Bristol-Myers Squibb

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February 16, 2017

Joshua P. Cook, P.E.
Environmental Engineer 2
New York State Department of Environmental Conservation
Division of Environmental Remediation
Region 7
615 Erie Boulevard West
Syracuse, NY 13204

Re: *Bristol-Myers Squibb Restoration Area*
Site ID No. C734138
Village of East Syracuse, Town of Dewitt, Onondaga County
Phase 2 Groundwater Remedial Investigation Work Plan, August 2016

Dear Mr. Cook:

By letter dated December 19, 2016, the Department conditionally approved the August 15, 2016 Phase 2 Groundwater Remedial Investigation Work Plan for the Bristol-Myers Squibb Restoration Area (site), with nine modifications and three groups of recommendations. Representatives of the Department and BMS met to discuss the modifications and recommendations on January 13, 2017. As a follow up to that meeting, BMS agrees with the Department regarding Modifications Nos. 1, 4, 8, and 9, and responds to the other modifications and recommendations as discussed at our meeting and as set forth below. For convenience, the Department's modification or recommendation is reproduced in italicized text, followed by BMS's response.

Modification #2. Section 2.1.2 – Consideration must be given to collect soil samples at additional intervals for certain borings in order to delineate contamination, including contamination identified during Phase 1/1A, in addition to the interval which would be sampled based on the rationale shown in Appendix A: RIWP Figure 3-3; and

Modification #3. Section 2.1.2 – It is recommended soil samples be collected from just above any confining or semi-confining layer in addition to the interval identified based on screening.

Response (#2 and #3): Soil cores will be collected continuously from surface grade through the planned depth of investigation in the deepest boring at each investigation well cluster (one to four wells per cluster). The soil cores will be visually inspected for lithology (e.g., confining layers, sand lenses, etc.) and grossly contaminated soils (refer to definition of "grossly contaminated media" in DER-10). Soil samples will be collected from the cores on approximate 12-inch depth increments and screened in the field for evidence of impact using a photoionization detector (PID). If more than one distinct interval of grossly contaminated soil is encountered, then the most heavily impacted soil sample from each grossly contaminated interval will be submitted for laboratory analysis. This screening approach may result in the collection and analysis of more than one sample from a given soil boring.

<u>Modification #5</u>. Section 2.1.4.3 – It is recommended BDA-10RX be installed following the initial three bedrock wells, developed, and sampled prior to installation of bedrock wells in its vicinity, in order to further assist in determining the appropriate screened interval for the other bedrock wells.

<u>Response</u>: It is anticipated that if appreciably water-transmissive fractures or zones are present in the bedrock, then movement of contaminants downgradient of source areas will be within these fractures or zones. Well BDA-10RX will be located in the CHAPA source area, and screened deeper than the existing shallow bedrock well in this location, which is essentially dry. Two bedrock wells (BDA-8RX and BDA-9RX) are planned in the vicinity of, and generally downgradient of, BDA-10RX. Of these two wells, BDA-8RX will be installed prior to BDA-10RX as one of three initial wells of the investigation. The three initial wells will be subject to geophysical testing to identify water-transmissive bedrock fractures or zones across the study area, if present. Screened intervals in the initial wells will then be accordingly focused on these fractures or zones, and this information will aid in installation of the remaining seven bedrock wells. After the planned bedrock wells (10 total) are installed and sampled, the hydrogeological information and analytical results will be used to evaluate whether to propose additional bedrock wells.

<u>Modification #6</u>. Other information that must be included in the monthly reports include: well development logs, groundwater sampling logs, waste characterization sampling results, proof of waste disposal.

<u>Response</u>: Well development logs and groundwater sampling logs will be included in the monthly reports. As discussed at our meeting, waste characterization and disposal activities will only be summarized in the monthly reports, with follow-up documentation provided in the Phase 2 RI report.

<u>Modification #7</u>. Section 4 – The following is hereby added to the schedule:

- *Solid investigation-derived waste (IDW) characterization sampling – no more than 30 days following completion of drilling. The Department must be notified at least 7 days in advance of waste characterization sampling.*
- *Liquid IDW characterization sampling – no more than 30 days following completion of each groundwater sampling event. The Department must be notified at least 7 days in advance of waste characterization sampling.*
- *Disposal of IDW – no more than 60 days following receipt of characterization sampling results, or sooner if required by law or regulation.*

<u>Response</u>: During the January 13, 2017 meeting, the Department clarified that these activities only apply to waste managed after field activities demobilization, and one day prior notification of waste characterization sampling is sufficient.

<u>Recommendation – Additional borings/wells where data is lacking</u>

- *Building 31, which includes the area downgradient of BLD 8D-1 (tetrachloroethene)*

<u>Response</u>: An additional soil boring will be advanced in the grass area downgradient (east) of the former location of Building 31, and completed as a water table well.

- *Shallow groundwater downgradient of T-42 (acetone, 4-methyl-2-pentanone, nitrate and nitrite, dicyclohexylamine [DCHA])*

Response: This area is adjacent to Building 25/25N, which is targeted for demolition. Any wells installed in this area would likely be damaged during the demolition activities.

- *Building 21 (particularly the north end), etc.*

Response: BMS has reviewed historical use of Building 21 and has confirmed it was a warehouse, with no bulk storage or handling of potential contaminants identified in the Phase 1/1A investigations, and as such, there is no reason to expect any contaminant impact from this area. The BDA-1 cluster is downgradient of former Building 21 and would be expected to provide downgradient monitoring of groundwater passing through the Building 21 area. Former temporary well PAN 1-1 was located north of Building 21, and no contaminants were identified above screening values in soil or groundwater at PAN 1-1. The need for a well north of former Building 21 is not supported by the existing data set, and will not be installed.

Recommendation – Additional groundwater delineation wells

- *BDA-09DT*

Response: If the till is sufficiently thick and water-transmissive at BDA-9, then the need for a second well screened in the till will be evaluated during drilling. Initial sonic drilling performed on site since January 2017 has recovered continuous cores of very dense, low transmissivity glacial till at all locations, thus far precluding the need for multiple till zone well completions. Continuity of the till zone will continue to be evaluated at all remaining locations, with the option to install additional wells should conditions warrant. Based on the current data set of observed till structure and hydration, the need for additional screen intervals will be very limited. This comment applies to all remaining till assessment locations pending drilling.

- *Downgradient of T-22 (DCHA)*

Response: Installation of a well downgradient of T-22, closer than site perimeter well cluster PW-3, is not feasible due to structures, buried utilities, and overhead piping and electrical power lines.

- *Downgradient of T-23 (triethylamine [TEA])*

Response: The BDA-6 cluster has been re-located to east of Building 48, and will now be directly downgradient of T-23.

- *BDA-03DT*

Response: If the till is sufficiently thick and water-transmissive at BDA-3, then the need for a second well screened in the till will be evaluated during drilling.

- *Downgradient of BDA-01 (trichloroethene)*

Response: Existing site perimeter well cluster PW-2 is downgradient of BDA-1. The cluster includes a till well (screened approximately 19 to 29 feet bgs) and formerly included a water table well (screened approximately 4 to 8 feet bgs). The water table well was typically dry, and was not previously sampled. Installation of a replacement water table well will be evaluated after completion of the Phase 2 activities.

- *Downgradient of BLD 36-1 (phenols, pH, alcohols, 1,1-dichloroethene)*

Response: Former well BLD 36-1 will be replaced by well BDA-2WT. As previously discussed above, a well will also be added downgradient of former Building 31. The added well, in concert with the BDA-1 cluster, will provide sufficient coverage downgradient.

- *B55-3 (purple staining)*

Response: The BDA-14 well cluster has been installed close to boring B55-3.

- *BDA-1WT (n,n-dimethylaniline and DCHA)*

Response: As stated in the laboratory analytical report, n,n-dimethylaniline and DCHA initially reported at low concentrations in BDA-1WT were an artifact of the laboratory matrix spike. A second round of groundwater samples will be collected from these wells as part of the Phase 2 sampling to confirm the results.

- *Downgradient of BLD 24A-1 (TEA and 1,4-dioxane)*

Response: The BDA-7 cluster will be shifted slightly south, and in concert with the BDA-8 cluster will provide sufficient coverage downgradient.

- *Downgradient of T-37 (1,4-dioxane)*

Response: This area will be investigated during the forthcoming Building 25N tank vault demolition (see response to T-42 above).

Recommendation – Additional contaminants not adequately delineated

- *Ammonia*
- *Sulfate*

Response: Ammonia and sulfate will be added to the list of groundwater (not soil) constituents for the first round of Phase 2 groundwater sampling. Based on the results, a determination will be made whether to include these parameters in subsequent groundwater testing.

Please call if you have questions.

Sincerely,

Susan Hynes
General Manager, Biologics Operations Syracuse
Bristol-Myers Squibb Company

ecc: Harry Warner (NYSDEC)
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December 19, 2016

Susan Hynes
Bristol-Myers Squibb Company
6000 Thompson Road
East Syracuse, NY 13057

Re: Bristol-Myers Squibb Restoration Area
Site ID No. C734138
Village of East Syracuse, Town of DeWitt, Onondaga County
Phase 2 Remedial Investigation Work Plan – Aug 2016

Dear Ms. Hynes:

The New York State Department of Environmental Conservation (Department) has reviewed the Phase 2 Remedial Investigation Work Plan (Phase 2 work plan) for the Bristol-Myers Squibb Restoration Area (site), dated August 2016, which was prepared by Arcadis of New York, Inc. (Arcadis) on behalf of the Bristol-Myers Squibb Company (BMS).

The Phase 2 work plan is hereby modified as set forth below in items 1 through 9.

1. Phase 1 locations adjacent to the proposed Phase 2 sampling locations must be surveyed and marked prior to Phase 2 sampling activities to ensure the Phase 2 locations are located properly.

2. Section 2.1.2 – Consideration must be given to collect soil samples at additional intervals for certain borings in order to delineate contamination, including contamination identified during Phase 1/1A, in addition to the interval which would be sampled based on the rationale shown in Appendix A: RIWP Figure 3-3.

3. Section 2.1.2 – It is recommended soil samples be collected from just above any confining or semi-confining layer in addition to the interval identified based on screening.

4. Section 2.1.2, Final Sentence – The phrase "as identified in the Phase 1/1A RI Report" is hereby deleted. Tentatively identified compounds (TICs), when reported, should be reported in the same manner as during Phase 1/1A. As discussed during the meeting on October 14th, if BMS wishes to eliminate TICs from certain locations

for the Phase 2 work, that can be considered. A list of any locations where TICs are to be omitted may be proposed in the response to this letter.

5. Section 2.1.4.3 – It is recommended BDA-10RX be installed following the initial three bedrock wells, developed, and sampled prior to installation of bedrock wells in its vicinity, in order to further assist in determining the appropriate screened interval for the other bedrock wells.

6. Section 3 – Other information that must be included in the monthly reports include: well development logs, groundwater sampling logs, waste characterization sampling results, proof of waste disposal.

7. Section 4 – The following is hereby added to the schedule:

    - Solid investigation-derived waste (IDW) characterization sampling – no more than 30 days following completion of drilling. The Department must be notified at least 7 days in advance of waste characterization sampling.
    - Liquid IDW characterization sampling – no more than 30 days following completion of each groundwater sampling event. The Department must be notified at least 7 days in advance of waste characterization sampling.
    - Disposal of IDW – no more than 60 days following receipt of characterization sampling results, or sooner if required by law or regulation.

8. Appendix B, Collecting and Describing Bedrock Core Samples, Section VI, Final Paragraph – The following is hereby added, “Photograph each core along with identifying information, which must include at a minimum, boring location name and depth interval.”

9. Appendix B, Monitoring Well Installation, Section VI, Paragraph 3. – The following is hereby added, “Photograph each core/spoon along with identifying information, which must include at a minimum, boring location name and depth interval.”

As discussed previously, the Department feels additional delineation of groundwater and/or subsurface soil impacts will be necessary in areas which are not currently addressed by the Phase 2 work plan. The Department feels that certain areas will require further work prior to completion of the remedial investigation phase of the project and selection of a remedy. Certain data gaps are listed below. It is strongly recommended borings and wells be installed at this time to further the delineation effort in those areas and any others BMS may identify. During the meeting on October 14, BMS stated certain areas downgradient of the site, but on the BMS property are largely inaccessible to drilling due to utilities. Indicate on a figure what feature limits accessibility to a given area (*e.g.*, overhead electric) and show the buffer that must be afforded each feature, including, if applicable, the maximum mast height that could be utilized below overhead lines in a given area.

- Areas where data is lacking include, but are not necessarily limited to:
  - Building 31, which includes the area downgradient of BLD 8D-1 (tetrachloroethene)
  - Shallow groundwater downgradient of T-42 (acetone, 4-methyl-2-pentanone, nitrate and nitrite, dicyclohexylamine [DCHA])
  - Building 21 (particularly the north end), etc.

- Areas where additional wells are needed include, but are not necessarily limited to:
  - BDA-09DT
  - Downgradient of T-22 (DCHA)
  - Downgradient of T-23 (triethylamine [TEA])
  - BDA-03DT
  - Downgradient of BDA-01 (trichloroethene)
  - Downgradient of BLD 36-1 (phenols, pH, alcohols, 1,1-dichloroethene)
  - B55-3 (purple staining)
  - BDA-1WT (n,n-dimethylaniline and DCHA)
  - Downgradient of BLD 24A-1 (TEA and 1,4-dioxane)
  - Downgradient of T-37 (1,4-dioxane)

- Contaminants which have not been adequately delineated include, but are not necessarily limited to: ammonia and sulfate.

The Phase 2 work plan is under review by the New York State Department of Health, so further comments may be forthcoming. If you have any questions, you may contact me at 315-426-7411 or joshua.cook@dec.ny.gov.

Sincerely,

Joshua P. Cook, P.E.
Environmental Engineer 2

ec: Reginald Parker (NYSDEC)
Harry Warner (NYSDEC)
Joshua Cook (NYSDEC)
Maureen Schuck (NYSDOH)
Richard Jones (NYSDOH)

Susan Hynes (BMS)
J. Richard Pooler (BMS)
John Killiany (BMS)
Anne Locke (BMS)
David Wright (Arcadis)

Bristol-Myers Squibb Company

PHASE 2 GROUNDWATER REMEDIAL INVESTIGATION WORK PLAN

Site #C734138

BMS Syracuse North Campus Restoration Area

East Syracuse, New York

August 2016

STATE OF NEW YORK
DAVID A. WRIGHT II
No. 086954
LICENSED PROFESSIONAL ENGINEER

08.15.2016

David A. Wright
New York State P.E. License No. 086954

I, *David A. Wright, certify that I am currently a New York State registered Professional Engineer and that this Phase 2 Groundwater Remedial Investigation Work Plan was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10).*

PHASE 2 GROUNDWATER REMEDIAL INVESTIGATION WORK PLAN

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

Prepared for:

Bristol-Myers Squibb Company

Prepared by:

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Date:

August 2016

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- Packer Testing
- Non-Aqueous Phase Liquid (NAPL) Contingency Plan
- Monitoring Well Installation
- Hydraulic Conductivity Testing

ACRONYMS AND ABBREVIATIONS

AOC	Area(s) of Concern
Arcadis	Arcadis of New York, Inc.
BDA	Brownfield Development Area
BMS	Bristol-Myers Squibb
bgs	below ground surface
CAMP	Community Air Monitoring Plan
DER	Division of Environmental Remediation
DNAPL	dense non-aqueous phase liquid
DUSR	data usability summary report
eV	electron volt
FAMSL	feet above mean sea level
FSAP	Field Sampling and Analysis Plan
IDW	investigation-derived waste
LNAPL	light non-aqueous phase liquid
mL/min	milliliters per minute
NAD	North American Datum
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBG	O'Brien & Gere Engineers
PID	photoionization detector
QAPP	Quality Assurance Project Plan
RI	remedial investigation
RIWP	Remedial Investigation Work Plan
RQD	rock quality designations
SVOC	semi-volatile organic compound(s)
TIC	tentatively identified compound(s)
VOC	volatile organic compound(s)

1 INTRODUCTION

This Phase 2 Groundwater Remedial Investigation Work Plan (Phase 2 Work Plan) has been developed for the Bristol-Myers Squibb (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site No. C734138) that is part of the BMS Facility located at 6000 Thompson Road in East Syracuse, New York. The BDA is subject to a Brownfield Cleanup Agreement between BMS and the NYSDEC. The groundwater investigation scope described herein has been prepared to address data gaps identified by the Phase 1 and Phase 1A (Phase 1/1A) remedial investigations of the BDA, as further discussed in the Phase 1/1A Remedial Investigation Data Summary Report (Phase 1/1A RI Report) (Arcadis, August 2016).

1.1 Site Description

The BMS Facility is an approximately 90-acre biologic drug substance manufacturing facility located within a mixed industrial/residential area in an urban setting (Figure 1). Most of the BMS Facility is covered with buildings, parking lots, mowed lawns, and access roads. The BDA occupies approximately 24 acres of the BMS Facility. A site transformation project has been implemented in the BDA, resulting in the demolition of numerous buildings and the conversion of much of the BDA to green space (Figure 2).

The topography of the BMS Facility generally slopes downward to the east-northeast, towards the local valley, which is drained by the South Branch of Ley Creek (referred to herein as Ley Creek). Ley Creek originates off-site to the south, runs north through the BMS Facility, passes through a culvert beneath the adjacent CSX railroad tracks, and continues northwesterly. An open channel/drainage ditch (known as Headson's Brook) intermittently flows parallel to the railroad tracks and discharges to Ley Creek adjacent to the BMS property.

1.2 Summary of Phase 1/1A Groundwater Investigation

The Phase 1/1A investigation of the BDA was conducted from 2012 to 2016. Phase 1/1A investigation activities pertaining to groundwater included:

- Installation and sampling of three temporary overburden monitoring wells in 2012;
- Installation and sampling of 88 additional temporary overburden monitoring wells and one bedrock monitoring well (CHP43RX) in 2013;
- Additional groundwater sampling at a subset of the temporary monitoring wells in 2014 to 2015; and
- Decommissioning of all temporary monitoring wells.

The Phase 1/1A investigation identified three primary areas of concern (AOCs) within the BDA (from north to south): Building 4/5/8 Alleyway, CHAPA Area, and Building 55 Area. The approximate center of each AOC is identified on Figure 2, along with the former locations of the temporary monitoring wells. The groundwater contaminants are associated with the historical manufacture of antibiotic pharmaceuticals within the BDA, and include volatile organic compounds (VOCs), semi-volatile organic compounds

(SVOCs), glycols, and alcohols. Details regarding the groundwater contaminant concentrations identified are provided in the Phase 1/1A RI Report.

1.3 Phase 2 Groundwater Remedial Investigation Objectives

Consistent with the NYSDEC-approved Remedial Investigation Work Plan (RIWP) (O'Brien & Gere Engineers, Inc. (OBG), 2013a), the objectives of the Phase 2 groundwater investigation include:

- Further delineate the horizontal and vertical extent of groundwater contaminants identified during the Phase 1/1A remedial investigations;
- Further characterize subsurface conditions within the BDA, including bedrock geology and hydrogeology;
- Collect additional data to support remedial action evaluation; and
- Provide a network of BDA monitoring points suitable for future monitoring of groundwater conditions.

1.4 Summary of Available Geologic and Hydrogeologic Information

1.4.1 Regional Geology

The BDA is located within the Erie-Ontario Plain physiographic province. The area is characterized by a lake-plain topography with scattered low hills or ridges of till or till-mantled bedrock. The stratigraphy of this region is characterized by glacial and postglacial sediments overlying Silurian-aged bedrock. The glacial deposits near the BDA consist of till and glaciolacustrine medium to find sands, silts and clays. Till was typically deposited directly on top of the bedrock at the base of glacial ice sheets. As the ice sheets melted and retreated to the north, rivers and glacial lakes were formed in low-lying areas. Alternating layers of medium to fine sands, silt and clay were deposited in the lakes. Postglacial sediments consisting of recent alluvial and marsh deposits are not found in the BDA, but exist along Ley Creek.

Bedrock in the vicinity of the BDA consists of the Upper-Silurian aged Salina Group (Leutze 1959; Rickard et al. 1970), specifically, the Vernon and Syracuse Formations. The BDA is located close to the suspected contact between these two formations (Figure A). The Vernon Formation consists of red and green shales, gray gypsiferous shales, and thin dolomites (USGS 2016) with a thickness in the Syracuse-Chittenango area of approximately 500 to 600 feet (Stone et al. 1920, Leutze 1959). The Syracuse Formation consists of interbedded shale, argillaceous dolomite, and evaporites, and varies in thickness from approximately 145 to 230 feet (Leutze 1959). The Bertie and Camillus Formations, which overlie the Syracuse Formation, have been completely eroded near and north of the BDA. Bedding of these formations dips to the southwest at approximately 50 feet per mile (Leutze 1959).

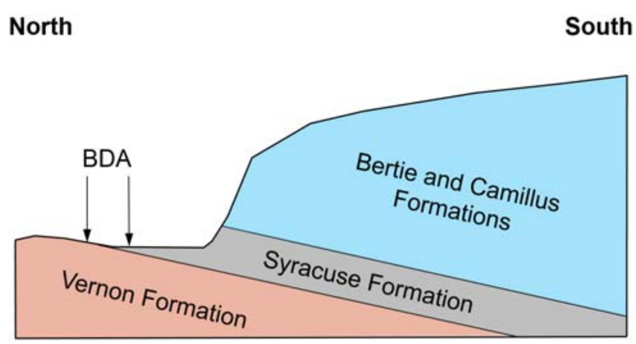


Figure A. *Generalized section showing the relationship of mapped geologic formations to the approximate location of the BDA. Bedding dip is approximately 50 feet per mile. Length of section is three miles.*

1.4.2 Local Geology and Hydrogeology

1.4.2.1 Overburden

Three overburden units have been identified at the BDA: (1) fill, (2) glaciolacustrine deposits, and (3) till. These units are shown on the generalized geologic cross-section through the center of the BDA (Figure 3).

The uppermost unit consists of previously disturbed sand and gravels characterized collectively as fill. Fill has been encountered throughout the BDA and varies in thickness from approximately 5 to 17 feet. The fill material consists primarily of brown gravel with varying amounts of concrete fragments, sand, silt, and clay. Wood, asphalt, cinders, ash, and brick are occasionally present within the fill material. Due to the extensive development history within the BDA, the fill unit is considered previously disturbed.

The glaciolacustrine deposits unit is located within the BDA and the BMS site where surface elevations are below approximately 420 feet above mean sea level (FAMSL), and may be overlain by the fill unit in limited locations due to regrading and construction activities. Elevation 420 FAMSL coincides with estimated lake levels within the Ley Creek drainage basin during the last period of regional glaciation. These deposits consist of laminated, brown to gray, medium to fine grained sands, silts, and clays. The glaciolacustrine deposits are up to 20 feet thick on the BMS Facility, east-northeast of the BDA boundary.

Till is present across the BDA and the BMS Facility. The till is composed of very dense red-brown silty clay and gravel with fine to coarse sand in varying proportions. The top of the till varies in depth from approximately five feet below ground surface (bgs) at the higher elevation portions of the BDA (i.e., along the western border) to approximately 12 feet bgs along the northeast edge of the BDA. On the southeast boundary of the BDA, the depth to the top of till may exceed 20 feet bgs (based on depth to top of till at well PW-6L). Data on the thickness of the till unit is limited to two wells where the top of bedrock has been confirmed (i.e., PW-5T [till thickness of 19.4 feet] and CHP43RX [till thickness of 27.1 feet]).

The water table beneath the BDA occurs in the overburden, and its depth varies from approximately five to 15 feet bgs across the BDA. Potentiometric data from the temporary wells formerly located in the BDA are presented in the Phase 1/1A RI Report, and indicate that groundwater in the water table and deep till units generally moves east-northeast, towards Ley Creek (towards the valley).

1.4.2.2 Bedrock

The available physical data regarding the bedrock beneath the BDA is limited to one 15-foot core sample collected from monitoring well CHP43RX (the only well in the BDA that is completely screened in bedrock). The rock is described as a grayish-green, laminated mudstone (shale), with occasional to frequent veins of white gypsum (Figure B). Because both the Syracuse and Vernon Formations contain gray-colored intervals of shales and limestones, as well as gypsum deposits, a formation name cannot be attributed based solely on the description of the rock penetrated at CHP43RX.

Figure B. *Rock core collected from the boring for well CHP43RX at a depth of 49.4-50.0 feet bgs.*

A 10-foot rock outcrop is located approximately 0.5 miles northwest of the BDA along the CSX railroad tracks and is described below by Leutze (1959):

Syracuse Formation, Transition Member	**Feet**	**Inches**
Dolomite, conglomeratic, contains shale and dolomite pebbles and grains of quartz sand…; fossils in the shaly partings between the beds…	3	0
Vernon Shale	**Feet**	**Inches**
Shale, soft greenish gray, weathers readily.	5	0
Dolomite, brown, silty, contains cubic (halite?) cavities lined with tiny quartz crystals.	0	2
Shale, gray, argillaceous, chunky, cut by high angle veins of selenite [gypsum] with pink borders.	2	0
Total Vernon shale measured, about	7	2
Total Thickness of Exposure	**10**	**2**

Leutze (1955) divided the Syracuse Formation into five members. Stratigraphically, he identified the lowermost member as the Transition member, and describes it as follows:

"*The Transition member is composed of alternating dolomite and shale beds. The dolomite beds are mostly argillaceous such as have been called "waterlime" in the past. The basal conglomerate contains fragments of calcareous shale and sand grains embedded in a matrix of dolomite with a thickness that ranged from 90-135 feet*."

Using the information noted above and an estimated land surface elevation at the railroad outcrop of 420 FAMSL, the elevation of the contact between the Syracuse and Vernon Formations is estimated to be approximately 430 FAMSL at the outcrop and, taking into account the bedding dip, 420 FAMSL at the center of the BDA. Based on this information, much of the area encompassed by the BDA is likely underlain by the Vernon Formation (Figure C) and well CHP43RX most likely screens the Vernon Formation. A dolomite conglomerate that is at least three feet thick marks the contact between the Syracuse and Vernon Formations, and will be a target marker during bedrock data collection.

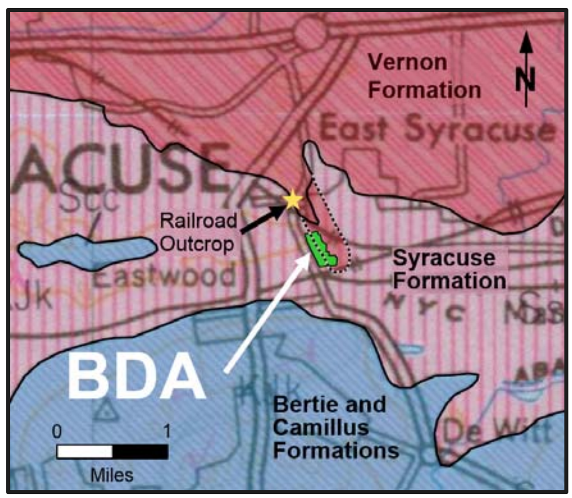


Figure C. *Estimated bedrock geology surrounding the BDA, revised (dotted line) based on site bedrock elevation data and the description of the bedrock exposed at the railroad outcrop (Leutze 1959). Location of railroad outcrop is approximated. Base map from Rickard et al. (1970).*

Leutze (1955) notes that the permeability of the Transition member is enhanced by the presence of the dolomite beds, where partings along the bedding planes are well developed. Leutze also notes that, for this reason, springs are common at the base of the Syracuse Formation (i.e., at the base of the Transition member). Based on its description, the permeability of the Vernon Formation is expected to be low. The poor yield observed at well CHP43RX supports this expectation.

Presently there are not sufficient potentiometric data for the bedrock to document bedrock groundwater flow directions across the BDA. For the purposes of this work plan, and based on the available local and regional hydrogeologic information, it is reasonable to assume that groundwater in the overburden and shallow bedrock forms a local flow system that is drained by Ley Creek. In such a flow system, the overall direction of groundwater flow will be towards Ley Creek (towards the valley).

2 SCOPE OF INVESTIGATION

Consistent with the investigation objectives, monitoring wells will be located:

- Within the BDA AOCs;
- At the perimeter of the BDA; and
- At select locations beyond the BDA (Non-BDA wells).

As shown on Figures 3 and 4, groundwater monitoring will extend horizontally a distance downgradient of the BDA, and vertically within the overburden and shallow bedrock units. The screened interval in bedrock will be generally limited to the upper 20 feet of bedrock (except in the CHAPA Area AOC, in which the upper 40 feet of bedrock will be monitored to extend deeper than existing well CHP43RX). Bedrock coring will be extended deeper than 20 feet in limited initial wells (PW-5RX, BDA-8RX, BDA-12RX) to validate position in the stratigraphic sequence (see flowcharts on Figures 5 and 6).

The proposed Phase 2 monitoring well locations are shown on Figure 4. Table 1 provides details of the proposed monitoring wells, including well identification, location, purpose, hydrogeologic unit, drilling method, and anticipated screen interval. A general summary is provided below:

Proposed Well Locations	Water Table Monitoring Well	Till Monitoring Well	Bedrock Monitoring Well
BDA Monitoring Wells	15[1]	13	10
Non-BDA Monitoring Wells	2	1	--
Total	17	14	10

The proposed monitoring well locations shown on Figure 4 are approximate, and will be adjusted in the field based on subsurface and overhead utilities and other potential hazards or obstructions. The anticipated well screen intervals provided in Table 1 are preliminary based on available information, and will be adjusted based on geologic conditions encountered. It is anticipated that additional monitoring wells will be proposed, after review of data from the Phase 2 groundwater investigation.

The following sections present general well installation methods that will be applicable to both overburden and bedrock monitoring wells, followed by information specific to each well type.

2.1.1 Overburden Drilling Method

Overburden monitoring wells will be drilled using the sonic drilling method to collect continuous, 4-inch diameter, 5-foot long soil cores. At monitoring well clusters, soil samples will only be collected for laboratory analysis or field screening from the deepest well within the cluster, and the remaining boreholes will be blind drilled based on the retrieved core data. The final depth of each boring will be equivalent to the depth to the bottom of the planned screened interval shown in Table 1, unless field conditions require adjustment to place well screens in the target overburden units. In that event, the

[1] Two water table monitoring wells (BDA-1F and BDA-1WT) were already installed in March 2016 as part of the Phase 1A soil vapor intrusion investigation.

rationale for the change in planned screened interval, and therefore the intended boring depth, will be presented to the NYSDEC representative overseeing the work for concurrence.

Recovered soil samples will be screened in the field for total VOCs using a photoionization detector (PID) equipped with an 11.7 electron volt (eV) lamp, and described as detailed in the Field Sampling and Analysis Plan (FSAP) (OBG, 2013b) (Section 5.2 – Subsurface Soil Sampling and Field Screening).

Because sonic drilling typically uses water to assist in the drilling process, it may be difficult to recognize when the water table has been penetrated from observing the recovered soils. Therefore, water level data from the Phase 1/1A investigation will be consulted in selecting the screened interval for water table wells.

2.1.2 Soil Sampling

As part of the continuing characterization of soil within the BDA, soil samples will be collected from each well cluster (or well if only one well is present at a location) and screened following the same methodology outlined in Figure 3-3: Sampling Decision Tree of the RIWP (provided in Appendix A for reference). One soil sample collected from each well cluster will be submitted for laboratory analysis, with the sample selected from either the depth interval exhibiting the greatest potential for impact based on field screening evidence or at the water table. The soil samples will be submitted for analysis of VOCs, SVOCs, glycols, and alcohols in accordance with the Quality Assurance Project Plan (QAPP) (OBG, 2013c) and the following methods:

- VOCs – USEPA SW-846 Method 8260C;
- SVOCs – USEPA SW-846 Method 8270D; and
- Glycols and alcohols – USEPA SW-846 Method 8015D.

Tentatively identified compounds (TICs) will be reported for the top 10 VOC TICs and top 20 SVOC TICs, as identified in the Phase 1/1A RI Report.

2.1.3 Bedrock Drilling Method

Bedrock borings will be advanced through the overburden and into competent bedrock, using sonic methods described in the FSAP (Section 5.1.3). After the sonic casing has been drilled three feet into competent bedrock, a 7 or 8-inch diameter “override casing” will then be advanced over the smaller inner casing to enlarge the rock socket. After the override casing reaches the target depth (3-feet into competent bedrock), the inner casing will be withdrawn from the borehole and the 4-inch permanent black steel casing will then be installed to the bottom of the 3-foot socket. Next, the 4-inch casing will be grouted in place from the bottom up using a cement-bentonite grout and tremie pipe as the override casing is withdrawn from the borehole.

After the grout has cured a minimum of 24 hours, the bedrock will be drilled using an HQ-sized core barrel (i.e., resulting in a 3.75 inch outside diameter borehole). The lithology and fractures of the recovered rock cores will be described in accordance with the procedures provided in Appendix B, and the cores will be screened for total VOCs using a PID. Rock Quality Designations (RQDs) for each 5-foot core run will be calculated during the field program to provide an estimate of the general competency of the bedrock. The rate of penetration (number of minutes per 5-foot interval) and qualitative observations regarding water production or loss will be recorded during bedrock coring. After drilling each 10-foot interval, the bottom 10 feet will undergo packer testing using a single-packer assembly, as further discussed in Section 2.1.6.

2.1.4 Bedrock Investigation

Data will be collected to characterize groundwater flow and quality within bedrock. Ten bedrock wells are proposed. Seven bedrock wells (BDA-1RX, BDA-5RX, BDA-6RX, BDA-8RX, BDA-12RX, BDA-15RX, and PW-5RX) will monitor the quality of bedrock groundwater around the perimeter of the BDA. The other three bedrock wells (BDA-3RX, BDA-9RX, and BDA-10RX) will monitor the quality of bedrock groundwater either downgradient of, or deeper than, known AOC impacts.

If non-aqueous phase liquid (NAPL) is identified at any time during bedrock drilling and/or packer testing, drilling will cease and the NAPL Contingency Plan (Attachment B) will be implemented.

2.1.4.1 Bedrock Well Screen Interval Selection

Groundwater movement through bedrock, such as the Syracuse and Vernon Formations, occurs primarily along fractures. Some fractures transmit appreciable quantities of water while others do not; therefore, it is important to not only identify fractures (or fracture zones) but also understand their relative yield of groundwater. To accomplish this, in-situ testing (i.e., packer testing) will be performed during drilling to identify and optimize the intervals across which to screen bedrock wells.

The groundwater yield of the bedrock will be tested at regular intervals, as described in Section 2.1.6. These data will be the primary information used to select the screened intervals of the monitoring wells. Other observations made during drilling, core-logging (including PID screening of the recovered rock cores), down-hole camera inspection, and geophysical testing (see Table 2 and Section 2.1.5), will also be considered for the selection of screen intervals. However, because the primary objective of the wells is to monitor the groundwater moving through the bedrock, the focus will be fractures believed to be capable of transmitting the greatest quantity of water.

Because open bedrock boreholes may provide a hydraulic connection between fractures that were not previously connected, effort will be made to limit the amount of time the bedrock boreholes remain open to minimize the potential for vertical cross-contamination between fracture zones.

Because information on groundwater flow and yield within the bedrock beneath the BDA is limited, the exact well depths, screened intervals, and boring depths cannot be determined in advance. For this reason, this work plan contains flow charts to guide the bedrock drilling effort (Figures 5 and 6). The strategy for this investigation is to drill a subset of the planned bedrock wells first, and collect a more robust data set for the bedrock penetrated (Table 2), and then use that information to target the depths and screened intervals of the remaining wells.

2.1.4.2 Investigation Approach for Initial Bedrock Wells

The subset of wells selected for initial installation consists of PW-5RX, BDA-8RX, and BDA-12RX (Figure 4). These wells were selected because they are located away from known source areas and are distributed across areas where the elevation of the bedrock surface is estimated to be the greatest (PW-

5RX) and the least (BDA-12RX) beneath the BDA, and at a point between these two estimated extremes (BDA-8RX). Down-hole geophysical data will be obtained from these three holes, and are further discussed in Section 2.1.5.

The length of the interval of bedrock drilled at each of these locations will vary. The planned boring depths are designed to sample a reasonable cross-section of the bedrock, accounting for the slope of its surface across the BDA. All bedrock drilled will be subjected to packer testing at 10-foot intervals as described in Section 2.1.6 to approximate groundwater yield. In fractured bedrock, the yield of different intervals can vary substantially, depending on the frequency and nature of the fractures present in the test interval. Therefore, it is possible that some test intervals will not produce enough water to support installation of a useful monitoring well. For this reason, a minimum-yield criterion of 200 milliliters per minute (mL/min) per 10-foot test interval has been established. Monitoring well screens will not be installed entirely in intervals that do not meet this criterion.

Once each boring is drilled and packer tested to its target depth, a decision will be made whether to drill deeper. If one or more packer tests meet or exceed the minimum yield criterion, then the boring will not be advanced further, and geophysical testing of the borehole will be conducted to further characterize the bedrock, including identification of the fracture(s) likely to be responsible for producing water during the packer tests. The packer and geophysical testing results, along with drilling and rock-core observation, will be collectively used to propose a screened interval for the well that strives to include all of the fractures believed to exhibit substantial yield without being excessively long. The targeted screen length will be 10 feet (effectively monitoring 12 feet including the two feet of sand that will be installed above the screen top). If none of the packer tests meets the minimum criterion, up to 20 more feet of bedrock will be cored and packer tested at 10-foot intervals. If the minimum yield criterion is met, then the borehole geophysics will be run and the screen interval selected as described above. In the event that the criterion is still not met, a decision will be made, in consultation with the NYSDEC, whether to screen the well across a lower yielding interval, or abandon the borehole.

2.1.4.3 Investigation Approach for Remaining Bedrock Wells

To the extent practical, information obtained from drilling the three initial bedrock wells will be used to refine the targeted depths and screened intervals for the remaining seven wells (BDA-11RX, BDA-3RX, BDA-5RX, BDA-6RX, BDA-9RX, BDA-10RX, and BDA-15RX). It is assumed that the targeted depths will be in the upper 20 feet of bedrock. For example, relatively transmissive bedding-plane fractures are often mappable across significant distances, and so if identified in one boring, can be targeted at others. The process for determining the drilling depth and screened interval of the remaining wells is shown in Figure 6. After identifying a targeted screened interval for each proposed well, the borehole will be cored to that depth, with a packer test conducted every ten feet. If the test results confirm that the minimum yield criterion is met, then the screened interval will be selected following the procedure described above. If the criterion is not met, up to 20 more feet of bedrock will be cored and packer tested at 10-foot intervals. If the minimum yield criterion is met, a well will be screened and installed accordingly. If not, a decision will be made, in consultation with the NYSDEC, whether to screen the well across a lower yielding interval, or abandon the borehole.

2.1.5 Geophysical Logging

In addition to viewing all bedrock boreholes with a down-hole camera, down-hole geophysical logging will be performed at three of the 10 planned bedrock wells (PW-5RX, BDA-8RX, and BDA-12RX), prior to well installation, to better characterize bedrock beneath the BDA. The geophysical logging will include:

Tool	Description/Use
Fluid temperature	Measures the temperature of water in the borehole with depth. Changes in temperature can indicate intervals where groundwater may be entering or exiting the borehole.
Fluid resistivity	Measures the electrical resistivity of water in the borehole with depth. Changes in resistivity can indicate intervals where groundwater may be entering or exiting the borehole.
Caliper	Records the borehole diameter. Changes in borehole diameter can be related to fracturing or caving along the borehole wall.
Natural gamma	Records the amount of natural gamma radiation emitted by the rocks surrounding the borehole. Can identify changes in lithology. For example, it may distinguish between dolomite and shale beds.
Single-point resistance	Records the electrical resistance from points within the borehole to an electrical ground at land surface. Can determine lithology, water quality, and location of fracture zones.
Acoustic televiewer	Records a magnetically oriented image of the borehole wall based on acoustic reflectivity. Televiewer logs indicate the location and strike and dip of fractures and lithologic contacts.

It is anticipated that the geophysical logging will commence no less than three business days after all three boreholes have been drilled to their final depth. A procedure for conducting geophysical testing is included in Appendix B. All logging equipment will be decontaminated following the procedure contained in the FSAP (Section 12.2.1 – Sampling Equipment Decontamination) prior to inserting into each borehole and before demobilizing from the site. Investigation-derived wastes (IDW) will be managed as prescribed in Section 2.8.

2.1.6 Packer Testing

During rock coring at the proposed bedrock monitoring well locations, packer testing will be completed every 10 feet. The purpose of the testing is to estimate the groundwater yield of each 10-foot interval of bedrock drilled. The approximate yield information will be compared among different test intervals to aid in selecting a screened interval for the monitoring well. A field hydrogeologist will oversee each test. Details regarding the test procedure are contained in Appendix B.

After each 10-foot interval of bedrock is cored, a packer assembly consisting of an inflatable rubber packer and standpipe will be lowered into the core hole and used to isolate the bottom 10 feet of the boring (i.e., the test interval). Once isolated, the water level *outside* the standpipe (above the packer) will be monitored for five minutes with a minimum of one reading performed per minute. These data will be used to assess the rate of water inflow or outflow from the portion of the borehole above the packer (i.e., above the interval to be tested). Next, a falling-head test will be conducted in the test interval by filling the standpipe with water to a level approximately two feet above the ground surface and the decline in the water level will be monitored and recorded for 15 minutes. An average flow rate for the test period will be calculated and recorded.

During the test, the water level outside the standpipe will also be monitored to assess packer seal integrity. A sustained rise in the water level outside the standpipe that cannot be attributed to the behavior of the water levels measured outside the standpipe during the pre-test interval noted above could indicate that the integrity of the seal is poor. In this case, the test will be aborted and the packer assembly removed from the borehole and inspected for leaks or damage. Leaks, if any, will be repaired. Regardless of whether leaks are detected/repaired, the packer assembly will be reinstalled and the test repeated. It is important to note that a water-level rise above the packer test interval is often not indicative of a poor packer seal, but rather may indicate a hydraulic connection between one or more fractures above the packer to one or more fractures below the packer (i.e., within the test interval).

At the completion of each test, the packer assembly will be removed, another 10 feet of rock will be cored, and the packer test process will be repeated for the newly drilled portion of the boring, until the final boring depth is reached.

2.1.7 Screening for NAPL

Soil, bedrock, and groundwater will be screened for NAPL at several points during the subsurface investigation and subsequent groundwater sampling, as summarized below:

- Soil samples will be screened for NAPL presence using a hydrophobic dye (oil in soil test kit) if PID measurements are greater than 100 parts per million (ppm) or if sheens are observed.
- Bedrock will be screened for the presence of NAPL through monitoring of return water and rock cuttings during well installation, rock cores recovered, and water purged from the test interval during packer testing for sheens and/or PID readings greater than 100 ppm.
- Monitoring wells will be screened for NAPL using an interface probe prior to collecting groundwater samples.
- For any monitoring wells where there is a positive indication of NAPL with the interface probe, or where indications of NAPL were identified during well drilling/installation, the presence of NAPL will be further examined by collecting a grab sample from the water surface in the well and from the well bottom using a clear bailer. If a NAPL-like material is observed, a sample will be tested using a hydrophobic dye (oil in soil test kit). If the test result is positive, and if a sufficient volume of NAPL can be obtained from the well (approximately 500 mL), then a sample will be analyzed for select physical parameters, as outlined in the NAPL Contingency Plan included in Appendix B.

All observations made during NAPL screening and results of any NAPL screening tests conducted will be recorded in a field notebook.

If NAPL is positively identified, drilling will be discontinued and the BMS Environment, Health and Safety (EHS) representative and Arcadis project manager will be notified immediately. The need for installing a temporary NAPL monitoring/collection well will be considered. If it is determined that such a well is needed, it will be constructed as described in the following section. If it is determined that such a well is not needed, the borehole will be abandoned following the procedure contained in Section 5.4 of the FSAP.

2.1.8 Monitoring Well Construction

Monitoring wells will be installed following the procedure provided in Appendix B. Table 1 provides a summary of well construction details. Groundwater monitoring wells will be installed in overburden soil borings or in bedrock core holes to provide groundwater elevation and groundwater quality information. Overburden monitoring wells will be installed through sonic drill casing. Bedrock wells will be installed as double-cased wells, with a screen and riser pipe installed through permanent steel casings that have been grouted into bedrock.

Overburden and bedrock monitoring wells will be constructed using 2-inch diameter, No. 304 stainless steel riser pipe and 0.010-inch spacing wire-wrap screens. Morie #0 or equivalent sand packs will be placed along the screened interval of each well to a height of approximately two feet above the top of screen. A 2-foot thick bentonite seal will be placed above the sand pack. If the seal is installed above the water table, it will be manually hydrated using potable water. The remainder of the annular space will be filled with cement-bentonite grout to within approximately two feet of ground surface.

If NAPL is identified at a given borehole and it is determined that a temporary NAPL monitoring well will be installed, additional well-construction measures will be implemented. If light NAPL (LNAPL) is identified, the well will be screened across the water table and the screened interval will be selected such that the top of the screen is at least two feet above the water table. If dense NAPL (DNAPL) is identified, the well will be fitted with a 2-foot long stainless steel sump below the screen. The annulus surrounding the sump will be filled with cement-bentonite grout and a formation packer (also known as a “shale trap”) will be attached to the outside of the well at the top of the sump. A shale trap consists of a bell-shaped piece of rubber that is secured to the well casing using a stainless-steel clamp (Figure D). The shale trap, in combination with the grout, will serve to seal the annular space between the sump and the borehole and direct DNAPL into the well.

Figure D. *Typical shale traps.*

All monitoring wells will be constructed of stainless steel screen and riser materials and completed at the surface with protective, black steel, stand up outer casings set in concrete pads. For bedrock monitoring wells, the outer black steel casing will extend at least three feet into competent bedrock, as discussed in Section 2.1.4.

2.2 Community Air Monitoring Program

Consistent with Phase 1 drilling activities in the BDA, perimeter air monitoring will be conducted as described in the Community Air Monitoring Plan (CAMP) (OBG, 2013d), but will be limited to VOC monitoring only. VOC and dust monitoring will be conducted in the worker breathing zone at the drill rig. This approach was previously approved by the NYSDEC based on the lack of perimeter dust exceedances during BDA transformation activities and the limited extent of intrusive activities to be conducted.

2.3 Survey

Following completion of the protective well covers, the top of the inner casings and ground surface at each well will be marked and surveyed to the nearest 0.01 foot, and the elevation will be determined relative to North American Vertical Datum of 1988 (NAVD 88) and North American Datum (NAD 83). The measuring point on all wells will be a mark on the innermost well casing.

2.4 Well Development

Monitoring wells will be developed following installation in accordance with Section 6.2 of the FSAP to remove fine material that may have settled in the well, to remove any drilling fluids that were used during well installation, and to allow for enhanced hydraulic communication with the aquifer. Monitoring wells will be allowed to set for at least two days following installation to allow the grout to cure before developing the well.

2.5 Groundwater Sampling

Following installation and development of the Phase 2 monitoring wells, two groundwater monitoring events will be conducted. The groundwater monitoring events will include all new wells and existing well CHP43RX, and be completed in the spring (high water table condition) and fall (low water table condition).

All monitoring wells will be screened for the presence of NAPL (both LNAPL and DNAPL) prior to the collection of groundwater samples. If NAPL is observed in the monitoring well, no groundwater samples will be collected and it will be assumed that high levels of contaminants are present at the monitoring well. NAPL will be characterized as described in the NAPL Contingency Plan.

The monitoring wells will be sampled using low-flow purge and sampling methods in accordance with the FSAP. Monitoring wells will be sampled using either a peristaltic or bladder pump (only to be used if the anticipated drawdown depth is greater than 20 feet bgs). Groundwater samples will be collected directly from the pump and submitted for laboratory analysis of VOCs, SVOCs, alcohols, and glycols plus the 10 highest VOC TICs and 20 highest SVOC TICs in accordance with the methods previously identified for soil. Quality assurance and quality control samples will be collected in accordance with the QAPP, and data validation will be completed and documented in data usability summary reports (DUSRs).

As part of the groundwater monitoring events, groundwater elevation measurement will be completed. These events will include measuring groundwater elevations in the BMS Facility perimeter monitoring wells and measuring surface water elevations at the stormwater outfalls on Headson’s Brook and Ley Creek.

2.6 Hydraulic Conductivity Testing

A hydraulic conductivity test will be performed at each new well to estimate the hydraulic conductivity of the formation screened. There are two methods that may be used: low-flow drawdown or slug testing. A procedure for conducting the hydraulic conductivity testing is included in Appendix B and is summarized below.

Low-flow drawdown tests are completed by pumping a well at a low flow rate (for the purposes of this work plan, 500 mL/min or less) until the water level in the well approaches stabilization, approximating steady-state conditions. These tests have been found to produce results comparable to other low stress hydraulic testing methods, such as slug tests (Bartlett et al. 2004; Robbins et al. 2009; and Aragon-Jose and Robbins 2011).

The steady-state flow data will be analyzed by selecting from different flow equations presented in Robbins et al. (2009) and Aragon-Jose and Robbins (2011). The flow equation selection will be based on test-interval specifics, such as the location of aquitards and whether the testing interval crosses the water table. The flow equations are based on analytical solution models by Dachler (1936), Muskat (1937), and Hvorslev (1951). In the case of an interval that crosses the water table, the radial flow model based on the Bouwer and Rice (1976) and Bouwer (1989) will be used.

The low-flow sampling of each new well, as described in the preceding section, constitutes a low-flow drawdown test; therefore, the time-drawdown data collected during sampling at each well will be used to estimate the hydraulic conductivity of the native material surrounding the screen, as described above. However, if the hydraulic conductivity of the screened interval is very low, it is possible that drawdown in the well will not approach stabilization at the time of sampling. In this case, a slug test will be performed at the well to estimate the hydraulic conductivity of the native material surrounding the screen.

Slug tests are hydraulic conductivity tests where the water level in the well is caused to change suddenly (rise or fall) and the subsequent water-level response (displacement or change from static) is measured through time. Collected data will be reduced in accordance with the methods of Bouwer and Rice (1976) and Bouwer (1989).

2.7 Investigation Water Source

Water used for drilling, decontamination of drilling/sampling equipment, grouting boreholes upon completion, or hydraulic testing will be municipal potable water. A representative sample of the source will be submitted for laboratory analysis for VOCs, SVOCs, alcohols, and glycols in accordance with the same methods used for investigation samples. Use of any other drilling fluids or materials that could impact groundwater quality will be avoided.

2.8 Waste Management

Waste generated during the Phase 2 activities will be managed in accordance with Section 12.3 (Management of Investigation-Derived Waste) of the FSAP. Soil cuttings, drilling fluids, purged groundwater, and decontamination fluids will be containerized for offsite disposal. Waste profile samples will be collected and analyzed in accordance with the FSAP.

3 REPORTING

Boring logs, well construction logs, validated analytical data tables, and DUSRs will be included in the monthly project status updates, as completed.

Following completion of the second round of groundwater monitoring, a Phase 2 RI data summary report will be prepared and submitted to the NYSDEC for review and approval. The report will include a discussion of analytical results, nature and extent of impact, site conceptual model, and recommendations, supported by updated tables and figures describing the analytical data and hydrogeology.

4 SCHEDULE

Mobilization for the Phase 2 groundwater investigation will be initiated within 45 days following receipt of written approval of this Phase 2 Work Plan by the NYSDEC. It is anticipated that well installation and development will be completed within three months thereafter, subject to weather and ground surface conditions.

5 REFERENCES

Arcadis. 2016. *Phase I/IA Remedial Investigation Data Summary Report.* August 2016.

Aragon-Jose, Alejandra T., and Gary A. Robbins. "Low-Flow Hydraulic Conductivity Tests at Wells that Cross the Water Table." Ground water 49.3 (2011): 426-431.

Bartlett, S.A., G.A. Robbins, J.D. Mandrick, M.J. Barcelona, W. McCall, and M. Kram. 2004. Comparison of hydraulic conductivity determinations in direct push and conventional wells. Naval Facilities Engineering Service Center, Technical Report TR-2252-ENV. http://water.uconn.edu/downloads/TR-2252-ENV.pdf (accessed September 28, 2008).

Bouwer, H., 1989. The Bouwer and Rice slug test--an update, Ground Water, vol. 27, no. 3, pp. 304-309.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Dachler, R. "Grundwasserstromung (Flow of Groundwater)." *Julius Springer, Wien* (1936): 141.

DeGroff, ER. 1950. Joint patterns in central New York: Syracuse, N.Y., Syracuse University, Department of Geology, unpublished master's thesis, 75 p.

Hvorslev, M. Juul. "Time lag and soil permeability in ground-water observations." 1951.

Getchell, FA, 1983. Subsidence in the Tully Valley, New York: Syracuse, N.Y., Syracuse University, Department of Geology, unpublished master's thesis, 108 p.

Leutze, WP. 1955. Stratigraphy and paleontology of the middle Salina in central New York, Syracuse University, unpublished master's thesis, 193 p.

Leutze WP. 1959. Stratigraphy and Paleontology of the Salina Group in central New York. Ph.D. thesis, Ohio State University, 463 p.

Muskat, Morris. "The flow of homogeneous fluids through porous media." *MacGraw-Hill, New York.* 1937.

NYSDEC. 2010. DER-10 Technical Guidance for Site Investigation and Remediation. May 3. Available online at: http://www.dec.ny.gov/regulations/67386.html

OBG. 2013a. *Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

OBG. 2013b. *Field Sampling and Analysis Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

OBG. 2013c. *Quality Assurance Project Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

OBG. 2013d. *Community Air Monitoring Plan: BMS Syracuse North Campus Restoration Area, Site No. C734138.* March 2013.

Rickard LV, Isachsen YW, and Fisher DW. 1970. Geologic map of New York: Finger Lakes sheet. New York State Museum, Map and Chart Series 15. Map Scale: 1:250,000.

Robbins, GA, Aragon-Jose, AT, and Romero, A. 2009. Determining Hydraulic Conductivity Using Pumping Data from Low-Flow Sampling. Ground water 47.2 (2009): 271-286.

Stone RW and others. 1920. Gypsum deposits of the United States. United States Geological Survey Bulletin 697. p. 193.

USGS. 2016. Available online at: http://mrdata.usgs.gov/geology/state/sgmc-unit.php?unit=NYScv%3B4 (retrieved April 14, 2016).

TABLES

Table 1
Proposed Phase 2 Monitoring Well Details

Phase 2 Groundwater Remedial Investigation Work Plan
Site #C734138 - BMS Syracuse North Campus Restoration Area
East Syracuse, NY

Proposed Monitoring Well ID	Proposed Well Location (AOC or Area of Site)	Purpose of Well	Hydrogeologic Unit	Drilling Method	Anticipated Screen Interval (ft bgs)	Screen Interval Comments
BDA Wells						
BDA-1F	BDA Perimeter	Downgradient perimeter monitoring	Fill	HSA	3.5 - 8.5	Well has already been installed.
BDA-1RX	BDA Perimeter	Downgradient perimeter monitoring	Bedrock	Coring	50 - 60	Estimated depth to bedrock based on depth to bedrock at T-5 (47 ft bgs) and that bedrock was not encountered at T-23 (total depth of boring was 28 ft bgs).
BDA-1WT	BDA Perimeter	Downgradient perimeter monitoring	Water Table	HSA	13 - 23	Well has already been installed.
BDA-2WT	Building 4/5/8 Alleyway AOC	Replace temporary monitoring well BLD 36-1	Water Table	Sonic	4 - 12	BLD 36-1 was screened from 3.8 to 13.5 ft bgs, and top of till was at 12 ft bgs; well will be set above the top of till.
BDA-3RX	Building 4/5/8 Alleyway AOC	Downgradient monitoring of Building 4/5/8 Alleyway AOC	Bedrock	Coring	50 - 60	Based on observations during the installation of T-5, top of bedrock is estimated to be 47 ft bgs.
BDA-3UT	Building 4/5/8 Alleyway AOC	Downgradient monitoring of Building 4/5/8 Alleyway AOC	Upper Till	Sonic	13 - 23	Screen interval same as T-5S.
BDA-3WT	Building 4/5/8 Alleyway AOC	Downgradient monitoring of Building 4/5/8 Alleyway AOC	Water Table	Sonic	4 - 12	Screen interval same as BLD 36-1.
BDA-4DT	Building 4/5/8 Alleyway AOC	Replace temporary monitoring well T-5D	Deep Till	Sonic	37 - 47	T-5D was screened from 32 to 42 ft bgs, replacement well will be screened to the top of bedrock at 47 ft bgs.
BDA-4UT	Building 4/5/8 Alleyway AOC	Replace temporary monitoring well T-5S	Upper Till	Sonic	13 - 23	T-5S was screened from 12.95 to 22.25 ft bgs.
BDA-4WT	Building 4/5/8 Alleyway AOC	Water table monitoring at the T-5 well cluster	Water Table	Sonic	6 - 11	Concrete from 0 to 5 ft bgs and till at 6.5 ft bgs in T-5. Well will be set below the concrete interval.
BDA-5RX	BDA Perimeter	Upgradient perimeter monitoring	Bedrock	Coring	30 - 40	Depth to top of bedrock at PW-5T was 24 ft bgs.
BDA-5T	BDA Perimeter	Upgradient perimeter monitoring	Till	Sonic	14 - 24	Proposed screen interval assumes that the top of till is at 14 ft bgs (based on BLD 41-1) and top of bedrock is at 24 ft bgs (based on PW-5T).
BDA-5WT	BDA Perimeter	Upgradient perimeter monitoring	Water Table	Sonic	4 - 14	Proposed screen interval assumes that the top of till is at 14 ft bgs (based on BLD 41-1); adjacent PW-1 was screened from 7 to 17 ft bgs and was dry.
BDA-6RX	BDA Perimeter	Downgradient perimeter monitoring	Bedrock	Coring	50 - 60	Estimated depth to bedrock based on depth to bedrock at T-5 (47 ft bgs) and that bedrock was not encountered at T-23 (total depth of boring was 28 ft bgs).
BDA-6T	BDA Perimeter	Downgradient perimeter monitoring	Till	Sonic	18 - 28	Replacement for T-23D, which was screened from 18 to 27.7 ft bgs.
BDA-6WT	BDA Perimeter	Downgradient perimeter monitoring	Water Table	Sonic	4 - 12	Top of till is assumed to be 12 ft bgs. Top of well screen will be set at 4 ft bgs to allow for an adequate seal.
BDA-7T	BDA Perimeter	Downgradient perimeter monitoring	Till	Sonic	20 - 30	Depth to till at BLD 24-1 was 16.8 ft bgs.
BDA-7WT	BDA Perimeter	Downgradient perimeter monitoring	Water Table	Sonic	4 - 14	Top of well screen will be set at 4 ft bgs to allow for an adequate seal.
BDA-8RX	BDA Perimeter	Downgradient perimeter monitoring	Bedrock	Coring	40 - 50	Estimated depth to bedrock.
BDA-8T	BDA Perimeter	Downgradient perimeter monitoring	Till	Sonic	20 - 30	Depth to till is assumed to be 15 ft bgs based on observations from DS 2-1.
BDA-8WT	BDA Perimeter	Downgradient perimeter monitoring	Water Table	Sonic	4 - 14	DS 2-1 was screened from 3 to 12.7 ft bgs. Top of well screen will be set at 4 ft bgs to allow for an adequate seal.
BDA-9MT	CHAPA Area AOC	Downgradient monitoring of CHAPA Area AOC	Middle Till	Sonic	20 - 30	Same interval as BLD 62-1S.
BDA-9RX	CHAPA Area AOC	Downgradient monitoring of CHAPA Area AOC	Bedrock	Coring	45 - 55	Same interval as CHP-43RX.
BDA-9WT	CHAPA Area AOC	Downgradient monitoring of CHAPA Area AOC	Water Table	Sonic	4 - 12	At BLD 62-1 S/D, the top of till was at 14 ft bgs but started to get hard at 12 ft bgs. Top of well screen will be set at 4 ft bgs to allow for an adequate seal.
BDA-10DT	CHAPA Area AOC	Replace temporary monitoring well BLD 62-1D	Deep Till	Sonic	30 - 35	BLD 62-1D was screened from 34.65 ft bgs to 36.53 ft bgs and top of bedrock was 35.5 ft bgs. Replacement well will screen the interval above the top of bedrock.

See Notes on Page 2.

Table 1
Proposed Phase 2 Monitoring Well Details

Phase 2 Groundwater Remedial Investigation Work Plan
Site #C734138 - BMS Syracuse North Campus Restoration Area
East Syracuse, NY

Proposed Monitoring Well ID	Proposed Well Location (AOC or Area of Site)	Purpose of Well	Hydrogeologic Unit	Drilling Method	Anticipated Screen Interval (ft bgs)	Screen Interval Comments
BDA Wells (Cont.)						
BDA-10MT	CHAPA Area AOC	Replace temporary monitoring well BLD 62-1S	Middle Till	Sonic	18 - 28	BLD 62-1S was screened from 20 to 30 ft bgs; screen interval adjusted to separate BMD 62-1MT from BLD 62-1DT.
BDA-10RX	CHAPA Area AOC	Vertical delineation of methylene chloride impacts observed in monitoring well CHP-43RX	Bedrock	Coring	60 - 70	CHP-43RX is screened from 44.5 to 54.5 ft bgs.
BDA-11WT	CHAPA Area AOC	Replace temporary monitoring well T-36	Water Table (Upper Till)	Sonic	8.5 - 13.5	T-36 was screened across the fill and till units and highest photoionization detector reading was at the top of the till (8 ft bgs), so replacement well will be screened in the till unit only.
BDA-12RX	BDA Perimeter	Downgradient perimeter monitoring	Bedrock	Coring	40 - 50	Estimated depth to bedrock.
BDA-12T	BDA Perimeter	Downgradient perimeter monitoring	Till	Sonic	25 - 35	Depth to till was at 23 ft bgs in BCP-B20-SB-003.
BDA-12WT	BDA Perimeter	Downgradient perimeter monitoring	Water Table	Sonic	4 - 14	Depth to water is assumed to be 4.5 ft bgs based on depth to water at BCP-B20-003.
BDA-13WT	Building 55 AOC	Downgradient monitoring of Building 55 AOC	Fill/Upper Lacustrine	Sonic	4 - 14	Same screen interval as BDA-14WT.
BDA-14T	Building 55 AOC	Vertical delineation in the Building 55 AOC	Till	Sonic	20 - 30	Screen interval based on till depth of 19 ft bgs at BCP-20-001.
BDA-14WT	Building 55 AOC	Replace temporary monitoring well B55-2	Fill/Upper Lacustrine	Sonic	4 - 14	B55-2 was screened from 3 to 12 ft bgs. Top of well screen will be set at 4 ft bgs to allow for an adequate seal.
BDA-15RX	BDA Perimeter	Upgradient perimeter monitoring	Bedrock	Coring	40 - 50	Estimated depth to bedrock based on drilling observations in PAS 1-1.
BDA-15T	BDA Perimeter	Upgradient perimeter monitoring	Till	Sonic	20 - 30	Estimated depth to till based on PAS 1-1 drilling observations.
BDA-15WT	BDA Perimeter	Upgradient perimeter monitoring	Water Table	Sonic	4 - 14	Depth to water is assumed to be 6 ft bgs based on PAS 1-2.
PW-5RX	BDA Perimeter	Upgradient perimeter monitoring	Bedrock	Coring	30 - 40	Depth to top of bedrock at PW-5T was 24 ft bgs and PW-5T is screened from 18 to 28 ft bgs.
Non-BDA Wells						
BLD-6-1T	--	Downgradient monitoring outside of BDA	Till	Sonic	25 - 35	Screen interval based on till depth of 19 ft bgs at BCP-20-001.
BLD-6-1WT	--	Downgradient monitoring outside of BDA	Water Table	Sonic	4 - 14	Same screen interval as BDA-14WT.
BLD-49-1-T	--	Downgradient monitoring outside of BDA	Water Table	Sonic	4 - 14	Same screen interval as BDA-14WT.

Notes:
1) Non-BDA wells are located outside of the BDA limit and are included in the Phase 2 Groundwater Investigation for completeness only.
2) The 'purpose of well' is a goal; depending on the associated analytical results, additional monitoring wells may be proposed in the future.
3) Anticipated screen intervals provided in the table are preliminary and based on available information; the actual screen interval will be determined in the field based on geologic conditions observed.
4) Proposed screen intervals are generally 10 feet in length. A shorter screen interval is proposed in some cases to avoid screening across a geologic unit.
5) Soil samples will be collected for visual characterization and laboratory analysis from the deepest overburden well in a cluster only. The remaining wells will be installed without collecting soil samples (blind drilled).
6) All monitoring wells will be constructed of 2-inch diameter stainless steel well materials.
7) Coring will be conducted with HQ size core barrel, resulting in an approximately 3-3/4 inches outside diameter hole.

Abbreviations:

AOC = Area of Concern	HSA = Hollow Stem Auger
BDA = Brownfield Development Area	MT = Middle Till
DT = Deep Till	RX = Bedrock
F= Fill	UT = Upper Till
ft bgs = feet below grade surface	WT = Water Table

Table 2
Bedrock Geophysics Program

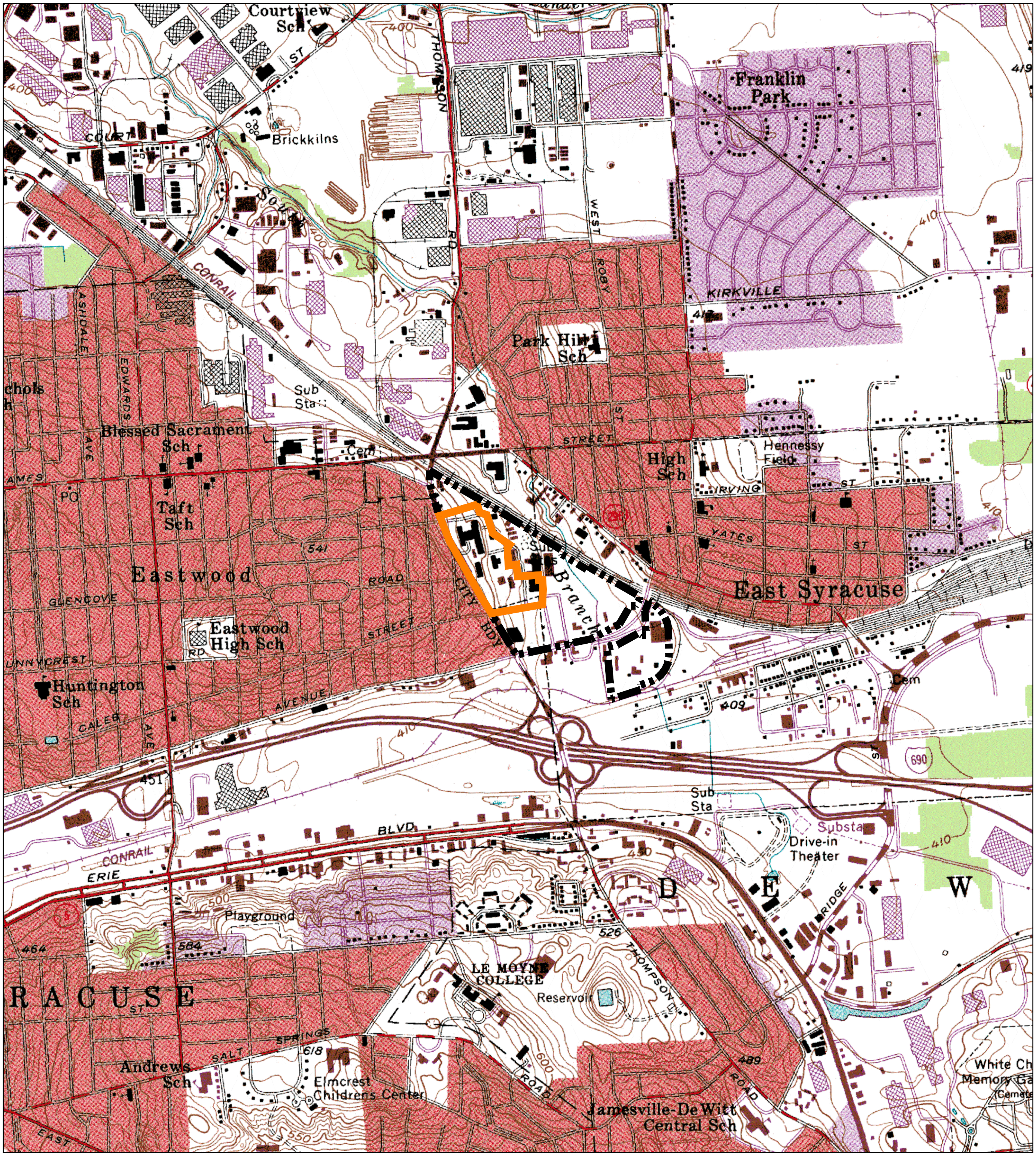
Phase 2 Groundwater Remedial Investigation Work Plan
Site #C734138 - BMS Syracuse North Campus Restoration Area
East Syracuse, NY

Proposed Monitoring Well ID	Proposed Well Location (AOC or Area of Site)	Acoustic Teleview	Gamma, Caliper, Temperature, and Fluid Resistivity Logging	Packer Hydraulic Testing	Down-hole Camera
BDA-1RX	Perimeter of BDA			X	X
BDA-3RX	Building 4/5/8 Alleyway AOC			X	X
BDA-5RX	Perimeter of BDA			X	X
BDA-6RX	Perimeter of BDA			X	X
BDA-8RX	Perimeter of BDA	X	X	X	X
BDA-9RX	CHAPA Area AOC			X	X
BDA-10RX	CHAPA Area AOC			X	X
BDA-12RX	Perimeter of BDA	X	X	X	X
BDA-15RX	Perimeter of BDA			X	X
PW-5RX	Perimeter of BDA	X	X	X	X

Notes:
1) Each column represents separate testing equipment.
2) No analytical samples will be collected during packer hydraulic testing.

Abbreviations:
AOC = Area of Concern
BDA = Brownfield Development Area
RX = Bedrock

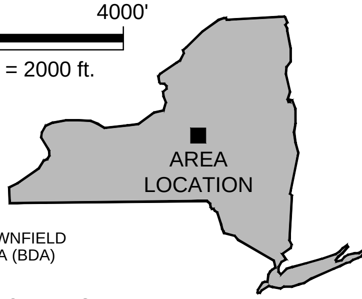
FIGURES



REFERENCE: BASE MAP USGS 7.5. MIN. TOPO. QUAD., SYRACUSE EAST, NEW YORK, 1957, PHOTOREVISED 1978.

0 2000' 4000'

Approximate Scale: 1 in. = 2000 ft.



LEGEND:

APPROXIMATE BROWNFIELD DEVELOPMENT AREA (BDA) BOUNDARY

APPROXIMATE BRISTOL-MYERS SQUIBB PROPERTY LINE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
PHASE 2 GROUNDWATER RI WORK PLAN

SITE LOCATION MAP

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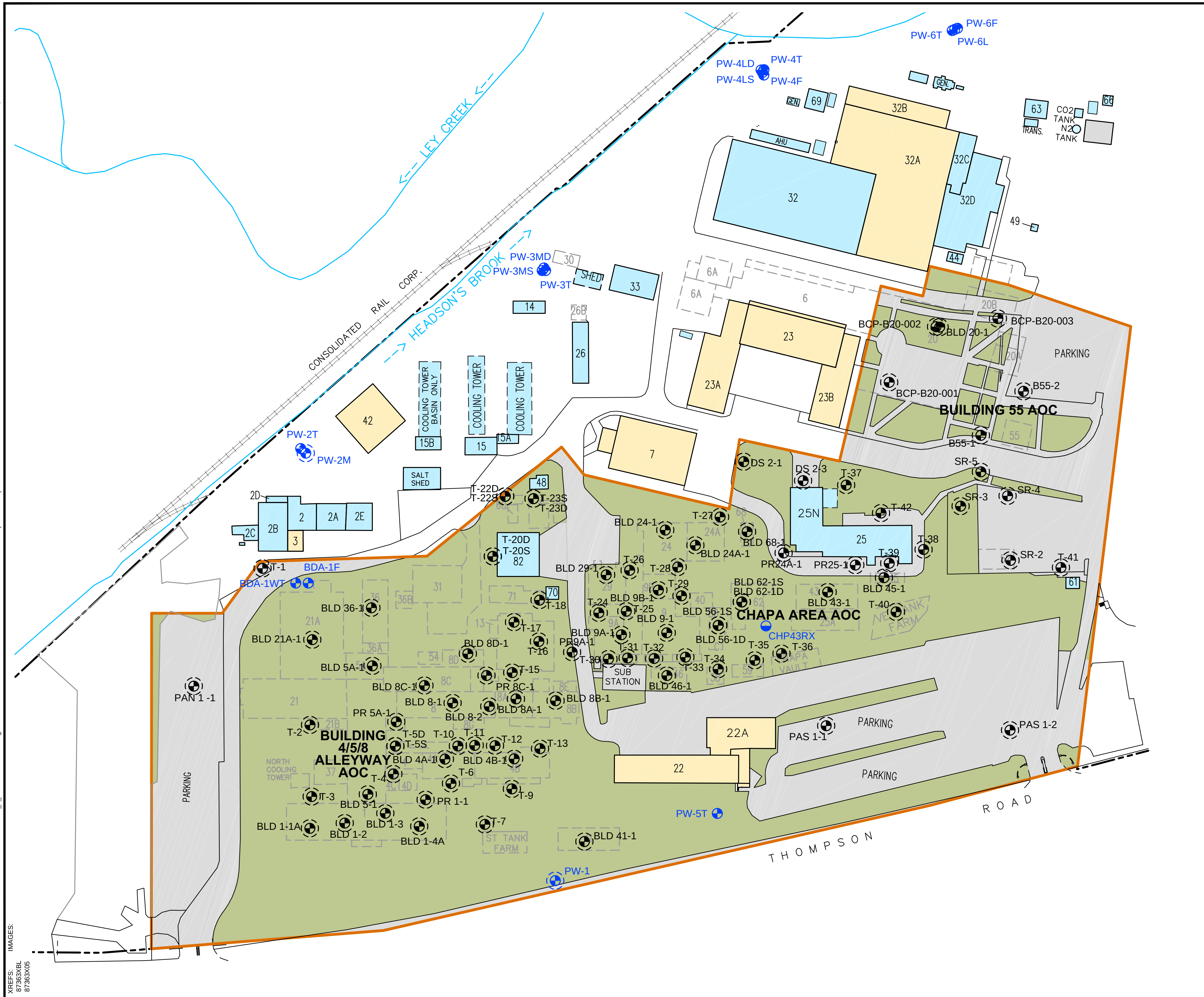
FIGURE
1



LEGEND:

- APPROXIMATE BROWNFIELD AREA BOUNDARY
- APPROXIMATE PROPERTY LINE, BRISTOL-MYERS SQUIBB
- OCCUPIED BUILDINGS
- UNOCCUPIED BUILDINGS / STRUCTURES
- DEMOLISHED BUILDINGS
- PAVED OR CONCRETE AREAS
- UNPAVED AREAS
- EXISTING RAILROAD
- DECOMMISSIONED TEMPORARY MONITORING WELL
- DECOMMISSIONED MONITORING WELL
- BEDROCK MONITORING WELL
- OVERBURDEN MONITORING WELL

NOTES:

1. BASEMAP SOURCE: MAP TITLED "BRISTOL-MYERS SQUIBB FOR PART OF LOT 41 - TOWN OF DEWITT AND PART OF THE VILLAGE OF EAST SYRACUSE ONONDAGA COUNTY NEW YORK", DATED MARCH 25, 2010 PREPARED BY COTTRELL LAND SURVEYORS, P.C.. UPDATED BASED ON SUBSEQUENT AERIAL IMAGERY AND SITE VISITS.
2. SAMPLE LOCATIONS AND ELEVATION SURVEY BY CT MALE ASSOCIATES, SYRACUSE, NY.

0 160' 320'

GRAPHIC SCALE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
PHASE 2 GROUNDWATER RI WORK PLAN

AOCs AND FORMER TEMPORARY WELL LOCATIONS

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FIGURE 2

CITY: SYRACUSE, NY DIV/GROUP: EBC-IM/DV DB/LD: L.POSENAUER PM/TM: D.WRIGHT LYR: ON=*;OFF=REF (FRZ) ACADVER: 19.1S (LMS TECH) PAGESETUP: C-PA-ADOBEPDF PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 8/15/2016 10:16 AM BY: POSENAUER, LISA
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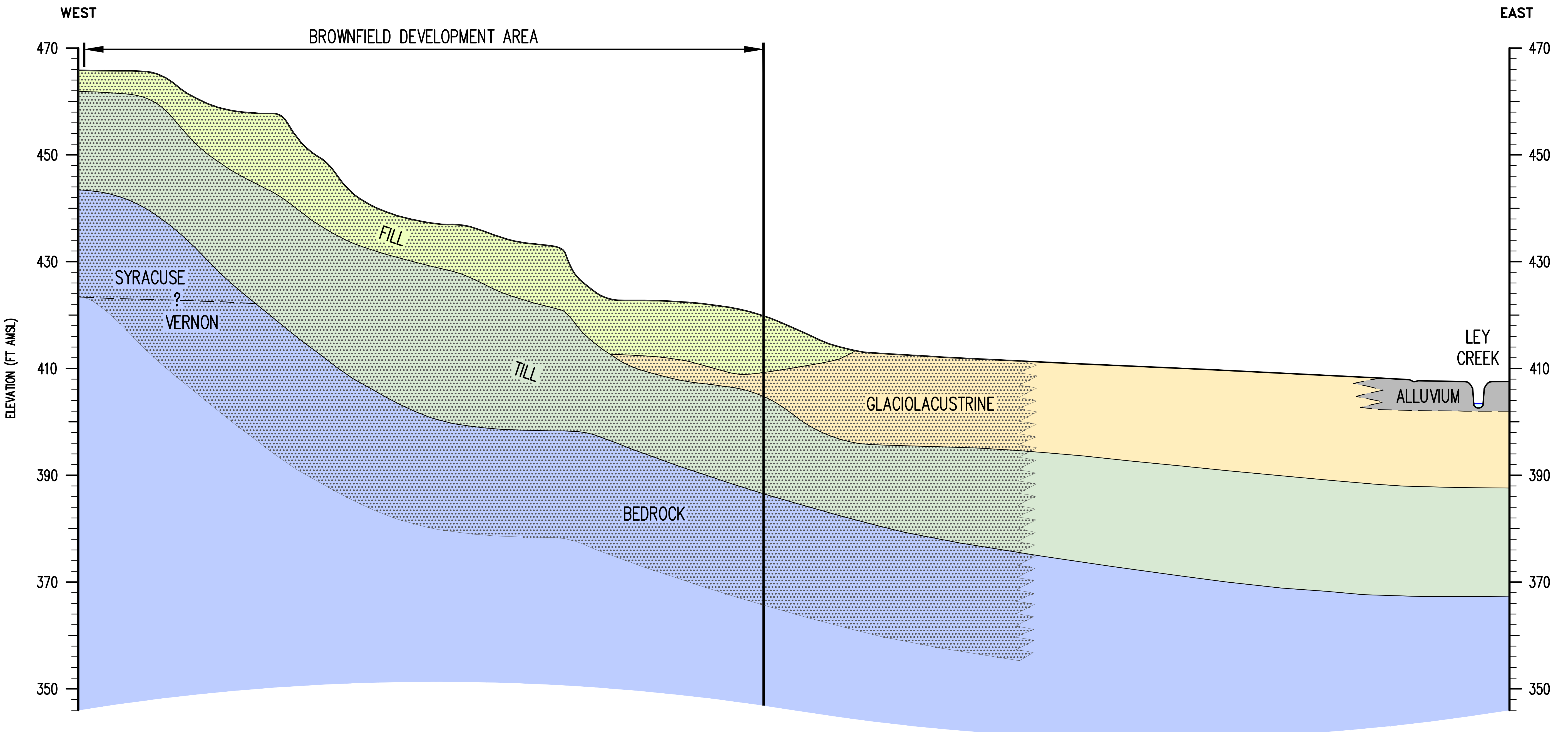

NOTES:

1. VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
2. GEOLOGICAL CONTACT LOCATIONS ARE GENERALIZED.
3. IN THE CHAPA AREA AOC, PROPOSED WELL BDA-10RX WILL BE SCREENED APPROXIMATELY 20 FEET DEEPER THAN PHASE 2 GROUNDWATER MONITORING ZONE SHOWN ABOVE.
4. BEDROCK CORING MAY EXTEND BELOW PROPOSED PHASE 2 GROUNDWATER MONITORING ZONE FOR CHARACTERIZATION PURPOSES.

LEGEND:

- PROPOSED PHASE 2 GROUNDWATER MONITORING ZONES
- FILL
- GLACIOLACUSTRINE
- ALLUVIUM
- TILL
- BEDROCK

VERTICAL EXAGGERATION = 5X

0 20' 40'
VERTICAL SCALE

0 100' 200'
HORIZONTAL SCALE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY

PHASE 2 GROUNDWATER RI WORK PLAN

GENERALIZED GEOLOGIC CROSS-SECTION AND PROPOSED PHASE 2 GROUNDWATER MONITORING ZONE

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FIGURE
3

CITY: SYRACUSE, NY DIV/GROUP: EBC-IM/DV DB/LD: L.POSENAUER PM/TM: D.WRIGHT LYR: ON=*;OFF=REF, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0087363\0020\00001\PHASE_2_GWRI\87363V03.dwg LAYOUT: 3 SAVED: 8/15/2016 10:09 AM ACADVER: 19.1S (LMS TECH) PAGESETUP: C-PA-ADOBEPDF PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 8/15/2016 10:16 AM BY: POSENAUER, LISA
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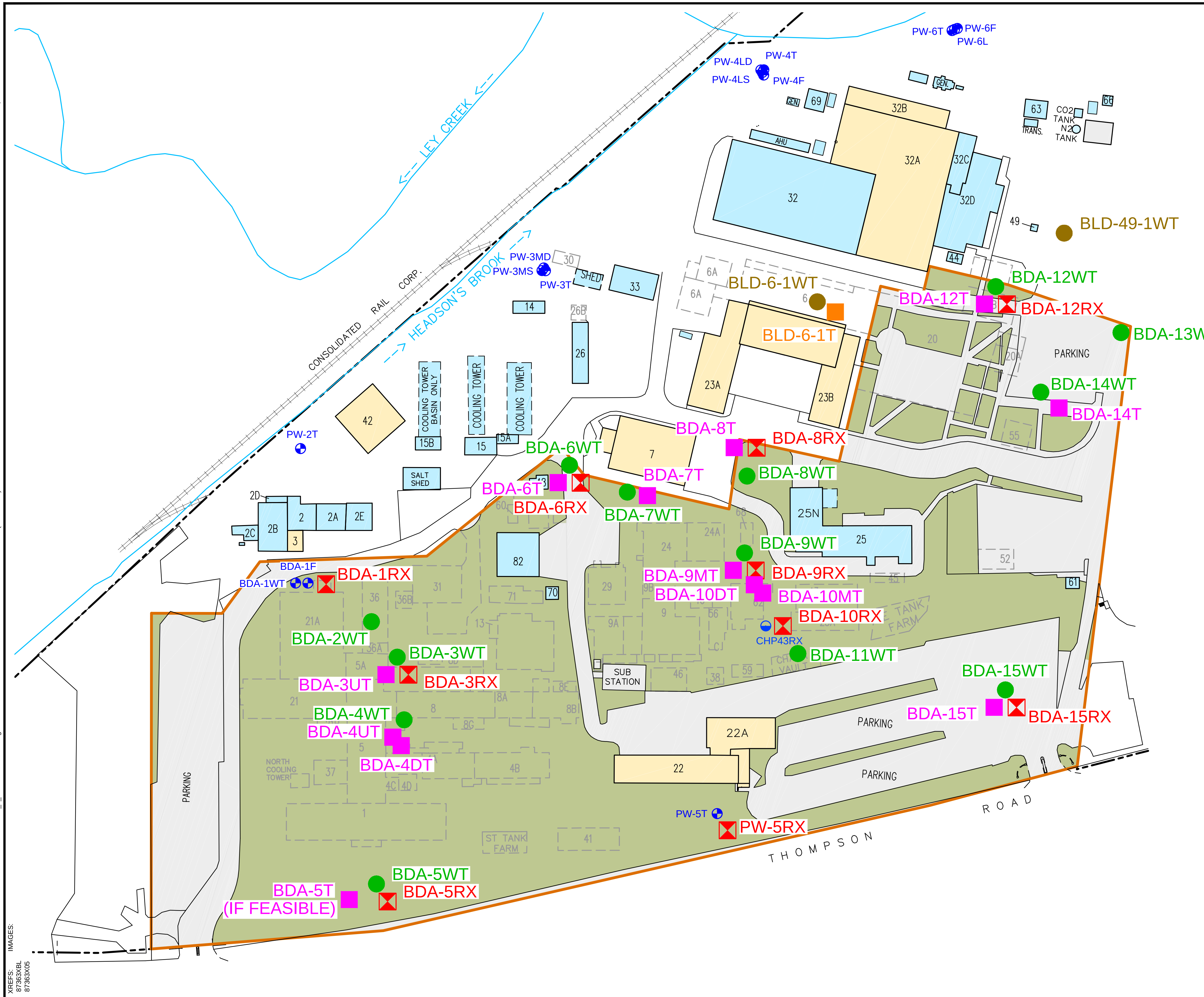


LEGEND:

- APPROXIMATE BROWNFIELD DEVELOPMENT AREA (BDA) BOUNDARY
- APPROXIMATE BRISTOL-MYERS SQUIBB PROPERTY LINE
- OCCUPIED BUILDINGS
- UNOCCUPIED BUILDINGS / STRUCTURES
- DEMOLISHED BUILDINGS
- PAVED OR CONCRETE AREAS
- UNPAVED AREAS
- EXISTING RAILROAD
- OVERBRUDEN MONITORING WELL
- BEDROCK MONITORING WELL

PROPOSED MONITORING WELLS:

- WATER TABLE
- TILL
- BEDROCK
- NON-BDA WATER TABLE
- NON-BDA TILL

NOTES:

1. BASEMAP SOURCE: MAP TITLED "BRISTOL-MYERS SQUIBB PART OF LOT 41 - TOWN OF DEWITT AND PART OF THE VILLAGE OF EAST SYRACUSE ONONDAGA COUNTY NEW YORK", DATED MARCH 25, 2010 PREPARED BY COTTRELL LAND SURVEYORS, P.C.. UPDATED BASED ON SUBSEQUENT AERIAL IMAGERY AND SITE VISITS.
2. SAMPLE LOCATIONS AND ELEVATION SURVEY BY CT MALE ASSOCIATES, SYRACUSE, NY.
3. PROPOSED MONITORING WELL LOCATIONS AND DEPTH INTERVALS ARE PRELIMINARY AND SUBJECT TO CHANGE BASED ON FIELD OBSERVATIONS.

0 160' 320'
GRAPHIC SCALE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
PHASE 2 GROUNDWATER RI WORK PLAN

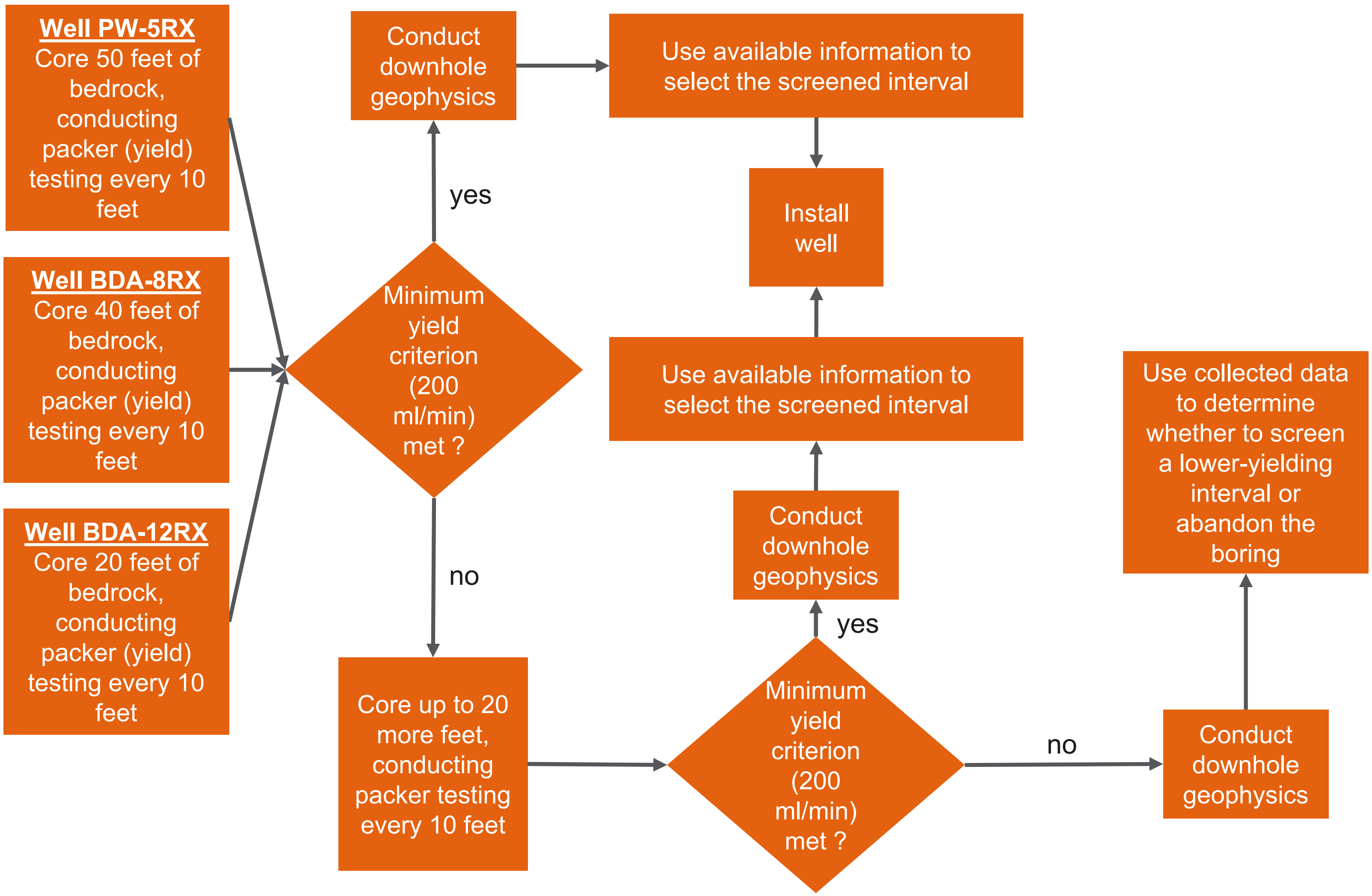
PROPOSED MONITORING WELL LOCATIONS

ARCADIS Design & Consultancy for natural and built assets

FIGURE
4

Figure 5: Bedrock Well Screen Depth Interval Flow Chart – Initial Wells

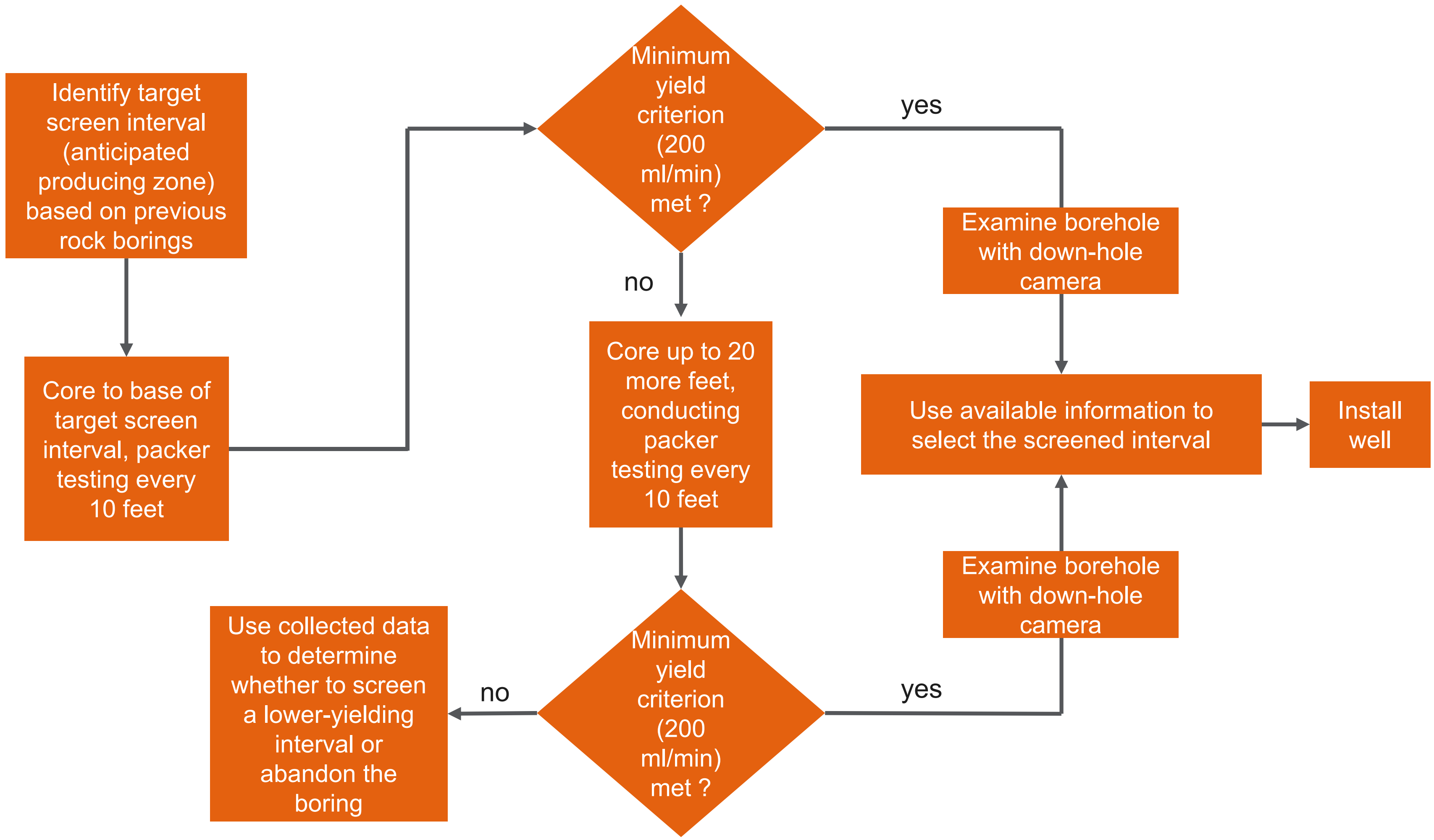
BMS Syracuse North Campus Restoration Area



Note: if at any time NAPL is confirmed, halt drilling and implement the NAPL Contingency Plan.

Figure 6: Bedrock Well Screen Depth Interval Flow Chart – Remaining Wells

BMS Syracuse North Campus Restoration Area

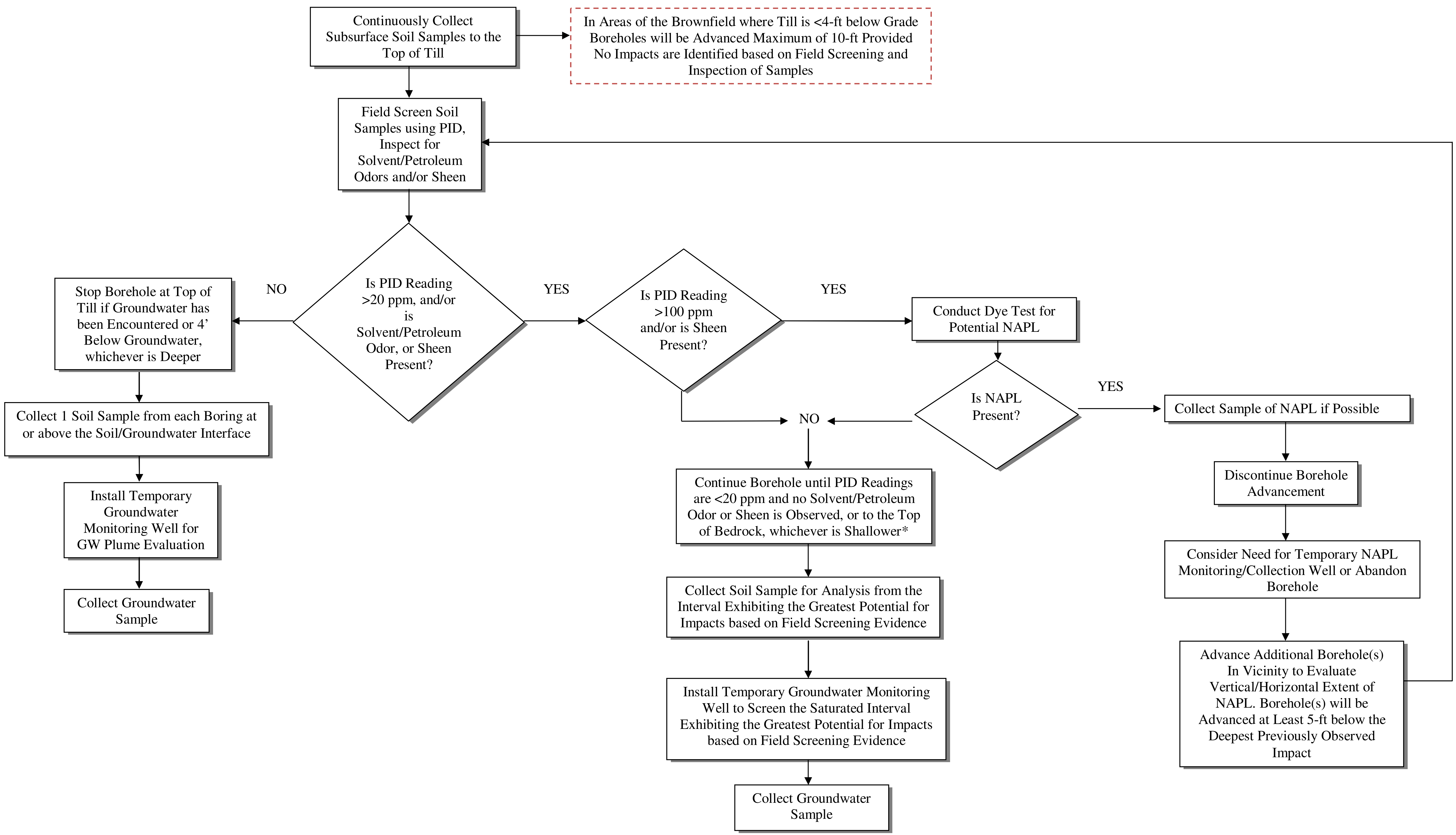


Note: if at any time NAPL is confirmed, halt drilling and implement the NAPL Contingency Plan.

APPENDIX A

Figure 3-3: Sampling Decision Tree of the RIWP

Figure 3-3: Sampling Decision Tree



*At a minimum, all borings will be advanced to the top of till if groundwater has been encountered, or to a depth of 4-ft below groundwater, whichever is deeper

APPENDIX B

Procedures

- Collecting and Describing Bedrock Core Samples
- Bedrock Geophysical and Video Logging Surveys
- Packer Testing
- Non-Aqueous Phase Liquid (NAPL) Contingency Plan
- Monitoring Well Installation
- Hydraulic Conductivity Testing

COLLECTING AND DESCRIBING BEDROCK CORE SAMPLES

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures to collect and describe bedrock core samples at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York. Bedrock cores will be collected in accordance with ASTM Method D 2113-99, Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation. The bedrock cores will be collected, labeled, and classified as outlined below.

II. PERSONNEL QUALIFICATIONS

Coring activities will be observed, and recovered cores logged, by an experienced geologist with a minimum of four years field experience.

III. EQUIPMENT LIST

- Work Plan, Field Sampling & Analysis Plan (FSAP[1]), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- Core boxes;
- Permanent marking pen for labeling boxes and cores;
- Wood blocks to separate core runs in core boxes;
- Hand lens;
- Water level probe;
- Munsell rock color chart;
- Tape measure; and
- Field notebook.

IV. CAUTIONS

Water used for drilling, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be municipal potable water, with laboratory analysis of a representative sample for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), alcohols, and glycols in accordance with the same methods used for investigation samples. Avoid using any other drilling fluids or materials that could impact the quality of the media being investigated/penetrated.

[1] Appendix A to the Remedial Investigation Work Plan (O'Brien & Gere, 2013).

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. PROCEDURE

Prior to coring, the driller will use water circulation to remove cuttings in the boring that may clog the barrel. The driller will maintain drilling bit pressure and water pressure at a consistent level throughout drilling, and runs will be completed without interruption, to the extent practicable, so penetration rates (in feet per minute) can be determined.

Core samples will be placed in core boxes with increasing depths aligned left to right and core runs separated by wood blocks. Man-made breaks will be marked with a pen across the break. Wood blocks separating core runs will be labeled to clearly indicate the run number. If the entire core run is not recovered, a wooden block will be inserted and labeled “L.C.” (lost core) with corresponding depth. Attachment 1 contains additional instructions for handling, packing, and labeling cores.

The supervising geologist or geotechnical engineer will record:

- The time required to drill each run and the run length so that the penetration rate for each run can be calculated;
- an estimate of the volume of drilling water lost during each run; and
- the drill type and size.

The following rock core characteristics will be described in the field, as appropriate:

- lithology (rock type);
- friability/fissibility;
- color;
- thickness;
- weathered state;
- voids;
- particle sizes;
- structure/bedding (bedding planes, joints, fractures);
- Rock Quality Designation (RQD, see Attachment 2 for additional information regarding RQD);
- rock core recovery length;
- description of discontinuities and fillings (including interpretation of natural vs. artificial bedrock fractures);
- formation name (if known);

- texture;
- odors/discoloration;
- hardness;
- fossils;
- depth to water;
- Munsell color; and
- geologic contacts when observed.

A key to abbreviations that may be used when describing rock core is presented below. Additional information for describing rock structure, weathering states, and other rock descriptive terms to be used is presented in Attachment 3.

KEY TO CORE DESCRIPTION ABBREVIATIONS

BkN - broken

CAL - calcareous or calcite

cl - clay

F - foliation

Fe - iron staining on joint surface

GOG - gouge

HJ - horizontal joint

J - joint *

J//F - joint is parallel to foliation

JxF - joint crosses foliation

l - laminae

// - parallel

m - mud in opening

MB - mechanical break

N◦ - angle of fracture surface from horizontal, where N is the angle in degrees

QTZ - quartz

s - solution enlargement

S - stratification

sa - sand

si - silt

SZ - sheer zone

U - unfoliated or unstratified

v - vuggy

VJ - vertical joint

w - weathered

WZ - weathered zone

x - crossing

Z - zone

* "Joint" indicates any natural fracture.

The geologist/geotechnical engineer will document drilling events in the field notebook. Documented drilling events will include:

- drilling start and finish dates;
- project name and location;
- project number and client;
- core hole numbers;
- sample number and depth;
- sample type and size;
- type of drilling equipment;
- casing size;
- names of contractor's drillers; and
- weather conditions.

It is advisable to photograph recovered core in the labeled core box. The core should be wet when photographed to improve contrast and visibility of rock features.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

Water level meters will be washed between boreholes with potable water and a phosphate-free detergent and then rinsed with potable water followed by a distilled water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O'Brien & Gere, 2013).

VIII. DATA RECORDING AND MANAGEMENT

Coring activities will be documented in a field notebook. Information will include personnel present on site, times of arrival and departure, significant weather conditions, rock descriptions, and quantities of materials used.

IX. QUALITY ASSURANCE

Take care not to break the core. If a core is broken, mark the break as described herein to show that the break was artificial. If pieces of core are removed for inspection, make sure to return them to the same position and orientation.

X. REFERENCES

ASTM, 1999. *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*, D 2113-99.

O'Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

ATTACHMENT 1

Rock Core Handling And Packing

Handling of Core
The top of the core will be placed at the back left corner of the core box. The remaining core will be placed to the right of the preceeding section. The core box will be filled moving to the front sections of the box as needed. The begining of each run will be marked on the core and noted with a wooden block.

Core Labeling
The top of the core will be marked on each piece of core with an arrow. The arrow will indicate which end of core is nearer to ground surface. Other marks made on cores may include mechanical breaks and drilling footages.

Core Loss
Missing core will be shown by wood spacer blocks. The site geologist will insert the spacer and the core box in place of the missing section. The spacer should indicate the run number and footage of the missing section.

Core Box Storage
Core boxes from all wells will be moved from well heads on a regular basis and stored in a designated secure area. Whenever possible, the storage area should be inside.

Core Box Labeling
Labeling should include the following information:

- Outer core box cover
  - Project name, city, state, project number
  - Core information - Example

    Monitoring Well (MW1)
    Box 1 of 2
    Core Run 2, 22.5' - 32.5'
    Beginning Core Run 3, 32.5' - 40.5'

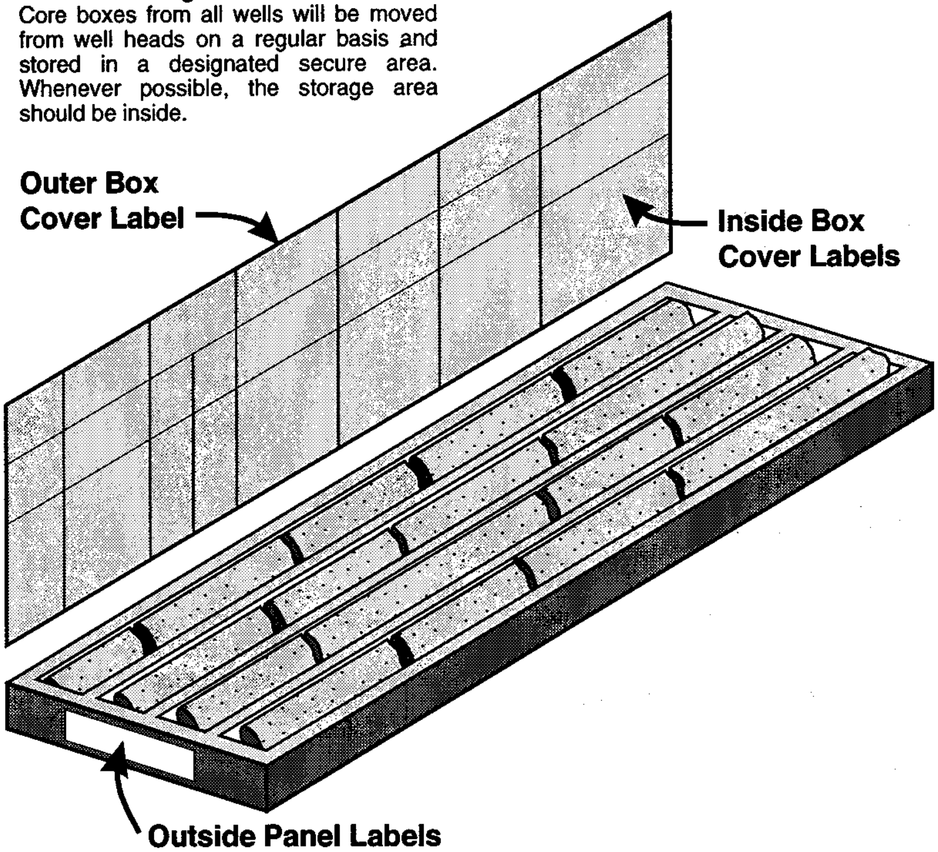
- Outside Panels:

Site Name ________ Well Number ______
Location ________ Box ___ of ______
Job Number ________ Run#
Footage

- Inside Box Cover:

Boring Well No.	Run No.	Depth (Ft. BGS) From	To	Actual Recovery	RQD %	FID/PID (ppm)	Comments

One row will be recorded for each core run or partial core run within the box.



ATTACHMENT 2

Rock Quality Designation (RQD) and Fracture Frequency

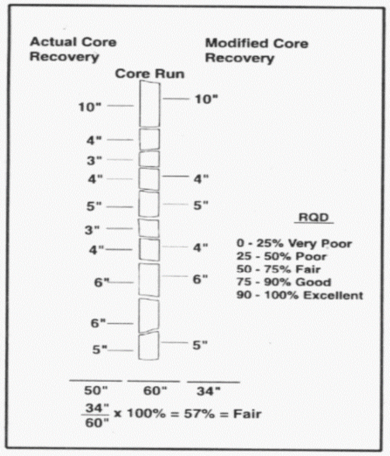
Core borings are a useful means of obtaining information about the quality of rock mass. The recoverable core indicates the character of the intact rock and the number and character of the natural discontinuities.

A quantitative index that has proved useful in logging NX core is a rock quality designation (RQD) developed by Deere (1963). The RQD is a modified core recovery percentage in which all the pieces of a sound NX core over 4 inches long are counted as recovery. The length of the core run is the distance to the nearest tenth of a foot from the corrected depth of the hole at the end of the subject run. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. The RQD is a more general measure of the core quality than is the fracture frequency. Core loss, weathered and soft zones, as well as fractures, are accounted for in this determination. The RQD provides a preliminary estimate of the variation of the in-situ rock mass properties of the "sound" portion of the rock core. Thus, a general estimate of the behavior of the rock mass can be made. An RQD approaching 100 percent denotes an excellent quality rock mass with properties similar to that of an intact specimen. RQD values ranging from 0 to 50 percent are indicative of a poor quality rock mass having a small fraction of the strength and stiffness measured for an intact specimen.

An example of determining the RQD from a core run of 60 inches measured from corrected depth to corrected depth is given in the adjacent figure. For this particular case, the core recovery was 50 inches and the modified core recovery was 34 inches. This yields an RQD of 57% (34"/60" x 100), classifying the rock mass in the fair category.

Problems arise in the use of RQD for determining the in-situ rock mass quality. The RQD evaluates fractures in the core caused by the drilling process, as well as in natural fractures previously existing in the rock mass. For example, when the core hole penetrates a fault zone or a joint, additional breaks may form that, although not natural fractures, are caused by natural planes of weakness existing in the rock mass. These fresh breaks occur during drilling and handling of the core and are not related to the quality of the rock mass. The skill of the driller will affect the amount of breakage and the core loss that occurs. Poor drilling techniques will "penalize" the rock by lowering its apparent quality. It is often difficult to distinguish between drilling breaks and those natural and incipient fractures that reflect the quality of the rock mass. In certain instances, it may be advisable to include all fractures when estimating RQD. Obviously, some judgement is involved in core logging.

Another problem with the use of the RQD index is that the determinations are not sensitive to the tightness of the individual joints, whereas in some instances, the in-situ deformation modulus may be strongly affected by the average joint opening.



RQD of a Single Core Run. Calculation is typical of a single core run. Note that the run is calculated from corrected depth to corrected depth. Rock core pieces which are included by the geologist as RQD should be marked with chalk, crayon, or marking pen so that RQD% can be checked and verified at a later time (i.e., after transit).

Engineering Classification of Rock Mass Quality		
Term	**RQD (%)**	**Velocity Index (V_F/VI)²**
Very Poor	0 - 25	0 - 0.2
Poor	25 - 50	0.2 - 0.4
Fair	50- 75	0.4 - 0.6
Good	75 - 90	0.6 - 0.8
Excellent	90 - 100	0.8 - 1.0

Strength of Intact Rock		
Term	**Field Test**	**Approximate Range of Uniaxial Compressive Strength (kg/cm² or tsf)**
Extremely Hard	Many blows with geological hammer required to break intact specimen.	>2,000
Very Hard	Hand held specimen breaks with hammer end of pick under more than one blow.	1,000 - 2,000
Hard	Cannot be scraped or peeled with knife; hand-held specimen can be broken with single, moderate blow with pick.	500 - 1,000
Moderately Hard	Can be scraped or peeled with knife. Indentation 1 mm to 3 mm shows in specimen with moderate blow with pick.	125 - 500
Moderately Soft	Material crumbles under moderate blow with sharp end of pick and can be peeled with a knife, but is too hard to hand-trim for triaxial test specimen.	50 - 125
Soft		12 - 50

ATTACHMENT 3

Additional Information for Describing Rock Core

Soil/Rock Structure Descriptions

Term	Description
Pocket	Small erratic deposit, usually less than 1 foot in size
Fissures	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated
Blocky	Cohesive soil can be broken down into small angular lumps with resist further breakdown
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout
Laminated	Alternating layers less than 1/4" thick

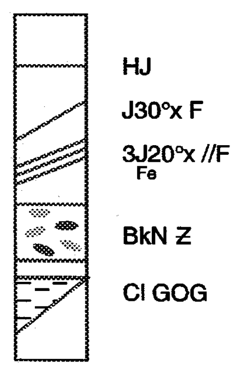
Rock Weathering States

Term	Rock Mass	Soil Mass
Fresh	No visible sign of decomposition or discoloration. Rings under hammer impact.	No visible sign of soil material weathering; perhaps slight discoloration on major discontinuity surfaces.
Slightly Weathered	Slight discoloration inward from open fractures; otherwise similar to fresh.	In fine soils, discoloration indicates weathering of soil materials and discontinuity surfaces; there is not a marked change in consistency of the discolored soil. Relics of fresh soil may be present. In coarse soils, individual fragments and discontinuities are discolored; there is no marked change in relative density.
Moderately Weathered	Discoloration throughout. Weaker minerals such as feldspar decomposed. Strength somewhat less than fresh rock, but cores cannot be broken by hand or scraped by knife. Texture preserved.	In fine soils, the soil is discolored; less than 35% of the soil shows marked change in consistency; relics of fresh and slightly weathered soil are present. In coarse soils, more than 35% of the soil has markedly lower relative density.
Highly Weathered	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becomes indistinct, but fabric preserved.	In fine soils, the soil is discolored and more than 35% of the soil shows marked change in consistency; relics of fresh and slightly weathered soil are present. In coarse soils, more than 35% of the soil has markedly lower relative density.
Extremely Weathered	Minerals decomposed to soil, but fabric and structure preserved (Saprolite). Specimens easily crumbled or penetrated.	In fine soils, the soil is discolored, relics of slightly weathered soil are absent; the soil shows a marked change in consistency from the fresh soil. In coarse soils, there is a marked decrease in relative density.
Decomposed (Residual Soil)	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed.	N/A

Rock Descriptive Terms

	Term	Defining Characteristics
Hardness	Soft Medium Hard Hard Very Hard	Scratched by a fingernail Scratched by a knife Difficult to scratch with a penknife Cannot be scratched with a penknife
Bedding Planes	Laminated Parting Banded Thin Medium Thick Massive	<0.04 in. <1 mm. 0.04 in. - 0.24 in. 1 mm - 6 mm 0.24 in. - 1 in. 6 mm - 3 cm 1 in. - 4 in. 3 cm - 9.1 cm 4 in. - 12 in. 30.5 cm - 1 M 12 in. - 36 in. 30.5 cm - 1M >36 in. >1 M
Joints and Fracture Spacing	Very Close Close Moderately Close Wide Very Wide	<2 in. <5.1 cm 2 in. - 1 ft. 5.1 - 30.5 cm 1 ft. - 10 ft. 30.5 cm - 91.4 cm 3 ft. - 10 ft. 91.4 cm - 3 M >10 ft. >3M
Voids	Porous Pitted Vug Cavity	Smaller than a pinhead. Their presence is indicated by the degree of absorbency. Pinhead size to 1/4 inch. If only thin walls separate the individual pits, the core may be described as honeycombed. 1/4 inch to the diameter of the core. The upper limit will vary with core size. Larger than the diameter of the core.

Sample Rock Core Sketch



Sample Abbreviations/Symbols

See key to core descriptions in SOP text.

BEDROCK GEOPHYSICAL AND VIDEO LOGGING SURVEYS

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures for bedrock borehole geophysical and video logging surveys at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York. Arcadis will self-perform the video logging and will engage a qualified subcontractor to conduct the required borehole geophysical surveys.

II. PERSONNEL QUALIFICATIONS

Geophysical survey activities will be observed by a geologist familiar with the specific geophysical methods to be employed. Video logging surveys will be conducted by an Arcadis scientist that has successfully performed borehole video logging within the past five years.

III. EQUIPMENT LIST

Arcadis Staff

- Work Plan, Field Sampling & Analysis Plan (FSAP[1]), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- Downhole video camera and associated apparatus;
- Decontamination materials (e.g., non-phosphate detergent solution, sponges, and bushes); and
- Field notebook.

Geophysical Subcontractor

- The subcontractor will prepare an equipment checklist before loading equipment into the field vehicle. Project-specific requirements (such as downhole pumps or materials needed for equipment decontamination) will be indicated on the equipment checklist and mobilized to the site.

All instrumentation that will be lowered into the borehole will be functionally checked and cleaned before use.

IV. CAUTIONS

The geophysical subcontractor will place generators and equipment boxes in visible locations where they are unlikely to be run over by vehicles or present a tripping hazard. Use proper lifting techniques to load and unload all equipment. Generators (fuel containing equipment) must only be placed on impervious surfaces or within secondary containment to prevent release of fuel/oil to ground.

[1] Appendix A to the Remedial Investigation Work Plan (O'Brien & Gere, 2013).

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with the site-specific HASP, a copy of which will be present on site during such activities. In particular, chemical-resistant gloves (or other protective clothing, as required by the HASP) will be worn when handling potentially contaminated wirelines and logging probes.

VI. PROCEDURE

General

Borehole logging instrumentation will be assembled consistent with the manufacturer's instructions. A tripod or pulley will be positioned over the borehole to be logged, to guide the logging probe into the borehole.

Geophysical Logging (to be performed by the geophysical subcontractor)

Geophysical logs to be run will consist of fluid temperature, fluid resistivity, caliper, natural gamma, single-point resistance, and acoustic televiewer. The desired logging probe will be attached to the cable head. The logging software will be initiated, and the correct probe driver selected.

The logging probe will be positioned so that either the probe top or cable head top is equal to the ground surface or casing top. The probe's preset depth will be calculated and entered into the data-acquisition software. The preset depth typically consists of the probe length provided by the manufacturer, minus the casing stickup height, plus the cable head length (if the cable head top is at the casing top).

A log data file will be opened, and data recording initiated after any necessary instrument-setting adjustments (most logs can be recorded with default probe-driver settings). If used, the acoustic televiewer recording window will be adjusted so as to ignore reflections that occur inside the televiewer probe (typical minimum recording time of approximately 80 microseconds).

Logging will be performed at a speed suitable for the data being recorded. Fluid temperature and fluid resistivity logs will be obtained in an undisturbed water column (to the extent possible) at a slow downward logging speed (typically less than 6 to 10 feet per minute). Caliper logs may be recorded at 10 to 15 feet per minute, while logging upwards. Polyprobe (logs that record more than one parameter at a time) or natural gamma logs may be recorded at speeds up to 15 feet per minute, while logging either upward or downward. Acoustic televiewer data will be recorded while logging upward or downward at speeds permitted by the data acquisition software (typically less than 4 to 5 feet per minute, depending upon the data-acquisition parameters).

The acoustic televiewer probe will be used only after less expensive logging probes (typically including at least a caliper log) have been lowered and raised through the borehole.

Video Logging (to be performed by Arcadis)

The video will be stored on a flash drive. The project name, date, and well identification will be recorded on the video image, either with an electronic title generator, or by using the downhole camera to record a handwritten placard that shows the pertinent information.

If the video camera is to be operated within a well that has a stickup above the ground surface (and if depths are to be referenced to ground surface), the casing stickup will be measured and temporarily indicated on the wireline with a piece of tape (or other nonpermanent means). This marker will be positioned by measuring up from the camera lens a distance equal to the casing stickup height. This depth adjustment is not needed if depths are to be measured below the top of casing.

The video logging instrumentation will be turned on after positioning the marker position at the casing top. The camera boom will be positioned so that the video cable spools smoothly over the depth measurement rollers (or encoder wheel, if used) and vertically downward into the borehole.

The video instrumentation's reference depth will be "zeroed", the video recorder turned on, and logging begun. The operator will lower the video camera as smoothly as possible while observing the image on a video monitor. Unusual features observed on the monitor and judged to be of interest to the client will be re-inspected, by raising the camera and re-lowering it to the desired depth.

The video wireline will be decontaminated with a non-phosphate detergent wash and tap water rinse while raising the camera upward out of the borehole. The camera will be decontaminated in the same manner.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

The logging cables and video wireline will be decontaminated with sponges soaked in a solution of phosphate-free detergent (e.g., Alconox) and a potable water rinse while raising each logging probe or camera upward out of the borehole. The probe and any accessories (centralizers, etc.) and video camera will be decontaminated using a detergent-solution wash and potable water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O'Brien & Gere 2013).

VIII. DATA RECORDING AND MANAGEMENT

Arcadis personnel will document the activities conducted by the geophysical subcontractor in a field notebook. Information will include personnel present on site, and times of arrival and departure. Video logs stored on flash drives will be backed up onto a separate medium as soon as practicable after logging is completed.

The geophysical subcontractor will maintain their own field notebook describing the wells or boreholes logged, the logging probes used, data file names, preset starting depths for each logging probe, or other field observations. Each field notebook will be labeled with the client's name, site name, job number, and dates of work.

The geophysical subcontractor will store all geophysical-log data-files on their field computer, and also copy them on-site onto another medium (thumb drive, CD-ROM, etc.) to assure redundant data storage.

IX. DATA ANALYSIS (TO BE PERFORMED BY THE GEOPHYSICAL SUBCONTRACTOR)

The geophysical subcontractor will present the results of their work in a report that describes the work performed, the collected data, and an analysis of the collected data.

Geophysical log data will be plotted using WellCAD or equivalent software. At a minimum, each log plot will be annotated with the client's name, project location, and well or borehole designation.

Log plot scales will be selected so as to present as much detail as possible. Wraparound of one or two times the log-display panel will be acceptable. If more than one or two wrap-arounds are needed to display both large and small inflections on the same log, then that log will be presented using two or more scales (on the same or different pages).

The logs will be edited for spurious data values (e.g. electric logs above the water table or within steel casing), and either annotated with key interpretations or discussed in the accompanying report text.

Any site-specific limitations of the geophysical log data will be noted on the log plot, or in the accompanying report text.

X. REFERENCES

O'Brien & Gere, Inc. 2013. *Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

O'Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

PACKER TESTING

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures for packer testing of bedrock boreholes at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York. The drilling subcontractor will supply, position, and remove the packer assembly at the direction of the Arcadis field geologist.

II. PERSONNEL QUALIFICATIONS

Packer testing will be directed and overseen by an experienced hydrogeologist with a minimum of four years field experience.

III. EQUIPMENT LIST

- Work Plan, Field Sampling & Analysis Plan (FSAP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- Decontamination equipment (e.g., brushes, non-phosphate detergent, potable water, etc.);
- Two electronic water level meters;
- Watches/stop watch;
- Packer assembly; and
- Field notebook.

IV. CAUTIONS

Make sure that the electronic water level meters are in good working condition and are properly calibrated such that readings can be taken to the nearest 0.01-foot. Water used for packer testing will be municipal potable water, with laboratory analysis of a representative sample for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), alcohols, and glycols in accordance with the same methods used for investigation samples.

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with the site-specific HASP, a copy of which will be present on site during such activities.

VI. PROCEDURE

Packer Assembly Setup

The packer testing will be conducted incrementally, after coring each 10-foot interval of the rock. After each interval is cored, the borehole will be flushed to remove rock cuttings, and a single inflatable rubber packer will be seated above the bottom 10 feet of borehole. A riser pipe will be attached to the top of the packer to provide a rigid, sealed standpipe. If the pipe contains joints, the driller shall use appropriate measures to ensure that the joints will not leak. Once the driller inflates the packer, sealing off the test interval, begin taking and recording water level measurements, using an electronic water level meter, in the portion of the borehole outside the standpipe (i.e., above the packer) for a period of five minutes. The measurement frequency will be no less than one reading per minute. If the rate of change in the water level exceeds 0.1 feet per minute at the end of the monitoring period, extend the monitoring period for up to 15 more minutes until the rate of change is less than 0.1 feet per minute. If the rate-of-change in the water level is still greater than 0.1 feet per minute after the 15-minute extension, change the measurement frequency to one reading per five minutes and contact the project hydrogeologist for guidance on when to start the falling-head test (described below).

These data will be used to assess the rate of water inflow or outflow from the portion of the borehole above the packer (i.e., above the interval to be tested).

Falling-Head Testing Procedures

Falling-head tests entail adding water to the test interval through the packer assembly standpipe and measuring the rate of decline of the water level. Two electronic water level meters will be used to record water level changes, one inside the standpipe to monitor changes in the water level of the test interval and the other in the borehole above the packer (outside of the standpipe) as an initial check on seal integrity.

Once the packer is in place and the interval has been sealed, fill the standpipe with potable water to a level of approximately two feet above the land surface and monitor the decline in the water level inside the standpipe, using an electronic water level meter, for a period of 15 minutes. Collect readings every 30 seconds for the first five minutes of the test and then every 1 to 5 minutes thereafter, at the discretion of the field hydrogeologist.

Water level measurements in the portion of the borehole outside the standpipe (i.e., above the packer) must also be monitored and recorded during the falling-head test. Collect these readings using a second electronic water level meter, approximately every minute for the first five minutes of the test and then every 1 to 5 minutes thereafter, at the discretion of the field hydrogeologist. These data are used to help assess packer seal integrity. NOTE: Do not try to use one water level meter to conduct measurements both inside and outside the standpipe.

A sustained rise in the water level outside the standpipe that cannot be attributed to the behavior of the water levels measured outside the standpipe during the 5-minute pre-test interval noted above (see “Packer Assembly Setup”), could indicate that the integrity of the seal is poor. In this case, stop the test and remove the packer assembly from the borehole, inspect it for leaks or damage, and repair any leaks identified. Regardless of whether or not leaks are detected/repaired, reinstall the packer assembly, isolating the same interval as before, and repeat the falling-head test, as described above. It is important to note that a water level rise above the packer-test interval is often not indicative of a bad packer seal, but rather may indicate a hydraulic connection between one-or-more fractures above the packer to one or more fractures below the packer (i.e., within the test interval). If the results of the second test are similar to the first test, the field hydrogeologist will determine whether to conduct further testing on the particular test interval in question or to deem the test complete. NOTE: If the rock interval at the packer depth is highly fractured, a proper seal may not be achieved. In this event, the field hydrogeologist may elect to test an alternate packer interval (greater or less than 10 feet) for which a good seal is possible.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

The packer assembly shall be cleaned with a high-pressure, hot water pressure-washing unit prior to its first use at each borehole. Water level meters will be washed between boreholes with potable water and a phosphate-free detergent and then rinsed with potable water followed by a distilled water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O'Brien & Gere, 2013).

VIII. DATA RECORDING AND MANAGEMENT

Packer-testing data and observations will be documented in a field notebook. Record time as military (24-hour) time. Record weather conditions at the time of the test, including the time(s) and duration(s) of rainfall events and their relative intensity.

IX. QUALITY ASSURANCE

Ensure that everyone taking manual water level measurements understands the units of measurement on the devices they will use and that all measurements are taken from a reference point (typically the rim of the packer assembly standpipe) that is established prior to starting the test.

X. REFERENCES

O'Brien & Gere, Inc. 2013. *Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

O'Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

NON-AQUEOUS PHASE LIQUID (NAPL) CONTINGENCY PLAN

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures related to drilling activities at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York. Based on groundwater analytical data collected during the Phase 1/1A Investigation, the potential exists that non-aqueous phase liquid (NAPL) may be present in the BDA subsurface. This plan provides procedures to:

1. Screen overburden and bedrock for NAPL during drilling;
2. Limit the potential to mobilize NAPL during drilling and sampling activities; and
3. Optimize the recovery of encountered NAPL (if any) in a safe and efficient manner.

II. PERSONNEL QUALIFICATIONS

NAPL contingency field activities will be performed using a drill rig operated by a New York State Registered Water Well Contractor, as directed by an experienced geologist with a minimum of four years field experience.

III. EQUIPMENT LIST

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Work Plan, Field Sampling & Analysis Plan (FSAP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- equipment specified under *Monitoring Well Installation* procedure;
- photoionization detector (PID), equipped with an 11.7 eV lamp;
- hydrophobic dye (Oil in Soil test kits);
- clean, empty jars for performing soil-water shake tests; and
- field notebook.

IV. CAUTIONS

Downward Mobilization

Dense NAPL (DNAPL) can migrate downward during drilling and well installation, or via the sand pack or screen of a monitoring well. The potential for light NAPL (LNAPL) to migrate downward exists at sites with strong downward hydraulic gradients or LNAPL layers perched in the vadose zone.

Other Considerations

The presence or absence of NAPL at a site can have significant implications in terms of site management, health and safety, and the feasibility of potential remedial alternatives. Therefore, field personnel must be attentive to the potential for NAPL, recognize when NAPL is encountered during drilling, and accurately document field observations indicating the presence of NAPL and interpreted NAPL depth.

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with the site-specific HASP, a copy of which will be present on site during such activities.

VI. PROCEDURE

NAPL Screening During Overburden Drilling

To screen for the potential presence of NAPL in soil, drilling procedures must allow for high-quality porous media samples to be taken. Soil samples should be taken continuously ahead of the auger or drill casing. Upon opening soil sample, the soil will immediately be evaluated for the presence of visible NAPL and screened for the presence of organic vapors using a portable PID with an 11.7 eV bulb. During screening, the soil will be placed in a sealed bag or jar and headspace measurements made. Such readings will be obtained along the entire length of the sample. If NAPL is immediately visible in the sample, its depth should be noted and the sampling team should skip to the fourth bullet below.

If the PID examination reveals the presence of organic vapors above 100 parts per million (ppm), the sample will undergo further detailed evaluation for visible NAPL. The assessment for NAPL will include a combination of the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sample – The NAPL sheen will be a colorful iridescent appearance on the soil sample. NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL. Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed with oils may appear brown.
- Soil-Water Shake Test – A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, jar containing an equal volume of potable or distilled water (40-mL vials are well suited to this purpose, but not required). After the soil settles into the water, the surface of the water will be evaluated for a visible sheen under natural light. The jar will be closed and gently shaken for approximately 10 to 20 seconds. Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam.
- Oil in Soil Test Kit – The Oil in Soil test kits will be used as per the manufacturer's instructions. The Oil in Soil test kits include a small quantity of Oil Red O, which will react with NAPL and change the small styrofoam indicator ball to a bright red color. Soil will be placed in the jar and the jar will be closed and gently shaken for approximately 10 to 20 seconds. The contents in the closed jar will be examined under natural light for visible bright red dyed liquid inside the jar.

Record the location of the NAPL within the jar (is it the NAPL floating on the water or at the base of the jar).

- Estimation of Relative Degree of NAPL Saturation – When NAPL is interpreted as present in a particular portion of soil, the field geologist should attempt to estimate the relative degree of NAPL saturation in the soil. Specifically, based on the apparent, visible continuity of NAPL within the soil, an interpretation should be made as to whether the observed NAPL is: apparently pooled (continuous interval of NAPL across entire diameter of soil sample in which the pore spaces are filled with a mixture of NAPL and water); apparently residual (isolated droplets of NAPL, surrounded by pore spaces containing only water); or inconclusive (unclear whether pooled or residual). If NAPL freely drains out of a soil sample, that indicates that the NAPL is in the form of a pool – however, pooled NAPL may not always freely drain out of soil samples.

The results of each test or observation will be recorded in the field notebook.

NAPL Screening during Bedrock Drilling and Packer Testing

To screen for the potential presence of NAPL in bedrock during drilling, return fluid[1] and core samples are monitored for the presence of sheens and organic vapors. Specifically, the return fluid will be screened with a PID and evaluated continuously for the presence of a sheen in the recirculation tub. Where core samples are obtained, they will be carefully evaluated for the presence of a sheen and/or stain on fracture surfaces and screened with a PID.

During packer testing, water pumped from the isolated test interval is monitored for the presence of sheens and organic vapors. Additionally, the packer assembly is similarly monitored as it is withdrawn from the borehole at the completion of a test.

If a sheen is observed with any of these methods, or if a PID reading greater than 100 ppm is measured, drilling will be temporarily discontinued and an evaluation will be undertaken to determine whether pooled NAPL is present. The drill stem will be retracted a minimum of three feet above the apparent depth where the sheen or PID reading was first encountered. Groundwater will be extracted from the borehole to produce a drawdown of approximately 5 feet below the approximate static water level for a period of 20 minutes to test for the presence of pooled, mobile DNAPL in the fractures surrounding the open borehole. The bottom of the borehole will then be evaluated for the presence of DNAPL using an interface probe or bottom-loading bailer. If no DNAPL is observed, the interpretation will be made that the sheen was not produced by pooled DNAPL and the vessel containing the water purged during pumping will be examined for the presence of LNAPL. If no measurable thickness of LNAPL is floating on the purge water, the interpretation will be made that the sheen was not produced by pooled LNAPL. In cases where no pooled NAPL is interpreted to be present, the recirculation water will be replaced by clean water and drilling will continue. Replacing the recirculation water reduces the potential for cross-contamination and facilitates observation of a newly created sheen, if any, at a deeper interval. Accumulation of DNAPL in the bottom of the borehole, however, indicates that the boring has encountered pooled DNAPL. If DNAPL has accumulated, it will be removed using

[1] "Return fluid" consists of the mixture of drilling fluid and drilling cuttings that is returned to the surface as bedrock is drilled.

a bottom-loading bailer or pump and the volume removed will be estimated and recorded in the field notebook.

Positive NAPL Determinations

If NAPL is positively identified, drilling will pause and the BMS Environment, Health and Safety (EHS) personnel and the Arcadis Project Manager will be notified immediately. The need for installing a temporary NAPL monitoring/collection well will be considered. If it is determined that such well is needed, it will be constructed as described in the *Monitoring Well Installation* procedure. If it is determined that such well is not needed, the borehole will be abandoned following the procedure contained in Section 5.4 of the FSAP.

NAPL Monitoring

New wells installed in borings where NAPL was encountered during drilling will be monitored for NAPL accumulation using an oil-water interface probe and bottom-loading bailer within approximately one day following installation. If NAPL is encountered, its thickness will be measured and recorded, a bottom-loading bailer or pump will be used to remove the NAPL, and the well will be checked for NAPL the following day. If accumulated NAPL is present on the following day, then a NAPL-recoverability plan will be prepared. The plan will lay out the approach to assessing NAPL recoverability, including data needs and objectives. At a minimum, in the case of DNAPL, efforts will be taken to prevent the level of accumulated DNAPL from overtopping the sump of any well where it accumulates.

Any NAPL recovered during drilling and monitoring activities will be analyzed for chemical composition, NAPL-water interfacial tension, density, and viscosity, provided that a sufficient volume (approximately 500 milliliters) can be collected. The physical tests will be performed at the approximate average groundwater temperature at the site. These parameters will allow for correlation of groundwater chemistry with suspected NAPL locations and will allow an estimate to be made of the volume and potential mobility of NAPL in the formation.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

Water level meters will be washed between boreholes with potable water and a phosphate-free detergent and then rinsed with potable water followed by a distilled water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O'Brien & Gere, 2013).

VIII. DATA RECORDING AND MANAGEMENT

Any occurrence of NAPL encountered during subsurface investigations will be documented in an appropriate field notebook, including the drilling location (boring or well identification), depth below surface, type of geologic material in which NAPL was observed, field screening and testing results, and apparent degree of NAPL saturation (pooled or residual), and visual characteristics of NAPL (e.g., color or qualitative viscosity). In addition, the volume of NAPL recovered at each well where it accumulates will be documented in the field notebook.

IX. REFERENCES

O'Brien & Gere, Inc. 2013. *Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

O'Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

MONITORING WELL INSTALLATION

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures to install overburden and bedrock monitoring wells at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York. The procedures contained herein are designed to produce standard groundwater monitoring wells suitable for: (1) groundwater sampling, (2) water level measurement, and (3) hydraulic conductivity testing.

Due to geologic conditions at the site, monitoring well boreholes advanced through unconsolidated (overburden) material will be drilled using rotasonic (sonic) methods. HQ-sized rock coring methods will be used to advance borings through consolidated material (bedrock) using a conventional drill rig.

II. PERSONNEL QUALIFICATIONS

Monitoring wells will be installed using a drill rig operated by a New York State Registered Water Well Contractor, as directed by an experienced geologist with a minimum of four years field experience.

III. EQUIPMENT LIST

The following materials will be available during drilling and monitoring well installation activities, as required:

- Site Plan with proposed well locations;
- Work Plan, Field Sampling & Analysis Plan (FSAP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, as necessary;
- appropriate soil sampling equipment;
- soil and bedrock logging equipment as specified in the FSAP, and the following procedures: *NAPL Contingency Plan* and *Collecting and Describing Bedrock Core Samples*;
- appropriate sample containers and labels;
- drum labels required for containing investigation-derived waste;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID), equipped with an 11.7 eV lamp;
- hydrophobic dye (Oil in Soil test kits);
- clean, empty jars for performing soil-water shake tests;

- zip-lock style bags;
- water level and oil/water interface meter;
- locks and keys for securing wells after installation;
- decontamination equipment as specified in the FSAP; and
- field notebook.

Prior to mobilizing to the site, contact the drilling subcontractor or in-house driller (as appropriate) and confirm that appropriate sampling and well installation equipment will be provided. Equipment provided by the driller specifically for the Phase 2 BDA work will include:

- a sonic drill rig to conduct overburden drilling;
- a conventional drill rig to conduct bedrock drilling;
- drill tooling, support equipment and pipe necessary to complete all overburden and bedrock drilling activities;
- packer-testing equipment;
- drums for containing investigation-derived waste;
- drilling and sampling equipment decontamination materials;
- decontamination pad materials and steam cleaner;
- permanent 4-inch steel pipe; and
- stainless steel well construction materials.

IV. CAUTIONS

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be cleared by BMS Facility personnel. An excavation permit will be filled out for each drilling location followed by a detailed review of existing utility drawings provided by BMS.

If non-aqueous phase liquid (NAPL) is known or expected to exist at a drilling location, refer to the *NAPL Contingency Plan* for additional details regarding drilling and well installation to reduce the potential for inadvertent NAPL mobilization.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be municipal potable water, with laboratory analysis of a representative sample for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), alcohols, and glycols in accordance with the same methods used for investigation samples. Avoid using any other drilling fluids or materials that could impact groundwater quality.

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with the site-specific HASP, a copy of which will be present on site during such activities.

VI. PROCEDURE

The procedures for installing groundwater monitoring wells are presented below:

Sonic and Bedrock Coring Drilling Methods

1. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
2. Advance boring to desired depth. Overburden drilling will be completed using sonic drilling methods which produce large diameter soil cores. Bedrock drilling will be completed by coring with a HQ-sized core barrel using a conventional drill rig. Use of this core barrel requires no subsequent reaming of the bedrock core hole prior to well installation. Collect soil and bedrock samples at appropriate interval as specified in the Work Plan and FSAP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan, FSAP, and *Collecting and Describing Bedrock Core Samples* procedure. Decontaminate equipment between samples in accordance with the Work Plan and FSAP.
3. Describe each soil sample as outlined in the FSAP and each bedrock sample as outlined in the *Collecting and Describing Bedrock Core Samples* procedure. Record descriptions and document all drilling events in the field notebook during drilling, including times, sample recoveries, PID readings, and the rate of penetration (minutes per foot) during bedrock drilling.
4. When installing a bedrock monitoring well, boreholes will be drilled through the overburden and approximately 3 feet into competent bedrock using sonic drilling methods. A larger diameter (7- or 8-inch) override casing will then be advanced to facilitate installation of a 4-inch permanent steel casing to the bottom of the rock socket. The annulus surrounding the casing will then be filled with grout to within two feet of the ground surface using the tremie method. The grout will be allowed to set for a minimum of 24 hours prior to drilling deeper through the casing. After the grout sets, advance the borehole by bedrock coring using a conventional drill rig through the permanent casing to the targeted bottom depth of the boring. Drilling will be completed using an HQ-sized core barrel.
5. Upon completing the borehole to the desired depth, install the monitoring well by lowering the screen and casing assembly through the sonic casing (overburden wells) or permanent steel casing (bedrock wells). Monitoring wells will be constructed of 2-inch-diameter, No. 304 flush-threaded stainless steel riser pipe and 0.010-inch spacing wire-wrap well screens. Morie #0 or equivalent sand packs will be placed along the screened interval of each well to a height of approximately 2 feet above the top of the screen. A 2-foot thick bentonite seal will be placed above the sand pack. If the seal is installed above the water table, it will be manually hydrated using potable water. Monitor the placement of the sand pack and bentonite with a weighted tape measure. The remainder of the annular space will be filled with cement-bentonite grout from the bottom up (using a tremie pipe) to within approximately 2 feet of ground surface. Drill tooling will

be extracted from the borehole as the sand, bentonite and grout are delivered to the annulus of the overburden well.

6. If NAPL is identified at a given borehole and it is determined that a temporary NAPL monitoring well will be installed, additional well construction measures will be implemented. If light NAPL (LNAPL) is identified, the well will be screened across the water table and the screened interval will be selected such that the top of the screen is at least two feet above the water table. If dense NAPL (DNAPL) is identified, the well will be fitted with a 2-foot long stainless steel sump below the screen. The annulus surrounding the sump will be filled with cement-bentonite grout and a formation packer (also known as a “shale trap”) will be attached to the outside of the well at the top of the sump. The shale trap, in combination with the grout, will serve to seal the annular space between the sump and the borehole and direct DNAPL into the well.
7. Place a locking, steel protective casing (extending at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 6-inches in all directions from the protective casing, and should slope gently away to promote drainage away from the well. Label monitoring wells with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.

   When an above-grade completion is used, the riser casing will be sealed using an expandable locking plug and the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug. Also, the top of the well will be the exposed thread. When a flush-mount installation is used, the riser pipe will be sealed using an unvented, expandable locking plug.
8. Place a permanent mark on top of the inner casing to identify the reference point from which all water-level and well-depth measurements will be made.
9. During well installation, record construction details and actual measurements relayed by the drilling contractor, as well as the approximate quantity of materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook.
10. After completing the well installation, lock the well, and clean the area.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with subsurface materials will be cleaned in accordance with the procedures outlined in the FSAP.

Water level meters will be washed between boreholes with potable water and a phosphate-free detergent and then rinsed with potable water followed by a distilled water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O’Brien & Gere, 2013).

VIII. DATA RECORDING AND MANAGEMENT

Document drilling activities in a field notebook. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, document the locations of newly installed wells photographically or in a site sketch. If appropriate, use a measuring wheel or engineer’s tape to determine approximate distances between important site features.

IX. REFERENCES

O’Brien & Gere, Inc. 2013. *Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138*. March 2013.

O’Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

HYDRAULIC CONDUCTIVITY TESTING

Site #C734138
BMS Syracuse North Campus Restoration Area
East Syracuse, New York

August 2016

I. SCOPE AND APPLICATION

This document identifies procedures for hydraulic conductivity testing of monitoring wells at the Bristol-Myers Squibb Company (BMS) Syracuse North Campus Restoration Area (New York State Department of Environmental Conservation [NYSDEC] Brownfield Development Area [BDA] Site #C734138) located at 6000 Thompson Road in East Syracuse, New York.

Two test methods are covered in this document: the low flow drawdown method and the slug test method. The low flow drawdown method is compatible with the methodology that will be used to sample the new wells; however, certain conditions must be met (as described in Section VI, below). As such, the time drawdown data collected during the initial sampling of each well will be used to estimate the hydraulic conductivity of the formation surrounding the well screen. If the appropriate conditions are not met, the well will be tested using the slug test method.

II. PERSONNEL QUALIFICATIONS

Hydraulic conductivity testing will be performed by field staff with at least two years of experience that includes conducting low flow sampling and slug testing. Staff will have a demonstrated familiarity with electronic measurement equipment, and in cases where a pressure transducer is used, data logging equipment.

III. EQUIPMENT LIST

General (required for all methods):

- Work Plan, Field Sampling & Analysis Plan (FSAP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- Electronic water level meter;
- Well-construction data for each well to be tested;
- Graduated beaker or similar device to measure water volumes;
- Timing device (e.g., stop watch);
- Decontamination equipment and supplies;
- Measuring tape; and
- Field notebook.

For Low Flow Drawdown Method:

- Appropriate sampling pump and associated discharge tubing.

For Slug Test Method:

- Clean rope/twine (chemical resistant, low stretch is optimal);
- Spring-loaded clamps or zip-ties;

- Solid slug(s) of known volume (for solid slug tests);
- Bailers of known size and capacity (for bail down tests);
- Vented pressure transducer (pressure range of 35 feet/11 meters/15 psi) and associated software (optional for slowly recovering wells)[1];
- Laptop computer or other suitable data-transfer device (with appropriate software) and a backup device (e.g., flash drive) if a pressure transducer is used; and
- Slug test log form (optional; but recommended).

IV. CAUTIONS

1. All down-well equipment must be cleaned prior to use in accordance with the procedures outlined in the FSAP.
2. A pressure transducer can be used to measure and record water level data when conducting tests according to the slug test method. If a pressure transducer is used, allow sufficient time (approximately 5 minutes) for the transducer to equilibrate with the groundwater temperature to avoid instrument drift. Also, be certain not to exceed the maximum depth rating of the transducer.
3. Note that both the low flow drawdown test and the slug test methods require that the water level in the test well at the start of the test is representative of the “static” hydraulic head at the well (i.e., it has not been perturbed by pumping or displacement caused by submerging equipment such as a pump).

V. HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with the site-specific HASP, a copy of which will be present on site during such activities.

VI. PROCEDURE

Low Flow Drawdown Method

Low flow drawdown tests consist of two steps: a pumping step and a recovery step. Do not use a pressure transducer to monitor water levels for the low flow drawdown method.

1. Prior to installing pumping apparatus, measure and record the depth to water in the well from the measuring point marked on the well casing and the time of the reading. If no measuring point is noted on the well casing, establish one. All measurements must be taken from the established measuring point.
2. Install pumping apparatus. Re-measure and record the depth to water in the well and the time of the reading. Once the water level in the well is within approximately 0.2 feet of the original

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1 Note: a non-vented transducer can be used, provided that a second transducer (referred to herein as a “barologger”) is used to measure atmospheric pressure. The atmospheric data are used to compensate the water level data collected by the non-vented transducer for barometric pressure.

measurement recorded under #1, above, begin pumping a low flow rate (500 milliliters per minute [ml/min] or less). Record flow rate and start time.

3. Follow the low flow sampling methods described in the FSAP. Recording accurate water levels and flow rates is important. As a general guide: measure and record water levels every 30 seconds for the first five minutes of the test, every minute for the next 10 minutes of the test, and then every five minutes thereafter.
4. Periodically measure the flow rate using a graduated beaker and adjust the rate, as needed to maintain a constant flow rate, or, if needed, to keep drawdown to within the limits prescribed in the FSAP, to the extent practicable. For each flow rate modification, record the new flow rate and the time that the adjustment was made in the field notebook.
5. This step of the test is completed when a steady head is reached and maintained for approximately 15 minutes, and at least 0.2 feet of drawdown are induced in the well at the time that sampling is completed. If, in the judgement of the project hydrogeologist, these conditions are not met, then the well will be retested using the slug test method. If these conditions are judged to have been met, then proceed with the recovery step of the test.
6. To conduct the recovery step of the test, turn off the pump and monitor the recovery of the water level in the well at the frequencies described under #3, above. Record recovery data for approximately 15 minutes or until the water level recovers to within 90% of its original (pre-pumping) level, in the event that this occurs in less than 15 minutes.

Slug Test Method

In general, slug tests can be conducted using either of two methods: solid slug and bail-down. Solid slug tests involve submerging a solid slug in the water column of the well, inducing an “instantaneous” rise in the water level in the well. The subsequent decline in the water level over time is monitored and recorded. If the slug is left in the well until the water level returns to its pre-test level, the slug can be removed, inducing an “instantaneous” decline in the water level in the well, and the subsequent rise in the water level over time is monitored and recorded. If the water level in the well is within the screened interval prior to testing, a solid slug test is not appropriate and a bail-down test will be conducted.

In a bail-down test, a bailer is used to remove a volume of water (slug) from a well in a near-instantaneous manner. The subsequent rise in the water level over time is monitored and recorded.

The procedures for conducting solid slug and bail-down tests are detailed in the attached Method Procedures Sheets.

VII. EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

Water level meters will be washed between boreholes with potable water and a phosphate-free detergent and then rinsed with potable water followed by a distilled water rinse.

Investigation-derived wastes will be managed as prescribed in the Remedial Investigation Work Plan (O’Brien & Gere, 2013).

VIII. DATA RECORDING AND MANAGEMENT

Record all collected data and relevant observations in a field notebook. When conducting tests according to the slug test method, data can be recorded on the attached Slug Test Log. In cases where a pressure transducer and data logger are used to acquire electronic data, save the data to the laptop computer (or other suitable data-transfer device) and to a separate storage medium (e.g., flash drive) as a backup. Use caution not to overwrite any previously recorded files.

IX. QUALITY CONTROL AND QUALITY ASSURANCE

1. Clean all down-well equipment prior to use in accordance with the procedures outlined in the FSAP.
2. Ensure that water level meters are in good working condition, calibrated to true depth, and that there are no breaks or splices in the cable.
3. When conducting slug tests, compare the theoretical head displacement (calculated from the slug volume) to the observed displacement. If the data are questionable, check field equipment to confirm proper working order and consult with the project hydrogeologist for guidance.

X. REFERENCES

Aragon-Jose, AT, and GA Robbins. 2011. Low-Flow Hydraulic Conductivity Tests at Wells that Cross the Water Table. Ground Water 49.3: 426-431.

Butler, JJ, Jr. 1998. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, New York, 252p.

O'Brien and Gere, Inc. 2013. Remedial Investigation Work Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. Appendix A – Field Sampling and Analysis Plan. Prepared for Bristol-Meyers Squibb Corporation.

Robbins, GA, AT Aragon-Jose, A. Romero. 2009. Determining Hydraulic Conductivity Using Pumping Data from Low Flow Sampling. Ground Water 47.2: 271.

Method Procedure Sheets

I. SOLID SLUG – Scope and Application

The use of a solid slug allows for both falling- and rising-head slug tests to be completed. Solid slug(s) of a known volume are inserted and removed from the water column in a well in a near-instantaneous manner. The water level response is observed using a data-logging pressure transducer or by using a manual water level meter for slowly recovering wells. Solid slug, rising-head tests are not to be used in wells where the initial water level is in the screened portion of the well.

II. Procedure

1. Measure depth to water and well depth. Determine the water column length.
2. Compare the measured well depth to its installed depth. If a discrepancy of greater than one foot exists, consult the project hydrogeologist for guidance.
3. If using a pressure transducer, program it to record water levels at the following suggested frequencies:
   a. In hydrologic settings where high hydraulic conductivity is expected, measure water levels at 0.5-second intervals, or the highest frequency available.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1 to 2 second intervals.
4. If using a non-vented transducer, program the barologger to record barometric pressure. Deploy the barologger at a location where it can measure atmospheric pressure (e.g. at or near grade, adjacent to the well being tested).
5. Install the pressure transducer deep enough within the water column so that it will not interfere with the testing equipment. Ideally the transducer should be 5- to 10-feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Take care not to contact the well bottom as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
6. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water level measurements.
7. Measure the slug and rope assembly length and mark the rope at a length as follows:

   Rope Mark #1 = Depth to Potentiometric Surface from TOC

   Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Slug + Safety Factor (Safety Factor = 10% of the Length of Slug)

   When deployed, Rope Mark #2 will be at the well top of casing, and the slug will be totally submerged. If insufficient water column is available to cover the slug assembly top, note the theoretical length of the slug to be inserted into the water column. Upon removal, measure the wet slug length.
8. Slowly insert the slug assembly into the well and stop just above the potentiometric surface (Rope Mark #1).

9. If using a pressure transducer, begin data collection.
10. Quickly drop the slug into the water column, placing the Rope Mark #2 at the top of casing. Clamp or zip-tie the rope to a static object to keep the slug stationary.
11. If using a pressure transducer, observe the water level response on the laptop computer while periodically collecting manual depth-to-water measurements, being careful not to interfere with the pressure transducer cable (two to three in the first minute, one reading a minute for the next five to ten minutes, and every two-to-five minutes thereafter). If the water level meter is used as the primary measurement device, the measurement frequency should be increased as practicable (e.g., every 15 seconds for the first two minutes, every 30 seconds for the next seven minutes, and every 2 to 5 minutes thereafter).
12. The test is completed when the water level in the well recovers to within 80% of its initial, pre-test level, or in the case of slowly recovering wells, when the test length reaches one hour.

    NOTE: A duplicate test can be conducted at this point, provided that the water level has recovered to at least 95% of its initial, pre-test level, by quickly removing the slug from the water column and collecting water level measurements at the same frequencies as used prior. If using a pressure transducer, the slug assembly should be left in the well above the static water level in order to limit disturbance of the pressure-transducer cable. Such duplicate tests are recommended.
13. Review the data collected to determine the reasonableness of the preliminary results. If a pressure transducer is used, this includes comparing compare the pressure transducer readings to the hand measurements collected using the water level meter. If apparently anomalous results are noted, contact the project hydrogeologist for guidance before conducting additional tests at the well in question or leaving the site.

I. BAIL-DOWN – Scope and Application

A bailer is used to remove a volume of water (slug) in a near-instantaneous manner to perform rising-head tests. The water level response is measured automatically using a pressure transducer or manually using a water level meter. The manual method is best for slowly recovering wells.

II. Procedure

1. Select a bailer according to a target initial displacement using the table below. A general guideline is that initial displacements are between 1 and 3 feet, but should depend on the anticipated response (i.e. larger initial displacements should be chosen for formations anticipated to have high hydraulic conductivity, smaller initial displacements can be used for formations anticipated to have low hydraulic conductivity).

Bailer Volume (gal)	Bailer Volume (mL)	Casing Diameter (in)	Theoretical Initial Displacement (ft)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

Notes:
gal = gallons, U.S. liquid
mL = milliliters
in = inches
ft = feet

2. Measure depth to water and well total depth. Determine the water column length.
3. Compare the measured well depth to its installed depth. If a discrepancy of greater than one foot exists, consult the project hydrogeologist for guidance.
4. If using a pressure transducer, program it to record water levels at the following suggested frequencies:
   a. In hydrologic settings where high hydraulic conductivity is expected, measure water levels at 0.5-second intervals, or the highest frequency available.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1 to 2 second intervals.
5. If using a non-vented transducer, program the barologger to record barometric pressure. Deploy the barologger at a location where it can measure atmospheric pressure (e.g. at or near grade, adjacent to the well being tested).
6. Install the pressure transducer deep enough within the water column so that it will not interfere with the testing equipment. Ideally the transducer should be 5- to 10-feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Take care not

to contact the well bottom as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.

7. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water level measurements.
8. Measure the bailer and rope assembly length and mark the rope at a length as follows:

   Rope Mark #1 = Depth to Potentiometric Surface from TOC

   Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Bailer + Safety Factor (Safety Factor = 10% of the Length of Slug)

   When deployed, Rope Mark #2 will ensure that the bailer is fully submerged.
9. Slowly insert the bailer into the well and stop just above the potentiometric surface Rope Mark #1.
10. With slack in the rope and the bailer being suspended above the water column, lower the bailer and place the Rope Mark #2 at the top of casing. Clamp the non-bailer end of the rope to a static object to keep in place.
11. Wait for water level to equilibrate using response from the computer (or data transfer device) connected to the transducer, or using a water level meter if a transducer is not being used.
12. If using a pressure transducer, begin data collection.
13. Quickly remove the bailer from the water column and carefully raise it to surface. Pour the removed water into an empty bucket.
14. If using a pressure transducer, observe the water level response on the laptop computer while periodically collecting manual depth-to-water measurements, being careful not to interfere with the pressure transducer cable (two to three in the first minute, one reading a minute for the next five to ten minutes, and every two-to-five minutes thereafter). If the water level meter is used as the primary measurement device, immediately lower the probe into the well after removing the bailer and begin collecting water level measurements. Use the following measurement frequency, as practicable: every 15 seconds for the first two minutes, every 30 seconds for the next seven minutes, and every 2 to 5 minutes thereafter.
15. The test is completed when the water level in the well recovers to within 80% of its initial, pre-test level, or in the case of slowly recovering wells, when the test length reaches one hour.

    NOTE: A duplicate test is recommended. If desired, the next test should be performed only after the water level from the first test has recovered to greater than 95% of its original (pre-test) depth.
16. Measure and record the volume of water removed by the bailer that was poured into the empty bucket using a graduated beaker.
17. Review the data collected to determine the reasonableness of the preliminary results. If a pressure transducer is used, this includes comparing compare the pressure transducer readings to the hand measurements collected using the water level meter. If apparently anomalous results are noted, contact the project hydrogeologist for guidance before conducting additional tests at the well in question or leaving the site.

Slug Test Field Logs

SLUG TEST LOG

Site Name: ______________________ Project No: ______________ Page: ____ of ______

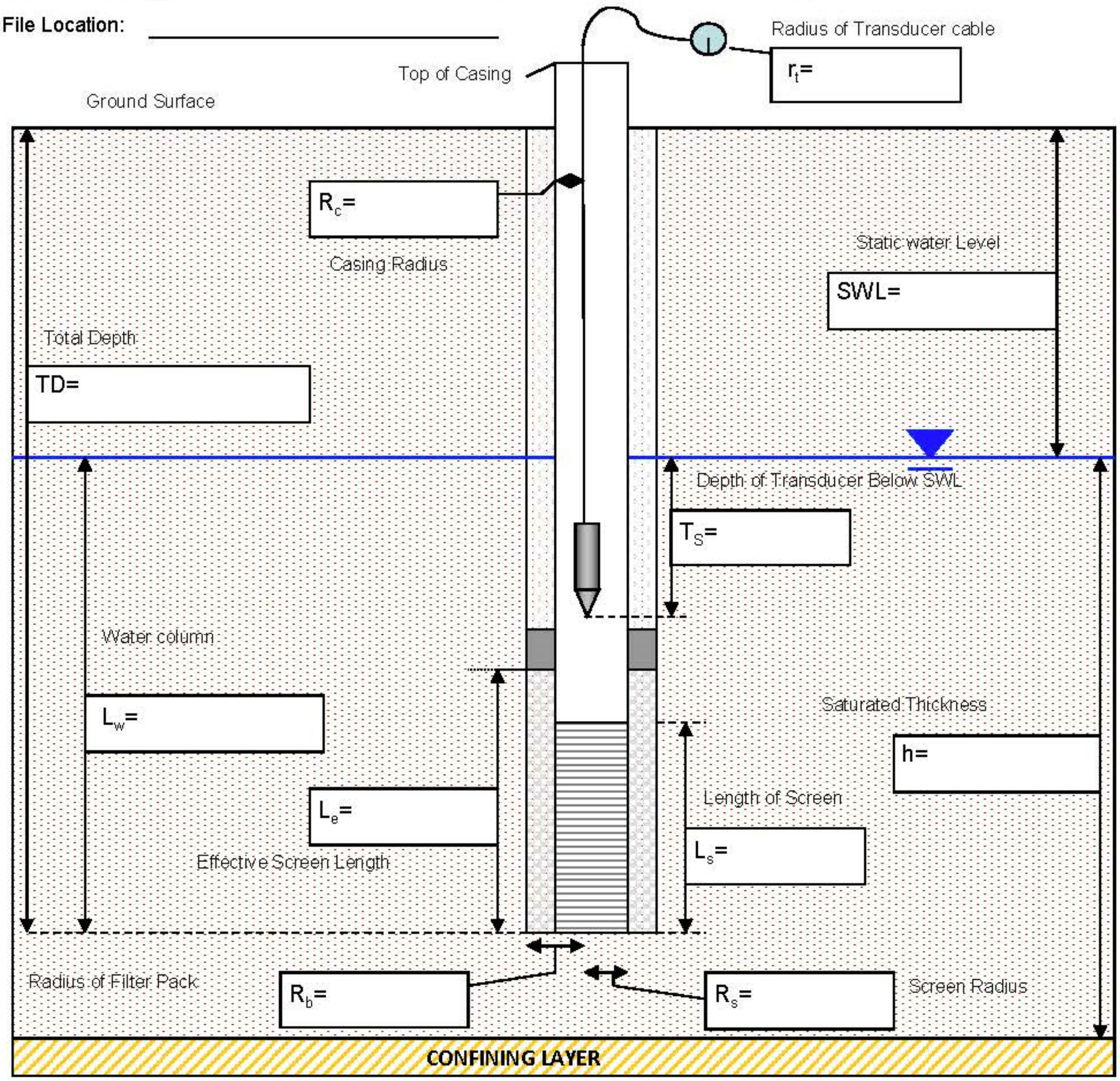
Test Well ID: ______________ Observation Well ID (if different): ____________________ Date: __________

Completed By: ______________________________ Weather: ______________________________

Test Type & No: Rising __________ Falling __________ Pressure Transducer SN: ______________

Data File Name(s): ______________ Barologger Serial No (if used): ______________

File Location: ______________________



WELL PARAMETERS REQUIRED FOR CALCULATING HYDRAULIC CONDUCTIVITY:

L_e = Effective screen length, including the sand pack
L_s = True screen length
L_w = Length of water column in Well (TD-SWL)
R_s = Screen radius
R_b = Radius of filter Pack or borehole
R_c = Casing radius
r_t = Radius of the transducer cable (can be ignored if less than 1/8 inch)

T_s = Depth the transducer is submerged below the SWL
SWL = Static water level
TD = Total depth of well/screen from reference point
h = Saturated thickness of aquifer
H_o = Initial head change at instant the slug test is started.
Aquifer Type = Confined or unconfined

COMMON CONVERSIONS:

1 foot = 12 inches
1 foot^3 ≈ 7.48 gallons
1 gallon ≈ 3.785 Liters
1 psi ≈ 2.3 feet of water

SLUG TEST DATA

Test Number: ______ Test Duration: ______

Start Test Time: ______ End Time: ______

Rising / Falling (circle) Slug Volume: ______

SWL Time / Depth (ft) ______

T_s Baseline Depth & Pressure: ______

Max. Displacement (H_0) : ______

Test Number: ______ Test Duration: ______

Start Test Time: ______ End Time: ______

Rising / Falling (circle) Slug Volume: ______

SWL Time / Depth (ft) ______

T_s Baseline Depth & Pressure: ______

Max. Displacement (H_0) : ______

Manual Depth to Water Measurements:

Time	Depth to Water (ft)	Time	Depth to Water (ft)

NOTES:

THEORETICAL HEAD CHANGE

Slug Volume (gallon)	Slug Volume (ml)	Well Casing Diameter (inches)	Theoretical Initial Displacement (feet)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

$$Displacement = \frac{Slug\ Volume}{Casing\ Area}$$

$$Slug\ Volume_{(cylinder)} = h\pi r^2$$

$$Casing\ Area = \pi r^2$$

Note: formulas based on consistent units

h = height (length)

r = radius (½ diameter)

$\pi \approx 3.1416$