UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NEW ENGLAND REGION
FIVE POST OFFICE SQUARE, SUITE 100, BOSTON, MA 02109

September 15, 2020

Bruce Thompson
de maximis, inc.
200 Day Hill Road, Suite 200
Windsor, CT 06095

Re: Approval of de maximis inc. report titled *Remedial Design Work Plan – Appendix D 1,4-Dioxane and VOCs in Bedrock Groundwater Pre-Design Investigation Work Plan (*the "1,4-D PDIWP"), dated September 2020.

Nuclear Metals, Inc. Superfund Site

Dear Mr. Thompson:

EPA, in consultation with the Massachusetts Department of Environmental Protection, has completed its review of the 1,4-D PDIWP, dated September 2020. The 1,4-D PDIWP was revised in response to EPA comments dated July 2, 2020 and August 31, 2020. The 1,4-D PDIWP is subject to the terms and conditions specified in the Consent Decree (CD) for Remedial Design / Remedial Action (RD/RA) for the Nuclear Metals, Inc. Site, which has an effective Date of December 6, 2019.

EPA has reviewed the revisions to the 1,4-D PDIWP and finds that they are acceptable. Therefore, EPA approves the 1,4-D PDIWP.

If there is any conflict between the Performance Standards as stated in the Work Plan and the Performance Standards as stated in the CD and statement of work (SOW), the CD and SOW shall control.

Please do not hesitate to contact me at (617) 918-1339 or at smith.christopher@epa.gov should you have any questions in this regard.

Sincerely,

Christopher Smith
Project Manager

NUCLEAR METALS, INC. SUPERFUND SITE

CONCORD, MASSACHUSETTS

Remedial Design Work Plan - Appendix D
1,4-Dioxane and VOCs in Bedrock Groundwater
Pre-Design Investigation Work Plan

Prepared for:

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200 Day Hill Road, Suite 200
Windsor, CT 06095

Prepared by:

Geosyntec consultants

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Revision: September 2020

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Geosyntec consultants

ACRONYMS AND ABBREVIATIONS

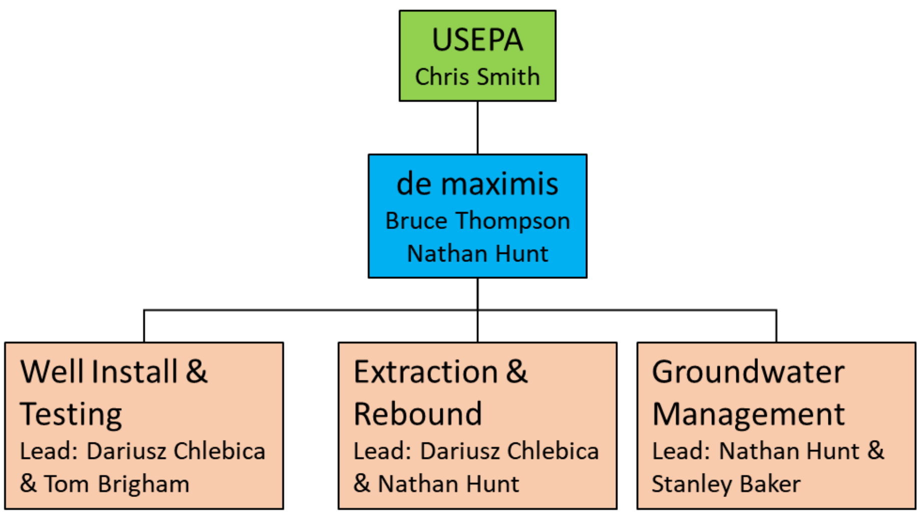
1,1, DCA	1,1-dichloroethane
FS	feasibility study
ft bgs	feet below ground surface
ft	feet/foot
ft/ft	feet per foot
GIS	geographic information system
gpm	gallons per minute
HB	Holding Basin
HPFM	heat pulse flow meter
ICP-MS	Inductively Coupled Plasma – Mass Spectrometry
IDW	investigation-derived waste
MCL	maximum contaminant level
μg/L	microgram(s) per liter
NMI	Nuclear Metals Inc.
NTCRA	Non-Time-Critical Removal Action
NTU	Nephelometric Turbidity Units
ORP	oxidation-reduction potential
PDI	predesign investigation
PVC	polyvinyl chloride
RA	remedial action
RD	remedial design
RDWP	remedial design work plan
RI	remedial investigation
ROD	Record of Decision
SIM	Selected Ion Monitoring
SOP	standard operating procedure
SOW	Statement of Work
SVOC	semivolatile organic compound
TCE	trichloroethene
TS	treatability study
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1. WORK PLAN OVERVIEW

The Non-Time Critical Removal Action (NTCRA) for 1,4-dioxane in groundwater that was implemented near the Town of Acton well field starting in 2015 has proven to be an effective remedy for containing the 1,4-dioxane plume and removing mass from overburden and bedrock at the toe of the plume (see section 2.4 of the Remedial Design Work Plan [RDWP]) located downgradient of the Nuclear Metals, Inc. (NMI) Property (Figure 1). However, 1,4-dioxane and volatile organic compound (VOC) impacts remain in bedrock upgradient of the NTCRA extraction well. To enhance removal of 1,4-dioxane from bedrock, this predesign investigation (PDI, and specifically PDI 14D-1) explores the use of extraction and treatment for groundwater from areas of elevated 1,4-dioxane. This approach is compatible with the current 1,4-dioxane treatment approach, which has a proven record of being effective, and integrates well with ongoing treatment since the existing treatment system has available capacity.

1.1 <u>PDI Team</u>

The PDI for assessing 1,4-dioxane and VOCs in bedrock groundwater will be conducted jointly by Geosyntec Consultants Inc. (Geosyntec) and *de maximis, inc* (*de maximis*). The schematic below identifies the team for this PDI. In general, Geosyntec will oversee PDI design, well installation, and groundwater extraction, and *de maximis* will lead groundwater sampling, analysis, and management.

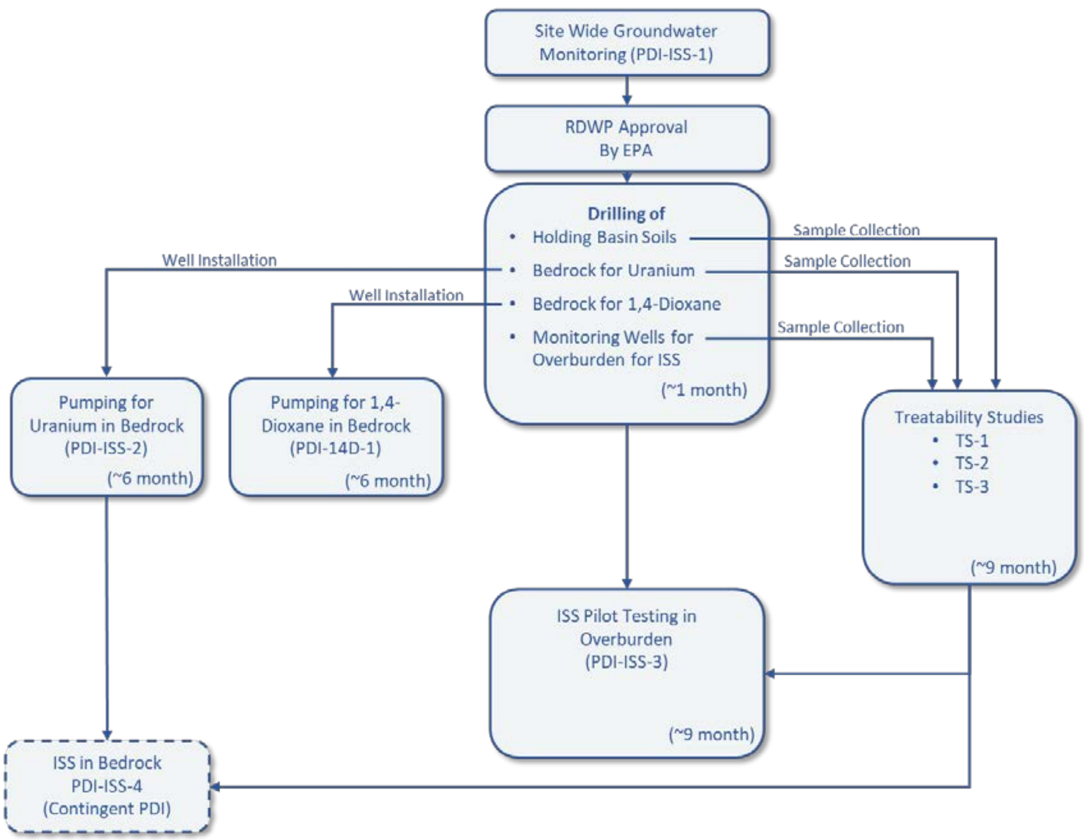


1.2 <u>Sequencing of PDI Work</u>

Implementation of this PDI is not contingent on other PDI or treatability study (TS) work being performed at the Site. Monitoring wells for delineation of 1,4-dioxane and VOCs in bedrock, as well as bedrock extraction wells, can be installed upon approval by the United States Environmental Protection Agency (USEPA). The drilling will be coordinated with a drilling subcontractor for other PDIs to make field mobilizations efficient.

Groundwater extraction will begin following installation and sampling of monitoring wells and analysis of the data (e.g., geophysical logging). Groundwater extraction will be contingent on water treatment capacity. The approach for water treatment and disposal will be determined after wells are installed because well development will assist in identifying the volume requiring disposal and contaminant concentrations. Disposal options being considered include pretreatment followed by on-site disposal at the NTCRA system or pretreatment with off-site transportation and disposal.

The figure below provides a review of how this PDI will be sequenced, and how this sequencing will correlate with PDIs developed to target uranium in groundwater (described in Appendix B of the RDWP).



1.3 Data Quality

To meet the objectives of this PDI, data of sufficient quality have to be collected. Standard field procedures and laboratory analyses provided in the Field Sampling Plan (Appendix I) and the Quality Assurance Project Plan (Appendix J) will be used throughout execution of the work described below to ensure data collected can achieve the objectives of the PDI. The table below summarizes the standard operating procedures (SOPs) applicable to this work plan. The detailed descriptions of the work call out these SOPs so that standard procedures are clear to field personnel conducting the work.

No.	Applicable Standard Operating Procedures
Soil	
NMI-S-004	Drilling
NMI-S-006	Soil Description
Groundwater	
NMI-GW-002	Monitoring Well Development
NMI-GW-003	Monitoring Well Installation
NMI-GW-009	Water-Level Measurement Procedures
NMI-GW-010	Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
NMI-GW-011	Groundwater Sampling for PFAS
NMI-GW-014	BarCad Well Sampling
NMI-GW-016	Packer Testing Procedures
NMI-GW-017	Specific Capacity Testing and Data Reduction
NMI-GW-018	Pumping Test
NMI-GW-019	Slug Test
Misc.	
NMI-001	Chain of Custody, Handling, Packing, and Shipping
NMI-002	Calibration of Field Instruments - Submersible Pump Operation
NMI-003	Calibration of Field Instruments - ORP, NTU, DO meters
NMI-005	Investigation-Derived Waste Handling and Storage
NMI-007	Field and Heavy Equipment Decontamination
NMI-009	General Survey Procedures

2. OBJECTIVE

The Consent Decree (CD) and the accompanying Statement of Work (SOW) for the Site describe the remedial design/remedial action (RD/RA) activities to be performed at the Site. Although 1,4-dioxane in bedrock groundwater was not included as part of the in situ sequestration portion of the CD SOW, this component has been added to the SOW following the lodging of the CD.

This PDI has been developed based on existing Site data collected during historical investigations summarized in the 2014 Remedial Investigation RI/FS (*de maximis* 2014), the NTCRA activities completed between 2015 and 2019, and analytical data collected during the November 2019 comprehensive groundwater monitoring event described under PDI-ISS-1 in Appendix B of the RDWP. The November 2019 event represents the baseline 1,4-dioxane distribution for the RD. Many of the components of this work plan are also relevant to PDI-ISS-2 Pumping and Rebound Analysis for Uranium in Bedrock, and thus, the procedures, figures, and tables in this Appendix overlap with those in Appendix B of the RDWP. Where applicable, this work plan is subordinate to the PDI-ISS-2 work plan and references the PDI-ISS-2 work plan where appropriate.

A Remedial Action Objective (RAOs) for 1,4-dioxane (and VOCs) stated in the Record of Decision (ROD) is the restoration of groundwater to meet project clean-up levels. The objective of this appendix is to describe pre-design work that will be performed to (1) expand the delineation of 1,4-dioxane in bedrock at the Site, and (2) collect data to assist in the design of the selected remedy for 1,4-dioxane and VOCs in bedrock as described the ROD in order to achieve this RAO. The recalcitrant 1,4-dioxane plume in bedrock covers a large footprint with concentrations several orders of magnitude above cleanup levels. Further, the crystalline bedrock is of low-permeability and relatively deep. As such, the selected remedy described in the ROD includes extraction and ex-situ treatment of VOCs and 1,4-dioxane. Based on the this, the objectives of the PDIs described below focus on design needs for a groundwater extraction remedy.

3. PURPOSE

The purpose of this work plan is to detail field activities to be conducted to further define the vertical and lateral distribution of 1,4-dioxane in bedrock groundwater, assess the hydraulic properties of the bedrock aquifer, and collect data required to evaluate the feasibility of a pumping remedy. As described above, a pumping remedy is proposed as the treatment approach for 1,4-dioxane and VOCs in bedrock.

With the exception of an additional delineation well along the western edge of the NMI Property line, this work plan focuses on the downgradient portion of the bedrock 1,4-dioxane plume (mainly areas near and to the north of Route 62) where 1,4-dioxane impacts in bedrock are not comingled with the uranium plume (Figure 2). Pre-design activities, and specifically pumping tests like those described in this Appendix, planned for the upgradient portion of the plume where 1,4-dioxane detections coincide with elevated uranium concentrations, are described in PDI-ISS-2 – Appendix B.

The following data will be collected as part of the scope presented in this work plan:

- Water quality data will be collected to further delineate the vertical distribution of 1,4-dioxane in the downgradient core and lateral delineation along the fringes of the plume relative to 2015 Record of Decision (ROD) Cleanup level (0.46 micrograms per liter [µg/L]).
- Hydraulic characteristics of the bedrock aquifer, including fracture connectivity, transmissivity, and yield, will be collected to characterize the bedrock formation in the area of 1,4-dioxane impacts allowing the project team to assess the effectiveness of a groundwater extraction remedy for 1,4-dioxane at the Site.

Although not specifically outlined, this work plan also targets the isolated detections of VOCs in groundwater. Because the exceedances of VOCs in bedrock groundwater are generally confined to the footprint of the 1,4-dioxane plume, it is anticipated that the pumping and remediation targeting 1,4-dioxane will also result in a decrease of VOC concentrations to below their respective remediation goals. In addition, bedrock wells installed as part of this work plan, will be sampled for specific metals that have exceeded MCLs in bedrock groundwater in November 2019 (see Sections 5.1.4 and 5.3.2).

4. BEDROCK HYDROGEOLOGY

Brief descriptions of the bedrock type, depth to bedrock and bedrock surface topography, depth to groundwater in bedrock wells, and hydraulic conductivity and hydraulic gradients are presented below. Further details are presented in Appendix B.

4.1 Bedrock Type

Descriptions of Site bedrock cores along with evidence from cores collected at the W.R. Grace Superfund Site north of the Assabet River (GeoTrans 2002) and the Rockland Avenue Well Site in Maynard (Walsh 2001), indicate that the Site is predominantly underlain by the Shawsheen Gneiss of the Nashoba Formation.

4.2 Depth to Bedrock and Bedrock Surface

The depth to bedrock at the Site ranges from about 37 feet below ground surface (ft bgs) at well MW-BS22 located north of the Holding Basin (HB) and Sphagnum Bog to over 150 ft bgs at MW-BS14, MW-BS28 and GZW-11-2 further downgradient, at the northwest corner of the NMI Property, where a thick accumulation of stratified drift is located. A depth-to-bedrock map is shown on Figure 3. The depth to bedrock in the focus area near and to the north of Route 62 ranges from 67.5 feet (ft) at ML-1-3 to 111 ft at GZW-8-2.

The bedrock surface at the Site is highest near the inferred bedrock ridge to the north of former Building D (100 ft above mean sea level) and slopes downward to the west reaching an elevation of approximately 30 ft at MW-BS14 and MW-BS15 located near and north of Route 62. A top-of-bedrock elevation is shown on Figure 4.

4.3 Depth to Groundwater, Potentiometric Levels, and Hydraulic Gradients in Bedrock

From upgradient of the HB to downgradient near the river, the depth to water in bedrock wells ranges from approximately 40 ft below ground surface in the upgradient area of the Site (MW-BS12 and MW-BS21) to approximately 55 to 60 ft downgradient of the HB (GZW-7-2, MW-BS02) to 23 ft at Route 62 (MW-BS25) to less than 10 ft near the Assabet River (GZW-8, MW-BS26). The greatest depth to groundwater is in the northwest portion of the NMI Property on the stratified, drift references in Section 4.2, where ground surface is higher, (elevation 190 to 195 ft), as compared to the lower elevations near MW-BS28 and MW-BS14 (65 ft and 70 ft, respectively)

The bedrock potentiometric level is typically within the deep overburden in the upgradient portions of the Site and within the shallow overburden in the downgradient areas near the Assabet River. The groundwater potentiometric elevation contours in bedrock, inferred from November 2019 depth-to-water measurements are presented on Figure 5. Similar to the overburden aquifer, there is approximately 20 to 25 ft of head drop from the upgradient area on the southeastern portion of the Site south of the Sphagnum Bog (elevation 146 ft) to the downgradient portion of the Site near the Assabet River (elevation 124 ft).

The hydraulic gradient in bedrock is oriented northwest from the HB towards the 2320 Main Street property (Skating Rink) near the Assabet River and then westward toward the Town of Acton's

Assabet 1A pumping well. The horizontal gradients in bedrock, based on depth-to-water levels measured in November 2019, range from an average 0.017 feet per foot (ft/ft) at the HB area to 0.005 ft/ft in the northwest portion of the Site (GZW-10 to MW-BS28 area). The gradients are flatter in the downgradient portion of the Site (i.e., the focus area of this work plan) to 0.002 ft/ft in the MW-BS31 to MW-BS34 area (Figure 5).

Vertical gradients observed downgradient of the NMI Property during the November 2019 water level round indicated upward groundwater flow from deeper rock to shallow rock (e.g., there is a 3-foot difference in head between BM15 and BS15). The vertical gradients between the bedrock and overburden were also typically from the bedrock to the overburden in downgradient monitoring well clusters such as those along the Assabet River (MW-BS32 at 125.25 ft to MW-SD32 at 125.11 ft, MW-BS34 at 125.39 ft to MW-SD34 at 125.10 ft, and MW-BS35 at 127.88 ft to MW-SD35 at 127.40 ft [see Table 2-2a]).

4.4 1,4-dioxane Source and Distribution in Bedrock

The mechanism for the release of 1,4-dioxane to the Site groundwater has not been defined. However, 1,4-dioxane was used as a stabilizer in 1,1,1-trichloroethane (1,1,1-TCE) and possibly other solvents, and these solvents were used at the Site and likely released as a co-contaminant. 1,4-dioxane was not detected in soil, surface water, or sediment at the Site, suggesting that there are no residual sources of 1,4-dioxane in these media.

The 1,4-dioxane distribution in bedrock groundwater and the general extent of the plume exceeding the ROD cleanup level (0.46 µg/L) as inferred from data collected in November 2019 is depicted on Figures 6, 7, and 8.

The plume in bedrock extends from the HB area (34.7 µg/L at GZW-7-2) to downgradient of the former facility footprint (99.1 µg/L at MW-BS13 and 55.4 µg/L at GZW-10-2), to the area between Route 62 and the Assabet River (73.6 µg/L at MW-BS15 and 36.2 µg/L at MW-BS32). It is inferred that groundwater containing 1,4-dioxane discharges from bedrock to deep overburden (Figure 8) in this area as demonstrated by persistent elevated detections of 1,4-dioxane in the deep overburden well MW-SD34. The plume was historically identified to extend beneath the Assabet River and toward the Assabet 1A municipal well (Geosyntec 2016); however, the concentrations west of the Assabet River have dissipated below the cleanup level after the hydraulic containment system at EW-1 began operation in June 2016.

5. BEDROCK WELL INSTALLATION

This section describes new bedrock well locations, drilling methods, monitoring activities to be performed during drilling, well development, and open borehole testing, including borehole geophysics and packer testing. The following subsections include the selection method used for additional well locations as well as plans for well installation methods, parameters to monitor during drilling, open borehole well development, water management, open borehole testing, and alternatives for installing well screens and managing an unstable borehole.

5.1 Bedrock Monitoring Wells

This work plan includes the installation of five new shallow bedrock monitoring wells to further delineate the 1,4-dioxane plume and provide supplemental data along the core of the plume and 1 additional monitoring well to replace existing monitoring well GZW-7-2 (discussed in section 3.4.2.3 of Appendix B). Details of the drilling and installation methods for monitoring wells are provided below.

5.1.1 New Monitoring Well Location Selection

The current distribution of 1,4-dioxane in bedrock groundwater, as inferred from data collected in November 2019, lacks delineation to the ROD cleanup level (0.46 µg/L) to the east near Route 62 and to the west in the area south of MW-BS14 and GZW-10-2. Two monitoring wells are proposed to inform the lateral extent of the 1,4-dioxane plume in those areas. Also, additional monitoring wells are proposed to provide more resolution along the plume axis and provide locations for water level and water quality monitoring during extraction and rebound testing. These wells are proposed to be installed within shallow (i.e., the top 25 ft) bedrock to monitor a similar interval as the wells installed for the NTCRA. The rationale, locations, and depths of the proposed wells are presented on Table 1, and their locations are presented on Figure 7. The primary purpose of the monitoring wells is briefly summarized below:

- MW-BS50 – Plume delineation between BarCad® wells GZW-8-2 and ML-1-3
- MW-BS51 – Increased resolution north of the plume axis near MW-BS25 and MW-BS26
- MW-BS52 – Increased resolution in the inferred 1,4-dioxane discharge area to overburden
- MW-BS53 – Increased resolution between existing wells MW-BS31 and MW-BS35
- MW-BS54 – Plume delineation to the south of wells MW-BS14 and GZW-10-2
- Additionally, Barcad™ well GZW 7-2 is being replaced with a traditional monitoring well; the purpose for this and specifics on the replacement well (MW-BS7-2) are provided in section 3.4.2.3 of Appendix B).

The proposed wells will also help in the evaluation of isolated VOC impacts in bedrock, specifically 1,1-dichloroethane (1,1-DCA) in the vicinity of MW-BS25. In addition to further delineation and added resolution, the proposed monitoring wells will serve as water level and water quality monitoring locations during pumping and will assist in evaluating bedrock fracture connectivity and zone of influence between the extraction wells.

5.1.2 Monitoring Well Installation Methods

The five proposed monitoring wells presented above and shown in Figure 7 will be advanced using rotosonic drilling methods. The driller will advance a borehole through the overburden and approximately 2–3 ft into bedrock using a 4.75-inch-diameter core barrel and 6-inch-diameter override casing (or similar). Once the override casing is properly seated into competent bedrock, the driller will install a 7-inch (or similar) override casing to accommodate rock coring tooling and retrieve the 6-inch casing. The driller will subsequently retool the drilling rig to advance a 3.75 -inch-diameter (HQ) or 4.8-inch diameter (PQ) (or similar) bedrock borehole using Wireline Coring methods to a depth of approximately 25 ft below the top of bedrock. Sonic drilling and wireline coring methods are described in SOP NMI-S-004.

The wells will be constructed using 5- or 10-ft-long, 2-inch-diameter, 10-slot Schedule 40 polyvinyl chloride (PVC) well screen and an appropriate length of 2-inch-diameter Schedule 40 PVC riser. Filter pack will consist of appropriately sized filter sand (Morie #0). Sand filter pack will be extended 2 ft above the top of the well screen and overlain by 1 ft of #00 "choker sand" followed by a 3-ft-thick bentonite chip seal. The annular space above the bentonite seal will be filled with a cement/bentonite grout to the ground surface. The well will be equipped with flush-mount or standpipe protective casing to prevent surface water inundation and provide security. Well construction is described in SOP NMI-GW-003. A construction report for each well will be completed in the field by the field geologist (see SOP NMI-GW-003). An inventory of number of investigation-derived waste (IDW) drums, contents, and origin will be included in the field notes. IDW will be handled and stored in accordance with procedures outlined in SOP NMI-005.

5.1.3 Field Monitoring Activities during Monitoring Well Installation

During drilling, the field geologist will inspect and log the rotosonic cores collected in the overburden for color, rock type, consistency, and rate to assess lithology changes. The field geologist will also monitor and document drilling rates and water losses. After drilling approximately 2–3 ft into bedrock, the field geologist shall inspect the rock cores and in coordination with the driller and project manager determine if competent bedrock has been reached. Once competent bedrock is confirmed, the driller will retool the sonic drilling rig for wireline coring. As the bedrock borehole is advanced using Wireline Coring methods, the field geologist will log the cores for rock type, fracture characteristics, and weathering. The drilling water loss will be tracked and will be targeted as the minimum volume to be removed during well development. The optimal well screen placement will be determined based on the location(s) of water-bearing fractures inferred from the rock cores. A construction report for each well will be completed in the field by the field geologist (see SOP NMI-GW-003). An inventory of number of IDW drums, contents, and origin will be included in the field notes. IDW will be handled and stored in accordance with procedures outlined in SOP NMI-005. The wells will be developed using a combination of mechanical surging, pneumatic surging and lifting, and pumping as described in SOP NMI-GW-002. Purge water from each well will be containerized in labeled drums or fractionation tanks per SOP-NMI-005. The new wells will be surveyed according to SOP NMI-011 or by a licensed surveyor following installation.

5.1.4 Groundwater Sampling

Following development, the new monitoring wells will be purged using a bladder pump (preferred) or peristaltic pump and sampled using a low-flow, flow-through apparatus and turbidity meter in accordance with the low-flow sampling requirements (see SOP NMI-GW-010). Samples for laboratory analyses of 1,4-dioxane via Method 8270 Selected Ion Monitoring (SIM) and VOCs via Method 8260 will be collected. The analytical results will be added to the existing plan portraying the distribution of 1,4-dioxane in bedrock, and the isoconcentration contours will be updated based on the detected concentrations (if needed). Because isolated maximum contaminant level (MCL) exceedances of metals have been detected in groundwater in the vicinity of the new monitoring wells, additional samples will be collected for total and dissolved arsenic, cobalt, manganese, thorium, and uranium (with speciation for U^{235} and U^{238}) via USEPA Method 6020A Inductively Coupled Plasma – Mass Spectrometry (ICP-MS).

5.1.5 Hydraulic Conductivity Testing

Well-point (slug) testing to estimate the bedrock hydraulic conductivity will be considered for specific new monitoring well(s) that do not exhibit a hydraulic response to pumping from a nearby proposed extraction wells (see section 5.2). If obtaining the hydraulic conductivity estimates via well-point tests is determined to be necessary, the slug testing will follow procedures outlined in SOP NMI-GW-019.

5.2 Bedrock Extraction Wells

This section provides a description for installing and monitoring the four proposed bedrock extraction wells targeted for 1,4-dioxane removal.

5.2.1 Location Selection

Four open bedrock extraction wells, BEW-3, BEW-4, BEW-5, and BEW-6, will be installed within the downgradient portion of the bedrock 1,4-dioxane plume using the methods described in Section 5.2.2. The locations of these wells are show on Figure 7. The location of BEW-4 was selected based on the elevated (10 µg/L contour) 1,4-dioxane concentrations in the vicinity of the bedrock ridge near monitoring wells ML-1-3 and MW-BS25. The locations of bedrock extraction wells BEW-5 and BEW-6 were selected to flank MW-BS15 where the highest 1,4-dioxane concentrations have been historically detected (north of Route 62).

BEW-3 (Figure 7) will be an extraction well installed closer to the HB and into bedrock where higher-concentration uranium and 1,4-dioxane are co-located. Testing at BEW-3 is discussed in Appendix B under PDI ISS-2 (Pumping and Rebound Analysis for Uranium in Bedrock Groundwater). Testing at BEW-3 described in PDI ISS-2 includes sampling for 1,4-dioxane. Because the scope of work for testing is this well is covered in detail in Appendix B, discussion of BEW-3 is not included in this PDI.

Although hydraulic connectivity in bedrock under pumping is not fully understood for the Site, based on testing as part of this work plan, it is hoped that this distribution of wells will result in zones of influence during pumping that will cover significant portions of the 1,4-dioxane plume in bedrock. The primary purpose for each well location is as follows:

- BEW-4 – Vertical delineation and lateral capture in the vicinity of the bedrock ridge (ML-1-3 and MW-BS25 area)
- BEW-5 – Vertical delineation and lateral capture along the axis of the plume upgradient of MW-BS15
- BEW-6 – Vertical delineation and lateral capture along the axis of the plume downgradient of MW-BS15

Further details pertaining to the proposed well locations, the expected depth to bedrock, and the target depths into bedrock are presented in Table 1. The total depth of the proposed open borehole bedrock wells was selected at 60 ft below the bottom depth of the nearest monitoring well exceeding the 1,4-dioxane ROD cleanup level (0.46 µg/L). The proposed target depths relative to the top of bedrock and the distribution of 1,4-dioxane concentrations are shown in cross section on Figure 8. It is anticipated that advancing the boreholes to these depths will be sufficient to provide vertical delineation of 1,4-dioxane and isolated VOC impacts within the 1,4-dioxane plume in bedrock.

5.2.2 Extraction Well Installation Methods

Similar to the extraction wells proposed for uranium rebound testing as part of ISS-2 in Appendix B, 6-inch nominal bedrock boreholes were selected for this PDI because this diameter can accommodate a suite of borehole geophysical tools, straddle packer equipment, and moderate-output (1–10 gallons per minute [gpm]) submersible pumps that are desired for sustained extraction during the pumping and rebound testing. The sampling of discrete fractures/fracture zones within the open boreholes will provide 1,4-dioxane and VOC analytical data to assess the vertical distribution of these contaminants above their respective cleanup goals within bedrock. Also, if the vertical delineation is not achieved based on the results from packer testing described below, then open borehole wells can be extended.

5.2.3 Overburden Drilling

It is anticipated that rotosonic or dual rotary methods will be used to drill through the overburden. Due to the limited availability of dual rotary drilling equipment, rotosonic methods are likely to be used in the overburden. Below are the expected drilling methods based on the discussions with the driller, however, means and methods may be adapted in the field depending on what is encountered, equipment, and other factors.

Rotosonic

If rotosonic drilling is used to advance the boreholes through the overburden, the driller will first advance a 9-inch core barrel and a 10-inch diameter override casing through the overburden and several feet into bedrock. Once the bedrock is intercepted, the field geologist will pay close attention to the rock cores to evaluate the integrity of the bedrock for the purpose of setting the permanent steel casing. If the bedrock is of sufficient integrity for the casing, the drilling will be suspended, and the driller will remove the drill string from the borehole. The driller will then assemble the permanent casing by lowering 10-foot sections of 6 or 7-inch threated flush-joint casing inside the 10-inch outer casing and into the bedrock socket. The permanent casing will be centered within the 10-inch casing and fitted with a drive shoe that will be spun approximately a few inches into the bedrock. The driller will subsequently grout the annular space between the permanent casing and the 10-inch temporary casing with cement and bentonite grout via a tremie pipe. As the grout is tremied into the annular space, the 10-inch casing will be incrementally removed from the borehole. Once the grout is determined to have cured, the driller will reconfigure the drilling rig for air rotary drilling and begin advancing the bedrock borehole as described below in Section 5.2.4.

Dual Rotary

This method will not require the mixing of mud or advancing a larger borehole to set a 6-inch casing through overburden. Dual rotary drilling is a combination of a top drive (drilling head) advancing an inner drill stem and the drill bit and bottom drive, which simultaneously advances a casing with a carbide-studded shoe welded to the bottom. The rotary top drive operates independently of the bottom drive and can be fitted with a tricone (i.e., roller) bit or an air hammer, which is advanced along with or slightly ahead of the casing. The top and bottom drives rotate in opposite directions and ensure a straight and vertical borehole. In heaving formations, the casing can be advanced slightly ahead of the bit to isolate the drill bit from the formation.

The driller will advance a cased borehole through the overburden in increments determined by the length of the steel casing and/or drilling rods. After a casing length is advanced, drilling will be suspended to weld on additional sections of steel casing and add drill rods. The cuttings will be evacuated from the annular space between the drill string and casing using air supplied by an onboard or auxiliary compressor. The cuttings will be directed into a cyclone suspended over drums or a roll-off. The field geologist will collect and describe the drill cuttings at approximately 5-ft increments. Once the bedrock is intercepted, the field geologist will pay close attention to the rock cuttings to evaluate the integrity of the bedrock for the purpose of setting the permanent steel casing. Once the bedrock socket is determined to be of sufficient integrity for the casing, the drilling will be suspended, and the driller will remove the drill string from the borehole. The driller will subsequently spin the outer casing up to within 1 to 2 ft of the top of bedrock and pump a volume of cement bentonite grout equal to 1.5 times the volume required to fill the bedrock socket to the bottom of the borehole. Once the grout is placed in the bedrock socket, the driller will spin the outer casing back down to the bottom of the borehole. The grout is intended to seal the bedrock borehole from the overburden and will be allowed to set overnight.

Once the grout is determined to have cured, the driller will reconfigure the drilling rig for air rotary drilling and begin advancing the bedrock borehole as described below.

5.2.4 Air Rotary Drilling in Bedrock

With a casing set into the top of rock, air rotary drilling is then used to drill through the casing and into bedrock. During air rotary drilling, transducers installed in nearby monitoring wells will be used to monitor the hydraulic response to air rotary drilling. This response enables evaluation of fracture connectivity. Prior to the drilling, the field geologist will measure the depth to water in the nearest deep overburden wells. The water levels will be monitored as the borehole is advanced to evaluate whether the grout seal remains intact during drilling. The cuttings will be containerized into drums or roll-offs and handled in accordance with procedures outlined in SOP NMI-005. Air rotary drilling methods are described in SOP NMI-S-004.

The air rotary drilling will be suspended to develop individual fractures/fracture zones by air lifting when these fractures/fracture zones are intercepted during drilling (air lifting consists of pumping compressed air down the drill string and through the drill bit to evacuate water, residual drill cuttings and fines). The specific field logging and monitoring activities during drilling are described in Sections 5.2.5.

Upon reaching the target borehole depth, the entire length of the borehole will be developed by air lifting per SOP NMI-GW-002. The borehole will be left open with steel casing sealing the overburden. The steel casing will be cut approximately 1.5 to 2.5 ft above the ground surface, and the top of the casing will be leveled. The top will be marked or notched to identify a measuring point for all water level measurements at the well. The well will then be fitted with a suitable slip-on cap or waterproof cap (e.g., Royer Locking Well Cap) on the top of the casing to reduce the potential for debris to enter the borehole. All wells will be secured with a padlock (SOP NMI-GW-004).

5.2.5 Field Monitoring Activities during Drilling

Several types of data, including geology inferred from drill cuttings and aquifer response, will be collected during drilling to help characterize the bedrock aquifer. The methods used to gather this data are described in the below.

5.2.5.1 Field Logging

During drilling, the field geologist will monitor and document drilling rates and water production or losses. Drilling fluid loss will be used to inform total volume of water to be purged during well development. The field geologist will also monitor, inspect, and log drill cuttings for color, rock type, consistency, and rate as well as minerology, including pyrite to the extent possible, to assess the mineral composition and lithology changes (see SOP NMI-S-006). During rotary drilling, the drill cuttings will be collected every 5 ft from the return stream using a screen (e.g., a strainer) and washed using potable water to expose the solid cuttings. When bedrock is first intercepted, the field geologist shall collect the cuttings at a higher frequency (i.e., every 1 or 2 ft) to assist in evaluating the integrity of the shallow bedrock for the installation of the steel casing. During air rotary drilling in bedrock, the observations of changes in the consistency, color, and volume of the cuttings in conjunction with the driller’s observations will be used to infer water-bearing fractures and zones of softer or less competent bedrock. The field geologist will record the time and depth of each inferred water-bearing fracture intercepted during drilling. Well installation and construction data will be summarized in the field notes. A construction report for each well will be completed in the field by the field geologist (see SOP NMI-GW-003). An inventory of number of IDW drums, contents, and origin will be included in the field notes. IDW will be handled and stored in accordance with procedures outlined in SOP NMI-005.

5.2.5.2 Aquifer Response Monitoring

Because a water level response at nearby monitoring wells during drilling is likely to help identify hydraulically active zones relative to particular depths at drilling locations, prior to the well installation, pressure transducers equipped with data loggers will be installed to monitor water levels. Transducer locations will be targeted for selected existing and newly installed bedrock monitoring wells (described in Section 5.1.1).

To monitor the background groundwater levels, the pressure transducers will be installed approximately one week prior to the start of drilling and will initially be programmed with a long logging interval (e.g., 15 or 30 minutes). Shortly before commencing drilling activities, the pressure transducers will be reprogrammed to record on a shorter time interval (e.g., 1 or 5 seconds) to ensure that the time of the water level response can be correlated to the depth of the borehole being advanced.

The transducers will be installed using the Pressure Transducer Installation Log provided in Attachment A of Appendix B. The pressure transducers will be a non-vented type (e.g., Solinst Levelogger Model 3001 or equivalent), and their data will be barometrically compensated using ambient air pressure data collected by a Barologger deployed at the Site. Geosyntec will compare the pressure transducer data to the field notes documenting the borehole advancement to evaluate fracture connectivity across the bedrock aquifer in the 1,4-dioxane plume areas as a response to air rotary drilling. The locations of the wells selected for transducers are presented on Figure 9, and the list of locations is presented on Table 2. In addition to monitoring of nearby bedrock wells, the field geologist will monitor the water levels in existing deep overburden wells per SOP NMI-GW-009 to evaluate the connection between the two aquifers.

5.2.5.3 Open Borehole Well Development

Intermediate development of water-bearing fractures/zones will be completed during air rotary drilling to remove fine particles to enhance the hydraulic connection between the borehole and the intercepted fractures. After a water-bearing fracture is intercepted, the borehole advancement will be suspended, and the zone will be developed by air lifting. The approximate volume of water generated during development will be tracked over time and used to estimate the fracture yield. Development of fractures will continue until the turbidity of water produced from the boring is low (e.g., <50 Nephelometric Turbidity Units [NTU]) and the water is clear to the naked eye, or fails to be less turbid with ongoing development. After a fracture zone is developed or goes dry, drilling activities will resume. After each successive water-bearing fracture is encountered and then developed, the volume of water generated during air lifting per unit of time will represent a cumulative yield of the fracture being developed and the previously intercepted fractures.

After drilling is completed, the entire open borehole will be developed by airlifting to remove fine particles that may have accumulated during well installation and improve the quality of the borehole water in preparation for downhole geophysical logging, particularly to improve the clarity of the optical televiewer image. The borehole development will continue until the turbidity of the generated water is low (e.g., <50 NTU), the water is clear to the naked eye, and, at a minimum, the volume of water generated exceeds any water lost to the formation during rotary drilling (if used). Development may cease if it no longer become less turbid with further development and the volume of water removed for development exceeds fluid lost during drilling.

Although, the open borehole wells are intended to be used as open borehole wells for pumping and rebound analyses, a possibility exists that the bedrock at the selected drilling locations is highly fractured/weathered and will not support an open borehole. In the event the borehole is unstable and well screens need to be installed in the borehole to span discrete fractures or fracture zones, additional development of the screen interval will be performed (see Sections 5.3.3 and 5.3.4). The screened interval will be developed using a surge block equipped with a check valve (e.g., Waterra inertial pump) to flush the filter pack, and then the screened interval will be purged using a submersible pump. The screened interval will be considered developed when turbidity readings are below 5 NTUs or at least five screened interval volumes total of purge water have been removed (see SOP NMI-GW-002). Purge water from each well will be containerized in labeled drums or fractionation tanks.

5.3 Open Borehole Testing

A variety of downhole testing methods, which are described in the sections below, will be implemented to improve the understanding of the bedrock aquifer hydraulics and 1,4-dioxane distribution at several depth into bedrock.

5.3.1 Borehole Geophysics

After the new bedrock wells are installed to target depths and developed, borehole geophysical logging will be conducted to confirm the locations of fractures and/or fracture zones and identify water-bearing fractures. To ensure that the turbidity of the borehole water has dissipated enough to yield high-quality geophysical logs, the geophysical logging will not start until at least 48 hours after drilling is complete. The geophysical logging will include the caliper log, acoustic and optical televiewer, fluid temperature and resistivity, and heat pulse flow meter (HPFM) testing under ambient and pumping conditions. The borehole geophysical data will be used in conjunction with field observations during drilling (e.g., water production) to identify intervals with significant inflow/outflow. A description of how each specific form of geophysical data will aid in understanding bedrock fracturing and water bearing zones can be found in Appendix B, Section 3.4.6.1

Overall, the borehole data collected during geophysical logging will inform the selection of borehole intervals for packer testing and the construction of permanent monitoring well(s) within the boreholes, as required.

The small amounts of IDW water generated during the pumping associated with HPFM logging will be containerized in a steel 55-gallon drum and combined and managed with the IDW generated during drilling and well development.

5.3.2 Packer Testing and Contaminant Monitoring

The packer testing intervals in the newly installed open borehole wells will be selected based on borehole geophysical data described above. Up to four discrete intervals per boring will be selected for packer testing. The packer spacing, inflation pressures, and pumping procedures will follow those outlined in SOP NMI-GW-016. The packer apparatus will consist of three pressure transducers that will monitor the water column pressure below, within, and above the zone isolated by packers. More details about packer testing are provided in Appendix B, Section 3.4.6.

The discharge water from each interval will be monitored for field geochemical parameters using a flow-through apparatus (see SOP NMI-GW-010). The samples will be collected when (1) the field geochemical parameters stabilize to the low-flow criteria and a volume equivalent to at least three isolated interval borehole volumes are removed or (2) if the isolated interval is low yielding and the three volumes cannot be purged in a reasonable time frame, the samples will be collected after three hours of pumping. Samples for laboratory analysis collected from the isolated intervals will include 1,4-dioxane by USEPA Method 8270 SIM and VOCs via USEPA Method 8260. Based on MCL exceedances of metals in the vicinity of the proposed extraction wells, additional samples will be collected from the isolated interval for the analyses listed below.

- BEW-4 – thorium by USEPA Method 6020A ICP-MS
- BEW-5/BEW-6 – cobalt and manganese by USEPA Method 6020A ICP-MS

Prior to the packer testing, pressure transducers will be deployed at nearby bedrock monitoring wells in which a water level response was observed during drilling to assess whether there is a response, indicative of connectivity, when pumping individual intervals of the bedrock.

5.3.3 Well Screen Installation Alternative

The project team may decide to convert one of the open boreholes into a single or nested monitoring well after pumping and rebound testing is complete. This recommendation will be contingent upon the evaluation of the feasibility of pumping as a remedy for bedrock groundwater. It is likely that, if the pumping appears to be a viable option for bedrock 1,4-dioxane mass removal, the wells will remain as open boreholes to accommodate 4-inch-diameter submersible pumps. In the event the wells are converted to permanent monitoring wells, the screen intervals will be selected based on the borehole geophysical data and the contaminant distribution in samples collected from discrete intervals isolated during packer testing. Should the decision be made to convert the open borehole into an extraction well, the method described in Appendix B, Section 3.4.7, will be followed.

5.3.4 Bedrock Instability Alternatives

A high degree of fracturing and borehole instability was observed in bedrock boreholes during installation of wells MW-BS15 and MW-BM15 located in the core of the 1,4-dioxane plume during the RI. Due to the bedrock instability, borehole geophysical testing could not be conducted at these locations. For planning purposes, it is anticipated that the bedrock formation in at least one of the proposed bedrock wells installed as part of the additional 1,4-dioxane delineation and extraction wells for the rebound testing wells will not support an open borehole. It is proposed that in preparation for the drilling, two 10-foot-long, 4-inch-diameter, 10-slot wire wound (e.g., Johnson Screens) will be purchased and mobilized to the Site. In the event of borehole instability, the screens will be installed in the 6-inch nominal bedrock borehole. The top of the well screen will be welded to a 4-inch steel riser or threaded to schedule 40 PVC well riser pipe that will be extended above the ground surface. The annular space will be filled with appropriate filter sand (e.g., Morie #0) to approximately 2 ft above the top of the screen, followed by a foot of #00 choker sand, followed by a 3-ft bentonite seal, and cement-bentonite grout to the ground surface. A centralizer device may be used to keep the screen centered in the bedrock socket.

5.4 <u>IDW Management</u>

Groundwater generated during rotary drilling and open borehole well development will be stored on-site, tested, and disposed of as IDW.

IDW generated during air rotary drilling will contain a mixture of water and cuttings and will be handled using procedures outlined in SOP NMI-005. At each drilling location, the driller will set up a plastic-lined drilling pad. The sides of the pad will be elevated (e.g., plastic over hay bales or similar) to contain the cuttings generated during drilling. Cuttings mixed with water will be transferred into a fractionation tank(s) staged on-site. IDW water generated during open borehole drilling and/or development will contain lesser amounts of solids and will be handled using the same methods. The liquid cuttings in the fractionation tanks will be allowed time for the solid particles to settle and provide the opportunity for samples to be collected for laboratory analysis. The fractionation tank(s) will be sampled for a suite of analytes, such as those listed below, for evaluating disposal and treatment options:

- VOCs by USEPA Method 8260
- Semivolatile organic compounds (SVOCs) by USEPA Method 8270D-SIM
- Total and dissolved calcium, iron, manganese, magnesium by USEPA Method 6020A ICP-MS
- Total uranium (U^{235}/U^{238}) via USEPA Method 6020A ICP-MS
- Bromine, chlorine, fluorine, iodine by USEPA Method 300.0
- Total dissolved solids by USEPA Method SM2540C
- Total suspended solids by USEPA Method SM2540D
- Additional cations (aluminum, barium, beryllium, cadmium, cobalt, copper, lead, magnesium, nickel, potassium, silver, sodium, titanium, tin, zinc, and arsenic)
- pH

The IDW will be sampled in accordance with procedures outlined in the QAPP. The final disposal of IDW will be determined and managed by *de maximis*.

6. BEDROCK PUMPING AND REBOUND EVALUATION

Following the installation of new bedrock wells and open borehole testing, submersible pumps will be deployed in the bedrock wells and pumped one at a time or in tandem to evaluate fracture connectivity, bedrock transmissivity, and 1,4-dioxane rebound. A decision whether to pump the wells in tandem or one at a time will depend on the yield of the newly installed wells, ability to manage pumped water, and other logistics. For instance, if the yield is high, then it is likely that pumping from a single well will impact a sizeable area of the bedrock, which is desirable. If the yield is low, pumping at two wells simultaneously will likely be manageable in terms of generated water and will reduce the time to complete the hydraulic testing. Pumping at the wells may also be initiated sequentially, such as the following:

- Day 1 – Pumping initiated at BEW-4
- Day 3 – Pumping initiated at BEW-5 and BEW-4 continues pumping
- Day 6 – Pumping initiated at BEW-6, and BEW-4 and BEW-5 continue pumping

The purpose of the rebound evaluation is to observe changes in 1,4-dioxane concentrations in bedrock after removing an appreciable portion of impacted groundwater. The duration of required pumping from each well will be an important factor in determining if the rebound testing data will be sufficient to adequately evaluate the likely success of a pumping remedy. The specific components of the testing to gather hydraulic and water quality data to evaluate the feasibility of a pumping remedy are detailed in the sections below and include step testing, constant rate testing, hydraulic monitoring, and water quality testing. Water management and equipment decontamination plans are also presented.

6.1 Step Testing

Step testing will be conducted at each well to select a pumping rate for long-term pumping. The step testing at each well will entail pumping the well at multiple rates to evaluate a maximum safe yield for long-term pumping. A submersible pump, such as Grundfos SP-10S05-9 (0.5 HP motor) or equivalent, will be lowered into the well and suspended approximately 10 ft above the bottom of the well. A pressure transducer will be installed in a stilling well within the borehole to monitor the drawdown during step testing. The testing activities will follow SOP NMI-GW-017. Successively higher pump rates will be pumped from each extraction well until drawdown stabilizes and quasi steady-state is achieved. Results will be evaluated to select a long-term rate for the constant test that is sustainable and efficient. If the specific capacity is shown to drop significantly at a particular flow rate, then the final selected rate should be lower than that rate. A detailed description of this method is described in Appendix B, Section 3.5.1.

6.2 Constant Rate Extraction Design and Monitoring

The sections below describe the basis of design for extraction and rebound analysis, and procedures, data, and rebound evaluation for the tests.

6.2.1 Estimated 1,4-Dioxane Mass in Bedrock Groundwater

The plume configuration inferred from data collected in November 2019 was used to estimate the 1,4-dioxane mass in bedrock groundwater. The area of each inferred groundwater concentration (0.46, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, and 90 µg/L) contour above the 2015 ROD cleanup level of 0.46 µg/L was calculated using geographic information system (GIS). The average saturated thickness of the bedrock aquifer where the 1,4-dioxane is exceeding the ROD cleanup level was assumed to be 25 ft. The porosity of the fractured bedrock is not known; however, it is assumed that the porosity of the metamorphic bedrock ranges between 0.5% and 4%. The concentration of the areas bound by each contour was taken as the average of the two binding contours (e.g., a 15 µg/L concentration was assigned to the area between the 10 and 20 µg/L contours). The mass of 1,4-dioxane within the area bound by each contour was estimated by multiplying the area, saturated thickness (assumed at 25 ft), and average concentration by the aquifer pore volume estimated from bedrock porosities at 0.5% increments between 0.5% and 4%. The estimated mass of 1,4-dioxane and the aquifer pore volume are presented on Figure 10 and summarized below.

Assumed Bedrock Porosity	Total Aquifer Pore Volume (gallons)	Number of Fractionation Tank Volumes at 20,000 gallons each	Total 1,4-dioxane Mass (g)	Days to Pump the Pore Volume at 9 gpm (3 gpm from each well)
0.5%	1,178,434	59	83	91
1.0%	2,356,868	118	166	182
1.5%	3,535,302	177	249	273
2.0%	4,713,736	236	332	364
2.5%	5,892,170	295	415	455
3.0%	7,070,604	354	497	546
3.5%	8,249,038	412	580	636
4.0%	9,427,472	471	663	727

Because the bedrock porosity is unknown and every 0.5% increase in porosity represents approximately 1.18 million gallons more water and three months of pumping, it is impossible to predict how long the pumping will need to be performed or how efficient the pumping will be at reducing the concentrations until further information is gathered. The reduction of 1,4-dioxane concentrations will be evaluated based on data collected from monitoring wells and the concentrations in the extraction well effluent.

6.2.2 Extraction Rate Estimates

As described above, the extraction rate at each bedrock well will be selected based on the results from the step testing. A sustainable pumping rate for the open boreholes is difficult to estimate ahead of the well installation; however, for the purposes of this work plan, it is anticipated that each new bedrock well will be able to yield 1–3 gpm. The total volume generated from each well after seven days of pumping at these rates is estimated at 10,080 to 30,240 gallons, and the cumulative volume removed from the three wells after a week of pumping will be between 30,240 (at 1 gpm) and 90,720 (at 3 gpm) gallons. Because each 0.5% of an assumed bedrock porosity represents an additional 1,180,000 gallons and 58 fractionation tanks per pore volume, it is proposed that the pumping only continue for weeks to perhaps a month depending on results.

6.2.3 Means and Methods

Pumping and flow control apparatus consisting of a submersible pump and flow meter, similar to that used for step testing, will be used for the long-term pumping. The pumps will be set in wells at the elevation coinciding with significant water-bearing fractures inferred from geophysical logging described in Section 5.3.1. If a significant water-bearing fracture was not identified during geophysical logging, the pump will be set to a depth where approximately 70% of the water column is above the pump to reduce the risk of the pump running dry. The setup and pumping procedures will follow SOP NMI-GW-018.

The discharge line from the pump will be equipped with the following:

- A backflow preventer (i.e., check valve)
- A mechanical or digital flow meter (Blue-White F-410N rotameter or equivalent)
- A mechanical or electronic totalizer (Neptune T-10 meter or equivalent)
- A globe or gate valve for flow adjustment
- A sampling port for water quality sampling

Additionally, pressure transducers will be set in 1-inch PVC stilling wells installed within each of the extraction wells to monitor and log the water level during pumping. The purpose of the stilling wells will be to protect the pressure transducer and prevent entanglement of the pump feed wiring and discharge line with the transducer communication cables. Water extracted during pumping will be stored in fractionation tanks or equivalent, as described in Section 6.2.6 below.

During the first week of pumping, field technicians will monitor changes in the water level and specific capacity of each extraction well on a 24-hour schedule to eliminate the potential for the water level to drop below the pump intake (unless an automated system is used to monitor for pump faults and system malfunctions). Following a week of pumping on a 24-hour schedule, the team may elect to continue pumping during working hours (e.g., 8 hours per day) and turn off the pumps during nonworking hours. The extended pumping will remove additional aquifer volume to help further evaluate the viability of a pumping remedy. The extracted groundwater will be stored in fractionation tanks and then either transported to NTCRA groundwater treatment plant, disposed of on-site under USEPA approval, or transported for off-site disposal by an authorized treatment provider.

6.2.4 Hydraulic Monitoring

Approximately one week prior to the pumping, Geosyntec will deploy pressure transducers equipped with dataloggers in monitoring wells shown on Figure 9 and listed in Table 2. The pressure transducers will be deployed to monitor background bedrock groundwater levels. Transducer installation will be documented using the Pressure Transducer Installation Log provided in Attachment B to Appendix B. The pressure transducers will be non-vented, and their data will be barometrically compensated using ambient air pressure data collected by a barometric pressure transducer (i.e., Barologger) deployed at the Site. The transducers will be set to record data at 5–10-minute intervals. All deployed transducers will be synchronized to take measurements simultaneously.

Immediately prior to the pumping, a round of manual depth-to-water measurements will be collected in wells instrumented with pressure transducers and additional bedrock wells in the area to document the groundwater heads prior to pumping. Precipitation will also be measured throughout the background monitoring period and the pump test using an on-site recording rain gauge (e.g., Onset bucket gage or equivalent). During pumping, the field staff will initially collect manual water level measurements in the wells instrumented with pressure transducers every 12 hours for comparison to the pressure transducer readings and as a means to evaluate and correct transducer drift (if any). A final round of manual water level measurements will be conducted at the end of the pumping period and before the pump is shut down; this gauging event will include the same wells gauged prior to the initiation of the test. The pressure transducers will continue recording data for at least a week after pumping ceases to capture the recovery period.

The pressure transducer data will be converted to drawdown relative to background conditions and groundwater elevation to evaluate the area of influence surrounding each bedrock extraction well. In addition, the data will be used to evaluate the direction and magnitude of hydraulic gradients under pumping conditions. A map showing the area of influence for each bedrock extraction well will be drafted to aid in evaluating a pumping remedy (if determined feasible) or in designing an injection remedy.

6.2.5 Water Quality Monitoring

The water quality of the extracted groundwater will be monitored during pumping. The water quality monitoring will entail measuring field parameters (i.e. temperature, pH, dissolved oxygen, oxidation-reduction potential [ORP], specific conductance, and turbidity) and collecting samples for analysis of 1,4-dioxane via Method 8270 SIM and VOCs by USEPA Method 8260. In addition, samples for metals exceeding the MCLs in the vicinity of the extraction wells will be collected as shown on Table 3.

Groundwater samples will be collected through a sampling port installed on the discharge piping prior to the totalizer and flow meter. The field parameters will be recorded at the beginning of pumping and as specified in Table 3. Samples for laboratory analysis will be collected at the beginning of pumping (day 0), and ½, 1, 2, 3, 4, 5, 7 and every other day after the 7^{th} day of pumping as shown on Table 3. All samples will be analyzed for the parameters listed in Table 3.

It is anticipated that approximately one day after the pumping is terminated, the water levels in the extraction well and the surrounding wells will recover to near pre-pumping levels. The recovery samples will be collected 1, 2, and 21 days following the termination of pumping. Additional recovery samples may be collected beyond 21 days if the pumping and post-pumping data suggest that longer-term monitoring would be beneficial to the rebound evaluation. The recovery samples will be collected using either the submersible pump mounted in the extraction well or a bladder pump lowered to the same depth where the submersible pump intake was set for the pumping test. If the submersible pump is used, the pump will be turned on for a sufficient period of time to flush two volumes of the piping and discharge hoses. The amount of time needed for the pump to remove the two piping volumes will be estimated in the field based on the flow rate and equipment.

6.2.6 Water Management

The groundwater generated as part of the pumping and rebound testing will be containerized into a series of fractionation tanks, or equivalent storage containers. It is assumed that nine tanks will be required to store the water generated during pumping. This storage capacity should support approximately 9 gpm of pumping (cumulative from all wells) for approximately two weeks. The water stored in fractionation tanks will likely be periodically pumped into tanker trucks and transported off-site for disposal while the pumping is occurring. Water may be pretreated for uranium using resins as described in IDW Management SOP NMI-005 included in the Field Sampling Plan (FSP) presented in Appendix I, especially if generated from location BEW-4 and sampled for the parameters listed in Section 5.4. Water management will be coordinated by *de maximis*. The water may be transferred to, treated, and disposed of through the NTCRA groundwater extraction system at certain intervals during the full bedrock pumping study or transported off-site for disposal.

6.2.7 Equipment Decontamination

Drilling equipment, including the drill rig, portable drilling mud tub, hoses, and cuttings tools, will be decontaminated between each well location and at the end of all drilling activities. The decontamination procedures will follow those presented in SOP NMI-007.

Geosyntec, in coordination with *de maximis* and Haley & Aldrich, will set up a decontamination pad on-site at an area that will not hinder other on-site activities. The decontamination pad will consist of a plastic-lined pad with elevated sides to contain decontamination fluids and will be wide enough to accommodate a drill rig. The pad will be constructed on a slightly sloped hard surface to withstand the weight of the drill rig. A sump pump will be placed on the lower side of the pad to transfer decontamination water into storage drums. The upper side will have an adjustable side/opening to allow the drill rig to drive in and out of the pad. A multistep decontamination procedure will involve the following:

1. Remove clods of soil from equipment using a shovel or trowel and place this soil into drums with soil IDW.
2. Remove residual soil and debris from drill rig and drilling tools with Alconox solution (using either scrub bush or pressurized water with an Alconox solution).
3. Run potable water with an Alconox solution through drill mud circulation hoses.
4. Rinse drill rig, tooling, and hoses with pressurized water.

Decontamination material, including washing fluids and mud from drilling tools, from each well location will be collected and transferred to 55-gallon drums or fractionation tanks and appropriately labeled pending laboratory analysis as outlined in Section 5.4. Additional wipe samples of the drill rig and tools will be collected at the end of all drilling activities for radiation screening before the drill rig is demobilized off-site. The wipe sampling will be performed by DDES, who is the site Radiation Safety Officer, in coordination with *de maximis*.

Disposable sampling equipment and personal protection equipment (e.g., nitrile gloves) will be placed into 55-gallons drums for off-site disposal.

6.2.8 Hydraulic Data Analysis

Hydraulic data collected during the testing, including pressure transducers and manual water level measurements, will be analyzed to characterize the hydraulic conductivity of the bedrock aquifer as well as the bedrock fracture connectivity and pumping zone of influence as described below.

6.2.8.1 Transmissivity

The drawdown-versus-time data collected during pumping will be used to estimate bedrock transmissivity. The transmissivity will be estimated at monitoring wells instrumented with pressure transducers where a hydraulic response greater than 0.1 ft was observed during pumping. The data will be processed and input into industry-standard aquifer test analysis software such as Aqtesolv©. The specific solution used to estimate transmissivity will be selected based on the shape of the drawdown curve, well construction, and assumed aquifer characteristics. The hydraulic conductivity of the open borehole wells will also be estimated using the drawdown in the extraction well. Plans depicting drawdown contours and directional transmissivity of fractures connecting the monitoring wells with the extraction wells will be drafted to show testing results.

6.2.8.2 Fracture Connectivity and Pumping Zone of Influence

The connectivity of the bedrock fractures across the bedrock plume will be evaluated using the hydraulic responses observed at surrounding monitoring wells. The fracture connectivity across the area will be evaluated to delineate a zone of influence (an area within which a measurable drawdown occurs at observation wells around a pumping well) for each pumping well at the pump rates selected for testing. Groundwater potentiometric plans under pumping conditions will be drafted depicting the changes in hydraulic gradient and an estimate of the zone of influence from which groundwater is assumed to flow through fractures to the extraction well during pumping. Another plan will be developed that will show the combined zones of influence for each well to ascertain the maximum area of influence relative to the mapped bedrock 1,4-dioxane plumes under a combined pumping scenario using pumping wells installed for this PDI. As part of this evaluation, the capture zone (the area within which groundwater flow direction is toward the pumping well) may be estimated and presented on plans. The fracture connectivity and zone of influence information will be critical for (1) understanding the viability of a short-term pumping remedy and (2) aiding in the design of a pumping option for 1,4-dioxane in bedrock groundwater.

6.2.9 1,4-Dioxane Rebound Analysis

6.2.9.1 Baseline Concentrations

The concentrations detected in the open borehole extraction wells at the beginning of pumping will be used as the baseline concentrations. Although the groundwater seepage velocity in bedrock is assumed to be very low, pumping is assumed to increase the seepage velocity by one or two orders of magnitude. Following pumping at the three open borehole wells, the project team will sample monitoring wells where a hydraulic response was observed during pumping and compare the post-pumping concentrations to the November 2019 results to evaluate whether there is an appreciable change in the concentrations and develop plans showing the post-pumping 1,4-dioxane distribution in groundwater. These wells will be sampled using the Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (SOP NMI-GW-010). Samples will be analyzed for laboratory analyses of 1,4-dioxane via Method 8270 SIM and VOCs via Method 8260. Estimates of the trend and magnitude of 1,4-dioxane mass removal from pumping relative to estimates of the total mass in bedrock groundwater will be attempted. These changes combined with the evaluation of zones of influence during pumping will form the basis of conclusions regarding the viability of a short-term pumping remedy.

The plans of pre- and post-pumping contaminant distribution will be used to evaluate whether pumping from this PDI caused a downward-trending reduction in plume mass. These results will indicate if the three proposed extraction wells are adequate at removing the bedrock plume or may lead to a conclusion that additional pumping from other areas may be needed.

6.2.9.2 Rebound Evaluation

The samples collected after pumping will be used to evaluate whether the change in concentrations during pumping persist. Data will be plotted and a trendline will be fit to the data (e.g., in Microsoft Excel) to assess changes/trends in concentration over time for 1,4-dioxane between the baseline concentrations and a time when natural gradients have returned following the pumping interval. These data will help to understand how 1,4-dioxane mass in bedrock can be mobilized toward the pumping wells and removed.

7. FEASIBILITY FOR BEDROCK GROUNDWATER REMEDY

Analysis of data from this bedrock pumping and rebound will be targeted at determining if a pumping remedy for the 1,4-dioxane-impacted groundwater in bedrock is viable. Because the mass of 1,4-dioxane in bedrock groundwater is assumed to be finite (i.e., there are no ongoing sources releasing additional 1,4-dioxane into bedrock groundwater), it is possible that removing 1,4-dioxane by pumping will hydraulically facilitate attenuation of 1,4-dioxane concentrations to below 0.46 µg/L. Results from this PDI will be used to assess what percentage of the total mass was removed during pumping and how much mass may be remaining in bedrock. Data will also be used to assess how much mass would be removed from bedrock if additional pumping was performed and whether 1,4-dioxane mass removal by pumping would decrease concentration to below the ROD Cleanup level in a reasonable time (e.g., 5 to 10 years). This time frame is used because it is similar to the anticipated time frame for the NTCRA groundwater extraction system to reduce the 1,4-dioxane concentrations below the ROD cleanup levels in the area west of the Assabet River. If the time frame of the pumping remedy for the 1,4-dioxane in bedrock significantly is unreasonable, then the project team may decide to pursue a stabilization remedy for 1,4-dioxane in bedrock.

8. REFERENCES

de maximis, Geosyntec Consultants, and Haley & Aldrich. 2014. Remedial Investigation/Feasibility Study Report, Nuclear Metals, Inc. Superfund Site, Concord, MA, October.

Geosyntec. 2016. *Extraction Well Installation and Pump Test Work Plan, Nuclear Metals Superfund Site.* June 21.

GeoTrans. 2002. *Draft Remedial Investigation Report, Operable Unit Three, W.R. Grace Superfund Site, Acton, Massachusetts*. GeoTrans, Inc. August 30.

Walsh, G.J. 2001. *Bedrock Geology in the Vicinity of the Rockland Avenue Well Site, Maynard, Massachusetts*. U.S. Geological Survey Open File Report.

Tables

Table 1. Proposed Bedrock Extraction and Monitoring Wells
Nuclear Metals Inc. Superfund Site Concord, Mass

Proposed Open Borehole Bedrock Wells

Location	Purpose	Summary of Drilling and Well Construction	Nearest Bedrock Well	Uranium Concentration November 2019 (µg/L)	1,4-Dioxane Concentration November 2019 (µg/L)	Nearest Well Depth to Bedrock (ft)	Nearest Well Depth to Bottom of Screen (ft)	Nearest Well Screen Bottom Depth Distance Below Top of Bedrock (ft)	Proposed Length of Well in Bedrock (ft)	Proposed Total Well Depth (ft)	Well Location Rationale
BEW-4	1,4-D Removal	OB - Dual Rotary - 6-inch casing BR - Air Rotary - 6-inch open borehole	ML-1-3	9.7	13	67.5	81.5	14	74	142	- Evaluate vertical distribution of 1,4-dioxane in the vicinity of the bedrock ridge. - Evaluate bedrock fracture connectivity and zone of influence in the vicinity of the bedrock ridge. - Extraction location for the northern portion of the 10 µg/L 1,4-dioxane contour within the property.
BEW-5	1,4-D Removal		MW-BS31	ND	2.7	117	129	12	72	189	- Evaluate the vertical distribution of 1,4-dioxane upgradient of MW-BS15. - Evaluate bedrock fracture connectivity and zone of influence in the downgradient portion of 1,4-plume. - Extraction location between the off-property and on-property high concentration areas.
BEW-6	1,4-D Removal		MW-BS32	0.8	36.4	87.1	102	14.9	75	162	- Evaluate the vertical distribution of 1,4-dioxane downgradient of MW-BS15. - Evaluate bedrock fracture connectivity in the downgradient portion of 1,4-plume. - Extraction location in the area of inferred bedrock groundwater discharge to the overburden.

Proposed Shallow Bedrock Monitoring Wells

Location	Purpose	Summary of Drilling and Well Construction	Nearest 1,4-D Bedrock Plume Well	Uranium Concentration November 2019 (µg/L)	1,4-Dioxane Concentration November 2019 (µg/L)	Nearest Well Depth to Bedrock (ft)	Nearest Well Depth to Bottom of Screen (ft)	Nearest Well Screen Bottom Depth Distance Below Top of Bedrock (ft)	Length of Well in Bedrock (ft)	Total Well Depth (ft)	Well Location Rationale
MW-BS50	1,4-delineation	OB - Sonic - 2-inch PVC grouted in 7-inch borehole BR - HQ (3.8-inch) or PQ (4.8-inch) Wireline Coring - 2-inch PVC Screen	MW-BS25	0.7	15.6	62.5	78	15.5	25	87.5	- Delineate the plume to 0.46 µg/L between BarCad Wells GZW-8-2 and ML-1-3. - Hydraulic and water quality monitoring location for extraction testing at BEW-4 and BEW-5. - Evaluate bedrock fracture connectivity and zone of influence for BEW-4 and BEW-5
MW-BS51	1,4-delineation		MW-BS26	ND	ND	105	124	19	25	130	- Evaluate 1,4-dioxane concentrations north of the plume axis between MW-BS25 and MW-BS26 - Hydraulic and water quality monitoring location for extraction testing at BEW-5. - Evaluate bedrock fracture connectivity and zone of influence for BEW-4 and BEW-5
MW-BS52	1,4-delineation		MW-BS32	0.8	36.4	87.1	102	14.9	25	112	- Evaluate 1,4-dioxane in the area of inferred bedrock groundwater discharge to overburden. - Hydraulic and water quality monitoring location for extraction testing at BEW-5 and BEW-6. - Evaluate bedrock fracture connectivity and zone of influence for BEW-5 and BEW-6
MW-BS53	1,4-delineation		MW-BS31	ND	2.7	117	129	12	25	142	- Evaluate 1,4-dioxane concentrations between MW-BS31 and MW-BS35. - Hydraulic and water quality monitoring location for extraction testing at BEW-5. - Evaluate bedrock fracture connectivity and zone of influence and BEW-5
MW-BS54	1,4-delineation		MW-BS14	0.1	7.31	168	180	12	25	193	- Delineate the plume to 0.46 µg/L to the south of MW-BS14 and GZW-10-2. - Hydraulic and water quality monitoring location for extraction testing at BEW-2 and BEW-3. - Evaluate bedrock fracture connectivity and zone of influence and BEW-2 and BEW-3.

Notes
1. Ground surface and top of bedrock elevations are inferred from the nearest existing wells with the available information.
2. The target bedrock extraction well depths were selected at 60 feet beneath the bottom of the screen of the nearest well exceeding the 2015 ROD Cleanup Level (0.46 µg/L).
3. The target well depths for the monitoring wells is 25 feet below the top of bedrock.
1,4-D: 1,4-dioxane
µg/L: micrograms per liter
amsl: above mean sea level
BR: bedrock
ft: feet
MCL: maximum contaminant level
OB: overburden
PVC: polyvinyl chloride
U: uranium with natural isotopic signature

Table 2. Drilling and Rebound Testing Hydraulic Monitoring Plan
Nuclear Metals, Inc Superfund Site Concord, Massachusetts

Monitoring Locations	BEW-4	BEW-5	BEW-6
Bedrock Monitoring Wells			
GZW-10-2		T/M	
MW-BM15		T/M	T/M
MW-BS01	T/M	T/M	
MW-BS02	T/M		
MW-BS03	T/M		
MW-BS13	T/M		
MW-BS15		T/M	T/M
MW-BS17	T/M		
MW-BS21 (Ambient)	T/M	T/M	T/M
MW-BS22	T/M		
MW-BS25	T/M	T/M	
MW-BS26		T/M	T/M
MW-BS28		T/M	T/M
MW-BS31		T/M	T/M
MW-BS32		T/M	T/M
MW-BS34			T/M
MW-BS35		T/M	
MW-BS50	T/M	T/M	
MW-BS51	T/M	T/M	T/M
MW-BS52		T/M	T/M
MW-BS53		T/M	T/M
Overburden Monitoring Wells			
MW-S15		M	M
MW-SD17	M		
MW-SD01	M		
MW-SD06	M		
MW-1		M	
OW-2		M	
MW-SD26		M	M
MW-SD32			M
MW-SD34			M
Pressure Transducer Locations	10	15	11

Note:
1. Baseline depth to water measurements will be collected at all presented monitoring wells prior to initiation of pumping at each extraction well.
2. Monitoring locations for the extraction testing may be revised based on aquifer response observed during drilling activi
M: manual water level monitoring locations
T/M: pressure transducer and manual monitoring locations

Table 3. Rebound Testing Water Quality Monitoring Plan
Nuclear Metals, Inc. Superfund Site Concord, Massachusetts

Pumping Monitoring Schedule	Field Parameters	BEW-4	BEW-5	BEW-6
		1,4-dioxane VOCs Thorium	**1,4-dioxane VOCs Cobalt Manganese**	**1,4-dioxane VOCs Cobalt Manganese**
Pumping				
Startup (baseline)	X	X	X	X
12-Hour (0.5 days)	every 6 hr	X	X	X
24-Hour (1 day)	every 6 hr	X	X	X
48-Hour (2 days)	every 6 hr	X	X	X
72-Hour (3 days)	every 6 hr	X	X	X
96-Hour (4 days)	every 6 hr	X	X	X
120-Hour (5 days)	every 6 hr	X	X	X
168-Hour (7 days)	every 6 hr	X	X	X
Every 48 hours (After 7 Days)	every 6 hr	X	X	X
Prior to Shutdown	X	X	X	X
Recovery				
Day 1	X	X	X	X
Day 2	X	X	X	X
Day 21	X	X	X	X
Duplicates	N/A	3	3	3
Trip Blanks	N/A	N/A	N/A	N/A
Equipment Blanks	N/A	3	3	3
MS/MSD	N/A	2	2	2

Notes:
1. Field parameters will be recorded at the beginning of pumping and include specific conductance, pH, oxidation reduction potential, temperature, dissolved oxygen, and turbidity.
2. The QAPP indicates that Duplicates and equipment blanks should be collected for 10% of samples, and that, Matrix Spike/Matrix Spike Duplicate (MS/MSD) should be taken at 5% of samples per matrix per parameter.
3. The method detection limit for 1,4-Dioxane analysis must be below 0.3 micrograms per liter (µg/L).

Figures

Figure 1

Site Location Map

Nuclear Metals, Inc. Site
Remedial Design Work Plan

Concord, Massachusetts

Description:

2229 Main Street Property

Map Legend:

Site Boundary

Spatial Projection:

N

Coordinate System:
MA State Plane Mainland
FIPS Zone: 2001
Units: US Survey Feet
Datum: NAD83

Plot Info:

File: Fig01_SiteLoc.mxd
Project No.: 3252
Plot Date: 11/19/2019
Arc Operator: LS
Reviewed by: HG

ddms
www.ddmsinc.com

de maximis, inc.

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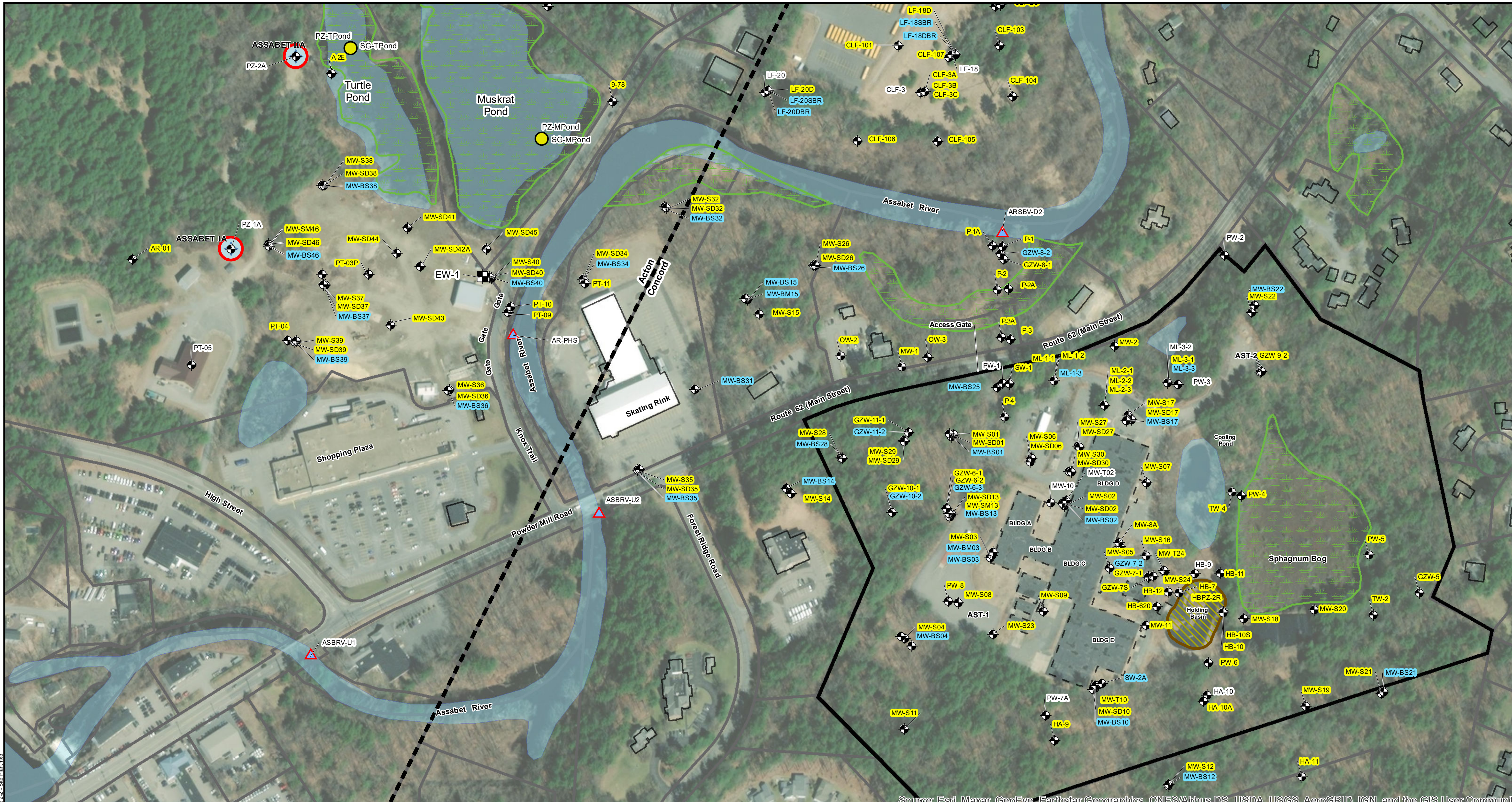


Legend

- Extraction Well
- Monitoring Well
- Staff Gauge and Drive Point Piezometer Locations
- Active Public Water Supply Well
- Assabet River Stage Elevation
- NMI Property
- Parcel Boundaries
- Building Outline
- Former Building Concrete Foundation
- Surface Water
- Wetlands
- MW-S32 Overburden Monitoring Well
- MW-BS32 Bedrock Monitoring Well

N

0 260 Feet

Site Plan

Nuclear Metals Inc. Superfund Site
Concord, MA

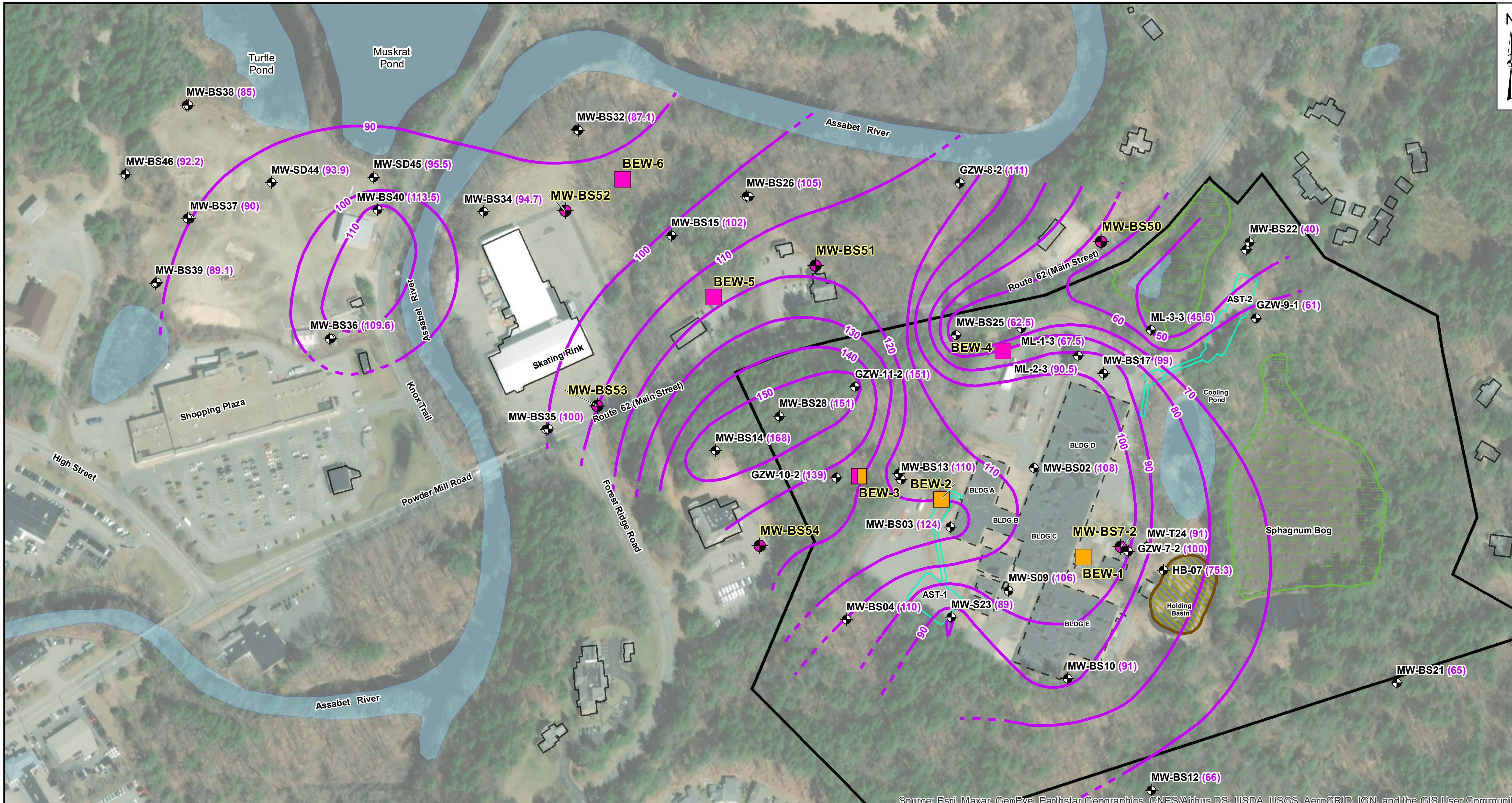
Geosyntec consultants

de maximis, inc.

Acton, MA | August 2020

Figure 2

O:\GIS\Projects\BR0090-NMISite\Projects\Updates_2020\Figure 2-2 - Site Plan.mxd



Legend

- Monitoring Well
- Proposed Bedrock Monitoring Well
- Proposed Open Bedrock Well for Uranium Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane and Uranium Rebound Testing
- Septic Fields
- Wetlands
- Surface Water
- Site Boundary
- Depth to Bedrock Contour (dashed where inferred)
- Former Building Concrete Foundations

N

0 220 Feet

Depth to Bedrock

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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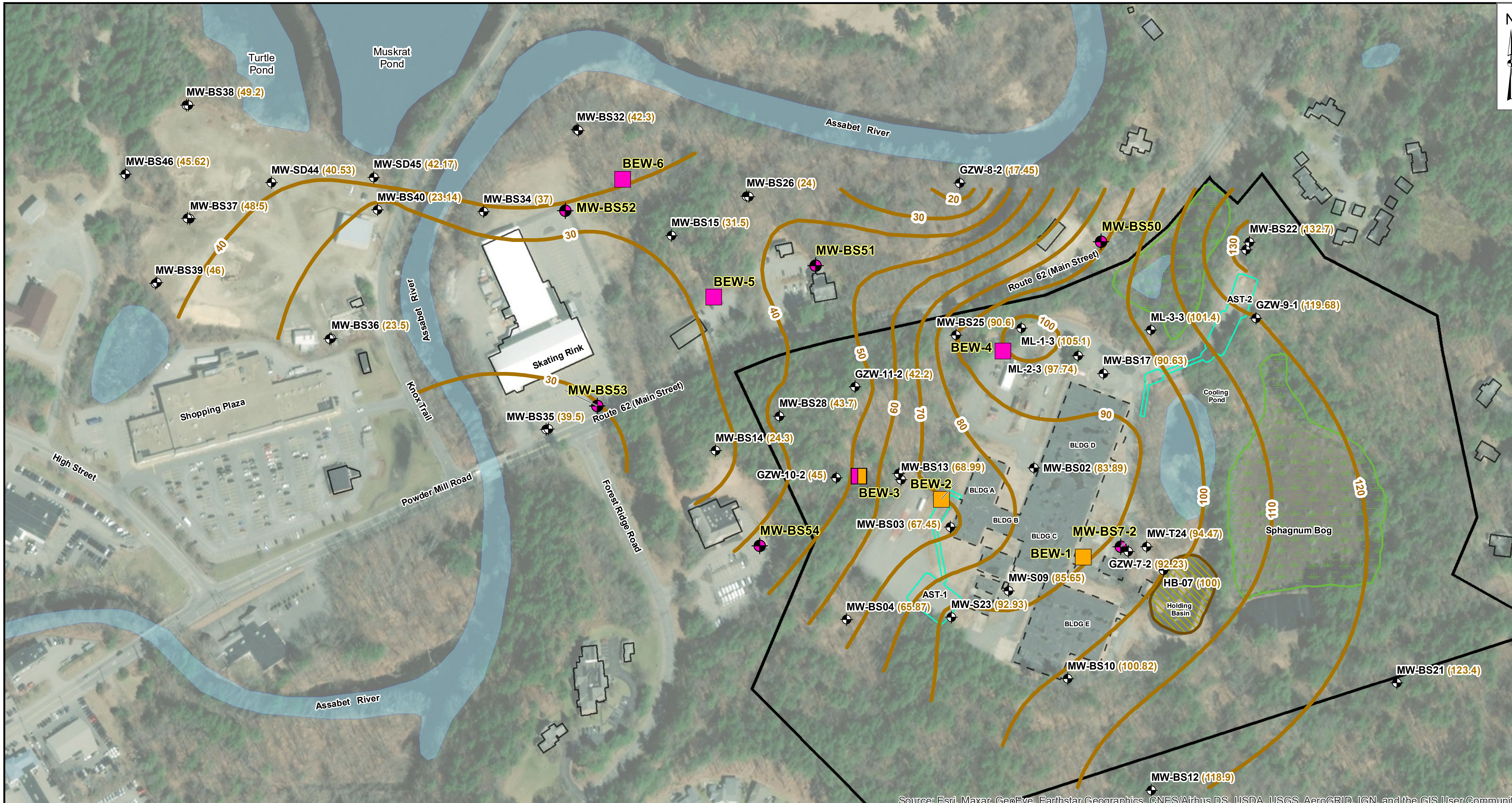
Figure 3

Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 3-1 Depth to Bedrock.mxd 6/8/2020 3:09:40 PM



Legend

- Monitoring Well
- Proposed Bedrock Monitoring Well
- Proposed Open Bedrock Well for Uranium Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane and Uranium Rebound Testing
- Septic Fields
- Wetlands
- Surface Water
- Site Boundary
- Top of Bedrock Contours (ft NGVD)
- Former Building Concrete Foundations

N

0 220 Feet

Top of Bedrock Elevations

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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Figure 4

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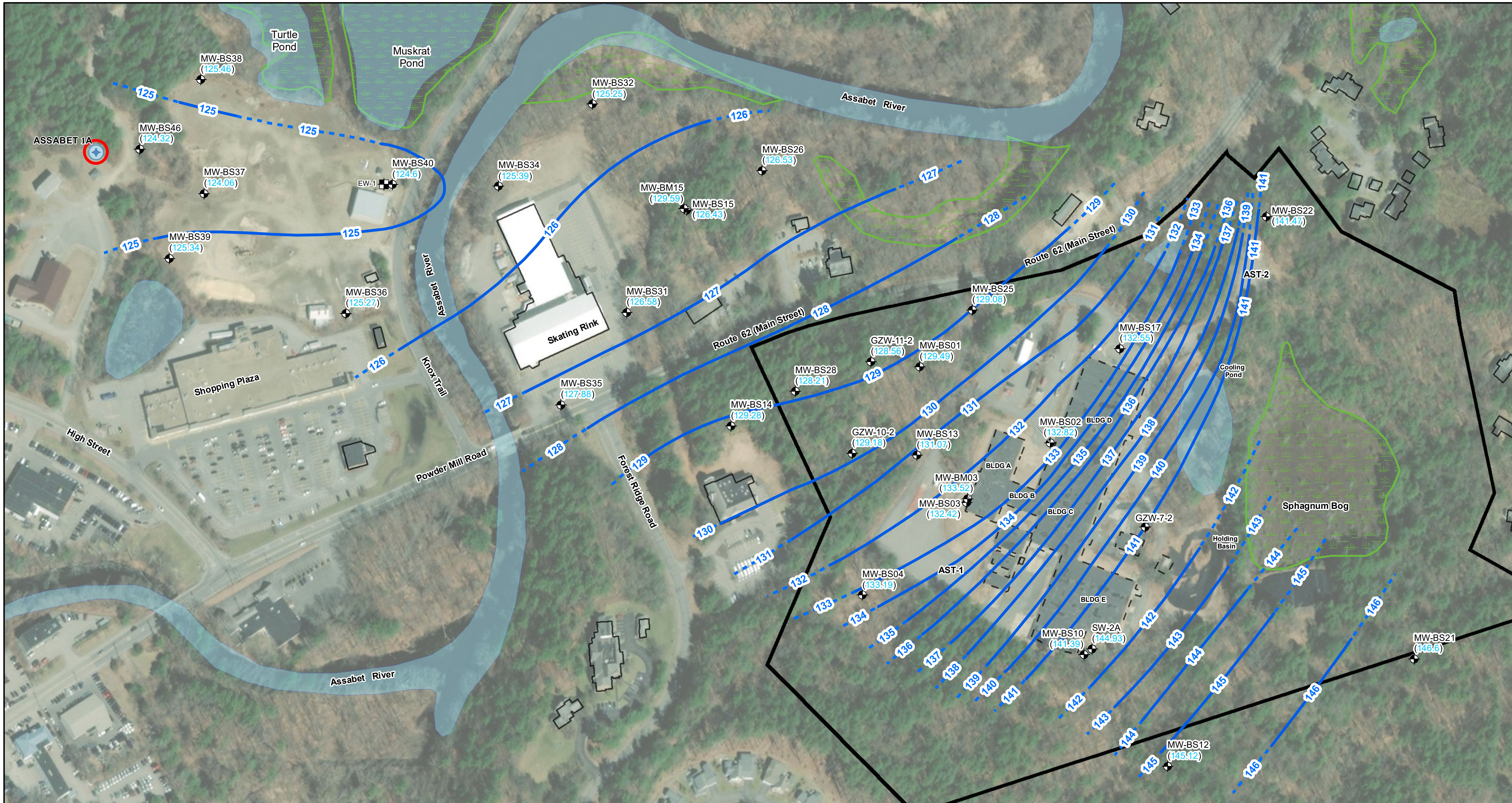
Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 3-2 Top of Bedrock Elevations.mxd 2/28/2020 4:54:01 PM



Legend

- Extraction Well
- Monitoring Well
- Active Public Water Supply Well
- Wetlands
- Surface Water
- Site Boundary
- Groundwater Elevation Contour in Bedrock (ft NGVD) - November 2019
- Estimated Groundwater Elevation Contour in Bedrock (ft NGVD) - November 2019
- Former Building Concrete Foundation
- (123.75) Groundwater Elevation November 10, 2019 (ft NGVD)

Notes:
1: Water levels were collected on 10 November, 2019.
2: The average pumping rate at municipal well Assabet 1A, for the 24-hour period prior to the water level round was 198 gpm, and for Assabet IIA was 116 gpm.
3: Equipotentials were estimated by kriging the water elevations using Surfer 9. Kriging is a weighted moving average interpolation (extrapolation) method that minimizes the estimated variance of a predicted point (node) with the weighted average of its neighbors. The contours were further adjusted using professional judgement.
4: Groundwater elevation contours are interpreted and may not represent actual flow directions or gradients.
5: Where multi-level bedrock wells exist at a single location, data from the shallower location was prioritized in drafting contours.

Groundwater Elevations in Bedrock November 2019

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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Figure 5

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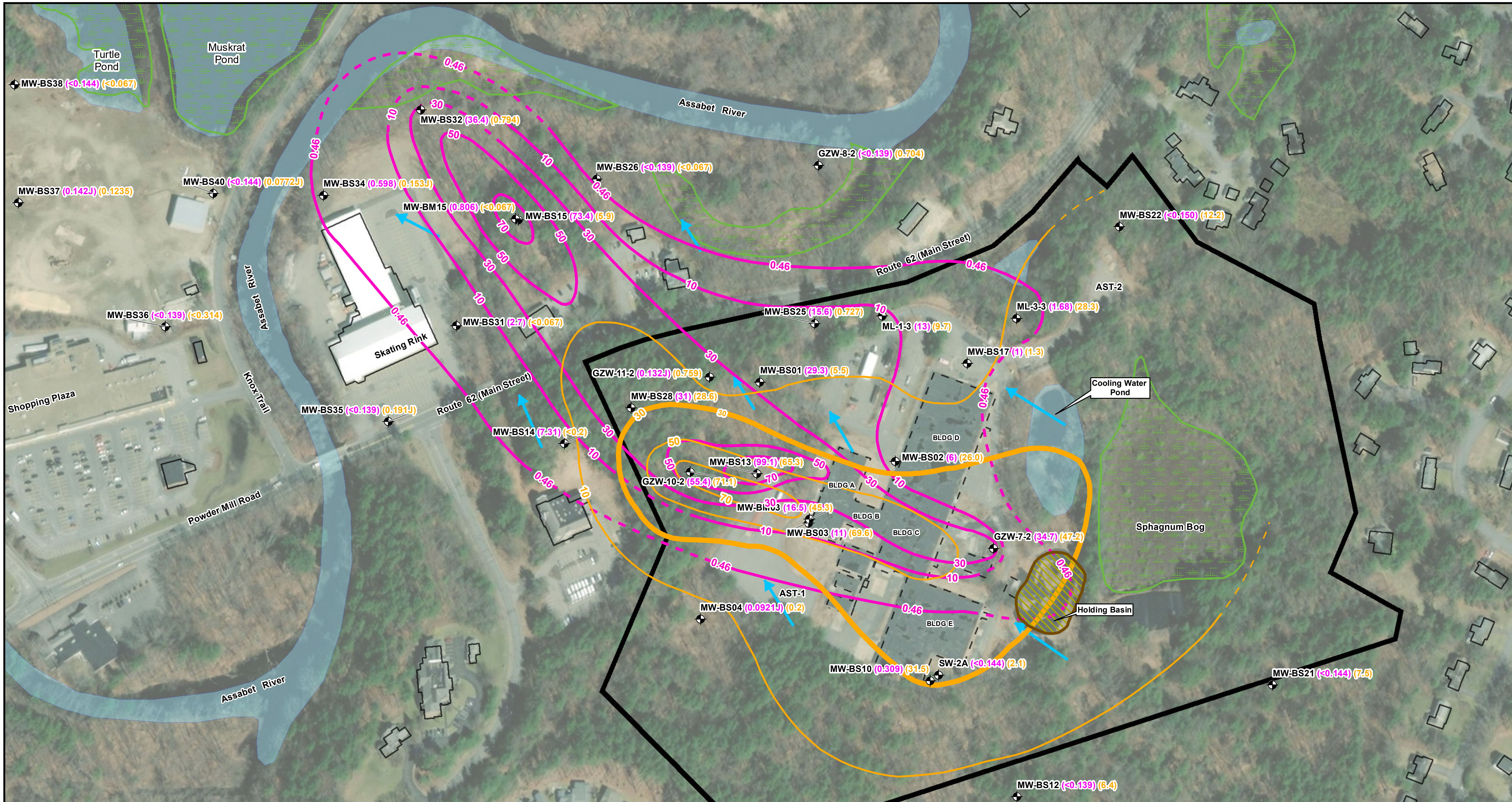
Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 2-4b - GWE BR November2019.mxd 8/4/2020 3:19:59 PM



Legend

- Bedrock Monitoring Well
- Site Boundary
- Building Outline
- Former Building Concrete Foundation
- Bedrock Groundwater Flow Direction Inferred from November 2019 Groundwater Elevations
- Surface Water
- Wetlands
- Uranium ISO Contour in Bedrock November 2019 (µg/L)
- Estimated Uranium ISO Concentration Contour in Bedrock November 2019 ug/L
- 1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)
- Estimated 1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)

0.57 1,4-Dioxane Concentrations November 2019 (µg/L)

76.9 Uranium Concentrations November 2019 (µg/L)

Note:
1. The uranium concentrations shown represent total uranium. Uranium in bedrock groundwater is characterized as isotopically natural (U-235% > 0.6%).
2. < = less than laboratory method detection limit.
3. J = estimated detection below method quantitation limit.

N

0 220 Feet

Uranium and 1,4-Dioxane Concentrations in Bedrock Groundwater - November 2019

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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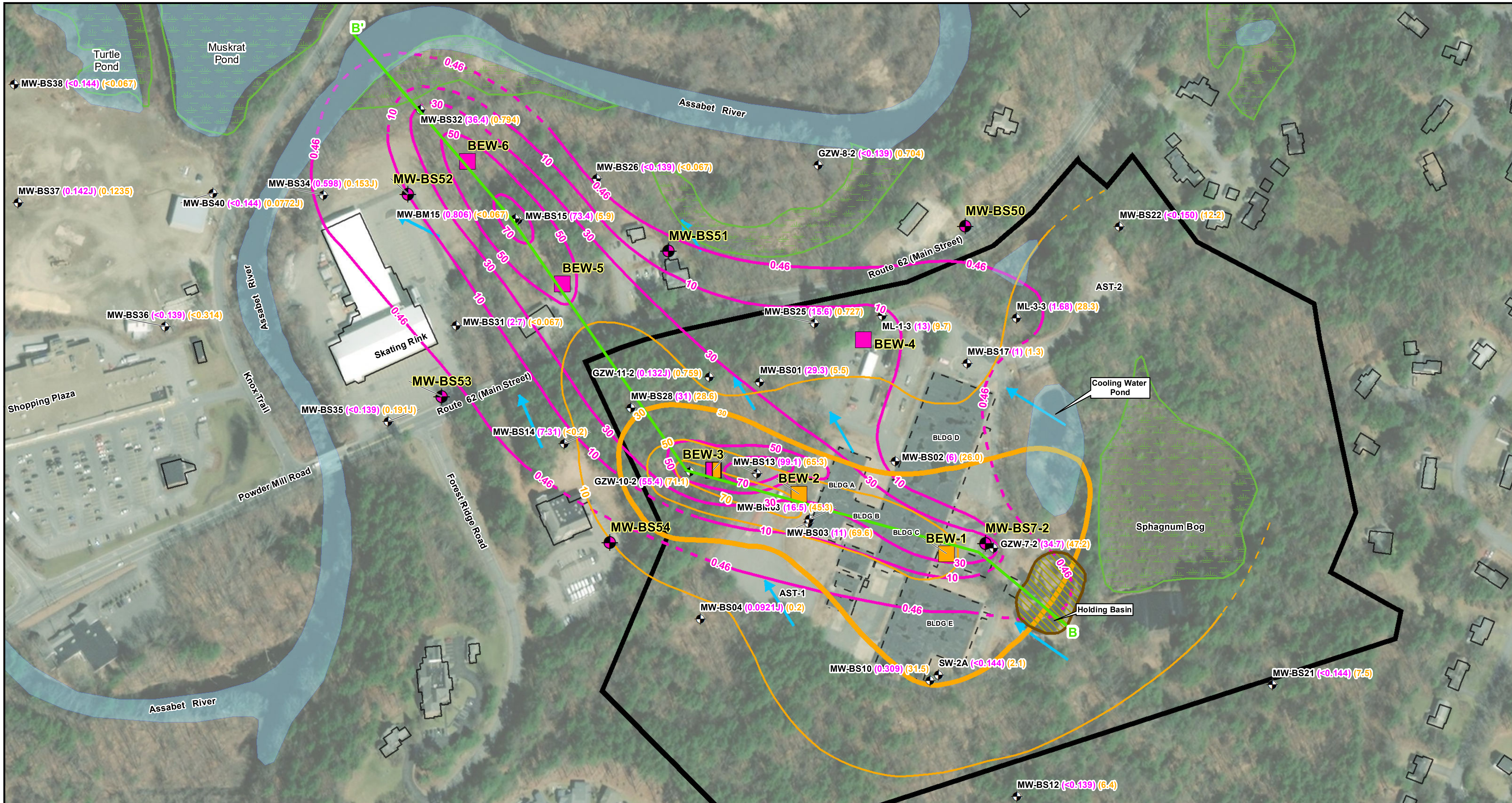
Figure 6

Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 2-7 - U 14D BR November 2019.mxd 4/7/2020 10:47:19 AM



Legend

- Bedrock Monitoring Well
- Proposed Open Bedrock Well for Uranium Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane Rebound Testing
- Proposed Open Bedrock Well for 1,4-Dioxane and Uranium Rebound Testing
- Proposed Bedrock Monitoring Well
- Site Boundary
- Building Outline
- Former Building Concrete Foundation
- Bedrock Groundwater Flow Direction Inferred from November 2019 Groundwater Elevations
- Wetlands
- Surface Water
- Cross Section B-B'
- Uranium ISO Contour in Bedrock November 2019 (µg/L)
- Estimated Uranium ISO Concentration Contour in Bedrock November 2019 ug/L
- 1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)
- Estimated 1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)
- 0.57 1,4-Dioxane Concentrations November 2019 (µg/L)
- 76.9 Uranium Concentrations November 2019 (µg/L)

Note:
1. The uranium concentrations represent isotopically natural uranium.

Proposed Bedrock Wells for Uranium Rebound and 1,4-dioxane Delineation and Rebound Testing

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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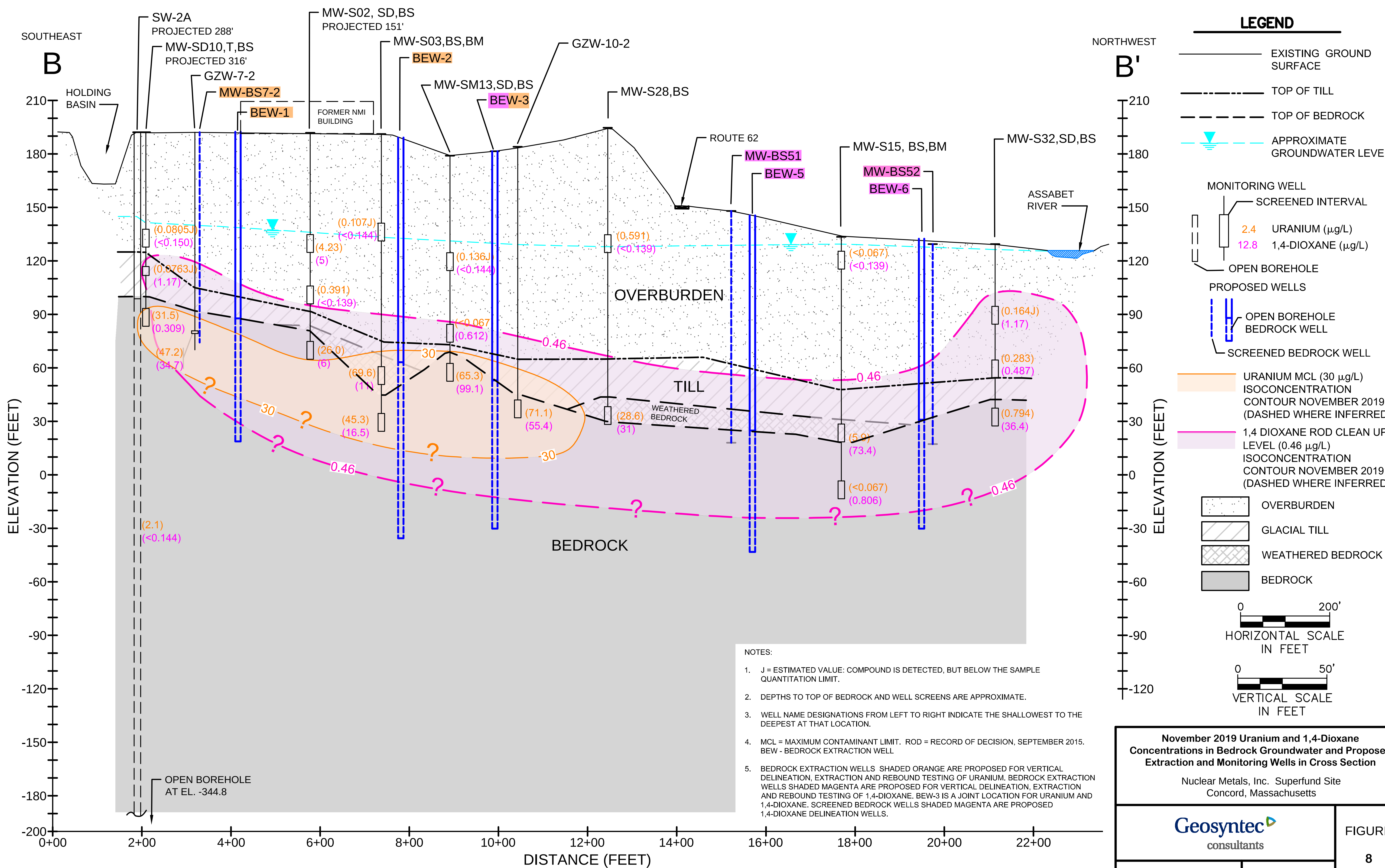
Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 3-3 - Proposed Bedrock Wells for Uranium Rebound and 1,4-dioxane Delineation and Rebound Testing.mxd 7/15/2020 2:13:04 PM



NOTES:

1. J = ESTIMATED VALUE: COMPOUND IS DETECTED, BUT BELOW THE SAMPLE QUANTITATION LIMIT.
2. DEPTHS TO TOP OF BEDROCK AND WELL SCREENS ARE APPROXIMATE.
3. WELL NAME DESIGNATIONS FROM LEFT TO RIGHT INDICATE THE SHALLOWEST TO THE DEEPEST AT THAT LOCATION.
4. MCL = MAXIMUM CONTAMINANT LIMIT. ROD = RECORD OF DECISION, SEPTEMBER 2015. BEW - BEDROCK EXTRACTION WELL
5. BEDROCK EXTRACTION WELLS SHADED ORANGE ARE PROPOSED FOR VERTICAL DELINEATION, EXTRACTION AND REBOUND TESTING OF URANIUM. BEDROCK EXTRACTION WELLS SHADED MAGENTA ARE PROPOSED FOR VERTICAL DELINEATION, EXTRACTION AND REBOUND TESTING OF 1,4-DIOXANE. BEW-3 IS A JOINT LOCATION FOR URANIUM AND 1,4-DIOXANE. SCREENED BEDROCK WELLS SHADED MAGENTA ARE PROPOSED 1,4-DIOXANE DELINEATION WELLS.

November 2019 Uranium and 1,4-Dioxane Concentrations in Bedrock Groundwater and Proposed Extraction and Monitoring Wells in Cross Section

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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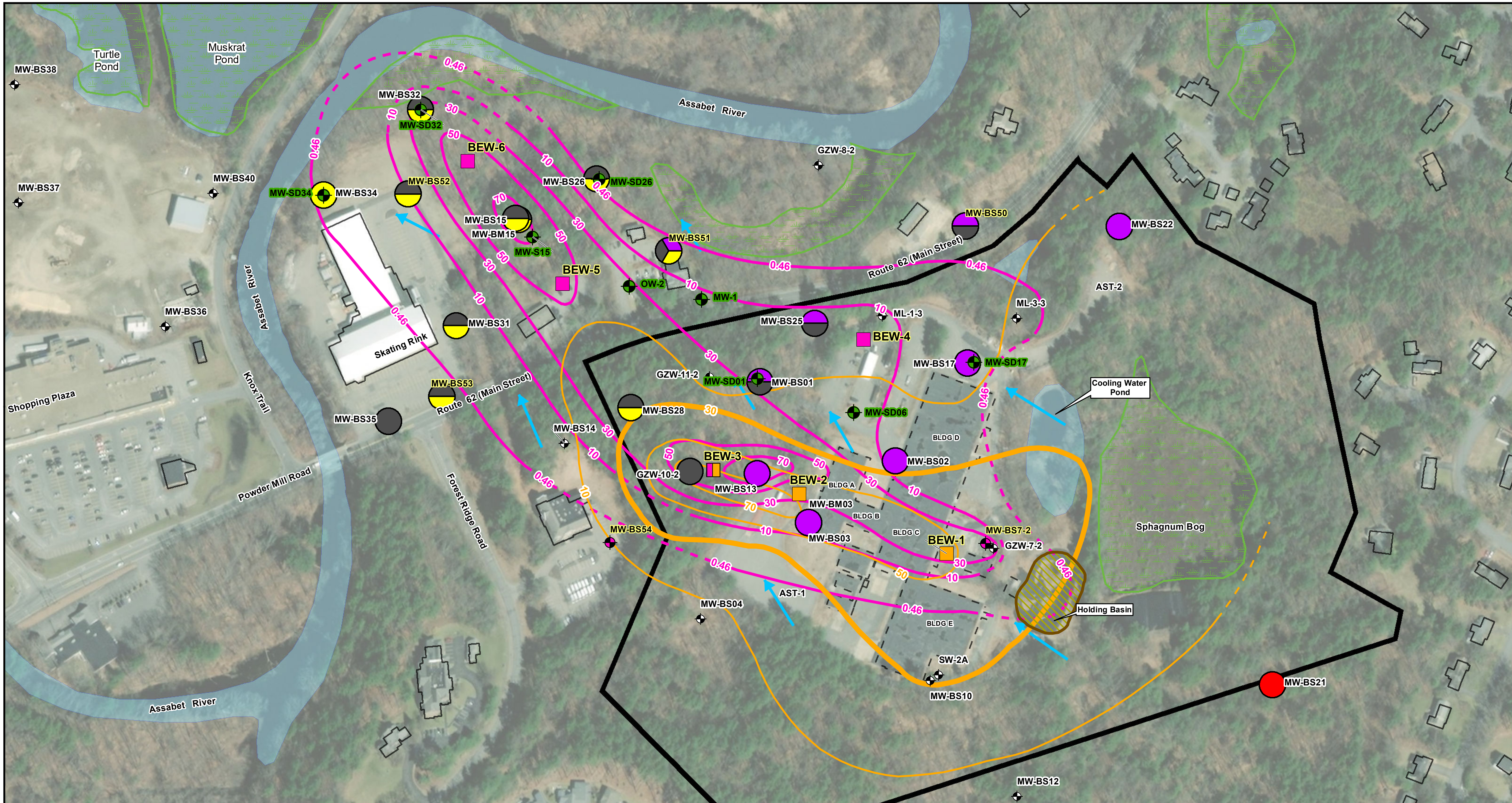
FIGURE 8



Bedrock Monitoring Well
Proposed Open Bedrock Well for Uranium Rebound
Proposed Open Bedrock Well for 1,4-Dioxane Rebound
Proposed Open Bedrock Well for 1,4-Dioxane and Uranium Rebound Testing
Proposed Bedrock Monitoring
Proposed Manual Water Level Monitoring Locations Drilling and Rebound Testing

Site Boundary
Wetlands
Surface Water
Building
Former Building Concrete
Bedrock Groundwater Flow Direction Inferred from November 2019 Groundwater Elevations

Uranium ISO Contour in Bedrock November 2019
1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)
Estimated 1,4-Dioxane ISO Concentration Contour in Bedrock November 2019 (µg/L)
0.57 1,4-Dioxane Concentrations November 2019 (µg/L)
76.9 Uranium Concentrations November 2019 (µg/L)

Ambient/Background Electronic Water Level Monitoring Location
Proposed Electronic Water Level Monitoring Locations for BEW-4 Drilling and Rebound Testing
Proposed Electronic Water Level Monitoring Locations for BEW-5 Drilling and Rebound Testing
Proposed Electronic Water Level Monitoring Locations for BEW-6 Drilling and Rebound Testing

N

0 220 Feet

Drilling and Pumping Monitoring Locations for Bedrock 1,4-Dioxane Rebound Testing

Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts

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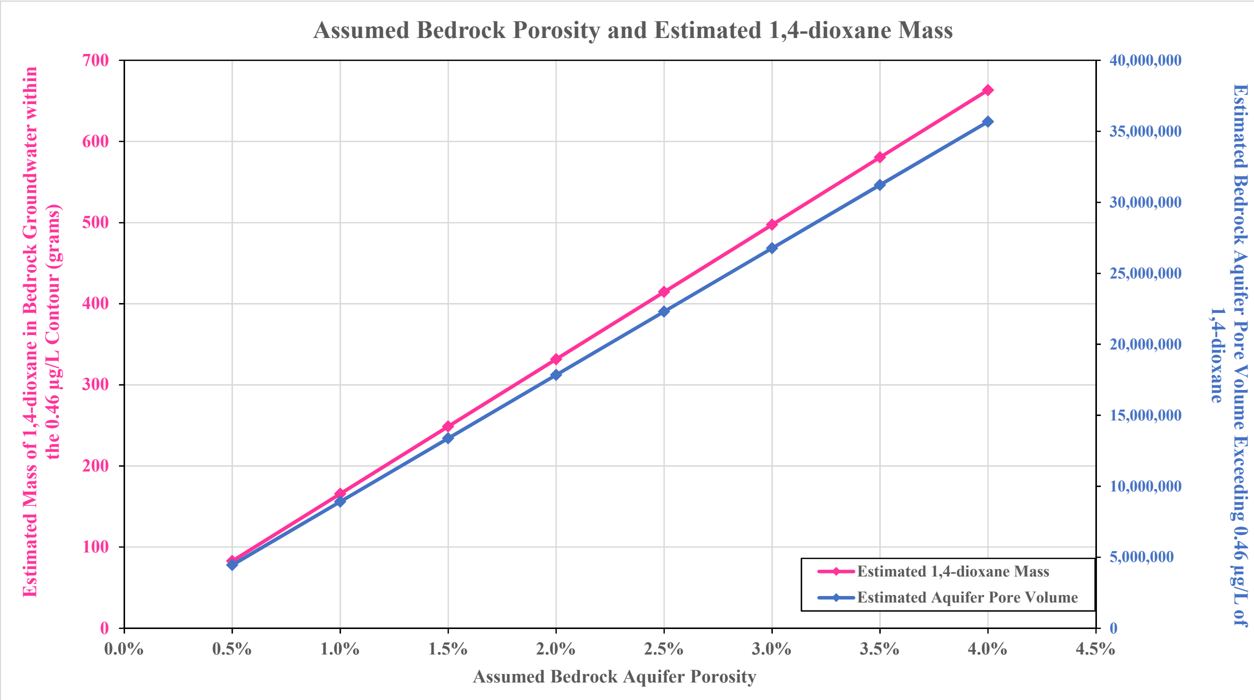
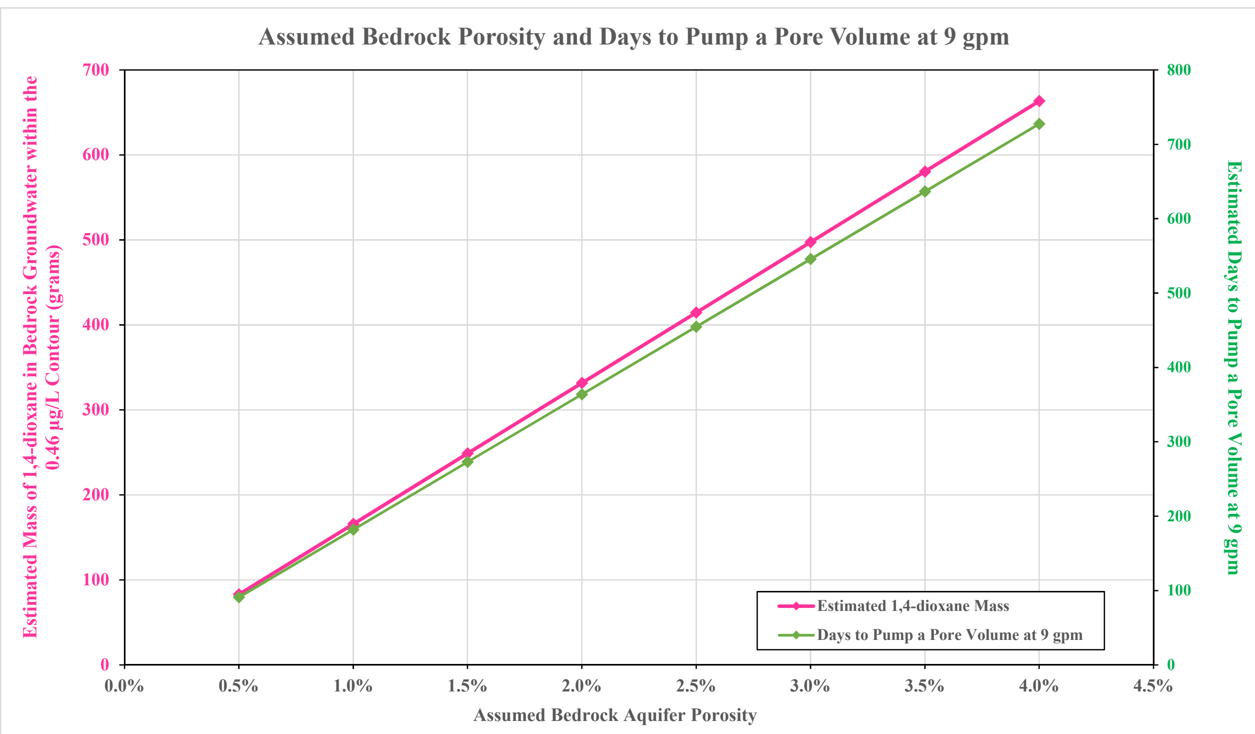
Figure 9

Q:\GISProjects\BR0090-NMISite\Projects\Updates_2020\Figure 9 - 14Dioxane Pie Charts.mxd 7/23/2020 4:24:21 PM

Figure 10
Estimated 1,4-Dioxane Mass and Aquifer Pore Volume for Extraction Design
Nuclear Metals, Inc. Superfund Site
Concord, Massachusetts





Note
1. The 1,4-dioxane mass was estimated by (i) calculating the area bound by each isoconcentration contour as inferred from November 2019 and an assumed saturated thickness of 25 feet, (ii) assigning the concentration as the average of the two contours binding the area, and (iii) multiplying by an assumed bedrock porosity.