proposed Plan), dated July 2024, prepared for U.S. Army Environmental Command (Army) by SpecPro Professional Services, LLC (SpecPro).

Background:

The Proposed Plan has been revised using more recent groundwater data, as requested by DNR. All figures have been updated using groundwater data from 2023 and an updated risk assessment was conducted using groundwater data from 2019 to 2023. Tables regarding Contaminants of Potential Concern (COPCs) and Contaminants of Concern (COCs) were revised based on the updated risk assessment.

The Army's preferred remedial alternative for the Central Plume, Deterrent Burning Ground (DBG) Plume, and Propellant Burning Ground (PBG) Plume is anaerobic bioremediation. This alternative includes in-situ bioremediation utilizing emulsified vegetable oil pumped into vertical injection wells, monitored natural attenuation (MNA), groundwater sampling of monitoring and residential wells, groundwater land use controls, and an alternate water supply provision. This alternative will target remediating impacted groundwater by dinitrotoluene (DNT) above the ch. NR 140, Wis. Adm. Code Enforcement Standard (NR 140 ES). The Army expects MNA to remediate groundwater impacted by volatile organic compounds (VOCs) via natural processes.

No remedial alternatives were evaluated for the Nitrocellulose Production Area (NC) Plume due to a lack of identified risk. The Proposed Plan states the Army will continue to monitor groundwater impacts associated with the NC Plume until it is deemed unnecessary by DNR.

DNR provides the following comments on the Proposed Plan.

DNR Comments:

The Proposed Plan uses a cancer risk threshold of $1x10^{-4}$ within the former Badger Army Ammunition Plant (BAAP) property line (on-site) and a cancer risk threshold of $1x10^{-6}$ outside the BAAP property line (off-site) as criteria for potential action or additional evaluation. DNR utilizes a $1x10^{-6}$ cancer risk threshold for establishing risk-based levels for groundwater and continues to request that COCs for all groundwater plumes be revised using a $1x10^{-6}$ cancer risk threshold on-site and off-site. Any additional COCs identified should then be reviewed for potential action or additional evaluation. DNR has previously made this request on June 2, 2023 and October 19 2023 in response to earlier versions of the Proposed Plan. Based on DNR's review of the updated risk assessment using a $1x10^{-6}$ cancer risk threshold on-site and off-site, the following revisions should be made to the Proposed Plan:

- PBG Plume: The following compounds should be added as COCs in Table 3.2: 1,2-dichloroethane, bromodichloromethane, and naphthalene. Additionally, benzene should be marked as a cancer risk in Table 3.2.

- DBG Plume: The following compound should be added as a COC in Table 4.2: 2,6-DNT.

- Central Plume: The following compound should be added as a COC in Table 5.2: 2,6-DNT.

- NC Plume: Section 6.4 should be revised to state the risk assessment has determined contaminated groundwater in the NC Plume poses an unacceptable risk to groundwater usage by humans, and the following compounds should be marked as a cancer risk in Table 6.2: 2,6-DNT and total DNT. Additionally, remedial alternatives should be evaluated for the NC plume as groundwater concentrations of DNT exceed the NR 140 ES.

DNR appreciates your efforts to investigate and remediate this site. If you have any questions, please contact me at (608) 206-5809 or luke.lampo@wisconsin.gov.

Sincerely,

Luke Lampo
Hydrogeologist
Remediation and Redevelopment Program

cc: Quang Nguyen, Army
Joel Janssen, SpecPro
Issac Ross, DNR

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
3911 Fish Hatchery Road
Fitchburg WI 53711-5397

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June 2, 2023

Quang Nguyen
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2455 Reynolds Road
Joint Base San Antonio Fort Sam Houston, TX 78234

SENT BY ELECTRONIC MAIL

Subject: DNR Comments on Draft Proposed Plan for Site-Wide Groundwater
Former Badger Army Ammunition Plant, Baraboo, WI
DNR BRRTS Activity #02-57-001002, 02-57-562629, and 02-57-526445

Dear Mr. Nguyen:

The Wisconsin Department of Natural Resources (DNR) has received and reviewed the document entitled "Draft Final Proposed Plan for Site-Wide Groundwater Former Badger Army Ammunition Plant Baraboo, Wisconsin" (Draft PP), dated February 2023, prepared for U.S. Army Environmental Command (Army) by SpecPro Professional Services, LLC (SpecPro).

Background:

The Draft PP identifies the Army's preferred alternative to address impacted groundwater associated with the former Badger Army Ammunition Plant (BAAP). The Army's preferred alternative for the Central Plume, Deterrent Burning Ground (DBG) Plume, and Propellant Burning Ground (PBG) Plume is anaerobic bioremediation.

This alternative includes in-situ bioremediation utilizing emulsified vegetable oil pumped into vertical injection wells, monitored natural attenuation (MNA), groundwater sampling of monitoring and residential wells, groundwater land use controls, and an alternate water supply provision. This alternative will include targeted remediation of impacted groundwater with dinitrotoluene (DNT) concentrations above the ch. NR 140, Wis. Adm. Code Enforcement Standard (NR 140 ES). The Army expects MNA to remediate groundwater impacted by volatile organic compounds (VOCs) via natural processes.

No remedial alternatives were evaluated for the Nitrocellulose Production Area (NC) Plume due to a lack of identified risk. The Draft PP states the Army will continue to monitor groundwater impacts associated with the NC Plume until it is deemed unnecessary by the DNR.

DNR Response:

The DNR has reviewed the Draft PP and provides the following comments:

<u>Draft Proposed Plan Comments</u>

- The DNR understands the Army will be conducting pilot scale testing as part of the remedial design phase. **The DNR requests involvement with pilot scale testing and would appreciate the opportunity to review and comment on all aspects of pilot scale testing efforts.**

- The data presented in the Draft PP are from between 2015 and 2018 and are thus outdated. **All relevant tables and figures should be updated using recently available data.**

- The Remedial Investigation/Feasibility Study (RI/FS) and Draft PP do not adequately demonstrate that site conditions are favorable for anaerobic bioremediation. **Provide data that has been collected to date that would indicate anaerobic bioremediation will be an effective remedy given site conditions. If limited information is available, the DNR recommends collecting data to help understand the effectiveness of anaerobic bioremediation.**

- The Human Health Risk Assessment (HHRA) used a cumulative cancer risk greater than $1x10^{-6}$ outside of the BAAP property line (off-site), and a cumulative cancer risk greater than $1x10^{-4}$ within the BAAP property line (on-site), as criteria for potential action or additional evaluation. The HHRA found no unacceptable risk associated with the Nitrocellulose Plume, which is only present on-site, or for several Contaminants of Potential Concern (COPCs) associated with the on-site portions of the Central Plume, DBG Plume, and PBG Plume. **The DNR utilizes a $1x10^{-6}$ excess lifetime cancer risk threshold for establishing risk-based levels for groundwater. The DNR considers any contaminant found in groundwater that exceeds the NR 140 ES or Maximum Contaminant Level (MCL), whichever is more stringent, a contaminant of concern (COC) for that plume, regardless of if on-site groundwater is considered under the control of the Army. The DNR recommends amending on-site COCs for all groundwater plumes using a $1x10^{-6}$ cancer risk threshold. Any additional on-site COCs identified should then be reviewed for potential action or additional evaluation.**

- The RI/FS and Draft PP state MNA is expected to reduce concentrations of VOCs via natural processes.
    - **Provide data that has been collected to date that would indicate MNA will be an effective remedy.**
    - **Consideration should be given to analyzing groundwater for additional geochemical parameters to support MNA effectiveness.**

<u>General Comments</u>

- Elevated concentrations of DNT in groundwater continue to be detected in the PBG Plume source area. The RI/FS and Draft PP suggest elevated DNT concentrations in groundwater are likely due to groundwater rising and coming into contact with contaminated soil underneath the PBG Waste Pits. **Describe how the proposed remedy will address this potentially continuous source of DNT contamination in groundwater.**

- The PBG plume continues to shift toward the east since the shutdown of the Interim Remedial Measure/Modified Interim Remedial Measure (IRM/MIRM) groundwater extraction systems. **Evaluate the need to modify the groundwater sampling program, for both monitoring wells and residential wells, to better understand eastern PBG Plume dynamics and potential risk to nearby residential wells.**

- Evaluate the need for additional monitoring wells compliant with ch. NR 141, Wis. Adm. Code to better define the degree and extent of groundwater impacted by DNT associated with the NC Plume.

- The DNR's acceptance of the preferred alternative will be determined after the public comment period ends and will be described in the Record of Decision (ROD).

The DNR appreciates your efforts to restore the environment at this time. If you have any questions or comments, please contact the DNR Project Manager, Luke Lampo, at 608-206-5809 or at luke.lampo@wisconsin.gov

Sincerely,

Luke Lampo
Hydrogeologist
Remediation & Redevelopment Program

cc:
Dwight Hollon, Army
Clayton (Matt) Dayoc, Army
Joel Janssen, SpecPro
Issac Ross, DNR

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October 19, 2023

Dwight Hollon
U.S. Army Environmental Command
2455 Reynolds Road
Joint Base San Antonio Fort Sam Houston, TX 78234

SENT BY ELECTRONIC MAIL

Subject: DNR Comments on Revised Draft Proposed Plan for Site-Wide Groundwater
Former Badger Army Ammunition Plant, Baraboo, WI
DNR BRRTS Activity #02-57-001002, 02-57-562629, and 02-57-526445

Dear Mr. Hollon:

The Wisconsin Department of Natural Resources (DNR) has received and reviewed the document entitled "Draft Final Proposed Plan for Site-Wide Groundwater Former Badger Army Ammunition Plant Baraboo, Wisconsin" (Revised Draft PP), dated August 2023, prepared for the U.S. Army Environmental Command (Army) by SpecPro Professional Services, LLC (SpecPro).

In February 2023, DNR received an initial Draft Proposed Plan for Site-Wide Groundwater (Draft PP). DNR provided comments to the Draft PP in a letter dated June 2, 2023. The Revised Draft PP sufficiently addresses many of the comments provided by DNR. DNR provides the following comments to the Revised Draft PP:

- **DNR comment – June 2023:** The Human Health Risk Assessment (HHRA) used a cumulative cancer risk greater than $1x10^{-6}$ outside of the BAAP property line (off-site), and a cumulative cancer risk greater than $1x10^{-4}$ within the BAAP property line (on-site), as criteria for potential action or additional evaluation. The HHRA states there is no unacceptable risk associated with the Nitrocellulose Plume, which is only present on-site, or for several Contaminants of Potential Concern (COPCs) associated with the on-site portions of the Central Plume, DBG Plume, and PBG Plume. The DNR utilizes a $1x10^{-6}$ excess lifetime cancer risk threshold for establishing risk-based levels for groundwater. The DNR considers any contaminant found in groundwater that exceeds the [Wis. Admin. Code ch. NR 140 Enforcement Standard] NR 140 ES or Maximum Contaminant Level (MCL), whichever is more stringent, a contaminant of concern (COC) for that plume, regardless of if on-site groundwater is considered under the control of the Army. The DNR recommends amending on-site COCs for all groundwater plumes using a $1x10^{-6}$ cancer risk threshold. Any additional on-site COCs identified should then be reviewed for potential action or additional evaluation.

  Army response – August 2023: The Army acknowledges the DNR's $1x10^{-6}$ risk policy; however, the cancer risk thresholds were selected in compliance with NCP and EPA guidelines. Based on the NCP and EPA guidance, cumulative carcinogenic risks 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 risks above $1x10^{-4}$ indicate unacceptable levels of risk where remedial 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.

The Army will review the determination of on-site or off-site COCs for all groundwater plumes. The Army will update the COC tables in the PP.

DNR response – October 2023: When a Federal facility is not on the National Priorities List (NPL), State laws concerning removal and remedial actions, including State laws regarding enforcement, apply to Federal facility actions as long as the State law is not more stringent for Federal facilities than for private facilities. CERCLA § 120 applies to federal facilities, and CERCLA § 120(a)(4) states "State laws concerning removal and remedial action, including State laws regarding enforcement, shall apply to removal and remedial action at facilities owned or operated by a department, agency, or instrumentality of the United States or facilities that are the subject of a deferral under subsection (h)(3)(C) when such facilities are not included on the National Priorities List. The preceding sentence shall not apply to the extent a State law would apply any standard or requirement to such facilities which is more stringent than the standards and requirements applicable to facilities which are not owned or operated by any such department, agency, or instrumentality."

DNR considers the groundwater on-site and off-site to be waters of the State, and ch. NR 140, Wis. Adm. Code groundwater standards apply as an Applicable or Relevant and Appropriate Requirements (ARARs) for determining risk and for setting groundwater cleanup levels at the site, regardless of whether the Army is in control of the groundwater.

As previously requested by DNR, the Revised Draft PP should be updated to identify COCs based on a cumulative cancer risk of $1x10^{-6}$ and any contaminant found within on-site or off-site groundwater plumes in exceedance of an NR 140 ES. Any additional COCs identified should then be reviewed for potential action or additional evaluation.

- **DNR comment – June 2023:** Evaluate the need for additional monitoring wells compliant with ch. NR 141, Wis. Adm. Code to better define the degree and extent of groundwater impacted by [dinitrotoluene] DNT associated with the [Nitrocellulose] NC Plume.

  Army response – August 2023: There is no risk associated with the NC Plume. The Army acknowledges the WDNR's request, but the Army's focus is on the groundwater plumes that indicate potential risk to the public and their drinking water. The Army is planning to develop a comprehensive groundwater sampling plan that may include additional wells to define the NC Plume.

  DNR response – October 2023: Associated with the previous October 2023 DNR response, DNR notes the NC Plume is located on-site and was reviewed for potential action or additional evaluation using a cumulative cancer risk threshold of $1x10^{-4}$. The HHRA calculated a cumulative cancer risk of $4x10^{-6}$ for the NC Plume and concentrations of DNT in groundwater exceed the NR 140 ES.

The DNR appreciates your efforts to restore the environment at this time. If you have any questions or comments, please contact me at 608-206-5809 or at luke.lampo@wisconsin.gov

Sincerely,

Luke Lampo
Hydrogeologist
Remediation & Redevelopment Program

cc:
Quang Nguyen, Army
Joel Janssen, SpecPro
Issac Ross, DNR

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September 9, 2020

Bryan Lynch, Physical Scientist (Environmental)
Army Environmental Command, Midwest Services Division
2450 Connell Rd
Fort Sam Houston, TX 78234

Subject: Request for Additional PFAS Sampling
Badger Army Ammunition Plant, Sauk County, Wisconsin
BRRTS #02-57-001002

Dear Mr. Lynch:

The Wisconsin Department of Natural Resources (Department) previously reviewed the document entitled "Draft Final Preliminary Assessment of Per- and Polyfluoroalkyl Substances, Badger Army Ammunition Plant, Sauk County, Wisconsin, dated March 2020 prepared for U.S. Army Corps of Engineers, Baltimore District by Arcadis U.S. Inc." The Department provided comments on that document (PA/SI) in a letter to you dated May 15, 2020. Those comments were focused on our authority to regulate PFAS compounds, identified the list of parameters that should be included in the analytical testing program, and referenced the process for establishing site-specific cleanup standards.

The sampling conducted during the PA/SI was focused on a few areas of the site that were thought to be the most likely to have PFAS contamination based on a review of limited historical information. The PA/SI discovered detectable levels of PFAS compounds in soil and groundwater at several locations. Although the detected PFAS concentrations in groundwater were generally below the Wisconsin Department of Health Services' recommended groundwater quality standard of 20 ppt of PFOA and PFOS separately or combined, their presence, and the presence of PFAS compounds in some soil samples, suggests the possibility of a discharge to the environment of these chemicals from site activities. The Department believes there is considerable uncertainty regarding potential discharges of PFAS at this site.

Therefore, the Department is requesting that a more comprehensive investigation of the nature and extent of PFAS in soil and groundwater be conducted at the site as defined in NR 716.09. The parameters for testing should follow those outlined in our May 15, 2020 letter.

We want to thank the Army for their work on this challenging project. Please feel free to contact me with any questions or comments by telephone at 608-293-0112 or via e-mail at stevenl.martin@wisconsin.gov.

Sincerely,

Steven L. Martin, P.G.
South Central Region Team Supervisor
Remediation & Redevelopment Program

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May 15, 2020

Bryan Lynch, Physical Scientist (Environmental)
Army Environmental Command, Midwest Services Division
2450 Connell Rd
Fort Sam Houston, TX 78234

Subject: Comments on the Draft Final Preliminary Assessment of Per- and Polyfluoroalkyl Substances, Badger Army Ammunition Plant, Sauk County, Wisconsin
BRRTS #02-57-001002

Dear Mr. Lynch:

The Department of Natural Resources (Department) has reviewed the document entitled "Draft Final Preliminary Assessment of Per- and Polyfluoroalkyl Substances, Badger Army Ammunition Plant, Sauk County, Wisconsin, dated March 2020 prepared for U.S. Army Corps of Engineers, Baltimore District by Arcadis U.S. Inc.

The Department has the following comments on that document:

- CERCLA does not give the federal government sovereign immunity from adhering to State regulations. Specifically, according to CERCLA § 120(a)(4), State laws concerning removal and remedial actions, including State laws regarding enforcement, apply to federal facility actions owned or operated by the federal government.

- When discharged to the environment, per- and polyfluoroalkyl substances (PFAS) meet the definitions of hazardous substance and environmental pollution under Wis. Stat. § 292.01. Discharges of PFAS to the environment are subject to regulation under Wis. Stat. ch. 292 and the requirements for immediate notification, investigation, and remediation in Wis. Admin. Code chs. NR 700 through 754. For more information, see dnr.wi.gov, search "RR Report", then search "PFAS authority".

- The lack of promulgated numerical cleanup standards for a hazardous substance does not prevent an entity in Wisconsin from responding to a discharge of PFAS in Wisconsin, in accordance with Wis. Admin. Code § NR 722.09.

- The soil analytical results were compared to screening levels using the USEPA RSL Calculator. The State of Wisconsin has established procedures for calculating soil cleanup standards. Specifically, Wis, Adm. Code NR 720.07, NR720.10 and NR 720.12 specify these procedures. We request that the Army develop site specific soil cleanup standards for direct contact and migration to groundwater in accordance with these regulations and subsequently compare the analytical results to those calculated standards.

- The groundwater analytical results were compared to screening levels using the USEPA RSL Calculator. The State of Wisconsin has established procedures for calculating groundwater standards in the absence of promulgated standards. Specifically, Wis, Adm. Code NR 722.09(2)(b)(2) specifies these procedures. We request that the Army develop site specific groundwater standards in accordance with these regulations and subsequently compare the analytical results to those calculated standards.

We want to thank the Army for their work on this challenging project. Please feel free to contact me with any questions or comments by telephone at 608-293-0112 or via e-mail at stevenl.martin@wisconsin.gov.

Sincerely,

Steven L. Martin, P.G.
South Central Region Team Supervisor
Remediation & Redevelopment Program

CSWAB Fact Sheet

Overview of Certain Badger Army Testing Parameters for the Village of Prairie du Sac Well #3

*The U.S. Army currently tests the Village of Prairie du Sac Well Municipal Well #3 on an annual basis for some of the groundwater contaminants associated with Badger Army Ammunition Plant. Based on a careful review of dozens of reports by the U.S. Army, WDNR, and WI Division of Public Health, CSWAB found that the Army currently tests Well #3 for all six forms of the explosive Dinitrotoluene (DNT) but does not test for **ANY** of the possible degradation (breakdown) products of DNT.*

No.	Degradation Products of the Explosive DNT	CAS #	Agency that identified parameter as Deg Prod of DNT	WDNR Parameter Code	Maximum Conc. At PBG **March 2010** (ug/L)	NR 140 Public Health ES (ug/L)	WI DHS/ US EPA Lifetime HAL/CR (ug/L)	Parameter included in Army testing PDS Well #3 **March/June/ Aug 2013**	Army Result PDS Well #3 **March/June 2013** (ug/L)	Army Result PDS Well #3 **Aug 2013** (ug/L)
1	2-Nitroaniline	88-74-4	WDNR	78142	150	None found	*None found*	YES/YES/NO	<0.5	Not tested
2	3-Nitroaniline	99-09-2		78300	3.4			YES/YES/NO	<0.5	
3	4-Nitroaniline	100-01-6		73605	< 1.3			YES/YES/NO	<3	
4	2-Nitrotoluene (*o*-Nitrotoluene)	88-72-2		77394	8.4		0.15 (a)	NO	Not tested	
5	3-Nitrotoluene (*m*-Nitrotoluene)	99-08-1		46341	3.4		200 (a)	NO		
6	4-Nitrotoluene (*p*-Nitrotoluene)	99-99-0		77395	12.6		2 (a)	NO		
7	2-Methyl-3-Nitroaniline	603-83-8		49143	400		4 (a)	NO		
8	2-Methyl-5-Nitroaniline	99-55-8		73622	1,350		4 (a)	NO		
9	2-Methyl-6-Nitroaniline	570-24-1		99544	16.7		4 (a)	NO		
10	4-Methyl-2-Nitroaniline	89-62-3		99545	54.5		4 (a)	NO		
11	4-Methyl-3-Nitroaniline	119-32-4		78898	165		4 (a)	NO		
12	5-Methyl-2-Nitroaniline	578-46-1		99546	93.7		None (c)	NO		
13	2-Amino-4,6-Dinitrotoluene	35572-78-2		78901	*Not Tested*		1 (a)	NO		
14	2,4-Diaminotoluene	95-80-7		78888			*None found*	NO		
15	2,6-Diaminotoluene	823-40-5		99543				NO		
16	Nitrite (as N)	14797-65-0		615	8,160	1,000		NO		
17	Benzofuran	271-89-6		*None*	*Not Tested*	*None found*		NO		
18	3-Methylbenzofuran	21535-97-7						NO		
19	5-Methylbenzofuran	18441-43-5						NO		
20	3-Methyl-2-Nitroaniline	601-87-6						NO		
21	3-Methyl-4-Nitroaniline	611-05-2						NO		
22	3-Methyl-5-Nitroaniline	618-61-1						NO		
23	1,3-Dinitrobenzene	99-65-0	WI DHS	45622			1 (a)	NO		
24	Nitrobenzene	98-95-3	WDNR	34447			0.35 (b)	YES/YES/NO	< 0.5	

Source: (a) Wisconsin Division of Public Health. ***The HAL for the methylnitroanilines is intended as the summed total concentration of all five isomers or 4 ug/l.***
(b) U.S. Environmental Protection Agency (c) No WI DHS HAL based on lack of evidence of mutagenicity, in contrast to the other methyl-nitroaniline isomers listed (Wi DHS, R. Wozniak, PhD, 27 March 2014)

NOTATIONS:

- *The Army is required to test Village Well #3 annually for all six forms of DNT (2,3-DNT, 2,4-DNT, 2,5-DNT, 2,6-DNT, 3,4-DNT, and 3,5-DNT). DNT has not been detected in Village Well #3. CSWAB successfully petitioned for WI Groundwater Enforcement Standards (ES) for all six DNT isomers. The ES for the summed total concentration of all six isomers of DNT is 0.05 ug/L.*
- *Of the DNT degradation products listed in this table, only Nitrite has a State Drinking Water or Groundwater Enforcement Standard. The Village monitors Well #3 for Nitrates and **Nitrites**.*
- *So far, CSWAB has successfully petitioned the State for Health Advisory Levels (HALs) for five degradation products of DNT. A HAL is a non-regulatory concentration of a contaminant in water that is likely to be without adverse effects on health and aesthetics.*
- *Concerning active groundwater remediation at Badger Army Ammunition Plant, the MIRM system wells near the plant boundary (which are still functional) are still running. Treated groundwater is discharged to Lake Wisconsin. The IRM system (close to the Propellant Burning Ground source area) is currently shut down as of March 19, 2014, according to Army officials at Badger.*
- *Carbon Dioxide was also identified by the WDNR as a degradation product of DNT but was not included in the above table.*

No.	Other Groundwater Contaminants of Concern	CAS #	Parameter Code	Maximum Level Detected at Plant Boundary **October 2013** *(ug/L)*	NR 140 Public Health ES *(ug/L- except as noted)*	WI DHS/US EPA Lifetime HAL/CR *(ug/L)*	Parameter included in Army testing PDS Well #3 **Mar/June/Aug 2013**	Army Results PDS Well #3 March/June/Aug 2013 *(ug/L)*
1	Ethyl ether	60-29-7	61056	7,690	1,000	--	**YES/YES/YES**	< 0.1 *(all)*


Groundwater monitoring wells north of the Village.
June 29, 2012

Citizens for Safe Water Around Badger (CSWAB)
E12629 Weigand's Bay South
Merrimac, WI 53561
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CAS Registry Number = Chemical Abstracts Service (CAS) Registry Number
NR 140 Public Health ES = NR 140 Wis. Adm. Code, public health related groundwater quality Enforcement Standard (ES)
PBG = Propellant Burning Grounds at Badger Army Ammunition Plant
PDS = Village of Prairie du Sac. The U.S. Army tests Well #3 (PDS-3) under License 3497, Point 911.
WI DHS/US EPA Lifetime HAL/CR = United States Environmental Protection Agency (US EPA) or Wisconsin Dept. of Heath Services (WI DHS) established lifetime health advisory level (HAL) or estimated 10-6 cancer risk (CR)
WDNR = Wisconsin Department of Natural Resources
ug/L= micrograms per liter (parts per billion)

References:

U.S. Army, Case Narrative Groundwater Monitoring License Number 2814, Propellant Burning Grounds, March 2010, Badger Army Ammunition Plant.
U.S. Department of Health and Human Services, Health Consultation, Dinitrotoluene in Private Wells, Badger Army Ammunition Plant, September 30, 2006, Table 2.
Wisconsin DNR GEMS Database (Public access to landfill environmental monitoring data), accessed online at http://dnr.wi.gov/topic/landfills/gems.html (Notation: Despite the DNR's best efforts to provide accurate data, there may be errors and omissions.)
Wisconsin DNR *Response to Public Comments on the Army's Alternative Feasibility Study for Groundwater*, 2012, pages 39-40.

Important Questions for Follow-up:

- Should monitoring of Village Well #3 by the U.S. Army at Badger Army Ammunition Plant be expanded to include **all 24** DNT degradation products identified by the Army, health officials, and WDNR?
- Are **offsite** groundwater monitoring wells and **private** drinking water wells being regularly tested for these DNT degradation products?
- Is it possible for DNT degradation products to be present in groundwater in the **absence** of DNT (parent product)?
- Are there **sentinel** groundwater monitoring wells screened at appropriate depths upgradient of drinking water wells in the Village?
- Are there seasonal or other **trends** in groundwater contaminants (from Badger) near the Village?
- Could **irrigation wells** located between Badger and the Village affect the groundwater contaminant plumes and/or groundwater movement near the Village?
- What are the **historical trends in ethyl ether** in groundwater at Badger? Are the current high levels of ethyl ether a new problem? What is the source?
- In addition to those listed in this report, are there **health-based drinking water standards or advisories** for the DNT degradation products identified by the WDNR and health officials?

Report Date: March 31, 2014

Environ. Sci. Technol. 2003, 37, 3382–3391

what factors limit the biodegradation of DNT in the vadose zone? For example, are high concentrations of DNT in the source area inhibiting or toxic to bacteria? Could high concentrations of 2,4-DNT inhibit 2,6-DNT degradation? nitrite levels? pH? Last paragraph - good questions here.

Soil Column Evaluation of Factors Controlling Biodegradation of DNT in the Vadose Zone

JOHN D. FORTNER,[†] CHUNLONG ZHANG,[‡] JIM C. SPAIN,[§] AND JOSEPH B. HUGHES*,[†]

Department of Civil and Environmental Engineering, Rice University, 6100 Main Street, Houston, Texas 77005, School of Natural and Applied Sciences, University of Houston—Clear Lake, Houston, Texas 77058, and Air Force Research Laboratory/MLQR, 139 Barnes Drive, Suite 2, Tyndall AFB, Florida 32403-5323

High concentrations of 2,4-dinitrotoluene (2,4-DNT) and 2,6-dinitrotoluene (2,6-DNT) are present in vadose zone soils at many facilities where explosives manufacturing has taken place. Both DNT isomers can be biodegraded under aerobic conditions, but rates of intrinsic biodegradation observed in vadose zone soils are not appreciable. Studies presented herein demonstrate that nutrient limitations control the onset of rapid 2,4-DNT biodegradation in such soils. In column studies conducted at field capacity, high levels of 2,4-DNT biodegradation were rapidly stimulated by the addition of a complete mineral medium but not by bicarbonate-buffered distilled deionized water or by phosphate-amended tap water. Biodegradation of 2,6-DNT was not observed under any conditions. Microcosm studies using a DNT-degrading culture from column effluent suggest that, after the onset of 2,4-DNT degradation, nitrite evolution will eventually control the extent of degradation achieved by two mechanisms. First, high levels of nitrite (40 mM) were found to strongly inhibit 2,4-DNT degradation. Second, nitrite production reduces the solution pH, and at pH levels below 6.0, 2,4-DNT degradation slows rapidly. Under conditions evaluated in laboratory-scale studies, 2,4-DNT biodegradation enhanced the rate of contaminant loss from the vadose zone by a factor of 10 when compared to the washout due to leaching.

Introduction

Dinitrotoluenes (DNT) are formed in the second step of toluene nitration during 2,4,6-trinitrotoluene (TNT) synthesis. In particular, two DNT isomers [2,4-dinitrotoluene (2,4-DNT) and 2,6-dinitrotoluene (2,6-DNT)] are formed at yields of 76% and 19%, respectively (a small percentage of other isomers are produced) (*1*). Poor handling and disposal practices associated with the production of TNT have led to substantial DNT contamination problems at ammunition production and handling facilities worldwide (*2*). 2,4-DNT and 2,6-DNT are both listed as priority pollutants by the U.S. EPA, thus requiring remediation at contaminated sites.

Tg-DNT

(Badger was a recover/recycle facility, not manufacture.)

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Because both DNT isomers can be biodegraded by aerobic bacteria, bioremediation of contaminated media has been an area of research and development for some time. The use of various ex-situ processes to biodegrade DNT in soil and groundwater has been reported (*3–9*), but little attention has been given to in-situ processes (either natural attenuation or accelerated bioremediation) despite the ability of specific bacteria to use both 2,4-DNT and 2,6-DNT as carbon, energy, and nitrogen sources (*3, 10–15*).

During aerobic biodegradation, DNT depletion and oxygen consumption are coupled with nitrite evolution, CO_2 production, and biomass growth (*10–12*). Daprato et al. (*16*) described the stoichiometry of the overall process (eq 1) using a simple empirical formula for biomass composition ($C_5H_7O_2N$):

$$C_7H_6N_2O_4 + 5.61O_2 \rightarrow 1.63NO_2^- + 1.63H^+ + 5.17CO_2 + 0.89H_2O + 0.37C_5H_7O_2N \quad (1)$$

On the basis of this stoichiometry and observations in laboratory studies, it would seem as if oxygen and appropriate microbes would be sufficient for the onset of DNT degradation. Both isomers, however, often display an unexpectedly high degree of recalcitrance in aerobic environments. This is particularly true in contaminated vadose zone soils where much of the existing DNT contamination resides.

The observed persistence of DNT isomers in vadose zone soils raises questions regarding the factor(s) that limit natural biodegradation processes, the extent to which natural bioattenuation may be lowering contaminant levels, and the ability to induce activity in-situ. Whereas the availability of carbon or nitrogen is not a concern, several other factors may result in the recalcitrance nature of DNT in vadose zone soils. First is the potential absence of DNT-degrading strains; however, we have been able to culture DNT degraders from all historically contaminated sites examined to date (*17*). Second is the potential for high concentrations of DNT to be inhibitory or toxic to bacteria. Previous studies in ex-situ reactors demonstrated that high concentrations of 2,4-DNT will inhibit 2,6-DNT degradation but not 2,4-DNT degradation. Other possible factors that may contribute to the recalcitrance of DNT include demands for phosphorus (*15, 16, 18*) (or other essential nutrients), low pH from nitrite production during DNT biodegradation (*4, 15, 18*), and the accumulation of inhibitory nitrite levels when the replenishment of water does not allow for significant nitrite dilution (*17*).

In this paper, we present the results of a laboratory-scale evaluation of factors that control the aerobic biodegradation of DNT in a simulated vadose zone. Aged vadose zone soils containing a high concentration of 2,4-DNT and a low concentration of 2,6-DNT were obtained from Badger Army Ammunition Plant (BAAP) in Baraboo, WI. Initial experiments were conducted in column systems to assess the factors required to initiate rapid biodegradation of DNT. Additional column studies were conducted to investigate how the operational parameters of interest in vadose zone bioremediation, including aeration frequency and water recycling, will impact the degradation activity. A series of respirometer studies were conducted using cultures obtained from column systems to further investigate the factors that control the extent of degradation achievable before nitrite accumulation, pH drop, or nutrient limitations slow degradation activity. Results from these studies suggest that, at field capacity, nutrient availability is the controlling factor in the onset of

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TABLE 1. BAAP Soil Characteristics

parameter	value	method
Physical Parameters		
pH	7.4	
sat paste moisture (%)	17.7	
moisture (%)	0.4	
SP EC (mΩ/cm)	2.0	
texture (%)		3.4.3.5[a]
sand	90.0	
silt	8.0	
clay	2.0	
soil class	sand	
bulk density	1.99 g/cm^3	14−3[b]
moisture retention (0.33 bar)	4.2%	
Plant Available Nutrients (mg/kg)		
ammonia-N	3.0	350.3[c]
nitrate-N	4.0	353.2[c]
nitrite-N	<1.0	353.2[c]
o-phosphate	30.0	365.4[c]
copper	2.1	200.7[c]
iron	8.1	200.7[c]
manganese	6.4	200.7[c]
zinc	2.8	200.7[c]
molybdenum	<0.05	200.7[c]

[a] EPA 600/4-79-020. [b] Blake, G. R.; Hartage, K. H. In *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*. Klute, A., Ed.; American Society of Agronomy: Madison, WI, 1986; pp 363−375. [c] EPA 600/2-78-054.

activity and that the extent of degradation that follows will be controlled by nitrite accumulation.

Materials and Methods

Chemicals. 2,4-Dinitrotoluene (97%) and 2,6-dinitrotoluene (98%) were obtained from Aldrich (Milwaukee, WI). The following reagent grade chemicals were used as media constituents: $CaSO_4\cdot5H_2O$, $MgSO_4\cdot7H_2O$, $FeSO_4\cdot7H_2O$, $CaCl_2\cdot7H_2O$, NaCl, $ZnSO_4\cdot7H_2O$, $Na_2MoO_4\cdot2H_2O$, and H_3BO_3 (Fisher Scientific, J. T. Baker Chemical Co., and Mallinckrodt Inc.). All reagent grade buffers for media, KH_2PO_4, K_2HPO_4, $NaHCO_3$, and $Na_5P_3O_{10}$ were obtained from Fisher Scientific.

Soil Preparation and Analysis. Aged DNT-laden soil was collected previously from BAAP (Baraboo, WI) at an average boring depth of 30 ft and homogenized as described by Zhang et al. (*15*). Initial DNT concentrations in the soil were determined as described by Zhang et al. (*15*). Soil contained 8700 (± 420) mg of 2,4-DNT and 148 (± 14) mg of 2,6-DNT/kg of soil (dry basis). This composite soil was used for all soil column experiments. Additional soil analysis was performed by Soil Analytical Services Inc. (College Station, TX). The analytical methods used for soil characterization and corresponding results are reported in Table 1.

Analytical Methods. DNT analysis was performed on a Waters Millennium II HPLC system equipped with a diode array detector with compounds quantified at A_{230}. Initially, separation was achieved at ambient temperature with a Nova-Pak C_{18} 60 Å 4-μm silica-based HPLC column (3.9 × 150 mm, Waters, USA) with a mobile phase of 2-propanol/water (19:81) at 1 mL/min. Subsequently, HPLC was performed with a Hypercarb porous graphite column (5 μm × 150 mm, Thermohypersil, U.K.) with a mobile phase of acetonitrile/water (90:10) containing trifluoroacetic acid (0.55 mL/L) (*3*).

Nitrite analysis was performed using a colorimetric method, coupling diazotized sulfanilamide with *N*-(1-naphthyl)ethylenediamine producing an azo dye, and measured using a spectrophotometer (Turner SP-830; Dubuque, IA) at 543 nm (*19*). Soil nitrite extraction was performed with 2 M KCl solution displacing soil-bound NO_2^- into solution (*20*). Nitrate analysis was performed with ion chromatography (Dionex IC20, Sunnyvale, CA) (*21*).

Column Studies. BAAP soil was placed into custom-fabricated plexiglass columns (10.2 cm i.d. × 30.5 cm) designed to support the soil above the column base to allow for sample collection and to provide an even flow of air into the bottom of the soil pack. To support the soil, wire mesh cloth (0.145 cm) was used and held in place above the bottom of the column (3.8 cm) by four small plexiglass rods (0.64 cm diameter). A layer of gravel (7.6 cm) was placed on the wire mesh to prevent soil washout. Soil (2 kg) was placed in the columns at even intervals (5 intervals, 400 g each) with consistent packing to minimize variation between columns. A layer of gravel (7.6 cm) was then placed on top of the packing to stabilize the soil. Sampling ports were fitted with a 0.64-cm ball valve (Swagelok, Niagara Falls, ON, Canada) centrally placed at the bottom of the column to drain the effluent. Air inlets were placed approximately 1.9 cm from the bottom of the column and fitted with a 0.95-cm quick-connect valve (Swagelok, Niagara Falls, ON, Canada).

Aqueous medium (50 mL) was added daily to the top of the column and allowed to infiltrate into the soils. Effluent was collected from the bottom of the columns as it eluted. The nominal hydraulic retention time (based on the infiltration rate and soil field capacity) was approximately 5 d. All column studies were operated with the water content of the soil at field capacity (0.15 g of water/g of soil) and under aerobic conditions. Humidified air was delivered to the column base with a peristaltic pump and allowed to exit to the atmosphere at the top.

Medium compositions were changed periodically in the column experiments but can be grouped into three categories. First was distilled, deionized (DI) water with bicarbonate buffer. Second was tap water with bicarbonate buffer and polyphosphate. Last was a mineral medium containing phosphate buffer and in some cases additional buffering capacity as bicarbonate. Mineral medium was prepared in DI water with the following: $MgSO_4\cdot7H_2O$ (50 mg/L), $FeSO_4\cdot7H_2O$ (3 mg/L), $CaCl_2\cdot7H_2O$ (100 mg/L), NaCl (500 mg/L), H_3BO_3 (100 mg/L), $CaSO_4\cdot5H_2O$ (50 mg/L), $ZnSO_4\cdot7H_2O$ (50 mg/L), $Na_2MoO_4\cdot2H_2O$ (50 mg/L) (*11*), and variable buffer strength. Table 2 lists, in chronological order, the media composition used in all column experiments.

An initial column study was conducted to determine whether it was possible to stimulate aerobic DNT degradation through the daily addition of medium (50 mL) and air (532 mL at 26.6 mL/min for 20 min). In this 175-d study, duplicate columns served as the experimental systems while duplicate abiotic control columns were operated with sodium azide added to the medium. Subsequent column tests involved three sets of columns, operated in duplicate. The three sets of columns were employed to assess different strategies to sustain and enhance DNT bioremediation of the BAAP soil. The first of the three column sets served as a baseline (repeating the operation of initial experimental systems), being fed mineral medium (50 mL) and air (532 mL at 26.6 mL/min for 20 min) on a daily basis. The second set of columns (enhanced aeration) was operated similarly, except that air was added continuously (24 h/d at 27 mL/min). The third set of columns was operated in a recycle mode. The recycle columns were aerated as carried out in the baseline columns (532 mL at 26.6 mL/min for 20 min), but the composition of the medium added was primarily that of the effluent from the previous day. Of the roughly 50 mL of effluent taken each day, 5 mL was retained for various analyses; the rest (~45 mL) was stored at 4 °C and reused the following day as the influent. Before the stored liquid was added to the column influent, the pH was adjusted to 8.3 with NaOH, and fresh medium was added (~5 mL) to bring the final volume to 50 mL. The three-column system was operated continuously for 90 d.

TABLE 2. Soil Column Studies: Influent Composition Time Line

column[a]	Julian days	medium composition
A, B1	0–45	DI water 10 mM buffer ($NaHCO_3$) pH 7.5
	46–56	tap water 20 mM buffer ($Na_5P_3O_{10}$ and $NaHCO_3$, 1:1) pH 7.5
	57–69	tap water 15 mM buffer ($Na_5P_3O_{10}$ and $NaHCO_3$, 2:1) pH 7.5
	70–85	mineral medium 10 mM buffer (K_2HPO_4 and KH_2PO_4, 1:1) pH 8.3
	86–138	mineral medium 20 mM buffer (K_2HPO_4 and KH_2PO_4, 1:1) pH 8.3
	139–171	mineral medium 40 mM buffer (K_2HPO_4, KH_2PO_4, and $NaHCO_3$, 1:1:2) pH 8.3
B2, O, R	0–4	mineral medium 10 mM buffer (K_2HPO_4 and KH_2PO_4, 1:1) pH 8.3
	5–61	mineral medium 20 mM buffer (K_2HPO_4 and KH_2PO_4, 1:1) pH 8.3
	61–94	mineral medium 40 mM buffer (K_2HPO_4, KH_2PO_4, and $NaHCO_3$ 1:1:2) pH 8.3

[a] Column id: A, abiotic control; B1, baseline 1; B2, baseline 2; O, enhanced aeration; R, recycle.

TABLE 3. Respirometer Studies: Design Matrix

parameter	range tested
baseline	
carbon, nitrogen source	10 mM 2,4-DNT as TOC
medium	mineral medium (100 mL per flask)
buffer	20 mM (10 mM K_2HPO_4, 10 mM KH_2PO_4)
pH	8.0, maintained with addition of dilute NaOH
bacteria	2,4-DNT degrading culture, enriched from column effluent (approximately 80 mg of washed biomass added in 1 mL of medium)
pH	baseline conditions with initial pH ranging from 5.5 to 9.0 at an increment of 0.5; pH was not maintained over the course of the study
media	baseline conditions with medium strength at 1×, 2 ×, and 4×
nitrite	baseline conditions with initial nitrite concentrations of 0, 10, 15, 20, and 40 mM
buffer strength	baseline conditions (20 mM phosphate buffer) with additional buffer strength of 0, 20, 40, 60, and 80 mM $NaHCO_3$; pH was not maintained over the course of the study
phosphorus	baseline conditions with phosphate (1:1 K_2HPO_4 and KH_2PO_4) concentrations varied at 0, 0.4, 0.8, 1.6, and 8.0 mM; initial concentration of 2,4-DNT was 5 mM

Biodegradation in the columns was evaluated by the use of several indicators. First was the depletion of effluent DNT concentrations in comparison to abiotic controls. Second, nitrite production was quantified. Last, shake flask studies were established with column effluent and monitored daily for DNT disappearance and nitrite production. Shake flask studies were conducted using only column effluent (~40 mL) directly transferred to serum vials (120 mL), stirred continuously, fitted with foam stoppers to prevent evaporation, and analyzed for DNT and corresponding end products for a period of 9–10 d. The pH was adjusted to 8.0 with NaOH as needed.

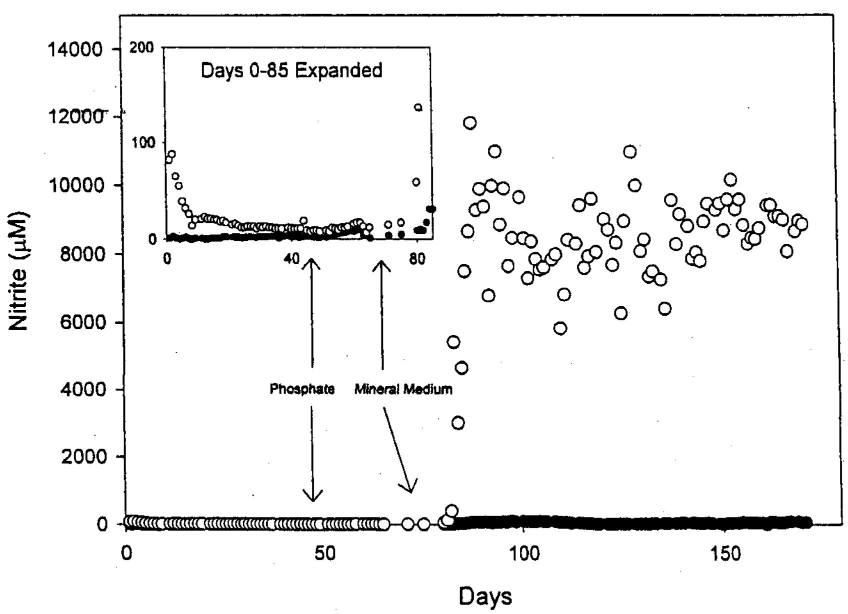

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FIGURE 1. Initial soil column studies. Average effluent nitrite concentrations: baseline 1 (○) and abiotic control (●).

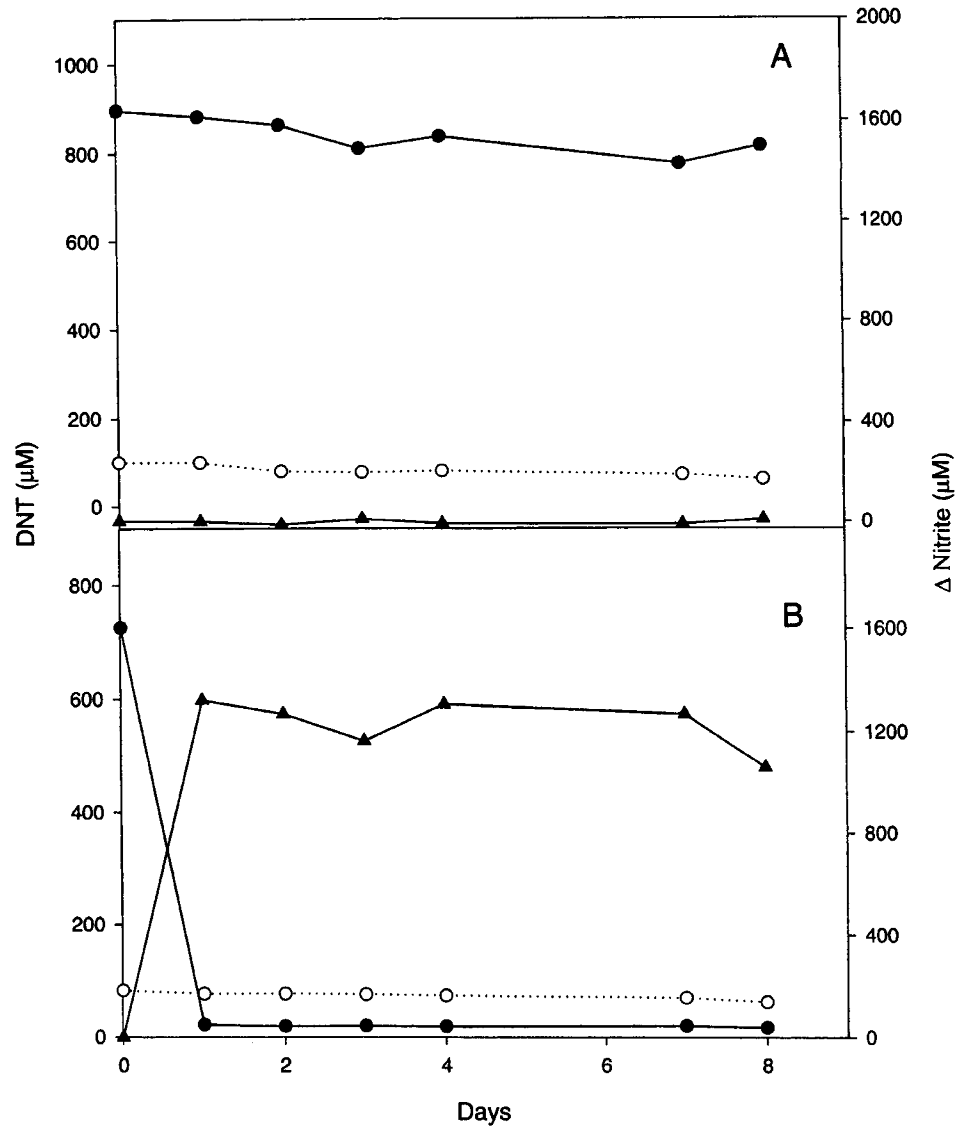

FIGURE 2. Column effluent shake flask studies. (A) Results (averaged) from abiotic control effluent. (B) Results (averaged) from biologically active column (baseline 1) effluent. For both studies, (●) 2,4-DNT concentration, (○) 2,6-DNT concentration, and (▲) as change in nitrite concentration.

To ensure accurate quantification of nitrite, shake flask studies were conducted to determine if biological nitrification, oxidizing nitrite to nitrate, would occur with the nitrite evolved from DNT biodegradation as shown in previous studies (*5*). The procedure was identical to that described above. Nitrite and nitrate analyses were performed over the course of 10 d.

With the exception of abiotic controls, after all columns had exhibited approximately 90 d of active 2,4-DNT degradation, all systems were destructively sampled by continuous coring through the soil. A zero contamination soil sampler (2.06 cm diameter; Cole-Palmer P-99025-40) was manually driven through the soil, and the resulting soil cores were extruded into plastic sleeves. The cores were then frozen (−4 °C) and cut into quarters after any gravel from column packing was discarded. These subsamples were analyzed for pore water nitrite levels.

DNT Enrichment Culture. A DNT-degrading mixed culture was developed from the original biotic column effluent. As inoculum, approximately 50 mL of effluent was transferred into a flask (2 L) containing mineral medium (900 mL) with 20 mM phosphate buffer and DNT as the only carbon and nitrogen source at concentrations roughly equal to those in column effluents (1000 µM 2,4-DNT and 400 µM 2,6-DNT). The culture was stirred continuously at room temperature, and nitrite and pH were measured daily. The pH was adjusted each day to 7.5−8.0. When the release of nitrite from the biodegradation of DNT neared 70−80% of theoretical, 10% of the suspension was transferred to fresh medium.

Respirometer Studies. 2,4-DNT biodegradation experiments were conducted with the DNT-enrichment culture in a 10-chamber O_2/CO_2 Micro-Oxymax respirometer (Columbus Instruments Corp., Columbus, OH) at room temperature. As previously described, both oxygen uptake (*5, 10–12*) and carbon dioxide production (*3, 22*) were used to measure DNT biodegradation rates. A confounding factor in some instances where rapid DNT biodegradation took place was the upper quantification limit for CO_2 evolution by the detector (i.e., CO_2 levels exceeded the dynamic range) and CO_2 production rates were underestimated in those instances. No such difficulty was encountered during O_2 uptake measurements. In all respirometer experiments, 2,4-DNT comprised the only

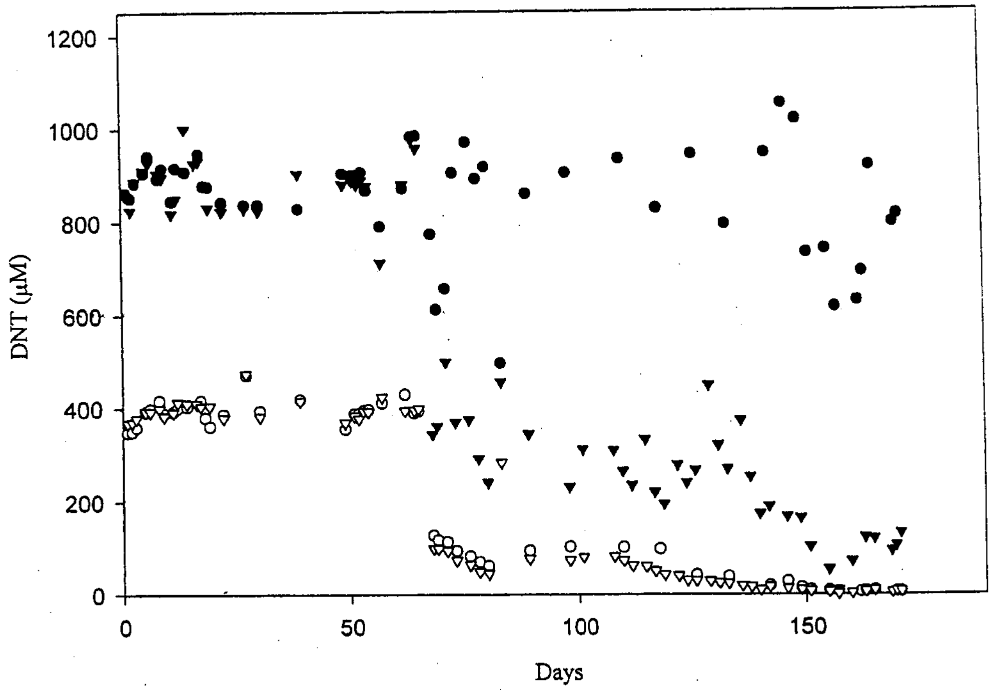

FIGURE 3. Initial soil column studies. Average effluent DNT concentrations: Baseline 1, (▼) 2,4-DNT and (▽) 2,6-DNT. Abiotic control, (●) 2,4-DNT and (○) 2,6-DNT.

organic carbon and nitrogen source. For each experiment, inoculum was taken from the enrichment culture described above. Preparation of the inoculum involved aliquots of the enrichment culture centrifuged (4 °C, 10000*g* for 10 min) with the supernatant being carefully poured off leaving only the bacterial pellet. The pellet was then resuspended (through vigorous shaking) in DNT-free mineral medium and centrifuged again. This process was repeated for a total of three washes with DNT-free media. In addition, a minimal volume (1 mL) of suspended inoculum was used for each respirometer flask containing 100 mL of mineral medium. Respirometer experiments evaluated the effects of pH, medium concentrations, initial nitrite concentration, phosphorus concentration, and buffer strength on the rate and extent of 2,4-DNT degradation. No carbon dioxide production or oxygen consumption was seen in a respirometer control containing mineral media, 2,4-DNT, but no bacterial inoculum. Table 3 describes the experimental protocols and details the matrix design of varied parameters.

Results and Discussion

Column Studies. Preliminary column studies were conducted to evaluate the stimulation of DNT biodegradation by medium addition and aeration. Nitrite production was used as an indicator of DNT biodegradation (*3, 5, 10, 11, 23*) (Figure 1). The initial medium was bicarbonate buffer. Over the first 10 d of operation, there was an elevated but decreasing level of nitrite in the effluent from experimental systems. After 20 d of operation, however, nitrite levels in the biotic columns were similar to those in the control columns. On the basis of phosphate limitations cited in previous studies (*15, 16, 18*), the feed medium was changed on day 45 substituting phosphate for carbonate as a buffer and also as a nutrient. There was no significant increase in nitrite production.

On day 70, the influent was changed to a complete mineral medium, which resulted in the immediate elevation of nitrite levels in the column effluents. After stabilizing, nitrite concentrations averaged 8500 μM ($\pm$ 1460) for the remainder of the study. Commensurate with the onset of nitrite production, the pH of effluent began to decrease. After nitrite levels had stabilized, the pH of effluent medium was typically 6.75–7.25. Appreciable nitrate production was not observed during the study.

As nitrite concentrations stabilized, it was necessary to confirm that nitrite production was an accurate indicator of the DNT degradation activity in the column systems. Therefore, shake flask studies using only column effluent were initiated as described above. Results of these studies (Figure 2) show that 2,4-DNT was immediately depleted within 24 h to levels below the detection limit with a corresponding release of nitrite (approximately 1.7 mol of nitrite released/mol of DNT). Under no circumstances was 2,6-DNT depleted. Identical shake flask studies were conducted periodically as described throughout the remainder of the experimental period with similar results (data not shown). Also, no nitrification (conversion of nitrite to nitrate) was ever observed in these studies. *

The effluent 2,4-DNT concentrations in experimental and control systems were similar before the addition of the mineral medium (Figure 3). As concentrations of nitrite began to increase in the active systems, effluent 2,4-DNT levels dropped. No such drop occurred in the controls. Effluent 2,6-DNT concentrations also dropped after approximately 60 d of operation, but the decrease in concentration could not be due to biological activity because similar decreases were observed in both active and control systems. In accordance, periodic effluent shake flask studies showed no loss of 2,6-DNT.

Subsequent column studies were conducted to test whether high levels of 2,4-DNT biodegradation could be induced and sustained by the use of a mineral medium throughout the experimental period. We also sought to evaluate how changes in column operation might influence the extent of degradation achieved. 2,4-DNT degradation began immediately in all systems (Figure 4). Nitrite concentrations increased steadily for approximately the first 20 d and then stabilized. Nitrite concentrations were slightly higher in columns that were continuously aerated or operated

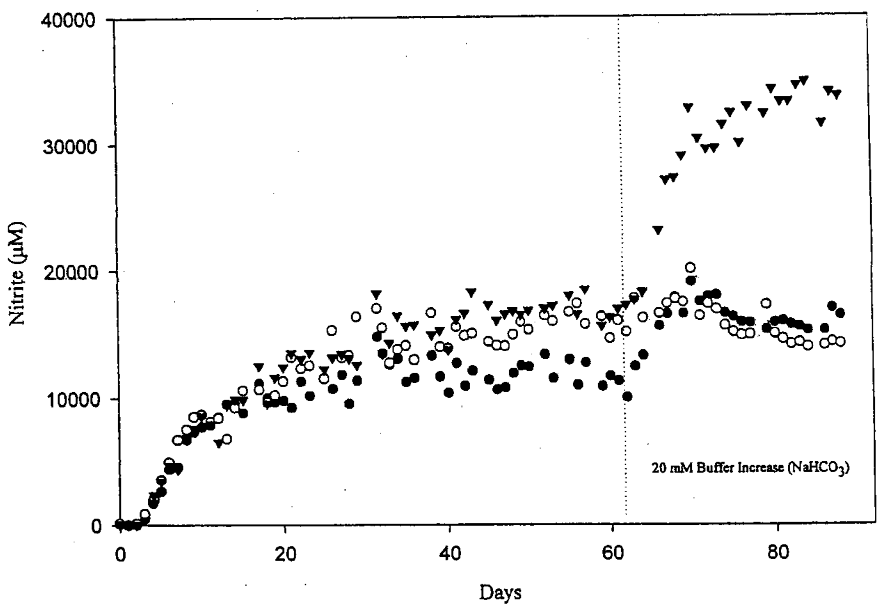

FIGURE 4. Column studies investigating parameter design. Average effluent nitrite concentrations: baseline 2 (●), extended aeration (○), and recycle (▼).

in recycle. Interestingly, the lack of continued nitrite accumulation in the recycle columns indicates a loss of rapid DNT biodegradation after an initial period of biological activity. Shake flask studies conducted, as described previously, confirmed 2,4-DNT biodegradation with no 2,6-DNT biodegradation observed.

The pH in all active columns dropped from 8.3 in the influent to approximately 6.75–7.25 in the effluent due to nitrite production. After bicarbonate buffer was added to the medium (day 61), the average nitrite concentration increased slightly in the baseline columns. In the recycle columns a brief period of increased nitrite production was followed by a decline to a low level.

At the completion of the column studies, soil cores were analyzed for pore water nitrite concentrations to better understand how 2,4-DNT degradation activity was distributed throughout the length of columns. In columns where active 2,4-DNT degradation was occurring, nitrite concentrations increased with the increase in column depth. These results indicate that there was activity throughout the length of the column and suggest that if columns had a longer residence time, additional activity could be expected. Conversely, in abiotic controls and recycle systems, nitrite concentrations remained nearly constant throughout the length of the columns (Table 4). It is important to note that high concentration of nitrite in the recycle columns (Table 4) does not imply continued activity of DNT biodegradation. The pore water nitrite concentration in the recycle columns approached the sum of the total nitrite production throughout the duration of study. As indicated earlier in this paper, 90% of the column effluent in the recycle mode was retained and reused in the following day as the influent diluted only by the 10% addition (vol/vol) of fresh mineral medium.

Estimates of DNT mass removal from the column systems were conducted as described by Ortega-Calvo et al. (*23*) using effluent DNT concentrations and nitrite analysis. To estimate the washout of both 2,4-DNT and 2,6-DNT, effluent concentrations were summed over the experimental period to provide the cumulative mass of washout that took place (when a sample was not taken on a given day, the concentration was extrapolated using a central differencing method). Similarly, nitrite concentrations were used to calculate the 2,4-DNT mass that had been degraded based on the stoichiometry presented above where the degradation of 1 mol of DNT yields 1.63 mol of nitrite. As can be seen from Table 5, the measured 2,6-DNT washout was high for all columns other than those operated in recycle, as 90% 2,6-DNT in the effluent from those columns was reintroduced as influent. The percentage of 2,4-DNT that washed out was much less than that of 2,6-DNT due to the higher initial concentrations of 2,4-DNT. Biodegradation (22–30%) of initial 2,4-DNT mass (Table 5) indicates that the biologically active systems have the potential to rapidly reduce the mass of 2,4-DNT present in a vadose zone bioremediation system. In the columns fed mineral medium without recycle, 2,4-

TABLE 4. Terminal Soil Column Dissections: Pore Water Nitrite Concentrations[a]

column	section	nitrite (pore water) (μM)
abiotic control[b]	1	0.27
	2	0.34
	3	0.34
	4	0.6
baseline 1[b]	1	179
	2	763
	3	819
	4	2 440
baseline 2[c]	1	320
	2	1 760
	3	4 260
	4	8 250
enhanced aeration[c]	1	530
	2	1 630
	3	3 340
	4	5 600
recycle[c]	1	39 900
	2	40 800
	3	36 300
	4	34 900

[a] Sections taken in 3.8-cm increments. Spatial distribution is shown as sections 1–4, with section 1 representing the top of the column. [b] Cores taken after 175 d of operation with the last 90 d being fed mineral media. [c] Cores taken after 90 d of operation, being fed mineral media for the duration of the study.

TABLE 5. Average Column DNT Mass Loss as a Percentage of Initial Concentration[a]

column	% washout		% biodegradation		total (% washout + % biodegradation)	
	2,4-DNT	2,6-DNT	2,4-DNT	2,6-DNT[b]	2,4-DNT	2,6-DNT
abiotic control	5.7	81	0.11		5.8	81
baseline 1	3.4	82	19		22	82
baseline 2	1.8	91	25		27	91
enhanced aeration	1.9	85	28		30	85
recycle	0.21	13	5.1		5.3	13

[a] Numbers are the average of the duplicate columns. b2,6-DNT was not found to degrade under any circumstances, thus the only mass was from washout.

DNT depletion from biodegradation was approximately 10 times that of dissolution and washout.

Several common conclusions can be drawn from the comparison of the two sets of column studies. First, the soils were quickly depleted of a required nutrient(s) because phosphate addition alone was not sufficient to support activity. In previous studies investigating rapid DNT biodegradation, 2,4-DNT biodegradation rates were clearly subject to phosphate limitations (*16, 18*). Similar depletion of phosphate or other nutrient may have occurred in columns after activity was established, but it was not the basis of limited activity prior to the addition of the mineral medium. High rates of 2,4-DNT biodegradation were initiated by providing moisture and mineral nutrients. After the onset of activity, the intermittent addition of mineral medium then became critical to sustain activity in the columns as nutrient concentrations were maintained and nitrite was flushed from interstitial pore water.

A second conclusion from these studies was that 2,6-DNT was not readily biodegraded. Whereas concentrations of both isomers decreased in the effluents of columns, the decrease of 2,4-DNT in the column effluent was likely the result of both the depletion of 2,4-DNT in the soil and the continued degradation in the column drainage system (i.e., gravel and sample reservoir). Shake flask studies with effluent samples revealed a continued rapid degradation of 2,4-DNT, which is consistent with the above hypothesis. Decreases in 2,6-DNT effluent concentrations could not be explained similarly. The fact that effluent shake flask studies did not demonstrate 2,6-DNT degradation activity suggests that the only loss of 2,6-DNT was through dissolution and washout. In the recycle columns, 2,6-DNT concentrations remained high because the removal of effluent was only 10% of that in other systems. Similar observations regarding the inability to actively stimulate 2,6-DNT degrading activity in BAAP soil has been reported by Nishino and Spain (*18*).

A third conclusion from these studies (enhanced aeration, Table 5) is that oxygen availability did not strongly affect the level of biodegradation achieved with the water content at field capacity and with periodic aeration. High levels of nitrite production were observed in all systems, and the continuous aeration of columns led to only small increases in activity.

It could not be established from the studies what factor(s) control 2,4-DNT biodegradation after the onset of activity. In systems not operated in recycle, a longer residence time should result in additional production of nitrite that may result in either direct inhibition or cause a pH drop, which can also become inhibitory. If not inhibited by nitrite accumulation, the development of nutrient limitations would be expected to develop as has been observed in ex-situ systems (*15*). In recycle columns, with long effective contact times, either the slow replenishment of medium, the high nitrite concentrations, or both appear to have caused the inability to sustain degradation activity. Because of the limited size of the column systems, such effects could not be assessed directly, thus a series of batch assays were conducted to evaluate how these various factors would eventually affect the extent of degradation with longer contact times.

Batch Respirometer Studies. The first set of batch respirometer studies investigated the direct effect of nitrite

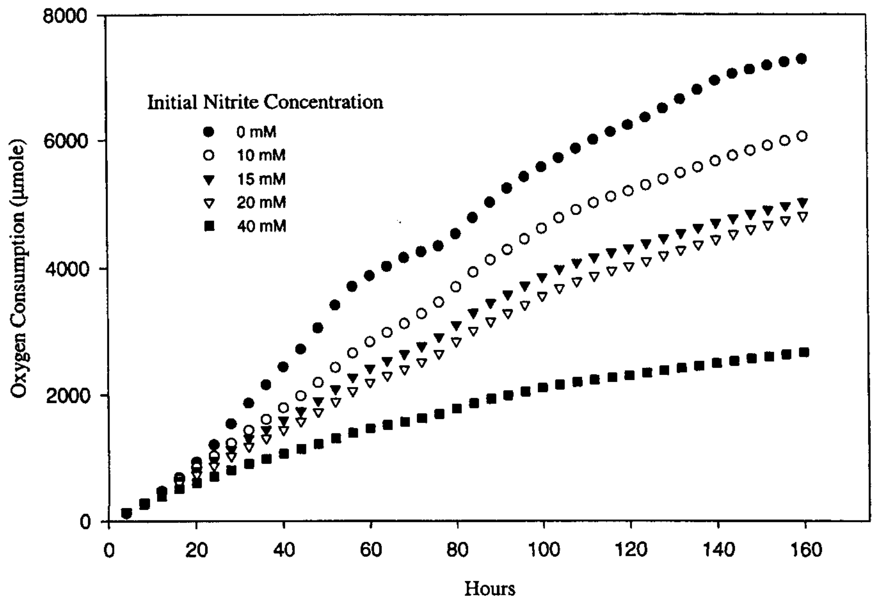

FIGURE 5. Effect of initial nitrite concentration on 2,4-DNT mineralization as measured by oxygen consumption (5.6 mol of O_2 consumed during the mineralization of 1 mol of 2,4-DNT (*16*)).

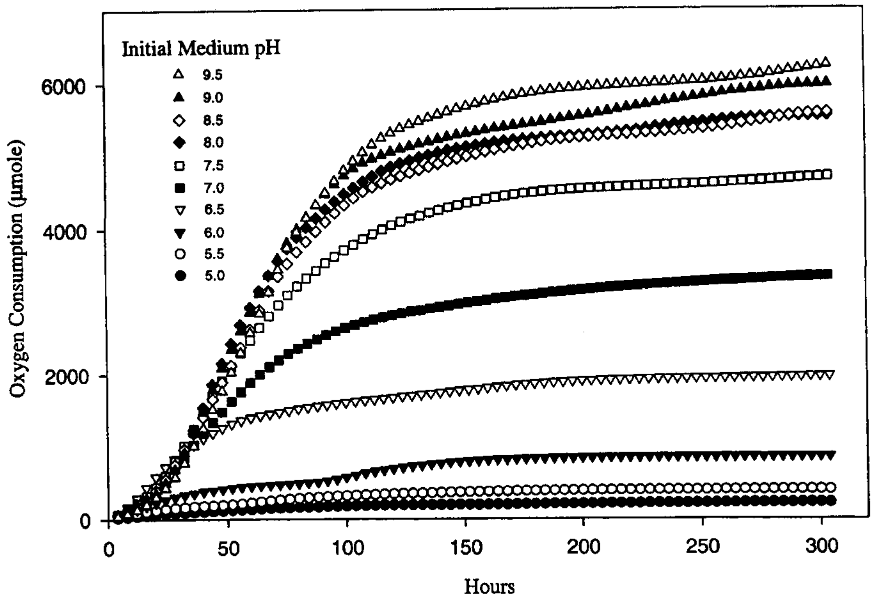

FIGURE 6. Effect of initial pH on 2,4-DNT mineralization as measured by oxygen consumption (5.6 mol of O_2 consumed during the mineralization of 1 mol of 2,4-DNT (*16*)).

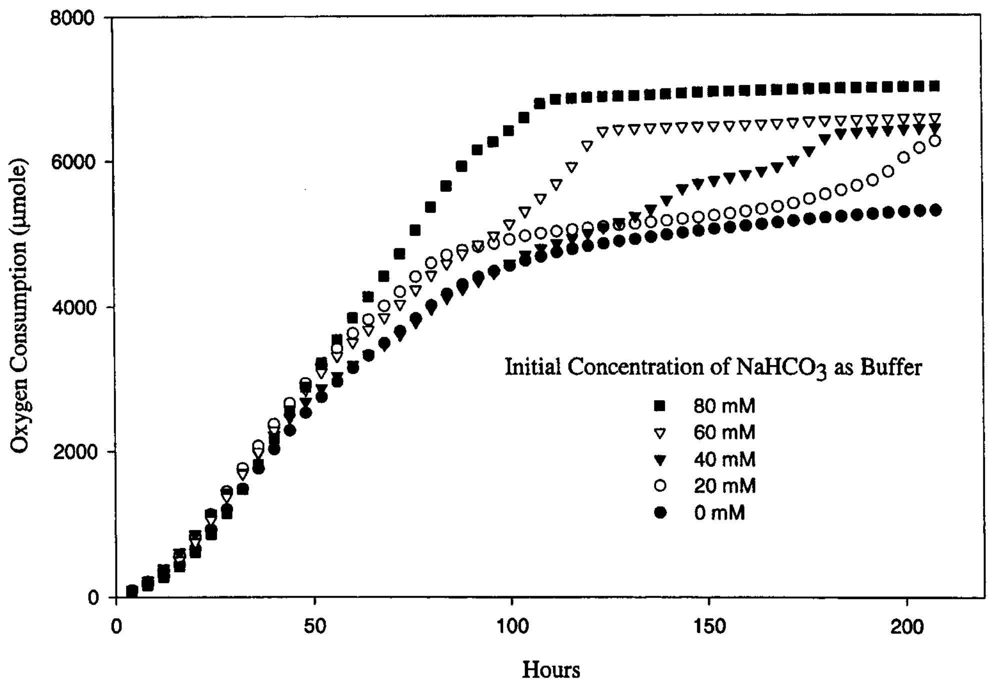

FIGURE 7. Effect of buffering strength on 2,4-DNT mineralization as measured by oxygen consumption (5.6 mol of O_2 consumed during the mineralization of 1 mol of 2,4-DNT (*16*)).

accumulation due to 2,4-DNT biodegradation and the indirect effect of pH drop from nitrite release. The impact of nitrite accumulation was measured using oxygen uptake and production of carbon dioxide from the aerobic biodegradation of 2,4-DNT at various initial nitrite levels but with the initial pH of 8.5. Increasing nitrite concentrations clearly exert a negative effect on biodegradation rate and extent, with a severe inhibition observed at 40 mM (Figure 5).

A secondary effect of nitrite production is the reduction of pH in the medium. To investigate the impact of pH, respirometer studies were conducted at a range of initial pH values with no nitrite added to the medium. The results (Figure 6) indicate that pH values of 6.0 and below severely limit the biodegradation of 2,4-DNT. Media with initial pH values of 6.0 and 6.5 supported immediate rapid initial rates of biodegradation that decreased sharply as the pH fell to inhibitory levels. When the initial pH was 7.5 and above, DNT biodegradation was rapid and sustained. Similar observations made by Nishino and Spain strongly support the apparent effect of pH on DNT biodegradation rates (*18*). Based on the nitrite production and pH drop in column studies, it appears that conditions in the lower portions of the columns were approaching those where reduced rates of 2,4-DNT degradation would be expected. In the case of columns operated in recycle, the accumulation of nitrite probably caused cessation of activity. In columns operated

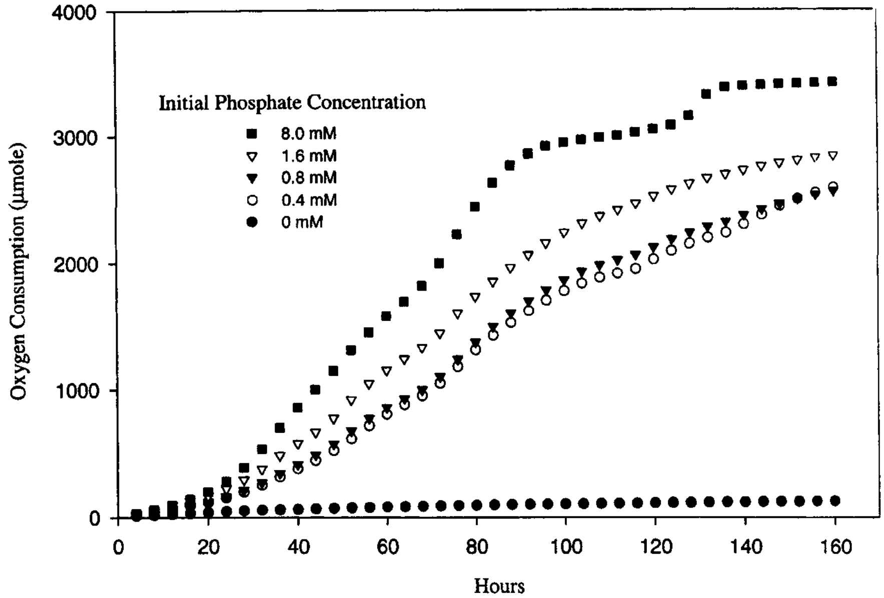

FIGURE 8. Effect of initial phosphate concentration on 2,4-DNT mineralization as measured by oxygen consumption (5.6 mol of O_2 consumed during the mineralization of 1 mol of 2,4-DNT (*16*)). Note that the initial concentration of 2,4-DNT is 5 mM; normally it is 10 mM 2,4-DNT for baseline conditions.

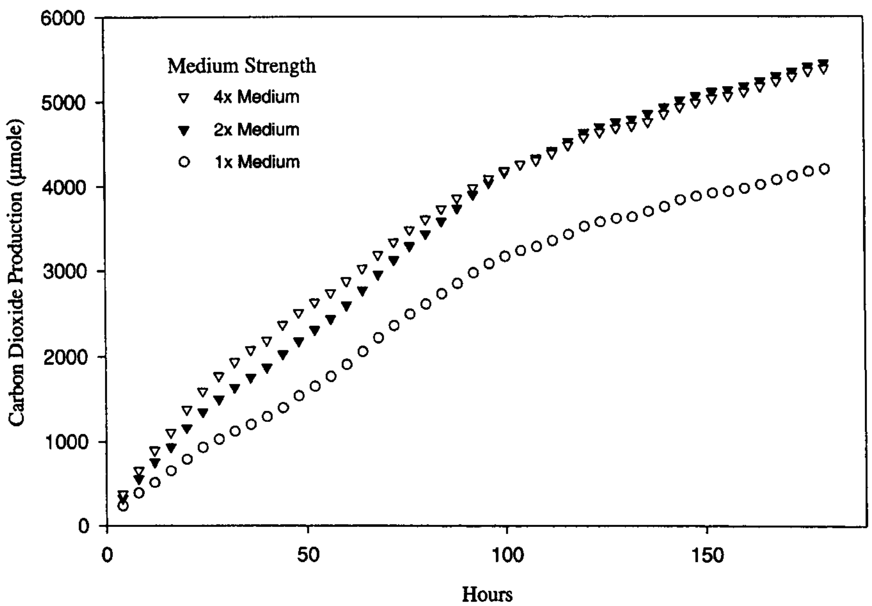

FIGURE 9. Effect of medium strength on 2,4-DNT mineralization as measured by carbon dioxide production (5.2 mol of CO_2 produced during the mineralization of 1 mol of 2,4-DNT (*16*)).

without recycle, charge balance calculations indicate that accumulation of 15 mM nitrite would have caused the pH drop to the range of 6.0–6.5 assuming 20 mM phosphate buffer and an initial pH of 8.5. At that pH and nitrite concentration, both variables would be expected to reduce rates of biodegradation with pH effects being the most acute. It is of note that the biological oxidation of nitrite to nitrate through nitrification did not occur in columns or effluent shake flask studies. Thus, maintaining high rates of biodegradation will, in part, be controlled by the ability to dilute nitrite concentrations at field capacity (i.e., flushing evolved nitrite from pore water).

nitrite ↓ nitrate did not occur

A further study investigated the role of the buffering capacity of the medium in maintaining pH and minimizing inhibitory effects. The mineral medium used in column studies contained 20 mM phosphate buffer. Additional buffer was added in the form of sodium bicarbonate ($NaHCO_3$) at concentrations of 20, 40, 60, and 80 mM. The initial pH was 8.5 with no further adjustment. At all buffer concentrations, 2,4-DNT was degraded immediately (Figure 7). Respiration rates were sustained in accordance with buffer concentration. These results indicate that by increasing buffer capacity of the medium and maintaining a favorable pH range, it is possible to sustain rapid rates of biodegradation for longer periods of time.

In column studies it became apparent that nutrient availability was also an important controlling factor in 2,4-DNT biodegradation activity. Previous studies revealed phosphorus as a limiting nutrient in the biodegradation of DNT in soil slurries (*4, 16*). To further investigate the limiting effects of phosphorus, respirometer experiments were conducted using mineral medium with various initial phosphorus concentrations. It is clear that a phosphorus-free medium cannot support the biodegradation process, whereas all phosphorus-amended media supported rapid biodegradation (Figure 8). Media with phosphorus concentrations of 0.4 and 0.8 mM displayed slower biodegradation rates relative to media amended with 1.6 and 8.0 mM phosphorus. Since the phosphate added is also a pH buffer, it is difficult to distinguish between the dual roles of phosphate in these experiments, but it is clear that phosphorus is required at minimal levels as a nutrient to support biodegradation.

On the basis of the results of column studies, nutrient additions are essential to initiate the biodegradation of 2,4-DNT in BAAP soils, and phosphate alone was *not* sufficient to induce activity. In respirometer experiments, it became apparent that phosphate is critical as a nutrient to induce and sustain degradation. The potential for phosphorus to become a limiting nutrient would be most likely to occur in the recycle mode of operation where the retention time is considerably longer. Interestingly, the analysis of effluent samples taken from the recycle column showed very low effluent phosphate levels (data not shown) as compared to other columns. This suggests that nutrient availability may have contributed to the cessation of activity in the recycle column along with nitrite accumulation and decreasing buffering capacity resulting from phosphate consumption.

A final respirometer study was conducted to investigate the potential to increase biodegradation rates as a function of mineral medium strength (i.e., the concentration of salts in the preparation of the medium). The results (Figure 9) indicated that it was necessary to have the medium concentration (with 20 mM phosphate buffer), which was the concentration used in all previous experiments, to support biodegradation. However, higher concentrations (2×, 4× media concentration, buffer held constant at 20 mM phosphate) did not increase rates of biodegradation.

The results presented in this study suggest that the recalcitrant nature of 2,4-DNT and 2,6-DNT are the result of different factors. Nutrient availability controlled biodegradation processes for 2,4-DNT when pH and nitrite levels were appropriate. The addition of nutrients did not, however, stimulate 2,6-DNT biodegradation. This inability to stimulate the simultaneous degradation of both isomers when present at high concentrations is consistent with previous reports (*5, 10, 15, 17*) and represents a challenge for the design of remediation systems. Without intervention (i.e., nutrient addition), the dominant process leading to the loss of DNT from soils will be the dissolution into waters percolating through the vadose zone into groundwater systems.

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