Bioaugmentation Design for Treatment of Munitions Constituents

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BACKGROUND

- Former West Virginia Ordnance Works was used by the US Army to manufacture 2,4,6-trinitrotoluene (TNT) during the early 1940s
- Located on the east bank of the Ohio River, six miles north of Point Pleasant, WV
- Added to the NPL in 1983 due to remaining contamination of surface water, soil, and groundwater
- Currently managed as part of the McClintic Wildlife Management Area
- OU-2 ROD, signed in 1988, selected pump and treat as the remedy for the former Red Water Reservoir (RWR) & Yellow Water Reservoir (YWR) Areas
- ESD signed in 2019 updated RGs and recommended optimization of the OU-2 Groundwater remedy via biostimulation

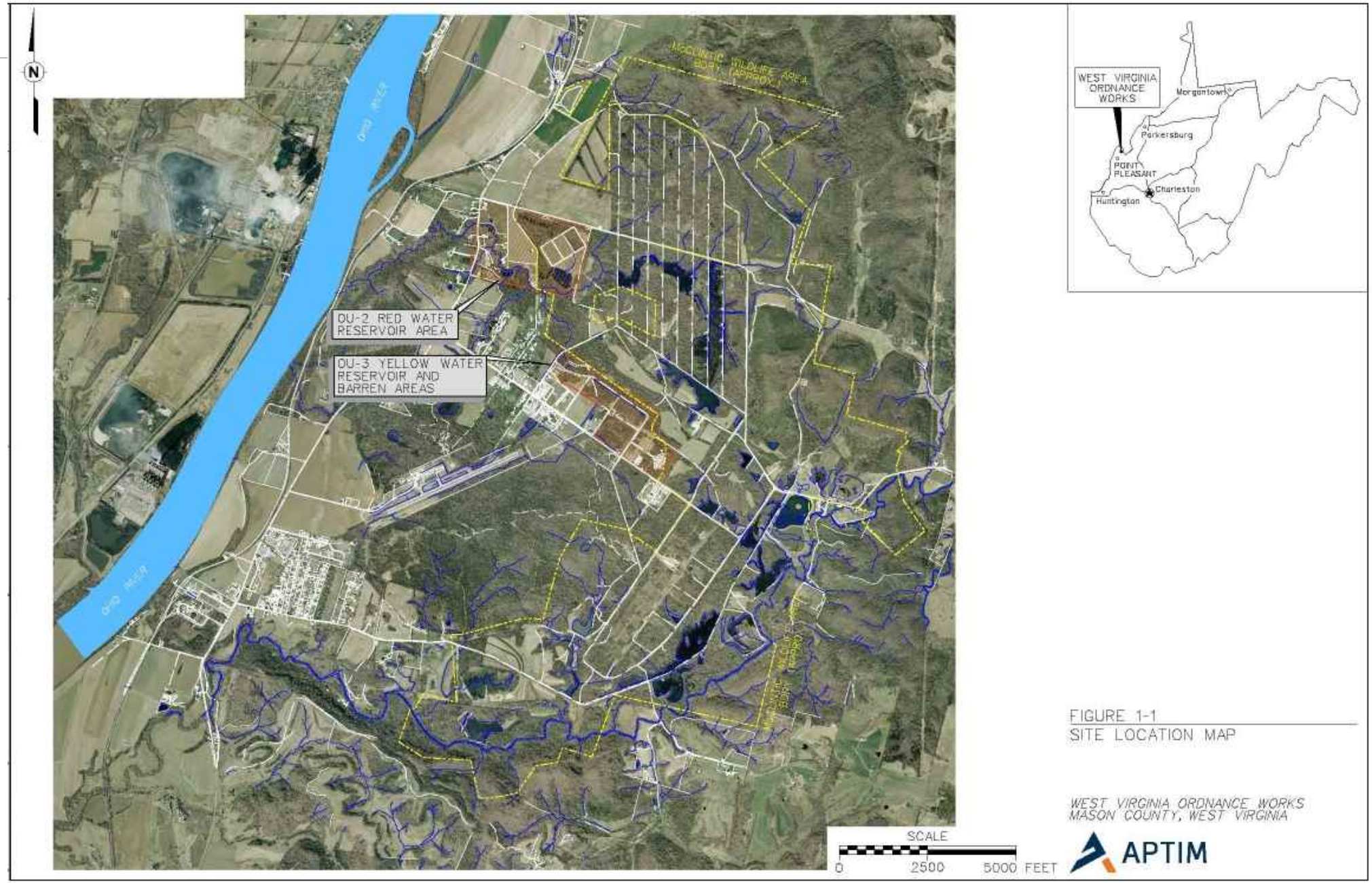


FIGURE 1-1
SITE LOCATION MAP

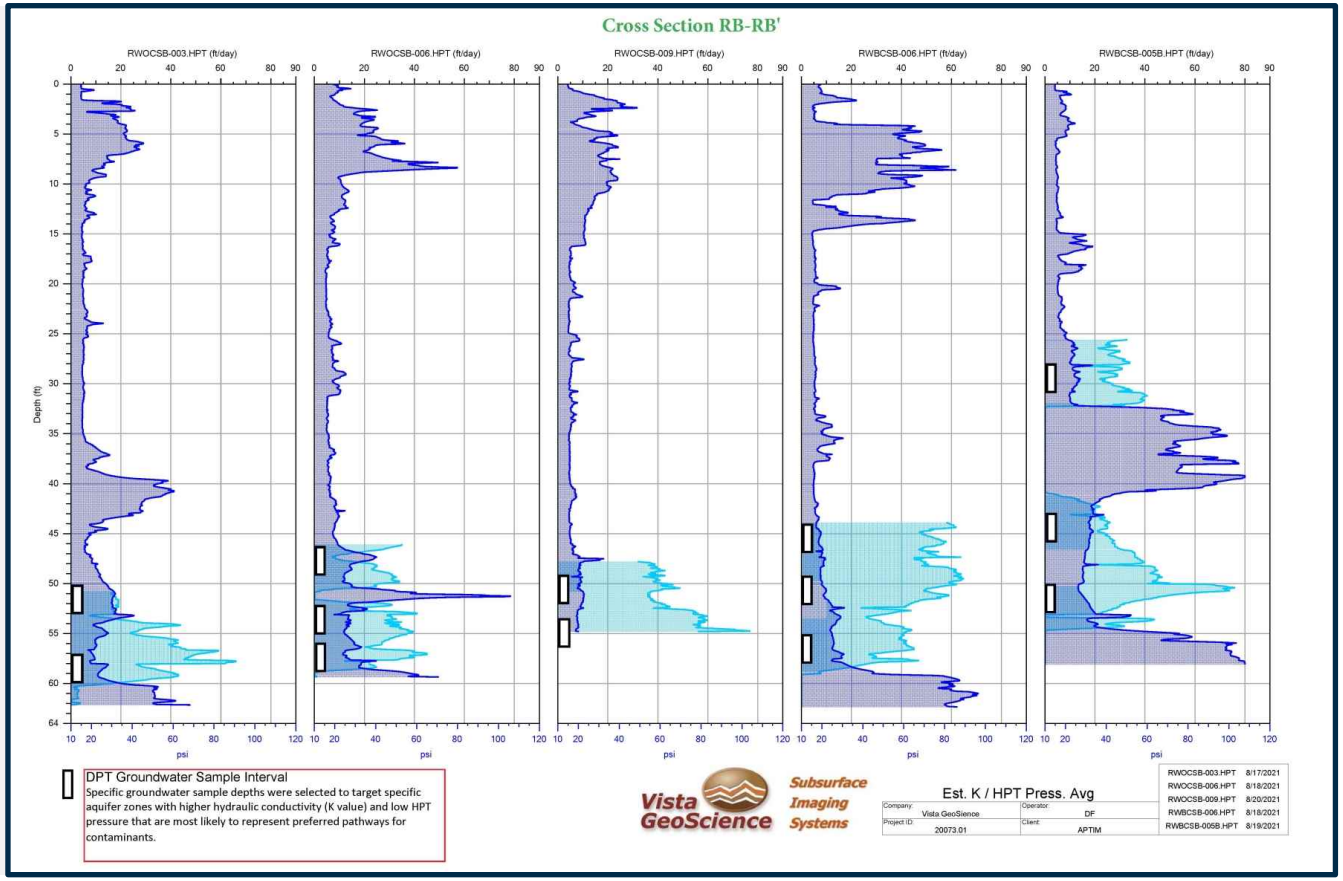
WEST VIRGINIA ORDNANCE WORKS
MASON COUNTY, WEST VIRGINIA

OBJECTIVES

- Aptim conducted an optimization study from 2013 to 2018, which included an evaluation of the current remedies
- The optimization study concluded that achieving response complete utilizing only the existing groundwater pump and treat system will take on the order of 30 to 100 years
- Aptim completed HRSC investigation to identify preferential flow paths, eliminate data gaps and better define nature and extent of contamination
- Objective is to design a remedial augmentation treatment utilizing biostimulation to accelerate cleanup
- Implement the Total Project Planning (TPP) process to involve all stakeholders throughout the design process

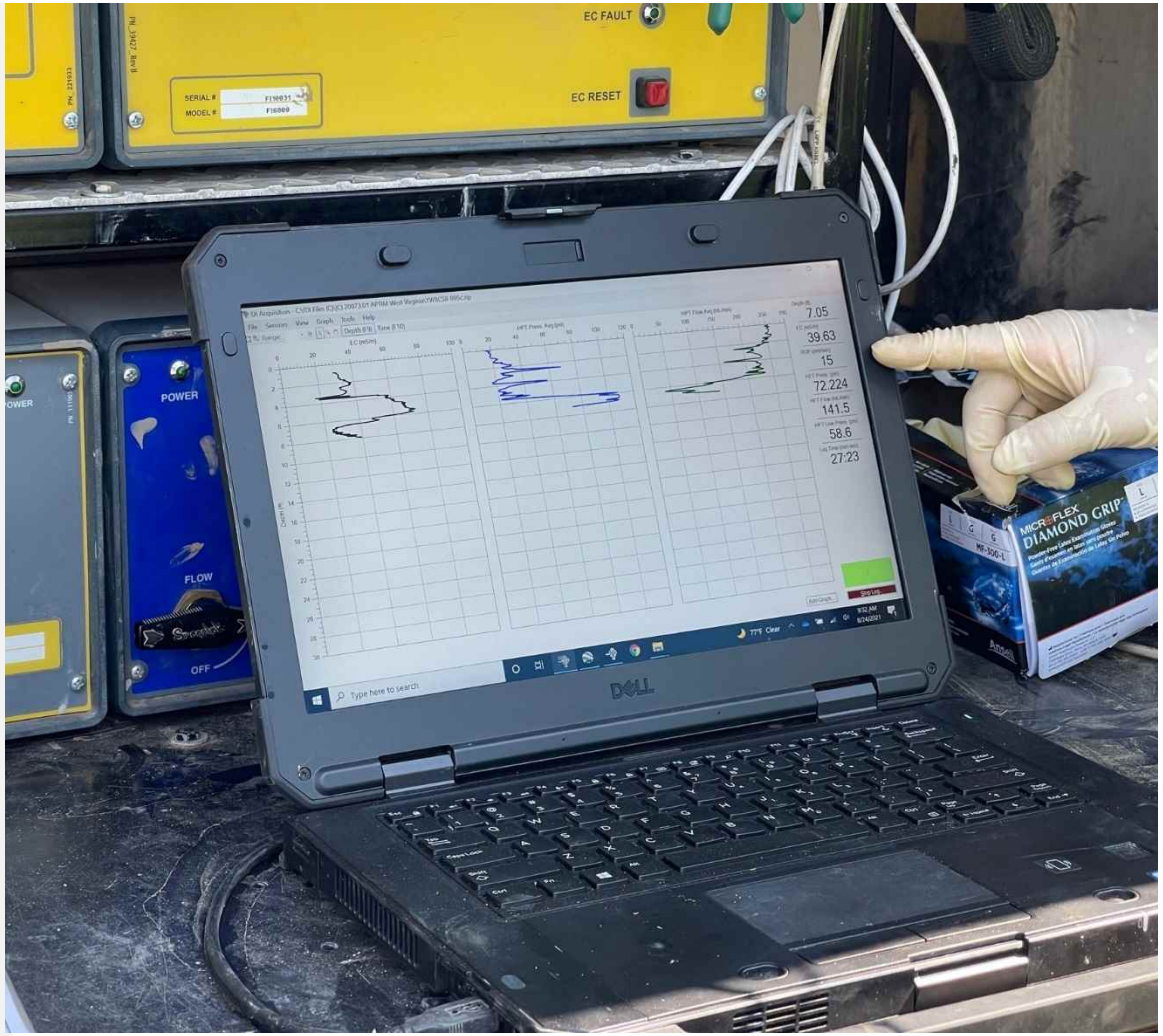
RWR HRSC & DPT SOIL AND GROUNDWATER SAMPLING

- Hydraulic Profiling Tool (HPT) and the conductivity sensors were used to determine:
  - Discrete groundwater sampling intervals
  - Discrete soil sampling locations and intervals
  - Most probable preferential pathways for contaminants
  - In situ treatment zones
- These HRSC tools were not used previously at this site and have shown to be very effective in determining permeable zones and groundwater treatment zones.

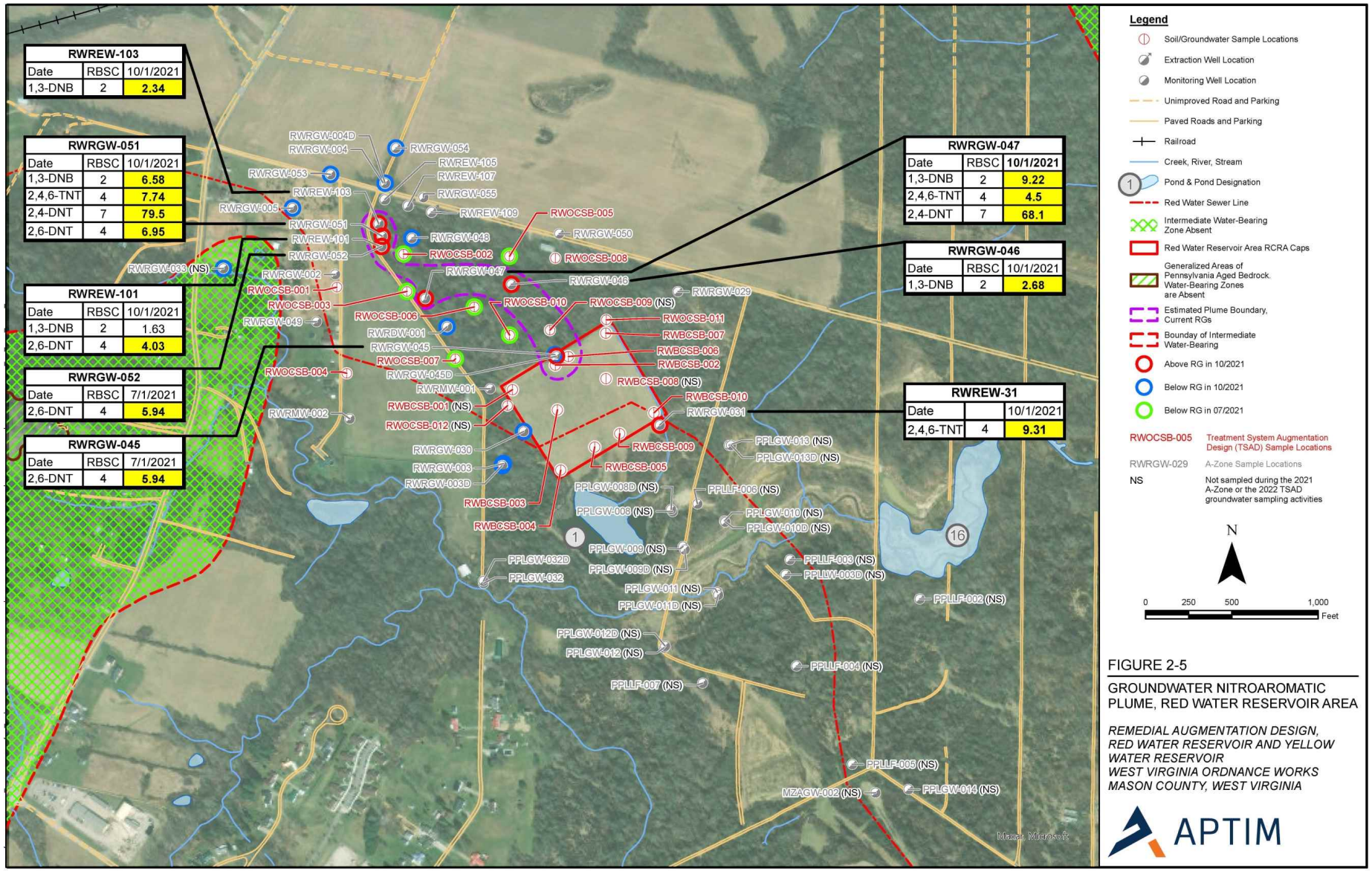


RWR HRSC & DPT SOIL AND GROUNDWATER SAMPLING

- Investigation indicated no COCs in the soil/vadose zone that could potentially contribute to groundwater contamination downgradient of the RWR RCRA caps
- DPT groundwater data in the RWR Area completed data gaps which have confirmed plume locations
- Soil data from underneath the RWR RCRA caps indicated that nitroaromatic contamination is not present at levels above EPA screening values
- The lack of nitroaromatic contamination in subsurface soil was also confirmed by the groundwater data collected beneath the RWR Area RCRA caps
- Soil and DPT groundwater data, along with the HRSC data, were used to update the RWR Area site conceptual model; this information was used to design the optimal treatment augmentation to reduce nitroaromatic COCs to below groundwater RGs



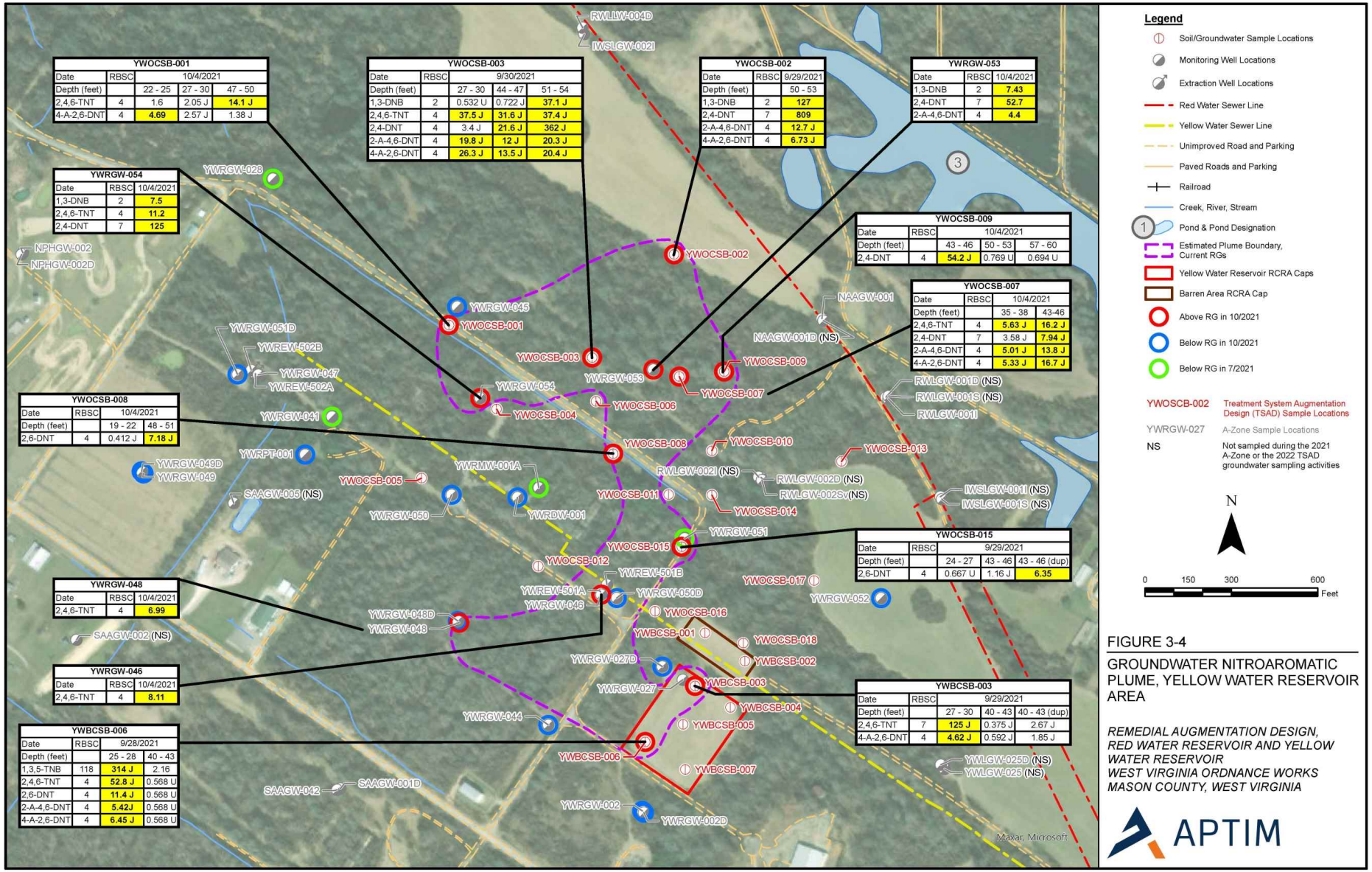
RWR HRSC & DPT SOIL AND GROUNDWATER SAMPLING



YWR HRSC & DPT SOIL AND GROUNDWATER SAMPLING

- Investigation indicated no COCs in the soil/vadose zone that could potentially contribute to groundwater contamination downgradient of the YWR and Barren Area RCRA caps
- DPT groundwater data in the YWR Area suggest that the plume size has expanded to the north-northwest but has decreased along the previously interpreted southern boundary
- Subsurface soil data from beneath the YWR and Barren Area RCRA caps also indicated that nitroaromatic contamination is not present at levels above EPA screening values contributing to groundwater contamination
- However, in DPT groundwater samples collected beneath the YWR and Barren Area RCRA caps, nitroaromatic compounds were detected in six of the seven locations, with concentrations above RGs in two borings locations. Specifically, boring location YWBCSB-006 exhibited the highest nitroaromatic values, indicating a remedial action may be required to reduce nitroaromatic levels in this isolated area
- The subsurface soil and DPT groundwater data, along with the HRSC data, were used to update the YWR Area site conceptual model. This information was then be used to determine the optimal treatment augmentation to reduce nitroaromatic COCs levels to below the groundwater RGs

YWR HRSC & DPT SOIL AND GROUNDWATER SAMPLING



TOTAL PROJECT PLANNING (TPP)

- The TPP process involves early and continuous engagement of stakeholders throughout all phases of the project.
- Stakeholders included the Army client, federal regulators, and state regulators
- First TPP meeting was held to review and adjust the strategy for the HRSC investigation to assure:
  - Data gaps would be addressed
  - Sufficient data would be obtained to fully characterize the plume
  - Design parameters (hydrogeologic data, flow rates, contaminant sources) would be determined
- Second TPP meeting was an interactive brainstorming session to develop design concept; specific discussion elements included:
  - Specific amendments being considered
  - Intervals with highest K values
  - Shut down of pump and treat system during bioaugmentation treatment
  - Monitoring during treatment
- A third TPP meeting will be held to review the Draft Final Design

RWR AND YWR AREAS – TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Selection

APTIM has conducted several field-scale treatability studies (TS) at WVOW, including RWR, YWR, Pond 13, and several areas within the TNT Manufacturing Area.

- 2008 EISB TS evaluated Emulsified Vegetable Oil (EVO) and yeast extract at the YWR and Pond 13 Areas and Hydrogen Release Compound (HRC) at the RWR Area. Results indicated EISB is an effective technology for reducing the levels of nitroaromatics in groundwater and that the EVO and yeast extract mixture was the most effective.
- 2010 EISB TS evaluated EVO with yeast extract, Extended Release HRC (HRC-X), and Lactoil at three hot spots in the TNT Manufacturing Area. EVO was also used in a 600’ long biobarrier configuration. The EVO with yeast extract proved very effective in a biobarrier configuration.
- 2017-2019 TS evaluated EVO and ZVI mixture at the Pond 13 Area; amendments were applied using soil mixing. A benefit of the EVO/ZVI mixture is the added longevity (i.e., extended treatment time) as compared to EVO alone.
- An injectable mixture of the EVO and a sulfidated-micro ZVI (S-mZVI) mixture has been selected as the appropriate in situ EISB groundwater treatment for the RWR and YWR Areas

RWR AND YWR AREAS – TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Delivery

- A July 2019 Memo recommended that the Project Delivery Team (PDT) evaluate the use of circulation cells to introduce carbon substrate on a continuous basis versus batch injection
- While it is agreed that recirculation systems are useful to apply amendments over a plume area, they are typically more successful in smaller plumes with more homogeneous lithologies
- HRSC performed at both the RWR and YWR Areas observed very heterogeneous lithologies throughout the plume areas that could be problematic for a recirculation system
- Biobarriers were selected due to their effectiveness in treating long plumes in heterogenous lithologies where groundwater flow allows for the contaminant mass to pass through the amendment "barrier" with relatively low maintenance
- In areas where the contaminant concentrations are higher or the groundwater gradient is low and therefore the flow rate is also low, the amendments will be distributed in a gridded pattern
- Direct push technology (DPT) was selected as the optimal delivery method
- The injection point spacing design is 15 feet apart as determined from experience during previous pilot/treatability injection activities at the WVOW site.

RWR AND YWR AREAS – TREATMENT SYSTEM AUGMENTATION DESIGN

Pre-Injection Testing

- Prior to injecting amendments, a clear water injection test will be conducted
- This test will be conducted to confirm or adjust the anticipated injection rates and pressures to achieve proper radius of influence
- Additionally, the injection test will determine if there are any tooling or injection modifications required prior to full scale implementation
- Water will be injected within a borehole approximately 4 feet from a monitoring well
  - The injection will start at the bottom of the target injection zone and continue in small increments up to the top of the injection zone
  - During the injection test, flow rates, pressure and total volume will be monitored and recorded. Near the end of the injection test, groundwater depth, dissolved oxygen, oxidation-reduction potential, conductivity, pH, and temperature changes will be recorded at the monitoring well
  - The observed head rise in the associated monitoring well, along with pressure and flow rate measurements, will provide an indication of how well the aquifer will accept the proposed volumes

RWR AREA – TREATMENT SYSTEM AUGMENTATION DESIGN

The HRSC information, including soil and groundwater sampling, HPT, and conductivity assessment, was used to determine the most effective placement of biobarriers and grid injection areas to treat the contaminated groundwater. The thickness of the treatment zones in the RWR area was determined by the HPT and conductivity logs, geological cross sections, and groundwater elevations. The HRSC information provided a localized depth of the deep clay, the groundwater elevation, and the permeable zones where groundwater is expected to flow and amendments can be delivered. This information also entered into the site groundwater model to aid in planning the full-scale design. A mixture of EVO (S-mZVI) will be injected into each point to reduce contaminant concentrations.

- RWR Area Biobarrier Locations:
  - Amendments will be injected into eleven biobarrier areas using 151 DPT injection points
  - The 11 biobarriers were determined by groundwater flow velocities and retardation factors for TNT, 2,4-DNT, and 1,3-DNT and nitroaromatic concentrations observed in the groundwater
  - The biobarriers are located 100 feet apart with an average contaminant migration of 3.7 years apart
- RWR Area Grid Injection Areas:
  - Amendments will be injected into only one grid area at the RWR Area using 207 DPT injection points
  - The RWR-001 Grid injection pattern was designed for location associated with wells RWRGW-051, RWRGW-052, and RWREW-103
  - The grid pattern was chosen for this area to treat nitroaromatic contaminants at three wells that are close in proximity and are located on the downgradient edge of the plume

RWR TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Quantities

Using mass balance calculations with a design safety factor of 2, EVO demand and mZVI demand for RWR Area is as follows:

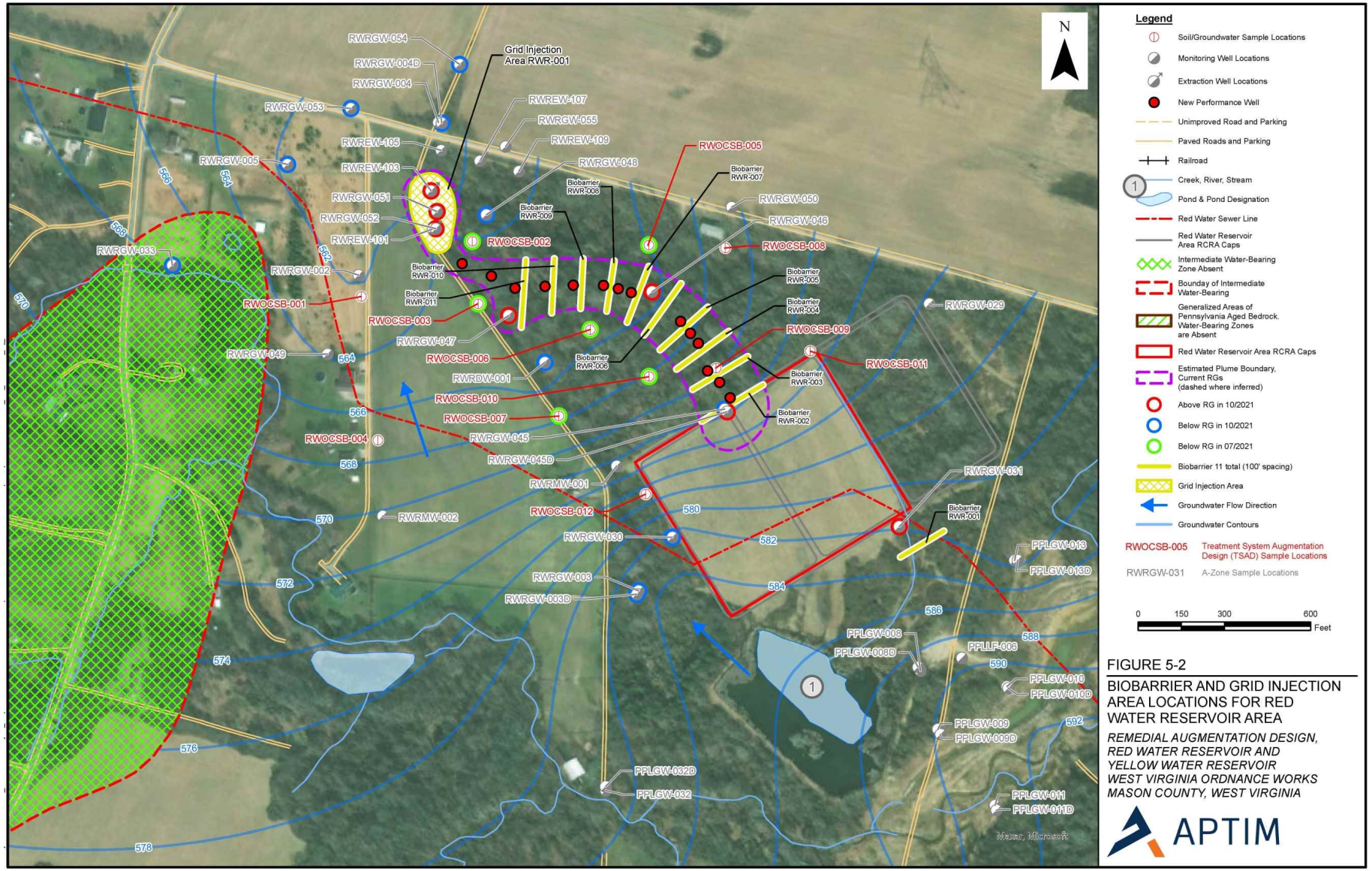
Treatment Area	Amendment Demand
RWR-001 Grid	• EVO: 99,775 pounds • mZVI: 49,887 pounds
Biobarriers (11 Total)	• EVO: 126,720 pounds • mZVI: 63,360 pounds

RWR TREATMENT SYSTEM AUGMENTATION DESIGN

Performance monitoring

- Performance monitoring will be performed to evaluate progress toward RAOs specified in the February 2019 OU 2 ROD ESD
- The current pump and treat system at the RWR Area will be shut down during in situ groundwater treatment
- The performance monitoring network will observe any potential plume migration due to the pump and treat system shutdown
- To evaluate treatment performance, a total of fourteen (14) new monitoring wells are proposed within, outside, and immediately downgradient of the plume area
- The fourteen (14) new performance monitoring wells will be utilized in combination with 10 existing RWR Area monitoring wells
- The twenty-four (24) performance monitoring wells will be sampled once a month for the first six months, quarterly for one year, semiannually for the following year, and then annually until final cleanup goals are achieved
- After three (3) years of groundwater performance monitoring, COC concentration trends and groundwater geochemistry will be evaluated to determine if reinjections into specific areas are warranted

RWR AREA TREATMENT SYSTEM AUGMENTATION DESIGN



YWR AREA – TREATMENT SYSTEM AUGMENTATION DESIGN

The HRSC information and site groundwater model were also used in the YWR Area to aid in planning the full-scale design. Amendments will be injections via DPT into eight areas. The groundwater gradient and flow rates at YWR are relatively flat and slow and therefore, the treatment areas and injection patterns were chosen to emplace the amendments where known elevated concentrations are present. Biobarriers are used to prevent plume migration and grid pattern injections are placed to reduce concentrations on the upgradient side of the plume or where elevated levels indicate a source of contaminants that may migrate. A mixture of EVO (S-mZVI) will be injected into each point to reduce contaminant concentrations.

- YWR Area Biobarrier Locations:
  - Amendments will be injected into five biobarrier areas using 99 DPT injection points
  - Three biobarriers will be completed along the downgradient western edges of the plume to prevent contaminant migration
  - The remaining two biobarriers will be completed on the upgradient and downgradient edges of the YWR RCRA Cap to prevent potential contaminant migration from the buried waste
- YWR Area Grid Injection Areas:
  - Amendments will be injected into four grid area at the YWR Area using 713 total DPT injection points
  - These locations represent a large area of contamination associated with locations YWOCSB-003, YWOCSB-007, YWOCSB-009, and YWRGW-053 and isolated hot spots

YWR TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Quantities

Using mass balance calculations with a design safety factor of 2, EVO demand and mZVI demand for YWR Area is as follows:

Treatment Area	Amendment Demand
Grids (4 total)	• EVO: 691,322 pounds • mZVI: 345,661 pounds
Biobarriers (5 Total)	• EVO: 138,996 pounds • mZVI: 69,498 pounds

YWR TREATMENT SYSTEM AUGMENTATION DESIGN

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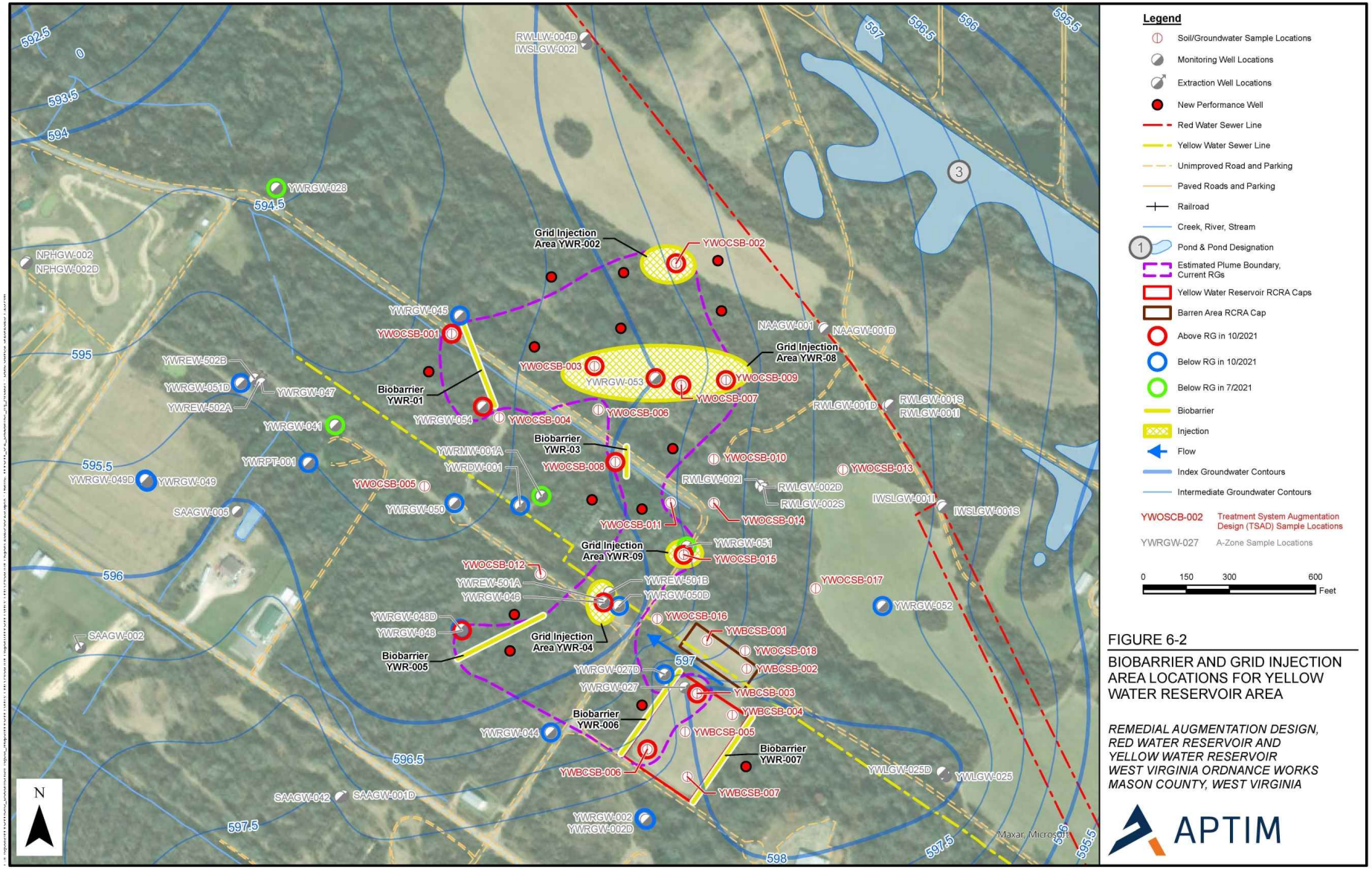

QUESTIONS

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