PRE-DESIGN INVESTIGATION REPORT
For
VESTAL WATER SUPPLY WELL 1-1 SUPERFUND SITE
PRE-DESIGN INVESTIGATION, OPERABLE UNIT 2 (OU2) SOIL REMEDIATION

Contract No. W912DQ-15-D-3016
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ACRONYMS

1,1-DCA	1,1-dichloroethane
1,2,4-TMB	1,2,4-Trimethylbenzene
1,3,5-TMB	1,3,5-Trimethylbenzene
ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
cis-1,2-DCE	cis-1,2-dichloroethene
CLP	Contract Laboratory Program
cm/sec	centimeters per second
COC	Contaminants of Concern
CSM	Conceptual Site Model
DESA	Division of Environmental Science and Assessment
DNAPL	Dense Non-Aqueous Phase Liquid
DUR	Data Usability Report
EPA	United States Environmental Protection Agency
ERH	Electrical Resistance Heating
ERT	Environmental Response Team
EVS	Environmental Visualization System
ft/day	Foot/day
gpm	Gallons Per Minute
HDR	Henningson, Durham and Richardson Architecture and Engineering, P.C., in association with HDR Engineering, Inc.
HPT/EC	Hydraulic Profiling Tool/ Electrical Conductivity
IDW	Investigation-Derived Waste
ISTR	In Situ Thermal Remediation
kg	Kilogram
LCS	Laboratory Control Spike
LCSD	Laboratory Control Spike Duplicate
LNAPL	Light Non-Aqueous Phase Liquid
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAPL	Non-Aqueous Phase Liquid
NTU	Nephelometric Turbidity Units
NPL	National Priorities List
NYSDEC	New York State Department of Environmental Conservation
OU	Operable Unit
PCB	Polychlorinated Biphenyls
PDI	Pre-Design Investigation
PID	Photoionization Detector
PVC	Polyvinylchloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QL	Quantitation Limit
RAS	Routine Analytical Service
RCRA	Resource Conservation and Recovery Act
REAC	Response, Engineering & Analytical Contract
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	Relative Percent Difference

RSO	Remedy System Optimization
SQL	Sample Quantitation Limit
SRIP	Stage Road Industrial Park
SVE	Soil Vapor Extraction
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TCL	Target Compound List
TCH	Thermal Conductive Heating
UFP	Uniform Federal Policy
USACE	United States Army Corps of Engineers
µg/kg	Micrograms per kilogram
µg/l	Micrograms per liter
VOC	Volatile Organic Compound

1 Introduction

The Henningson, Durham and Richardson Architecture and Engineering, P.C. (HDR) and O'Brien & Gere (OBG) Joint Venture (HDR OBG JV) completed a Pre-Design Investigation (PDI) for the United States Army Corps of Engineers Kansas City District (USACE KC) to support Remedial Design (RD) activities for Operable Unit 2 (OU2) soil remediation at the Vestal Water Supply Well Superfund Site (Site) in Vestal, New York (Figure 1-1). The Site is located south of the Susquehanna River, approximately 10 miles west of Binghamton, New York.

The Site is 5.5 acres located at 200 Stage Road. A 60,000 square foot building at the Site was used to manufacture transformers and later, electronic circuit boards. The circuit board manufacturing operations ceased in May 2002. From 2007 through 2013, the building was used to recycle electronic equipment. Currently, a portion of the building is being used for auto body repair.

In 1979, a chemical release occurred from an underground storage tank at the IBM Endicott facility, located on the north side of the Susquehanna River (approximately one mile north of the Site). In response to the spill, all drinking water supply wells in the area were tested for synthetic organic chemicals. Water samples from Vestal Well 1-1 were found to contain high concentrations of chlorinated volatile organic compounds (VOCs). However, subsequent investigations determined that the presence of VOCs in Well 1-1 was not related to the IBM. Vestal Well 1-1 was added to the National Priorities List (NPL) on September 8, 1983.

A remedial investigation/feasibility study (RI/FS) conducted by the New York State Department of Environmental Conservation (NYSDEC) in 1985-1986 focused on the VOC groundwater contamination in the Vestal Well 1-1 area. The contaminants of concern (COCs) were primarily VOCs including 1,1,1-trichloroethane (TCA), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and 1,1-dichloroethane (1,1-DCA). This RI/FS showed the source of VOC contamination in groundwater was located in the Stage Road Industrial Park (SRIP).

A supplemental RI/FS conducted by the U.S. Environmental Protection Agency (EPA) in 1988-1989 confirmed the VOC contamination originated from the SRIP. The supplemental RI/FS also showed that releases of VOCs had occurred in several potential source areas, identified as Areas 1 through 4 (Figure 1-2). The four areas include:

- Area1- the part of the Vestal Asphalt property adjacent to Route 17;
- Area 2- the truck parking area between 200 Stage Road and the Erie Lackawanna railroad tracks;
- Area 3- the area of 200 Stage Road between the north side of the Chenango Industries building and an existing drainage ditch; and
- Area 4- the area of 200 Stage Road between the south side of the Chenango Industries building and the Erie Lackawanna railroad tracks.

Soil and Groundwater contamination is addressed in two operable units, or OUs (EPA, 2013). Operable Unit 1 (OU1) involved groundwater extraction (using Well 1-1A) and treatment (via air stripping), which has been in operation since 1993. In 2014, NYSDEC performed a remedy system optimization (RSO) of the OU1 groundwater remedy which determined the treatment system was effective in treating contaminated groundwater down to maximum contaminant levels (MCLs). The RSO also showed VOC concentrations within the aquifer remain constant indicating the presence of a continuing source.

To address contaminated soil in Areas 2 and 4, the USACE provided project oversight for the EPA and its contractor during the construction and operation of two separate in situ soil vapor extraction (SVE) systems. Remediation of contaminated soil in Area 2 was completed in November 2000. An SVE system was installed in Area 4, with system start-up in June 2003. EPA conducted soil and groundwater sampling in Area 4 to evaluate the cleanup progress in November 2005. Soil sampling results showed very high levels of VOCs still remained at two locations beneath a parking lot just south of the Site building. To continue cleanup of the Site, EPA determined that supplemental remedial action would be required since the SVE system could not remove VOCs from the fine-grained soils or from the saturated zone. The Area 4 SVE system was shut down in January 2006 after removing approximately 2,300 pounds of VOCs from the subsurface. Area 3 has been sub-divided into Area 3 and Area 3b and Area 4 has been sub-divided into Area 4-1, 4-2, and 4-2b as shown on Figure 1-3.

Follow-up Site investigations by EPA Environmental Response Team (ERT) and Lockheed Martin Response, Engineering & Analytical Contract (REAC) personnel delineated the horizontal and vertical extents of the two sources and showed that the contamination extended beneath the building. A third source containing VOCs (TCA and TCE) and polychlorinated biphenyls (PCBs) was discovered on the northeast side of the building. The VOCs appeared to have originated from a different source as further investigation within this area identified the presence of residual non-aqueous phase liquid (NAPL) containing 1,2,4-Trimethylbenzene (1,2,4-TMB) and 1,3,5-Trimethylbenzene (1,3,5-TMB) above the water table.

1.1 Preliminary Conceptual Site Model

EPA/ERT prepared a Conceptual Site Model (CSM) for the Site in 2015. The CSM report summarized key points of the CSM as follows:

- In 1980, Vestal Water Supply Well 1-1 was closed because the groundwater was found to be contaminated with several VOCs, including TCA and TCE. The source of the contaminants was eventually traced back to the Site.
- The horizontal and vertical extents of two source areas (in a parking lot and just south of a building) were delineated at the Site. The horizontal extent of contamination was found to extend beneath the building. The primary contaminants within these areas included TCA and TCE.

- A third source, containing a different suite of VOCs, was also delineated on the northeast side of the building. Contaminants unique to this area include 1,2,4-TMB and 1,3,5-TMB, which suggest an origin from a different source as compared to the two areas on the south side of the building. Floating free-phase Light Non-Aqueous Phase Liquid (LNAPL) has also been observed in two monitoring wells within this area (ERT-1S and MW-F).
- The shallow unconsolidated deposits at the Site include fill material and alluvial deposits (having low hydraulic conductivities) down to an average depth of 19 feet. Occasional interbedded sand lenses occur within the alluvial deposits. Glaciofluvial sand and gravel deposits (with higher hydraulic conductivities) occur beneath the alluvial deposits, having an average thickness of 18.5 feet beneath the Site.
- Average groundwater depths at the Site range from approximately 13 to 15 feet. Groundwater generally flows in a west/northwest direction across the Site (toward Vestal Well 1-1 and Well 1-1A).
- Past releases or spills at the Site have resulted in contamination of the shallow deposits and groundwater. At the source areas, the vertical extent of contamination within the subsurface deposits is limited to 25 feet below ground surface (bgs). Groundwater contamination has been detected in on-Site monitor wells at depths up to 69 feet. Observed groundwater heads and derived vertical gradients indicate vertical migration of dissolved contaminants from the shallow deposits into deeper strata (i.e., glacial till and weathered bedrock).
- Soil analytical results from previous subsurface sampling investigations indicate the primary COCs at the Site are TCA, TCE, cis-1,2-DCE, 1,2,4-TMB and 1,3,5-TMB.
- NAPL occurs on the northeast side of the building and appears to be restricted to a relatively small area that encompasses wells ERT-1S and MW-F. Nearby wells that surround the impacted wells do not contain LNAPL, which suggests minimal or very limited NAPL migration.
- TCA and TCE were apparently released into the low hydraulic conductivity alluvial deposits.
- TCA and TCE (including degradation compounds) have migrated from the fill/fine sand and silt alluvium into the underlying glaciofluvial sand and gravel creating a groundwater contaminant plume that extends toward Vestal Wells 1-1 and 1-1A, consistent with the groundwater flow direction.
- Based on detailed spatial evaluations of the contaminant data, estimates were made regarding the impacted volumes of subsurface deposits and total masses of TCA, TCE, and 1,2,4-TMB at the Site. The data indicate that TCA has the greatest total mass (estimated at 1,404 kg).

EPA issued an Amendment to the OU2 Record of Decision (ROD) in September 2016. The major components of the amended OU2 remedy, to be supported by a PDI, include In Situ Thermal Remediation (ISTR) of approximately 28,000 cubic yards of soils in the fill and alluvial silt and clay deposits contaminated with VOCs in Area 3, 4-1, and Area 4-

2 and the excavation and off-Site disposal of approximately 730 cubic yards of soils contaminated with PCBs from Area 3.

1.2 Scope of Work

The primary objectives of the PDI are to horizontally and vertically delineate the extent of contamination in the designated Areas 3, 4-1, and 4-2, and to obtain hydraulic, lithologic, groundwater quality and groundwater elevation data necessary to complete the RD. The PDI was completed in two phases. The following field tasks were conducted during the Phase I PDI:

- Well inventory and assessment;
- Geophysical utility markouts;
- Soil delineation boring and laboratory analysis;
- Hydraulic Profiling Tool/Electrical Conductivity Borings (HPT/EC);
- Geotechnical borings and laboratory testing;
- Monitoring well sampling and analysis;
- Well installation and development;
- Slug-type permeability testing;
- Aquifer pump test; and
- Well/boring location and topographic surveys.

A draft PDI Report was prepared summarizing the horizontal and vertical extent of contamination in the designated Areas 3, 4-1, and 4-2. The results showed the horizontal and vertical delineation was not complete in Area 4-2 and Area 4-2B. A Phase II PDI was completed to further delineate impacts in Area 4-2 and Area 4-2B.

- The following field tasks were conducted during the Phase II PDI: Geophysical utility mark outs;
- Soil delineation boring and laboratory analysis;

1.3 Report Organization

This PDI report is organized into seven sections:

Section 1 – Introduction includes a general Site description and information on Site history and previous investigations.

Section 2 – Methods and Procedures presents the methods and procedures used to conduct the investigation and collect the data presented in this report.

Section 3 – Geology and Hydrogeology presents the geology and hydrogeology of the area and site.

Section 4 – Investigation Results describes the results of this PDI.

Section 5 – Revised Conceptual Site Model presents a revised CSM.

Section 6 - Conclusions discusses the conclusions of this PDI.

Section 7 – References lists the reference documents used in preparation of this report.

2 Methods and Procedures

The Phase I PDI field program was completed between January 24, 2018 and April 5, 2018. The Phase II PDI field program was completed between February 25 and March 1, 2019. Each of the activities listed in Section 1.2 are described in greater detail below.

2.1 3D Visualization Model

HDR OBG JV prepared a computer-based three dimensional (3-D) visualization model of the geology and primary COCs (e.g., TCE, TCA, cis-1,2-DCE, 1,2,4-TMB, 1,3,5-TMB, and PCBs) detected in the three source areas (Area 3, Area 4-1, and Area 4-2) using historical Site geologic and soil COC data available before conducting the PDI. The model incorporated depth of the water table and the primary geologic strata including fill/fine sand and silt alluvium, glaciofluvial sand and gravel, glacial till (till), and shale and siltstone bedrock. The 3-D model was developed using the Environmental Visualization System (EVS) software, an industry standard tool commonly used for 3-D volumetric modeling, analysis, and visualization.

The 3-D model was initially developed during planning stages of the PDI using the existing historical data. The preliminary model was then used to identify data gaps in the existing data set and to finalize soil delineation boring locations and sample depths planned for the PDI. Monitoring well screen depths and soil boring sample depths, relevant surficial features, and relevant Site features are also incorporated into the 3-D model.

The initial 3-D geologic model was developed using stratigraphic data from 187 borings at the site with an aerial photo overlay. The model extent is defined by the extent of the Vestal Site as depicted in the CSM. The four-layer geologic model, consisting of fill/fine sand and silt alluvium, glaciofluvial sand and gravel, till, and shale and siltstone bedrock to a vertical depth of 69 feet below surface (756 ft msl), was compared with Figure 7 of the CSM Report and the top of glaciofluvial sand and gravel surface in the model was compared with that same surface presented in Figure 9 of the CSM Report for consistency (CSM figures have not been reproduced for this report).

The initial 3-D chemical model was developed using soil analytical results from approximately 500 samples. The data was interpolated with a kriging algorithm to map the plume distribution for 1,1,1-TCA, TCE, cis-1,2-DCE, 1,3,5-TMB, 1,2,4-TMB, and PCBs. Portions of the 3D model were compared to similar figures of VOC distribution in the CSM Report to confirm consistency with previous work.

A rasterized image of the shallow groundwater surface was also imported into the model, and geospatial data for the proposed 126 soil boring and sample locations depths were presented within the model domain for evaluation and optimization prior to implementing the PDI field work.

Following the PDI field investigation, the 3D model was updated to include the additional data collected from the soil delineation borings during the Phase I and Phase II PDI to provide a more complete visualization of source area geology and COC distribution.

2.2 Well Inventory and Assessment

A well inventory and assessment survey was performed on January 24, 2018 to locate and evaluate the condition of existing wells. The survey included an inspection of the surface completion of each well to determine if they were secure and whether any damage was evident. The presence of total organic vapors was monitored with a photoionization detector (PID) and the depth to groundwater and total depth was measured in each well. EPA Region 2 Superfund Well Assessment Checklists were completed for each of the wells. Monitoring wells included in the well inventory and assessment survey are shown on Figure 2-1.

2.3 Geophysical Utility Markouts

Geophysical surveys were performed by Advanced Geological Services on February 27, 28, April 4, 2018 (Phase I PDI) , and February 25, 2019 (Phase II PDI) to determine if utilities are located at each boring/well location and to identify the presence of subsurface utilities in each of the areas. The survey was performed using a combination of ground penetrating radar, radio frequency, and metal detection methods. The subcontractor cleared each of the proposed boring and well locations along with a five-foot diameter around each proposed location. The locations and paths of subsurface utilities were physically marked on the site property, and a report was prepared with a scaled map depicting the locations of subsurface utilities at the site.

2.4 Soil Delineation Boring and Laboratory Analysis

HDR OBG JV, and our drilling subcontractor Parratt-Wolff, Inc. of East Syracuse, New York (Parratt-Wolff) drilled 20 soil delineation borings (19 borings plus 1 contingency boring) between March 6 and March 17, 2018 during the Phase I PDI and seven borings between February 25 and March 1, 2019 during the Phase II PDI at the locations shown on Figure 2-2. Five borings were located in Area 4-1, nine borings were located in Area 4-2, nine borings were located in Area 4-2B, and four borings were located in Area 3. Only one of the two originally proposed contingency borings was drilled. The elimination of boring CB-205 was documented in a Field Change Request 1 (Appendix A). The selection of final boring locations was based on the 3-D model and evaluation of historical site data.

The 27 borings were hand-cleared to a depth of 5 feet bgs and advanced from 5 feet to a total depth of 35 feet by direct push methods. One location, boring PSB-207, required the use of a limited-access rig and was only drilled to a depth of 19.5 feet, equivalent to the thickness of the fill/fine sand and silt alluvium, because of limited capabilities of the smaller rig. The borings were sampled continuously from 5 feet to their total depth with 2-inch diameter, 4-foot long macro-core samplers.

Soil samples were logged for relative grain size distribution, visual evidence of contamination and odors, and were field-screened with a PID by an onsite HDR OBG JV geologist. Eight samples were collected from 24 of the 27 borings using En Core® Samplers. Only 7 samples were collected from ABS-7 and four samples were collected from PSB-207 because samples could not be recovered from the glaciofluvial sand and gravel. Nine samples were collected from ASB-3. The samples were selected to represent each 4-foot depth interval of the boring. Within each interval, samples were biased toward the highest levels of contamination based on field screening results.

Samples were analyzed for EPA Target Compound List (TCL) VOC by EPA Contract Laboratory Program [CLP] method SOM02.4. Quality Assurance/Quality Control (QA/QC) samples were collected as described in the Uniform Federal Policy (UFP) Quality Assurance Project Plan (QAPP). Soil samples were analyzed at Shealy Laboratories during the Phase I and Phase II PDI, through the EPA contract laboratory program. Soil cuttings were drummed and staged in the staging area and disposed as described in Section 2.13.

2.5 HPT/EC Borings

Hydraulic Profiling Tool/Electrical Conductivity (HPT/EC) logging was performed from March 13 to March 15, 2018 at ten locations to characterize the vertical distribution of hydraulic conductivity in the study area. HPT/EC boring locations are provided on Figure 2-2. Each location was hand-cleared to a depth of 5 feet below the ground surface. HPT/EC logging was performed from 5 feet to 52 feet bgs.

Logging was performed by Parratt-Wolff, using a direct push rig and a Geoprobe® HPT System. Logging was performed in accordance with Geoprobe's Standard Operating Procedure Technical Bulletin No. MK3137 (January 2015).

2.6 Geotechnical Borings

Two geotechnical soil borings (GEO-001 and GEO-02B) were completed from March 19 to March 21, 2018 using hollow-stem auger drilling methods. GEO-001 was advanced in Area 3 northeast of the building and GEO-002B was advanced in Area 4-2, south of the building and Area 4-2B. The locations of the geotechnical borings are shown on Figure 2-2. The first 5 feet of each boring was hand cleared and continuous split-spoon samples were collected by standard penetration test methods (ASTM D1586) from 5 to 35 feet bgs. An HDR OBG JV geologist recorded blow counts for each 6-inch advance of the sampler and visually described each split-spoon sample in a field book.

Undisturbed samples were collected from two depth intervals at each boring location using thin-walled Shelby Tubes in accordance with ASTM D1587 methods. One sample of the fill/fine sand and silt alluvium and one sample of the underlying glaciofluvial sand and gravel were collected at each location.

Samples were also collected at depths of 10 to 12 feet, 30 to 32 feet and 32 to 35 feet in boring GEO-001 and 10 to 12 feet, 12 to 14 feet, 20 to 22 feet and 24 to 25.5 feet from boring GEO-002B for geotechnical tests that required undisturbed samples. Bulk samples were also collected from depths of 5 to 22 feet and 22 to 35 feet in boring GEO-001 and 5 to 18 feet and 18 to 36 feet in boring GEO-002B for tests that did not require undisturbed samples.

The following ASTM test methods were performed on each of the four sample intervals by Advance Testing Company, Inc. located in Campbell Hall, New York:

- electrical resistivity by ASTM G187-12a;
- moisture content by ASTM D2216;
- soil density by ASTM D7263;
- grain size by sieve analysis using ASTM D6913 and hydrometer analysis using ASTM D7928;
- Atterberg limits by ASTM D4318;
- unconfined compressive strength by ASTM D2166; and
- vertical hydraulic conductivity (triaxial permeability) by ASTM D5084.

Tests for electrical resistivity, soil density, unconfined compressive strength and triaxial permeability were performed on undisturbed samples

2.7 Well Installation

HDR OBG JV’s drilling subcontractor Parratt-Wolff, Inc. drilled, installed and developed one new pumping well (PW-1) and four new observation wells (OW-1, 2, 3 and 4) for the aquifer test from March 19, 2018 to March 27, 2018 (Figure 2-1). The pumping well was installed by standard mud rotary methods using an organic polymer-based drilling mud (Revert ®). The observation wells were installed using hollow-stem auger drilling methods.

The observation wells were developed by air lift methods for a period of approximately 2 hours each. The estimated development rate was between 1 and 2 gallons per minute (gpm), which equates to approximately 30 well volumes. Temperature, pH, specific conductivity, and turbidity were also monitored until the parameters stabilized (i.e. 10 percent change between four consecutive readings). The target turbidity was less than 50 nephelometric turbidity units (NTUs).

The pumping well was developed over a 13.5-hour period using a combination of air lift and pump and surge methods. An initial dose of chlorine solution was added to the well and the well was left idle overnight to breakdown the Revert®. The following day, development was performed using airlift methods for a period of 7 hours, at an approximate rate of 1-2 gpm. After initial development was complete, a second dose of chlorine solution was added and the well was left idle over the weekend. The following Monday, the well was developed for a period of 6.5 hours using pump and surge methods.

Soil cuttings and drilling fluids were drummed and staged in the onsite staging area. Development water was transferred to 20,000 gallon fractionation tanks located in the staging area. Drums and bulk aqueous waste from well installation and development activities were characterized, transported and disposed of at an off-Site disposal facility by the JV's Investigation-Derived Waste (IDW) subcontractor ACV Environmental as described in Section 2.13.

2.8 Groundwater Level Measurements

HDR OBG JV measured two rounds of water levels, one during the well condition survey on January 24, 2018, and one prior to groundwater sampling on March 29, 2018. Groundwater levels were measured from all accessible onsite monitoring wells during the well condition survey and from the five newly installed wells and the 25 existing onsite monitoring wells during the groundwater sampling event. New wells included pumping well PW-1 and observation wells OW-1, OW-2, OW-3 and OW-4. Existing wells included ERT-1S/I/D, ERT-2S/I/D, ERT-3S/I/D, ERT-4S/I/D, ERT-5, ERT-6, ERT-7, ERT-8, MW-A, MW-B, MW-C, MW-D, MW-E, MW-F, MW-G, MW-H, and MW-I. Well locations are shown on Figure 2-1.

Groundwater levels were measured over six hours during the well condition survey and over one hour before the groundwater sampling event. Water levels were measured by removing the well cap, monitoring headspace with a PID, and lowering an electronic water level measuring device into the well until the audible alarm sounded. An interface probe was used to measure depth to product and depth to groundwater levels in wells in Area 3 where LNAPL was observed. The depth to groundwater measurements were made to the nearest 0.01 foot from the top of the well casing.

2.9 Monitoring Well Sampling

Groundwater samples were collected from six existing monitoring wells on March 29 and 30, 2018. The groundwater in two wells, one shallow and one intermediate depth, were sampled from Areas 3, 4-1, and 4-2. Groundwater samples were collected from ERT-1S and ERT-1I in Area 3, ERT-3S and ERT-3I in Area 4-2, and ERT-4S and ERT-4I in Area 4-1 (Figure 2-1). Trip/field/equipment blanks and duplicate samples were collected/prepared for groundwater samples in accordance with Worksheet #20 of the QAPP.

Intermediate depth wells were purged and sampled using EPA Region II Low-Flow Groundwater Sampling Protocol. The sample collection method for shallow wells was modified to a no-purge, grab sampling procedure because of the limited volume and slow recharge of water in the wells. The modified method was documented and approved in Field Change Request Number 2 and used a peristaltic pump to collect the no-purge samples. Although there was a limited volume of water in the wells, the well produced a sufficient volume for the lab to perform analyses for all of the target parameters. The Field Change Request form is presented in Appendix A.

A further modification was needed to collect the samples from ERT-1S because of the layer of LNAPL on top of the water column. The peristaltic pump was operated in reverse while lowering the tubing through the LNAPL layer to prevent the liquid from entering the tubing. The pump was then operated in standard mode to collect samples from the underlying layer of groundwater. The volume of water in ERT-1S was sufficient to fill containers for all of the target parameters. The sampling method for ERT-1S was approved in a Field Change Request Number 3 (Appendix A)

Groundwater samples were analyzed for VOCs, 1,4-dioxane, PCBs (Aroclors), metals, and wet chemistry parameters at EPA's Division of Environmental Science and Assessment (DESA) laboratory in Edison, New Jersey as per the QAPP. Purge water was drummed and staged in the staging area. Drums of purge water were characterized, transported and disposed of at an off-Site disposal facility by the JV's IDW subcontractor ACV Environmental as described in Section 2-13.

2.10 Slug Tests

Slug tests were performed on six existing wells (MW-G, ERT-1I, ERT-1D, ERT-2I, ERT-4I and ERT-4D) and two new wells (OW-2 and OW-4) from March 16, 2018 to April 3, 2018. Three wells are located in Area 3, two wells are located in area 4-1, and three wells are located in area 4-2 (Figure 2-1). The original shallow well in Area 3, ERT-1S, was replaced by MW-G because there was a layer of NAPL in ERT-1S. One additional shallow well (ERT-4S) was not tested because there was not a sufficient water column in the well to perform the test.

Pneumatic tests were performed on wells that were completed in highly conductive strata, including ERT-1D, ERT-2I, ERT-4I, ERT-4D, OW-2 and OW-4. Pneumatic tests were performed using a well head assembly to pressurize the well test zone and hydraulic head pressure transducers were used to monitor the change in hydraulic head during the test. The hydraulic head in the test zone was instantaneously increased or decreased by adjusting the pressure in the line to perform rising and falling head tests and the return to initial head conditions was monitored with the pressure transducer. Recovery measurements were made until groundwater levels were at least 90 percent of the original value. Nitrogen was used to inflate the packers and change the line pressure.

A conventional test was performed on shallow well MW-G because it is screened across the water table and a pneumatic test assembly could not effectively pressurize the test zone. A conventional test was also performed at ERT-1I because it was completed in a low conductivity interval in the underlying glaciofluvial sand and gravel and there was a potential that the pneumatic test seal could not be sufficiently maintained throughout the long recovery time. Conventional tests were performed by inserting and removing a solid slug into the well to effect an instantaneous change in the hydraulic head. Only the rising head test was performed on well MW-G because the water level was within the screened section of the well. Under these conditions, increasing the head in the well to perform a falling head test results in water entering the unsaturated zone, which is inconsistent with the underlying assumptions of the test method. The use of conventional slug tests and limiting testing to rising head tests for wells completed at the water table was approved in Field Change Request Number 4, presented in Appendix A.

2.11 Aquifer Pump Test

HDR OBG JV, with the support of our drilling subcontractor Parratt Wolff, Inc., performed an aquifer pump test to characterize the transmissivity and other hydraulic properties of the glaciofluvial aquifer. The aquifer test consisted of a preliminary period of background groundwater level monitoring, a step-drawdown test to establish the pumping rate for the aquifer test, and a constant-rate aquifer pump test consisting of drawdown and recovery phases. Groundwater levels were monitored with pressure transducers with data logging capabilities and barometric pressure was recorded with a barometric transducer during all phases of the test.

Parratt Wolff, Inc. installed a 4-inch submersible pump in the sump just below the screened section of the pumping well. The pump was fitted with a shroud to promote cooling of the motor, and a check valve to prevent backflow during the recovery phase of the test. Instantaneous and totalizing flow meters were installed at the wellhead to measure flow rate and a sufficient length of tubing was attached to the riser pipe to transfer the groundwater directly into fractionation tanks placed in the staging area.

Background water level data were collected at OW-2 prior to the step-drawdown and constant rate aquifer pump tests (March 23, 2018 through March 26, 2018). Data from this antecedent monitoring period were downloaded and reviewed before proceeding with the pumping phases of the aquifer test. To provide additional background monitoring following the completion of the constant rate aquifer pump test, automated data logging pressure transducers were installed in monitoring wells ERT-2S, ERT-4I, and OW-1 from March 29, 2018 through April 3, 2018.

A step-drawdown test was performed on March 27, 2018 to provide information to select the pumping rate for the drawdown phase of the aquifer test. The test was planned to be conducted at four successive 60-minute steps at rates of 5 gpm, 7.5 gpm, 9 gpm and 16 gpm, based on estimates of potential well yield from well development. However, the final step could not be completed due to excessive drawdown experienced 40 minutes into the step.

The drawdown phase of the test was performed from 8:00 AM on March 28, 2018 to roughly 12:00 AM on March 29, 2018. Observation wells OW-1, OW-2, OW-3, and OW-4 were monitored during the test. These wells are located at distances of 30.5 feet, 15.7 feet, 16.0 feet and 33.6 feet. Drawdown measurements in the pumping well were made manually with an electronic water level recorder.

Recovery measurements were made over a 16-hour period in observation wells OW-1, OW-2, OW-3 and OW-4 using pressure transducers. Recovery measurements were made in the pumping well manually with an electronic water level recorder for a period of approximately 35 minutes, at which point the well had recovered to 95 percent of its original water level.

The discharge water from the aquifer pump test was stored in fractionation and characterized, transported and disposed of at an off-Site disposal facility by ACV Environmental as described in Section 2.13.

2.12 Surveying

GEOD Corporation, a New York-licensed surveying subcontractor, performed a well and boring location survey on March 29 and 30, 2018 and a baseline topographic survey on April 2 through April 5, 2018. Horizontal locations were provided in North American Datum (1983), New York State Plane Central 3102, and elevations were provided based on North American Vertical Datum (1988). The baseline survey included property boundaries, buildings and other structures, utilities, ground surface topography at a contour interval of 1 foot and the location of ISTR delineation borings, HPT borings, geotechnical borings, and newly installed and existing wells.

2.13 Management of Investigation-Derived Waste Material

ACV Enviro Corporation (ACV) managed and disposed of all IDW for the Vestal PDI in accordance with local and Federal regulations. ACV provided 43 55-gallon steel drums and four 20,000 gallon fractionation tanks to store soil cuttings, drilling fluids and groundwater. ACV set up a fenced in staging area and secondary containment for the drums and fractionation tanks. Solid and liquid waste material was temporarily stored in the containment area. Four samples of solid waste and two samples of liquid waste were collected by ACV and analyzed by Fairway Laboratories in Altoona, Pennsylvania for:

Solids
VOCs by EPA Method 8260
SVOCs by EPA Method 8270
PCBs by EPA Method 8082
Inorganics (metals) by EPA Method 6010B
Ignitability (flashpoint) by EPA Method 1010
pH (corrosivity) by EPA Method 150.1
DRO by EPA Method 8015B
GRO by EPA Method 8015B
Paint Filter by EPA Method 9095B

TCLP
TCLP VOCs by EPA Method 1311/8260B
TCLP SVOCs by EPA Method 1311/8270C
TCLP metals by EPA Method 1311/6010B
TCLP mercury by EPA Method 1311/7470/7471
TCLP Herbicides by EPA Method 1311/8151A
TCLP Pesticides by EPA Method 1311/8081

Aqueous
VOCs by EPA Method 8260

SVOCs by EPA Method 8270
PCBs by EPA Method 8082
Inorganics (metals) by EPA Method 6010B
Ignitability (flashpoint) by EPA Method 1010
pH (corrosivity) by EPA Method 150.1
DRO by EPA Method 8015B
GRO by EPA Method 8015B

The results show all of the IDW was non-hazardous. The waste was transported to an EPA-approved facility for disposal as described in Section 4.14.

3 Geology and Hydrogeology

3.1 Regional Geology

The town of Vestal is situated in a low-lying, relatively flat area of the Susquehanna River Valley. Vestal is bordered to the east, south and west by moderately rolling, hilly terrain. Elevations range from approximately 810 feet above mean sea level (AMSL), along the Susquehanna River, to approximately 1,831 feet AMSL, south of Vestal.

Vestal is located within the glaciated Appalachian Plateau Physiographic province (Coon, et al., 1998; Wolcott and Coon, 2001). The general landscape developed when an ice sheet encroached on the area during the last stage of continental glaciation, which ended some 10,000 to 15,000 years ago at the end of the Pleistocene Epoch. Glacial erosion in the Vestal area widened the Susquehanna River Valley and rounded the mountains to the east to form the large rolling hills characteristic of the region today. The retreat of the glaciers resulted in the deposition of various types of glacial sediments. Glacial deposits in the area can be subdivided into three types: glacial till, glaciofluvial, and glaciolacustrine deposits. Glacial till was deposited beneath the glacier from material scoured by the ice sheet as it advanced. Glacial till is very poorly sorted and ranges in size from clay to large boulders. Till deposits overlie most of the bedrock within the glacial valleys and lower foot-hills. Glaciofluvial deposits were formed by meltwater streams and are predominantly comprised of sand and gravel. Most of the valley-fill material beneath the Susquehanna River floodplain consists of glaciofluvial sediments. These deposits have high permeability and porosity, and comprise the primary aquifer within the Vestal area.

Glaciolacustrine deposition occurred in ponded water and small lakes that formed near the glacial meltwater streams. Glaciolacustrine sediments characteristically occur as fine sand, silt, and clay, and are generally (though not always) found above the till. Thin, laminated layers, representing seasonal changes in deposition, often occur within these sediments. Glaciolacustrine deposits in the Susquehanna River Valley are overlain by post-glacial alluvium which was deposited as over-bank deposits during river flood stages. These deposits occur as approximately 15 to 20 feet of silt to fine sand that may include organic-rich layers, which commonly overlie or are interbedded with five to 15 feet of sandy-pebble to cobble-gravel. The upper unit may limit infiltration from floods and heavy rain. The lower unit can be highly permeable and may facilitate infiltration to deeper units.

Bedrock underlying till in the area consists primarily of Devonian shale and siltstone that dip approximately 0.5 degrees to the southwest.

3.2 Regional Hydrogeology

Glaciofluvial and post-glacial alluvial deposits, which comprise the major aquifer in the Vestal area, are composed predominantly of highly permeable sands and gravels, with only moderate amounts of silt and clay. These deposits typically provide very high well yields. Glaciolacustrine deposits in the river floodplain and terrace areas consist primarily of low permeability clays and silty clays and are not a viable source of groundwater. However, small quantities of groundwater can be found in localized lenses of sand and gravel (Wolcott and Coon, 2001).

Glacial till, which underlies the glaciolacustrine and glaciofluvial deposits, consists of low permeability silt and clay, with some sand and gravel. This unit acts as a barrier to infiltration along valley walls and hillsides. Siltstone and shale, which underlie the glacial till, have a low permeability and effective porosity. The small amount of available water within these bedrock formations is of little economic value.

Natural recharge to the aquifer within the study area occurs through percolation of precipitation where sand and gravel strata exist on the land surface, and via infiltration from the Susquehanna River and adjoining tributaries. The largest source of recharge is precipitation that directly infiltrates the valley-fill aquifer system. Precipitation in the Susquehanna River valley averages 36 inches per year, of which 21 to 24 inches per year reaches the water table (Wolcott and Coon, 2001). Natural infiltration from tributary streams and rivers that cross the valley floor, and induced infiltration from streams and rivers near production wells, each provide nearly as much recharge as precipitation. However, the amount of natural and induced infiltration from streams and rivers varies locally and occurs only where the head in the underlying aquifer is lower than the stage in the stream or river. Induced infiltration is greatest near supply wells that are both close to and hydraulically connected to the streams and rivers (Wolcott and Coon, 2001).

Only a small percentage of the precipitation infiltrates along the hills to the south due to the low permeability of the surficial till. The surface runoff flows down slope, on or immediately below the land surface until it reaches the valley, where it then seeps into the surficial deposits. The small amount of precipitation that infiltrates bedrock on the hills flows toward the valley where it recharges the glacial aquifer. Recharge decreases during the warmer months of the year due to increased evapotranspiration.

Groundwater discharges from the unconsolidated aquifer to 1) municipal and industrial supply wells, 2) the Susquehanna River, (3) tributary streams that cross the valley floor, and 4) the atmosphere through groundwater evapotranspiration (Wolcott and Coon, 2001). Pumping constitutes by far the largest discharge from the aquifer system. Under non-pumping conditions, the largest discharge would be seepage from the aquifer to the Susquehanna River. Pumping alters the groundwater flow patterns and decreases the discharge of groundwater to rivers and streams. Tributary streams that cross the valley floor generally recharge the aquifer system along their courses. Exceptions occur where they enter the Susquehanna River and where the head in the aquifer is higher than the stream or river stage (resulting in the discharge of groundwater from the aquifer to the streams and rivers). Groundwater evapotranspiration is seasonally variable and may be substantial in areas with a shallow water table. Evapotranspiration in the study area averages about 12 to 15 inches per year (Wolcott and Coon, 2001).

The direction of groundwater flow in the principal aquifers along the Susquehanna River prior to large scale pumping was toward the Susquehanna River or its tributaries. Pumping in the area has changed the natural flow directions in many of the valley aquifers used for public and private water supply (Wolcott and Coon, 2001).

3.3 Site Geology and Hydrogeology

A number of distinct stratigraphic units are known to occur beneath the Site and surrounding areas based on examination of records and drilling logs from previous investigations. The individual units are briefly described below:

Fill/Fine Sand and Silt Alluvium: Primarily silt and clay with occasional inter-bedded lenses of sand and infrequent gravel. Surficial silty "fill" material occurs from approximately 0 to 5 feet bgs in most areas of the Site. The average thickness of this layer, as depicted in the cross section, is approximately 19 feet. The horizontal hydraulic conductivity of these unconfined deposits ranges from approximately 0.04 to 1.4 feet per day based on slug tests in on-Site wells, literature values, and Emergency Response Team/Scientific, Engineering, Response & Analytical Services (ERT/SERAS) groundwater modeling results (Lockheed Martin/SERAS, 2014b).

Glaciofluvial Sand & Gravel Deposits: As the name denotes, a mixture comprised of sand and gravel. The average thickness beneath the Site is approximately 18.5 feet. The horizontal hydraulic conductivity of these semi-confined deposits ranges from approximately 120 to 380 feet per day based on slug test results, literature values (Yager, 1993; Wolcott and Coon, 2001), and ERT/SERAS groundwater modeling. Groundwater velocities within this layer have been estimated to range from approximately 5 to 15 feet per day.

Glacial Till: An un-stratified mixture of sand, silt, clay, and gravel. The average horizontal hydraulic conductivity of this layer is estimated to be less than 1-foot per day based on ERT/SERAS groundwater modeling.

Bedrock: Shale and siltstone. The upper 10 to 15 feet of bedrock is highly weathered and broken. Fractures and bedding planes form a small part of the unweathered rock volume and provide the only significant void spaces in which water can be stored and transmitted. The horizontal hydraulic conductivity of this upper, leaky-confined layer is estimated to range from less than 1 foot per day to approximately 3 feet per day (based on literature values and ERT/SERAS groundwater modeling).

4 Investigation Results

4.1.1 Data Usability

The data for the PDI sampling event fulfilled the site-specific QA/QC requirements, as all of the results were determined to be usable. Therefore, the results are acceptable for use to support Site decisions. An evaluation of data precision, accuracy, representativeness, comparability, completeness, sensitivity and blank contamination is provided below. The Data Usability Reports are provided in Appendix C.

Precision

Precision is the measurement of agreement in repeated tests of the same or identical samples, under prescribed conditions. Precision data indicate how consistent and reproducible the field sampling or analytical procedures have been. For the Site data, precision was determined through replicate measurements of the same or identical samples, i.e., field duplicate samples.

One groundwater field duplicate and seven soil field duplicates were collected and analyzed. The acceptance criterion for the duplicate is a relative percent difference (RPD) of less than 50 percent for all analytes in soil and groundwater. The RPD was not calculated for any set of sample pairs where concentrations were not detected in both of the data sets; agreement between the original sample and the duplicate can be inferred when both of the results are non-detects.

All of the sample pairs that contained detections in both of the data sets were within the RPD limits prescribed with the exception of TCE (108.9%) and carbon disulfide (105.9%) in the groundwater duplicate sample for ERT-4I and 2-hexanone (58.8%) in the duplicate sample for ASB-3 20-25 feet. Considering the overall number of duplicate pairs evaluated and that only three were greater than 50 percent, the results indicate the sampling program achieved overall good reproducibility.

Accuracy

Accuracy is the degree of agreement of a measured sample result or average of results with an accepted reference or true value. It is the quantitative measurement of the bias of a system, and is expressed in terms of percent recovery. Accuracy of the data can be determined through the use of surrogate compounds, internal standard compounds, matrix spike samples, and laboratory control spike samples. Laboratory Control Samples/Laboratory Control Sample Duplicates (LCS/LCSDs), surrogate recoveries, and matrix spike/matrix spike duplicates (MS/MSDs) were all within QC limits except as noted above. Based on the information provided and available results, the laboratories achieved a good degree of accuracy.

Representativeness

Representativeness is the degree to which the results of the analyses accurately and precisely represent a characteristic of a population, a process condition, or an environmental condition. In this case, representativeness is the degree to which the data reflect the contaminants present and their concentration magnitudes in the sampled site areas. Representativeness of data occurs through the selection of appropriate sampling locations and the implementation of approved sampling procedures. The sampling locations for the PDI were as defined in the UFP QAPP, and field personnel followed the procedures outlined in the UFP QAPP (HDR OBG JV, 2018).

Comparability

To increase the degree of comparability between data results and between past, present and future sampling events, standard environmental analytical methods were employed by the off-site laboratories. Routine Analytical Service (RAS) sample analyses available through Division of Environmental Science and Assessment (DESA) and the EPA CLP were utilized for the organics and inorganics analyses as specified in the Scope of Work (SOW). Modified analyses (MAs) were prepared by the CLP laboratory to accommodate project-specific Contract-Required Quantitation Limits (CRQLs) and additional analytes required.

Completeness

Completeness is determined by the percentage of samples that meet or exceed all of the criteria objective levels (i.e., the number of usable sample results for the data set). All of the sample results were determined to be usable.

Sensitivity

Sensitivity is the ability of the analytical method or instrument to detect a target analyte at the level of interest. The method detection limit (MDL) is a statistically-derived value that represents a 99 percent confidence level that the reported instrument signal is different from a blank sample. The quantitation limit (QL) is the minimum concentration of an analyte that can be routinely identified by the laboratory, and is generally between three and ten times the MDL. Analytical methods are matrix-, moisture- and dilution-dependent. The sample quantitation limit (SQL) actually determined for a constituent for a specific sample may be higher than the QL due to these issues. The laboratory was able to achieve the CRQLs, where applicable, for each analyte requested with the exception of those noted in the summary above that were due to issues with the initial calibration curve and/or dilutions that were required due to high concentrations of target analytes.

Blank Contamination Elimination

Blanks were prepared to identify any contamination that may have been introduced into the samples. Validation determines the need for qualification of sampling analytical results based on blank contamination.

There were no contaminants detected in the method blank samples analyzed by the DESA laboratory during Phase I and II PDI. Of the laboratory and ambient blank samples analyzed by the CLP laboratory, there were no detectable concentrations of target compounds; however, one or more Tentatively Identified Compounds (TICs) were noted in the blank samples in the majority of Sample Delivery Groups (SDGs) at estimated, below the reporting limit, concentrations. As noted above TICs are not validated by EPA Region 2 staff. Ten trip blank samples were submitted during the Phase I PDI. No contaminants were noted in the trip blank samples that were collected and analyzed. Eighteen equipment blank samples were collected and analyzed. As noted above several VOCs including 1,2,4-TMB, acetone, toluene, ethylbenzene, xylenes, methyl acetate, 2-butanone, and/or styrene were noted in the equipment blank samples. Results were qualified, as necessary.

Four trip blank samples were submitted during the Phase II PDI sampling. Toluene was detected in one trip blank at a concentration of 0.034 μg/l which was estimated as it was below the reporting limit. Four equipment blank samples were collected and analyzed. Several VOAs were noted in the equipment blank samples at concentrations that were estimated, below the respective reporting limits. Toluene was detected at a concentration of 1.1 μg/l in all four equipment blanks. Results were qualified, as necessary.

4.2 Well Inventory and Assessment Survey

The well inventory and assessment survey located 25 existing monitoring wells at the Site. Two of the wells, ERT-2D and MW-I, could not be accessed for inspection at the time because the flush-mount casings were filled with ice. One well, MW-E, was not located during the January survey but was located in March during the geophysical utility markout survey. Two shallow monitoring wells located in Area 3 were confirmed to have layers of LNAPL at the water surface. Table 4-1 provides a summary of well location and construction details.

Several of the wells in Area 3, and well ERT-8 showed signs of physical damage and most of the wells at the Site were judged not to be secure from runoff. EPA Region 2 Superfund Well Assessment Checklist forms for each of these wells are provided in Appendix B.

4.3 Geophysical Utility Markouts

The surface geophysical surveys cleared all of the 44 proposed boring and well locations for drilling. There were no utilities identified at any of the boring or well locations that required relocation from the original proposed locations.

The utility surveys of the designated areas identified several known and unknown features that will have to be considered in the remedial design. The utilities identified in the exterior portions of the areas are shown on Figure 4-1. A storm water conveyance system including catch basins and piping was identified in Area 4-1, along with a utility that could not be readily identified. Subsurface lines from a former treatment system were identified in Area 4-2 and one line of unknown origin was identified in Area 3.

The survey of areas inside of the building also identified utility lines that will need to be considered during remedial design. A floor drain system, an electrical line and a utility of unknown origin were located in Area 4-2b. Sanitary lines were observed to run overhead within the building interior. A floor drain system was also identified in Area 3b in the northeast corner of the building. Utilities identified in areas inside of the building are shown on Figure 4-2. Reports for the interior and exterior surveys are presented in Appendix D.

4.4 Soil Delineation Borings

The soil delineation borings encountered two types of geologic formation in the upper 35 feet of the subsurface at the Site. The surficial unit was 16 to 20 feet in thickness and described as a fill/fine sand and silt alluvium with 10 to 15 percent clay size particles. An isopach map of the fill/fine sand and silt alluvium is shown in Figure 4-3. The upper 5 feet of this layer under the building contained crushed stone. Underlying the fill/fine sand and silt alluvium were glaciofluvial sand and gravel containing a mixture of medium to coarse sand and gravel with as much as 10 to 35 percent silt and clay. An isopach map of the glaciofluvial sand and gravel unit is shown on Figure 4-4. Boring logs are provided in Appendix E and a photo log of soil cores is included as Appendix F.

Soil samples collected for laboratory analysis are listed on Table 4-2. The laboratory results were compared to NYSDEC 375-6.8(b) Restricted Use Soil Cleanup Objectives for the Protection of Groundwater (screening criteria) to delineate the portion of the fill/fine sand and silt alluvium above the screening criteria.

Area 3

Four borings, PSB-201, PSB-202, PSB-203 and PSB-204, were drilled in Area 3. The depth of the glaciofluvial sand and gravel aquifer ranged from 22 to 25 feet. A "strong" odor was noted at the water table in borings PSB-202 and PSB-204. Visual evidence of a NAPL was also noted at the water table in PSB-202. Elevated PID measurements were recorded in both of these borings. PID measurements ranged from 15 to 833 ppm at PSB-202 between the ground surface and a depth of 24 feet. PID measurements are reported on boring logs in Appendix E. The highest level was recorded at the 16 to 20 foot interval. PID measurements ranged from 30 to 127 ppm at PSB-204 between the ground surface and a depth of 12 feet, with the highest reading from the 8 to 12 foot interval. Soil samples were not recovered between the depths of 12 and 20 feet. Boring PSB-202 is 20 feet west of monitoring wells ERT-1S, where LNAPL has been observed. Boring PSB-204 is 54 feet to the east of ERT-1S.

Analytical results show the presence of several petroleum-related compounds, including 1,2,4-TMB and 1,3,5-TMB, methylcylcohexane, toluene, ethylbenzene and xylenes, primarily in unsaturated and saturated soil between the depths of 7 and 16 feet at PSB-202 and 7.5 and 12 feet in PSB-204. The approximate depth to groundwater in this area was 11 to 12 feet. Analytical results are presented in Table 4-3 and Figure 4-5. Figure 4-5 shows the detected compounds with depth at each boring location.

The data on Figure 4-5 show the following:

PSB-201: The results show TCE ranging (690 to 1,100 ug/kg) was detected above screening criteria (470 ug/kg) from 18 to 20 feet bgs in the fill/fine sand and silt alluvium. TCE (850 to 960 ug/kg) and cis-1,2-DCE (270J to 370 ug/kg) were detected above their respective screening criteria (470 and 250 ug/kg respectively) in the glaciofluvial sand and gravel to a depth of 35 feet bgs which is the final depth of the boring.

PSB-202: The results show seven compounds TCA (16,000 ug/kg), 1,2,4-TMB (23,000 41,000 ug/kg), cis-1,2-DCE (590 to 100,000 ug/kg), ethyl benzene (3,000 ug/kg), toluene (5,800 ug/kg), TCE (12,000 to 530,000 ug/kg), and vinyl chloride (620 ug/kg) were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA (900 J ug/kg), Cis-1,2-DCE (360 J to 26,000 ug/kg), and TCE (31,000 ug/kg) were detected above the screening criteria (680, 250, and 470 ug/kg respectively) in the glaciofluvial sand and gravel to a depth of 35 feet bgs which is the final depth of the boring.

PSB-203: The results show TCE (2,400 to 5,100 ug/kg) and cis-1,2-DCE (780 to 950 ug/kg) were detected above screening criteria (470 and 250 ug/kg respectively from 15.5 to 18.5 feet bgs in the fill/fine sand and silt alluvium. TCE (700 to 750 ug/kg) was detected above the screening criteria (470 ug/kg) in the glaciofluvial sand and gravel to a depth of 27 feet bgs. Samples collected below 27 feet bgs did not detect VOCs above the screening criteria.

PSB-204: The results show 1,2,4-TMB (13,000 to 59,000 ug/kg), ethyl benzene (10,000 ug/kg), and toluene (940 ug/kg) were detected above screening criteria (3,600, 1,000, and 700 ug/kg respectively) from 7.5 to 10.5 feet bgs in the fill/fine sand and silt alluvium. TCE (990 to 2,400 ug/kg) was detected above the screening criteria (470 ug/kg) in the glaciofluvial sand and gravel to a depth of 25.5 feet bgs. Samples collected below 25.5 feet bgs did not detect VOCs above the screening criteria.

Area 4-1

Five delineation borings, PSB-215, PSB-216, PSB-217, PSB-218 and PSB-219, were competed in Area 4-1. The depth of the glaciofluvial sand and gravel aquifer in this area ranged from 16 to 19 feet in depth. A “gasoline” odor was noted between the depths of 8 and 16 feet in boring PSB-217 with a light brown discoloration observed in the soil samples. PID measurements through this interval ranged from 650 to 1,500 parts per million (Appendix E). Elevated PID measurements were not observed at the other Area 4-1 borings.

Analytical results for soil samples in Area 4-1 are presented in Table 4-4 and Figure 4-6. Figure 4-6 shows the detected compounds with depth at each boring location superimposed over a map of Area 4-1.

The data on Figure 4-6 show the following:

PSB-215: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA was detected (690 ug/kg) above the screening criteria (680 mg/kg) in the glaciofluvial sand and gravel at a depth of 33-33.5 feet bgs. Samples collected below 33.5 feet bgs did not detect VOCs above the screening criteria. Samples collected below 33.5 feet bgs did not detect VOCs above the screening criteria.

PSB-216: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA (7,700 ug/kg) and 1,1-dichloroethene (1,1-DCE) (640 ug/kg) was detected and above the screening criteria (680 mg/kg and 330 respectively) in the glaciofluvial sand and gravel at a depth of 24-24.5 feet bgs. Samples collected below 24.5 feet bgs did not detect VOCs above the screening criteria.

PSB-217: The results show TCA (710 – 470,000 ug/kg), 1,1-DCE (4,100 ug/kg) , and TCE (4,700-570,000 ug/kg) were detected above screening criteria (680, 330, and 470 ug/kg respectively) in the fill/fine sand and silt alluvium. TCA (2,100 – 66,000 ug/kg), 1,1-DCE (340 to 490 ug/kg) , and TCE (1,300-35,000 ug/kg) were detected above the screening criteria (680, 330, and 470 ug/kg respectively) in the glaciofluvial sand and gravel to a depth of 33 feet bgs which is the final depth of the boring.

PSB-218: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA (840 ug/kg), cis-1,2 DCE (360-420 ug/kg), and TCE (870-3,400 ug/kg) were detected above their respective screening criteria (680, 250, and 470 ug/kg respectively) in the glaciofluvial sand and gravel to a depth of 30.5 feet bgs. Samples collected below 30.5 feet bgs did not detect VOCs above the screening criteria.

PSB-219: The results show TCE (890-970 ug/kg) were detected above the screening criteria (470 ug/kg) in the fill/fine sand and silt alluvium. TCA (720 ug/kg), 1,1-DCA (780 ug/kg), and 1,1-DCE (370 ug/kg) were detected above their respective screening criteria (680, 270, and 330 ug/kg respectively) in the glaciofluvial sand and gravel to a depth of 34.5 feet bgs which was the final depth of the boring.

Area 4-2

Five delineation borings, PSB-210, PSB-211, PSB-212, PSB-213 and PSB-214, were competed in Area 4-2 during the Phase I PDI. Three delineation borings, ASB-5, ASB-6, and ASB-7, were completed in Area 4-2 during the Phase II PDI. The depth of the sand and gravel aquifer in this area is approximately 20 feet below grade. An odor was noted between the depths of 16 and 20 feet in boring PSB-211 with a light brown mottling observed in the soil samples. PID measurements above background were observed in PSB-211, PSB-213,, ASB-5, ASB-6, and ASB-7 as noted in Appendix E. Elevated PID measurements were not observed at the other Area 4-2 borings.

Analytical results for soil samples in Area 4-2 are presented in Table 4-5 and Figure 4-7. Figure 4-7 shows the detected compounds with depth at each boring location superimposed over a map of Area 4-2.

The data on Figure 4-7 show the following:

PSB-210: The results show no VOCs were detected in the fill/fine sand and silt alluvium. TCA (730-880 ug/kg) was detected above the screening criteria (680 ug/kg) in the glaciofluvial sand and gravel. Samples collected below 28 feet bgs did not detect VOCs above the screening criteria. These data show the vertical extent of VOCs was delineated above the screening criteria in this portion of Area 4-2.

PSB-211: The results show TCA (21,000,000 ug/kg), 1,1-DCE (460,000 ug/kg), and TCE (43,000J ug/kg) were detected above their respective screening criteria (680, 330, and 470 ug/kg) in the fill/fine sand and silt alluvium. TCA (1,200-12,000 ug/kg) and 1,1-DCE (440J ug/kg) were detected above their respective screening criteria (680 and 330 ug/kg respectively) in the glaciofluvial sand and gravel at a depth of 32.5 feet bgs which was the final depth of the boring.

PSB-212: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA (1,100 ug/kg) was detected above the screening criteria (680 ug/kg) in the glaciofluvial sand and gravel at 27.5-28 feet bgs. Samples collected below 28 feet bgs did not detect VOCs above their respective screening criteria.

PSB-213: TCA (1,300,000 ug/kg) was detected above the screening criteria (680 ug/kg) in the fill/fine sand and silt alluvium. TCA (950-22,000 ug/kg) and 1,1-DCA (520 ug/kg) were detected above their respective screening criteria (680 and 270 ug/kg respectively) in the glaciofluvial sand and gravel at 30-30.5 feet bgs. A sample collected below 30.5 feet bgs did not detect VOCs above their respective screening criteria.

PSB-214: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA (1,600-16,000 ug/kg), 1,1-DCA (710 ug/kg), and 1,1-DCE (600 ug/kg) were detected above their respective screening criteria (680, 270, and 330 ug/kg respectively) in the glaciofluvial sand and gravel to 30-30.5 feet bgs. A sample collected below 30.5 feet bgs did not detect VOCs above their respective screening criteria.

ASB-5: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium or in the glaciofluvial sand and gravel.

ASB-6: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. Cis-1,2-DCE was detected (570 ug/kg at 26.5-27 feet bgs and 250J at 30-30.5 feet bgs) above the screening criteria (250 ug/kg) in the glaciofluvial sand and gravel. Vinyl chloride was detected (26 ug/kg) at 26.5-27 feet bgs above the screening criteria (20 ug/kg) in the glaciofluvial sand and gravel.

ASB-7: TCA (13,000 ug/kg), 1,1-DCE (1,600 ug/kg), acetone (53 ug/kg), cis-1,2-DCE (13,000 ug/kg), trans-1,2-dce (190J ug/kg), and TCE (860-68,000 ug/kg) were detected above their screening criteria (680 ug/Kg, 330 ug/Kg, 50 ug/Kg, 250 ug/kg, 190 ug/Kg, 470 ug/Kg respectively) from 5 to 17.5 feet bgs in the fill/fine sand and silt alluvium. The results show no VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

Area 4-2B

Six delineation borings, PSB-205, PSB-206, PSB-207, PSB-208, PSB-209 and contingency boring CB-220, were competed in Area 4-2B (building interior portion of Area 4-2) during Phase I PDI. Four delineation borings, ASB-1, ASB-2, ASB-3, and ASB-4 were completed in Area 4-2B during the Phase II PDI. The depth of the sand and gravel aquifer in this area ranged from approximately 20 feet to 25 feet below grade. An odor was noted between the depths of 16 and 24 feet in boring PSB-206; however, no visual evidence of contamination was observed. The interval from 20 to 24 feet below grade recorded the highest PID measurement of 333 ppm (Appendix E). Lower levels were measured between 8 and 20 feet. The fine sand and silt alluvium extended at least to a depth of 24 feet at this location. There was no recovery from the sampling intervals between 24 and 32 feet. The 32 to 36 foot deep sampling interval recorded a PID measurement of 2.4 ppm. The only other boring to exhibit PID measurements above background was contingency boring CB-220, where low levels ranging from 0.4 to 28 ppm were recorded. The highest level in this boring was the 12 to 16 foot depth interval. Elevated PID measurements were not observed at the other Area 4-2B borings.

Analytical results for soil samples in Area 4-2B are presented in Table 4-6 and Figure 4-8. Figure 4-8 shows the detected compounds with depth at each boring location superimposed over a map of Area 4-2B.

The data on Figure 4-8 show the following:

PSB-205: cis-1,2-DCE (960-2,500 ug/kg) and TCE (720-2,700 ug/kg) were detected above their respective screening criteria (250 and 470 ug/kg respectively) in the fill/fine sand and silt alluvium. TCA (1,400 ug/kg), 1,1-DCE (660 ug/kg), cis-1,2-DCE (1,300 ug/kg), and TCE (4,400 ug/kg) was detected above the screening criteria (680, 330, 250, and 470 ug/kg respectively) in the glaciofluvial sand and gravel at 21.5-22 feet bgs. Samples collected below 22 feet bgs did not detect VOCs above the screening criteria.

PSB-206: TCA (1,200 to 80,000 ug/kg), 1,1-DCA (630 J to 1,100 ug/kg), 1,1-DCE (400 to 17,000 ug/kg), cis-1,2-DCE (400 to 34,000 ug/kg), toluene (1,900 to 7,500 ug/kg), trans-1,2-dichloroethene (trans-1,2-DCE) (280 J to 810 J ug/kg), and TCE (2,700 to 110,000 ug/kg) were detected above their respective screening criteria (680, 270, 330, 250, 700, 190, and 470 ug/kg respectively) in the fill/fine sand and silt alluvium. No VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

PSB-207: No VOCs were detected in the fill/fine sand and silt alluvium or the glaciofluvial sand and gravel.

PSB-208: No VOCs were detected in the fill/fine sand and silt alluvium. No VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

PSB-209: No VOCs were detected in the fill/fine sand and silt alluvium. No VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

CB-220: cis-1,2-DCE (1,400-2,400 ug/kg) and TCE (680-900 ug/kg) and were detected above their respective screening criteria (250 and 470 ug/kg respectively) in the fill/fine sand and silt alluvium. No VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

ASB-1: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium. TCA was detected (2,800-5,400 ug/kg) from 20-24.5 feet bgs above the screening criteria (680 ug/kg) in the glaciofluvial sand and gravel.

ASB-2: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium or in the glaciofluvial sand and gravel.

ASB-3: The results show no VOCs were detected above their respective screening criteria in the fill/fine sand and silt alluvium or in the glaciofluvial sand and gravel.

ASB-4: The results show acetone was detected (55 ug/kg) above the screening criteria (50 ug/kg) in the fill/fine sand and silt alluvium. The results show no VOCs were detected above their respective screening criteria in the glaciofluvial sand and gravel.

4.5 HPT Borings

Ten HPT borings, HPT-001 through HPT-010, were competed. HPT-001 and HPT-002 were located in Area 3. HPT-003, HPT-007 and HPT-008 were located in Area 4-2. HPT-004 through HPT-006 were located in Area 4-2B. HPT-009 and HPT-010 were located in Area 4-1 (Figure 2-2).

EC logs for the 10 HPT boring locations are presented on Figure 4-9. HPT logs for the 10 borings are presented on Figure 4-10. Individual EC, HPT pressure and estimated hydraulic conductivity logs, organized by boring location, are provided in Appendix G.

In general, the EC/HPT data indicate that there is variability in both the depth and thickness of the glaciofluvial sand and gravel aquifer. Based on HPT data, the aquifer ranged from 19 to 24 feet thick with the upper surface ranging between 16 and 24 feet bgs and the bottom ranging from 35.5 to 48.5 feet bgs.

EC data indicate that the electrical conductivity of the glaciofluvial sand and gravel aquifer is higher than the fill/fine sand and silt alluvium, suggesting that the fluid conductivity in the glaciofluvial aquifer may be higher than in the fill/fine sand and silt alluvium as finer-grained soil with clay typically has a higher conductivity than more permeable, coarser-grained deposits.

HPT data indicate that the hydraulic conductivity of the glaciofluvial sand and gravel ranges from a baseline value, generally between 75 and 100 feet per day, to 150 feet per day or more. The higher values are typically present at isolated depths indicating that vertical anisotropy in hydraulic conductivity is likely. These isolated zones of higher hydraulic conductivity appear to be less than a foot thick and may represent preferential pathways through the aquifer material.

The hydraulic conductivity of the saturated portion of the fill/fine sand and silt alluvium ranged between 0 and 25 feet per day. The data showed more gradual changes in hydraulic conductivity indicating that there is probably less vertical anisotropy. Below the aquifer, the hydraulic conductivity data return to the 0 to 25 feet per day range. Based on the hydrostratigraphy reported in historical documents, this material is interpreted to be the layer of lodgment till that separates the sand and gravel aquifer from the underlying bedrock.

HPT logs also showed the following:

Area 3: The top of the aquifer is from 22 and 24 feet bgs and the bottom is between 45 and 48.5 feet bgs.

Area 4-1: The top of the aquifer is from 16 and 16.5 feet bgs and the bottom is from 35.5 and 40 feet bgs.

Area 4-2: The top of the aquifer ranges from 18 to 20.5 feet bgs and the bottom is between 39.5 and 41.5 feet bgs.

Area 4-2B: The top of the aquifer ranges from 18 to 20 feet bgs and the bottom ranges 42.5 to 45 feet bgs.

4.6 3D Visualization Model

New geological and VOC data collected from 10 HPT borings, 27 soil borings, two geotechnical borings, and approximately 210 VOC soil samples from the soil borings were incorporated into the database and 3D visualization (model). The model was updated using the same kriging parameters as the initial modeling effort completed before implementing the PDI field effort. The data was interpolated using a 60 percent confidence value, meaning there is a 60 percent confidence that the predicted concentration is within a factor of 2 of the actual concentration. Updated model figures are presented in plan-view and in cross section in Figures 4-11 through 4-19 and are described below.

<u>Area 3</u>

The primary COCs in the fill/fine sand and silt alluvium are shown in plan-view in Figure 4-11. Comparing this image with the newly collected PDI data presented in Figure 4-5 show TCE was detected above screening criteria outside the previous area boundary (PSB-201). The fill/fine sand and silt alluvium 3D visualization of the updated data set incorporating the new PDI data show a generally similar footprint of VOCs that exceed their respective screening criteria in the fill/fine sand and silt alluvium interval as compared to the area boundary. A cross-section cut along a transect passing through or near PDI borings PSB-201, PSB-202, and PSB-204 is shown in Figure 4-12. This cross-section shows that primary COCs TCA, TCE, cis-1,2-DCE, 1,3,5-TMB, and 1,2,4-TMB exceed their respective screening criteria along this transect and TCE and cis-1,2-DCE extend down into the sand and gravel unit along this transect. PCBs were detected in the fill/fine sand alluvium above the screening criteria as shown on Figure 4-13.

Area 4-1

The primary COCs in the fill/alluvium fine sand and silt are shown in plan-view in Figure 4-14. Comparing this image with the newly collected PDI data presented on Figure 4-6 show TCE near the perimeter of the previous area boundary (PSB-219). The fill/alluvium fine sand and silt 3D visualization of the updated data set incorporating the new PDI data show a smaller footprint of VOCs that exceed the screening criteria in the fill/alluvium fine sand and silt interval as compared to the area boundary. A cross-section cut along a transect passing through or near PDI borings PSB-218 and PSB-219 is shown in Figure 4-15. This cross-section shows that primary COCs TCA, TCE, and cis-1,2-DCE exceed their respective screening criteria along this transect, and all three COCs extend down into the sand and gravel unit along this transect. A cross-section cut along a transect passing through or near PDI borings PSB-217, PSB-216, and PSB-215 is shown in Figure 4-16. This cross-section shows that primary COCs TCA, TCE, and cis-1,2-DCE, exceed their respective screening criteria along this transect and TCE and TCA extend down into the sand and gravel unit along this transect.

Area 4-2

The primary COCs in fill/alluvium fine sand and silt are shown in plan-view in Figure 4-17. Comparing this image with the newly collected PDI data presented in Figure 4-7 and Figure 4-8 show TCA, cis-1,2-DCE, 1,1-DCE, TCE, and toluene above screening criteria near or outside the perimeter of the previous area boundary (PSB-205, PSB-213, PSB-214 and CB-220). The fill/alluvium fine sand and silt 3D visualization of the updated data set show a footprint of VOCs that exceed their respective screening criteria is slightly smaller in size to the area boundary in Area 4-2 and 4-2B and has shifted to the northwest and farther under the building in Area 4-2B.

A cross-section cut along a transect passing through or near PDI borings CB-220, PSB-206, and PSB-208 is shown in Figure 4-18. This cross-section shows that primary COCs TCA, TCE, and cis-1,2-DCE exceed their respective screening criteria along this transect and all three COCs extend down into the top of the sand and gravel. However, the deepest sample to exhibit COCs above screening criteria was collected at ASB-6 at a depth of 30 to 30.5 feet, which is in the sand and gravel.

A cross-section cut along a transect passing through or near PDI borings PSB-206, PSB-211, and PSB-213 is shown in Figure 4-19. This cross-section shows that primary COCs TCA, TCE, and cis-1,2-DCE exceed their respective screening criteria along this transect and the three COCs extend down into the sand and gravel unit along this transect. This cross-section shows how incorporating the new data has separated the northwest portion of the soil COC plume beneath the building from the southeast soil COC plume beneath the parking lot. It also shows that TCA was detected above the screening criteria at the bottom of PSB-211 and near the bottom of PSB-213. The deepest soil sample to exhibit COCs above the screening criteria was collected at ASB-1 at a depth of 24 to 24.5 feet, which is in the sand and gravel.

4.7 Geotechnical Borings

Laboratory testing results for physical soil characteristics/parameters are included on Table 4-7, and boring logs for the geotechnical soil borings (GEO-001 and GEO-002B), completed to evaluate soil physical characteristics and obtain soil samples for geotechnical laboratory testing, are included as Appendix E. Laboratory reports are provided in Appendix H. Soil resistivity testing results for samples collected from the shallow (generally 5-20 feet bgs) fill/fine sand and silt alluvium and the deeper glaciofluvial sand and gravel (generally 25-35 feet bgs) yielded a relatively small range in soil resistivity values (in the range of 3,000-11,000 ohm-cm).

Soil resistivity values can vary across a wide range (from 100,000 ohm-cm or more for dry soils/certain bedrock types, to 10 ohm-cm or below in saturated soils where high-conductivity groundwater [e.g., salt water] is present). The soil resistivity values from the GEO-001 and GEO-002B samples are reasonable, given the general soil type/characteristics for the samples tested (e.g., sand/silt for the shallower fine-grained soils, and sand/gravel for the deeper soils) and their moisture content (ranging from 7 to 23 percent, as noted in Table 4-7).

While soil resistivity is generally not a design consideration for in-situ thermal conductive heating (TCH), soil resistivity values should be considered in design of electrical resistance heating (ERH) applications. Based on prior experience, ERH can be implemented in soils with a fairly broad range of soil resistivity values; generally as low as 100-200 ohm-cm to as high as 50,000 ohm-cm. The measured resistivity values for the soil samples tested fall well within this range, supporting the potential for ERH to be considered as an alternative to TCH for the planned ISTR remedial action. In addition, the soil resistivity values for the fill/fine sand and silt alluvium and deeper glaciofluvial sand and gravel are relatively similar, supporting that additional considerations for ERH design/implementation should not be required, relative to soil resistivity.

A potential component of the planned ISTR remedy for the Vestal site may include the injection of steam into the deeper glaciofluvial sand and gravel. Steam injection into the upper portion of the glaciofluvial sand and gravel (directly underlying the bottom of the fill/fine sand and silt alluvium) would provide additional heat/energy input to off-set the cooling effects from the higher groundwater flux in the glaciofluvial sand and gravel layer, and would also provide additional heat/energy input to the base of the fill/fine sand and silt alluvium (where the highest concentrations of Site COCs generally exist), helping to maintain targeted heating temperatures for effective COCs treatment. Based on the above, vertical permeability testing of the shallower fill/fine sand and silt alluvium and deeper glaciofluvial sand and gravel was conducted as part of the PDI, to evaluate the degree of anisotropy in the vertical permeability between these layers. The degree of anisotropy provides an indication of the potential design considerations relative to the use of steam injection as part of the ISTR implementation (specifically, the rate of rise in injected steam through the subsurface soils).

The vertical soil permeability testing results for the two samples collected from the shallower (generally 5-20 ft bgs) fill/fine sand and silt alluvium at GEO-001 and GEO-002B, yielded vertical soil permeability values of 2.3E-06 and 7.9E-07 centimeters per second (cm/sec), respectively, which are reasonable values for soils of this type. Soil permeability testing results for samples collected from the deeper (generally 25-35 ft bgs) glaciofluvial sand and gravel soils at GEO-001 and GEO-002B, yielded vertical soil permeability values of 1.6E-04 and 5.6E-05 cm/sec, respectively. These permeability values are somewhat lower than expected based on the general sand and gravel soil type/description; however, review of the sieve analysis results (refer to Table 4-6) indicates that greater than 10 percent of the soil particles for the sand and gravel soil samples passed the #200 sieve (indicative of some silt content in these samples), which may be attributable to the lower-than-expected vertical permeability values for this interval. The vertical permeability testing results were collected to be used in conjunction with the slug test and constant rate test results to provide a measure of the degree of anisotropy. The anisotropy calculations are discussed in the aquifer testing results in Section 4.11.

Soil unconfined compressive strength (UCS) testing was conducted to provide an indication of the general suitability of the soils relative to the anticipated remedial action construction work (e.g., ISTR installation, operation of heavy construction equipment), of primary importance in the shallow fluvial fine sand and silt. As shown on Table 4-6, UCS testing results for samples collected from the shallower (generally 5 to 20 ft bgs) fine-grained soils at GEO-001 and GEO-002B, yielded 957 and 1,357 pounds per square foot or roughly 0.5 tons per square foot. These results do not represent significant challenges relative to the anticipated ISTR installation, as soil loading/surcharges from the ISTR installation are expected to be minimal. Depending upon the ISTR contractor selected and design specifics, the ISTR installation may include up to 1 to 2 feet of stone/aggregate cover, serving as an air plenum, covered by up to 1 foot of lightweight concrete for insulation needs. However, other design approaches are possible. Certain heavy construction equipment typically used for the site work and ISTR installation (e.g., drilling rigs) may have to be carefully selected/operated to minimize mobility problems by limiting ground pressures applied to the subgrade. However, this would not typically be considered a significant challenge with respect to ISTR construction/implementation.

4.8 Well Installation

A test well was installed at the Site for use as a pumping well for the aquifer pump test. The test well was constructed with 25 feet of 6-inch diameter carbon steel casing, five feet of 6-inch diameter 0.030-inch continuous slot stainless steel screen, and a 5 feet of 6-inch diameter carbon steel sump. The test well was screened from 25 to 30 feet below the ground surface, which is equivalent to 5 to 10 feet below the base of the fill/fine sand and silt alluvium. Sand pack filter material (No. 1) was placed around the well screen from the bottom of the boring to 3 feet above the top of the screen. Grout was tremied into the annulus from the top of the sand pack to ground surface. The surface was completed as a flush-mount curb box with a concrete pad.

Four monitoring wells were installed near the test well for the measurement of water levels during the aquifer test. Monitoring wells were constructed with 2-inch, schedule 40, polyvinylchloride casing and 0.020-inch factory-slotted well screen. The four observation wells were installed and screened from 25 to 30 feet below the ground surface, which is equivalent to 5 to 10 feet below the base of the fill/fine sand and silt alluvium. Sand pack filter material (No. 00) was placed around the well screen from the bottom of the boring to 3 feet above the top of the screen. Grout was tremied into the annulus from the top of the sand pack to ground surface. The surface was completed as a flush-mount curb box with a concrete pad.

The wells were completed to the same depths to facilitate analysis of the aquifer pump test. The upper portion of the glaciofluvial sand and gravel aquifer was targeted because it is the most likely portion of the aquifer to be addressed during remedial action. Construction details of the new wells are summarized in Table 4-8. Well construction diagrams are presented in Appendix E.

4.9 Groundwater Level Measurements

Two rounds of water levels were measured in the monitoring wells (Table 4-9). The first round of water levels was measured on January 24, 2018 and the second round of water levels was measured on March 29, 2018. The water table ranged from 9 to 13 feet below grade at the site. Groundwater levels at the water table were generally 1 to 1.5 feet higher in elevation during the March 2018 event compared to the January 2018 event.

The monitoring wells at the Vestal facility are completed in four different hydrogeologic units; fill/fine sand and silt alluvium, glaciofluvial sand and gravel aquifer, till, and bedrock.

Groundwater levels in the fill/fine sand and silt alluvium were not mapped as the water levels show a high degree of variability and many of these wells were shown to be damaged during the condition assessment. Groundwater levels measured in the glaciofluvial sand and gravel were plotted on a map and contoured to show the general direction of groundwater flow in the glaciofluvial aquifer. Potentiometric surface contour maps of the glaciofluvial sand and gravel aquifer show groundwater flow is generally to the west-northwest (Figures 4-20 and 4-21). The hydraulic gradient ranges from 0.003 to 0.005. The contour maps are based on the limited number of wells on Site and should be considered to represent only general trends in the direction of groundwater flow. The potentiometric surface mapping and hydraulic gradient could also be affected by the damaged condition of many existing wells.

Groundwater levels measured in the till and bedrock were not contoured but they were used to evaluate the vertical hydraulic gradient at the Site.

Where nested wells are present, the vertical hydraulic gradient is generally downward from the fluvial fine sand and silt into the glaciofluvial sand and gravel aquifer. The data also shows vertical gradients are slightly upward from the till and bedrock into the glaciofluvial sand and gravel aquifer.

4.10 Monitoring Well Sampling

Six groundwater samples were collected during the PDI investigation. Groundwater samples were collected from one monitoring well in the glaciofluvial sand and gravel and from one monitoring well in the fluvial fine sand and silt installed in each of Areas 3, 4-1 and 4-2 to characterize the current groundwater quality in these areas (Table 4-10 and Figure 4-22). A QC Audit was completed during the groundwater sampling (Appendix I). The results show the field team completed the sampling according to the QAPP.

Laboratory results were compared to the National Primary Drinking Water Standards and the New York State Ambient Water Quality Standards and Guidance Values.

Area 3

The groundwater sample collected from ERT-1S, screened in the fill/fine sand and silt alluvium contained chlorinated solvents and petroleum-related compounds consistent with the soil samples collected in Area 3 as shown on Table 4-10 and Figure 4-22. PCE, TCE, cis-1,2-DCE and trans-1,2-DCE, vinyl chloride, TCA and 1,1,2-TCA, 1,1-DCA and 1,1,2-trichloro-1,2,2-trifluoroethane were detected in the groundwater sample. Cis-1,2-DCE was present at the highest concentration of 150,000 µg/l. Cis-1,2-DCE and trans-1,2-DCE, TCA, 1,1-DCE, TCE and vinyl chloride were all present at concentrations above 1,000 µg/l, and exceeded National Primary Drinking Water Screening Criteria and New York State Ambient Water Quality Screening Criteria. PCE was present at a concentration slightly over its regulatory limit of 5 µg/l. 1,4-dioxane was not detected in the groundwater sample collected at ERT-1S.

Petroleum-related compounds benzene, ethylbenzene, xylenes, 1,2,4-TMB and 1,3,5-TMB and carbon disulfide were detected in groundwater from trace concentrations to several hundred parts per billion. Benzene was the only compound to exceed its MCL; however, the other compounds listed above exceeded New York State Ambient Water Quality Screening Criteria. Groundwater collected from ERT-1S was the only sample with a detected concentration of PCB. PCB-1016 was detected at an estimated 7.94 J µg/l. Arsenic was also detected in both total and dissolved samples at concentrations of 52 and 49 µg/l. Both concentrations exceeded state and federal regulatory limits.

The groundwater sample collected from ERT-1I contained chlorinated compounds and 1,2,4-TMB at 0.52J µg/l. Cis-1,2-DCE was detected at 1,200 µg/l. Vinyl chloride was detected at 130 J µg/l. TCA and TCE were detected at 13 and 16 µg/l respectively. 1,1-DCA was also detected at 6.6 µg/l. cis-1,2-DCE, TCA, TCE, 1,1-DCA were detected at concentrations that exceed either the state and federal regulatory limits. Metals and PCB were not detected in the groundwater sample collected from ERT-1I. 1,4-dioxane was not detected in the groundwater sample collected from ERT-1I.

Area 4-1

Groundwater samples collected from ERT-4S and ERT-4I contained chlorinated compounds and metals as shown on Table 4-10 and Figure 4-22. TCE and TCA were detected at the highest concentrations, greater than 10,000 µg/l, in ERT-4S. TCA, 1,1,2-Trichloroethane, 1,1-DCE, carbon tetrachloride, methylene chloride, PCE, TCE, and vinyl chloride were detected in groundwater samples at concentrations exceeded both state and federal regulatory limits in the sample from ERT-4S. 1,4-dioxane was detected at 13.9 µg/l in the groundwater sample collected from ERT-4S

Chromium and lead were also detected in groundwater samples collected from ERT-4S. Total concentrations of these substances exceeded both state and federal regulatory limits. Dissolved concentrations were below regulatory limits.

Groundwater collected from ERT-4I contained chlorinated solvents. TCA was detected at 5,500 µg/l. TCA, 1,1-DCE and TCE were detected at concentrations that exceeded both state and federal regulatory limits. Cis-1,2-DCE was also detected at a concentration that exceeded NYS Ambient Water Quality Screening criteria. 1,4-dioxane was not detected in the groundwater sample collected from ERT-4I

Both arsenic and barium were detected in the sample from ERT-4I, but only arsenic was detected at a concentration that exceeded its federal MCL. No metals were detected at concentrations that exceeded NYS Ambient Water Quality Screening criteria.

Area 4-2

Groundwater sample collected from ERT-3S and ERT-3I contained chlorinated compounds as shown on Table 4-10 and Figure 4-22. Groundwater collected from ERT-3S contained TCA, 1,1-DCA, TCE, cis-1,2-DCE and 1,1-DCE at concentrations that exceed NYS Ambient Water Quality Screening criteria. 1,1-DCE was detected at a concentration (35 J µg/l) that exceeded the National Primary Drinking Water Standards. The groundwater sample collected from ERT-3S was not analyzed for 1,4-dioxane as the sample bottle was broken in shipment.

Groundwater collected from ERT-3I contained chlorinated compounds and metals. Groundwater collected from ERT-3I contained TCA, 1,1-DCA, TCE, 1,1-DCE at concentrations that exceed the NYS Ambient Water Quality Screening criteria. 1,1-DCE and TCE were detected at concentrations that exceed the National Primary Drinking Water Standards. Chromium was detected and a low concentration (14 µg/l) that is below state or federal criteria. PCBs were not detected. 1,4-dioxane was not detected in the groundwater sample collected from ERT-3I.

4.11 Slug Tests

Slug tests were performed on six existing monitoring wells (MW-G, ERT-1I, ERT-1D, ERT-2I, ERT-4I and ERT-4D) and two new monitoring wells (OW-2 and OW-4) to estimate the hydraulic conductivity of the fluvial fine sand and silt, glaciofluvial sand and gravel aquifer and bedrock. Slug-test response data (elapsed time and water level changes) were plotted as normalized displacement over time, and the plots of normalized head (h/h0) and the associated data analyses are provided in Appendix J. Evaluation of the time-displacement data resulted in the estimates of near-well hydraulic conductivity (K) data presented in Table 4-11.

The slug test data were analyzed using the Hvorslev, 1951 analytical method. The calculated hydraulic conductivity of the fluvial fine sand and silt interval monitored by well MW-G was 0.3 ft/day, which is consistent with previous tests conducted on other wells completed in that interval. Slug tests were completed in two wells screened within the bedrock, ERT-1D and ERT-4D, and the calculated hydraulic conductivity for those two wells was 0.9 and 1.2 ft/day, which is consistent with previous tests completed in that formation.

Slug tests were completed in five wells screened within the sand and gravel interval, ERT-1I, ERT-2I, ERT-4I, OW-2, and OW-4. The calculated hydraulic conductivity for ERT-1I was 0.6 ft/day which is consistent with the result of 0.4 ft/day calculated from a test completed in this well in 2010. The reason for the lower than expected hydraulic conductivity values is not clear from historical documentation. It could be the result of a high percentage of fines in the screen interval, borehole skin effects or a combination of the two. Hollow-stem auger drilling can smear silt and clay deposits along the borehole wall that can be very difficult to remove during development.

The calculated hydraulic conductivities for ERT-2I and ERT-4I were 146 and 225 ft/day, respectively. These values are within the range expected for the glaciofluvial sand and gravel aquifer. The calculated hydraulic conductivities for OW-2 and OW-4 were 22 and 25 feet per day, which are also lower than expected for the glaciofluvial sand and gravel aquifer. Hydraulic conductivity values calculated from the constant rate aquifer pump test for these two wells were approximately four times the values calculated from slug tests. The difference in values between the slug tests and the aquifer tests is likely the result of a borehole skin effect affecting the slug test more than the aquifer test.

4.12 Aquifer Test

A variable-rate step drawdown test was conducted in the test well as described in Section 2.11. The water levels measured during the step-drawdown test were plotted on semi-log graphs and the water level during each step was extrapolated to estimate the drawdown after 16 hours and compared to the available drawdown (distance between top of screen and static water level in feet) in the test well. Based on the data presented on Appendix K, 13 gallons per minute (gpm) was selected as the pumping rate for the constant-rate aquifer test.

A 16-hour aquifer test was conducted in a glaciofluvial aquifer overlain by fill/fine sand and silt alluvium that is partially saturated with water. The fill/fine sand and silt alluvium create a semi-confining unit that creates artesian conditions in the glaciofluvial sand and gravel aquifer. The aquifer test was analyzed to estimate the transmissivity and storativity of the semi-confined glaciofluvial sand and gravel aquifer.

Water levels measured from each of the four newly installed monitoring wells over the duration of the aquifer test were plotted on logarithmic and semi-logarithmic graphs. The logarithmic graphs were initially compared to artesian and leaky artesian analytical solutions but the short duration of the test and the recharge event that affected the data after 200 minutes precludes the use of artesian and leaky-artesian match curve fitting methods to potentially estimate the transmissivity, storativity, and the amount of vertical leakance through the fill/fine sand and silt alluvium. Therefore, water level data collected from OW-1, OW-2, OW-3, and OW-4 were evaluated using Cooper-Jacob (1946) Straight-Line Methods to estimate the transmissivity and storativity of the glaciofluvial sand and gravel aquifer. The results of these calculations are summarized in Table 4-12 and the data and analysis are provided in Appendix L.

Time-Drawdown Method

Water levels measured from OW-1, OW-2, OW-3, and OW-4 over the duration of the aquifer test were plotted on semi-logarithmic graphs. The results were used to estimate the transmissivity and storativity of the aquifer. The results show the transmissivity range of 2,100 to 2,300 square feet per day (ft^2/day) and the Storativity ranged from 1.1×10^{-5} to 2.5×10^{-6} (Table 4-12).

Time-drawdown data indicated that the test was impacted by several factors that needed to be considered when analyzing the data. The most important were related to casing storage and an apparent recharge event. A steep slope in the early data from PW-1 indicated that casing storage may have been a factor for approximately the first two minutes of the test. The impact of casing storage was further evaluated using an equation developed by Schafer (1978). Schafer developed an equation that predicts the length of time that casing storage might impact drawdown based on well and column pipe geometry. The equation is as follows:

$$t_c = 0.6(d_c^2 - d_p^2)/(Q/S)$$

Where:

t_c = time, in minutes, when casing storage becomes negligible
d_c = inside diameter of the well casing in inches or 6 inches
d_p = outside diameter of the pump column pipe or 2.5 inches
Q/S = specific capacity of the well or 2.47 ft/ft

Calculations indicate that casing storage affects were negligible after a period of approximately seven minutes.

Later time-drawdown data (after approximately 160 minutes) appear to be affected by offsite influences such as a rain event that occurred just prior to the aquifer test. Evaluation of drawdown in combination with derivative data were also used to select the appropriate portion of the time-drawdown data to calculate transmissivity. This evaluation indicated that the portions of the time-drawdown curves that best represent infinite radial flow conditions during the aquifer pump test, and therefore most closely align with the assumptions of the Cooper-Jacob method, are from approximately 16 to 160 minutes elapsed time.

In addition to impacts from casing storage and precipitation, both the pumping well and the observation wells were partially penetrating the aquifer. Partially penetrating wells will result in higher drawdown than fully penetrating wells because flow to the pumping well is not completely horizontal. The effects are typically felt within a distance of twice the aquifer thickness from the pumping well or a distance of 40 feet in the test area. The potential effects of partial penetration would not substantively affect the calculation of transmissivity; however, the potential effects of partial penetration will affect the storativity as the vertical movement of water through the aquifer would affect amount of drawdown in the well and the storativity. Therefore, the storativity will likely be underestimated with this method; calculated to range from 1.1×10^{-5} to 2.5×10^{-6} when it is more likely the storativity is closer to $1x10^{-3}$ given the fine sand and silt nature of the overlying semi-confining unit.

Distance-Drawdown Method

The water level in OW-1, OW-2, OW-3, and OW-4 at time (t=158 minutes) were plotted on semi-logarithmic graphs to calculate the transmissivity and storativity of the glaciofluvial aquifer. The result show the transmissivity is approximately 2,800 ft^2/day and the storativity is approximately $3.4x10^{-7}$ (Table 4-11). The potential effects of partial penetration will also affect the distance-drawdown analysis in a similar manner as the time-drawdown analysis. The potential effects of partial penetration would not substantively affect the calculation of transmissivity; however, the potential effects of partial penetration will affect the storativity. Therefore, the storativity will likely be underestimated with this method; calculated to be $3.4x10^{-7}$ when it is more likely $1x10^{-3}$ given the fine sand and silt nature of the overlying semi-confining unit. This can be further confirmed by identifying the r_0 (r_0=100,000 feet) on a distance-drawdown graph. Given that the Susquehanna River is only 1,400 feet from the pumping well, this r_0 is unrealistic as the cone of depression did not reach the Susquehanna River during the 16 hour aquifer test. Therefore, the storativity is more likely to be $1x10^{-3}$ that correlates to a r_0 = ~1,000 feet.

Although not encountered in the PDI aquifer test, future long-term pumping could be affected by one or more hydraulic boundaries. Potential boundary affects at the site include leakage from the overlying fill/fine sand and silt alluvium, the Susquehanna River (located approximately 1,400 feet to the north), the edge of the buried valley (located approximately 2,000 feet to the south), and increasing aquifer thickness to the north. The aquifer at the Susquehanna River is more than five times the aquifer thickness at the Site.

Theis Recovery Method

Water levels measured in OW-1, OW-2, OW-3, and OW-4 after the pump in the test well was turned off (Recovery Phase) were also reviewed in anticipation for use to calculate the transmissivity of the glaciofluvial aquifer. The recovery data shows the water in the aquifer recovered higher (up to 0.30 feet) than the static water level at the start of the test. These data show the aquifer received recharge during the aquifer test from the precipitation event that occurred before the start of the drawdown portion of the aquifer test. Therefore, the transmissivity of the aquifer was not calculated by this method.

Hydraulic Conductivity

Based on a saturated thickness of 20 feet, the individual hydraulic conductivity values calculated for these four wells were very consistent and ranged from 110 feet per day to 120 ft/day with an average of 110 feet per day rounded to two significant digits. The composite hydraulic conductivity calculated for these for wells using the Cooper Jacob distance-drawdown method was 140 feet per day. These values are consistent with the lower end of published values for this sand and gravel interval and will be used for future remedial design activities.

A potential component of the planned ISTR remedy for the Vestal site may include the injection of steam into the deeper sand and gravel soil horizon. Steam injection into the upper portion of the sand and gravel soils (directly underlying the bottom of the fine-grained soil horizon), would provide additional heat/energy input to off-set the cooling effects from the higher groundwater flux in the sand and gravel layer, and would also provide additional heat/energy input to the base of the fine-grained soils layer (where the highest concentrations of Site COCs are observed to be present), helping to maintain targeted heating temperatures for effective COCs treatment. Based on the above, vertical permeability testing of the sand and gravel soils was conducted as part of the PDI, to evaluate the degree of anisotropy. The degree of anisotropy provides an indication of the potential design considerations relative to the use of steam injection as part of the ISTR implementation (specifically, the rate of rise in injected steam through the subsurface soils).

As discussed previously in Section 4.6, vertical permeability was calculated for the glaciofluvial sand and gravel aquifer from samples collected at geotechnical borings GEO-001 and GEO-02B resulting in vertical hydraulic conductivities of 0.45 and 0.16 feet per day, respectively, with an average of 0.3 feet per day. The vertical-to-horizontal hydraulic conductivity anisotropy ratio (Kv/Kh) of the sand and gravel interval was calculated using the average Kh of 110 ft/day and the average K_V of 0.3 ft/day, indicating a vertical-to-horizontal hydraulic conductivity anisotropy ratio (Kv/Kh) of 0.003 (1:370) which is higher than expected for the glaciofluvial sand and gravel. However, as discussed in Section 4.6, the grain size analysis testing indicated the presence of more silt and clay sized particles present in the sand and gravel interval than expected (greater than 10 percent of the soil particles for the sand and gravel soil samples passed the #200 sieve), which led to a lower than expected vertical hydraulic conductivity, and the higher than expected vertical-to-horizontal hydraulic conductivity anisotropy ratio. This moderate to high vertical anisotropy is a desirable characteristic for effectively inducing the lateral propagation of steam throughout a treatment zone.

4.13 Surveying

The results of the well and boring location surveys are presented in Table 4-13. The table includes location in State Plane Coordinates and the elevation of the ground surface, inner casing and outer or protective casing for new and existing monitoring wells at the site. Location and ground surface elevation measurements were provided for ISTR, HPT and geotechnical borings installed as part of the PDI.

A copy of the baseline survey is presented as Figure 4-23. The figure was plotted as a D-size drawing (24 inches by 36 inches) and included in a pocket in the report.

4.14 Management of Investigation-Derived Waste Material

Forty-three drums and two partially filled fractionation tanks containing roughly 20,000 gallons of water were generated during the PDI field investigation. Four composite soil and two aqueous waste characterization samples were collected on April 4, 2018 and analyzed at ACV's subcontract laboratory.

Analytical results indicated that all of the waste material generated during the PDI field investigation was non-hazardous. Copies of the laboratory data reporting sheets are provided in Appendix M. The drums were transported to Republic Services Conestoga Landfill (a subtitle D facility) located in Morgantown Pennsylvania (PA0000015867). The liquid waste was transported to Clean Water of New York, located in Staten Island New York (NY0000968545). All of the IDW was transported with proper documentation. Copies of the documentation are provided in Appendix I.

5 Revised Conceptual Site Model

The Preliminary CSM has been revised with the data collected during this PDI. The key points of the CSM as follows:

- In 1980, Vestal Water Supply Well 1-1 was closed because the groundwater was found to be moderately contaminated with several VOCs, including TCA and TCE. The source of the contaminants was eventually traced back to the Site.
- The horizontal and vertical extents of two source areas were delineated at the Site, located in a parking lot, just south of an on-Site building. The horizontal extent of contamination was found to extend beneath the building. The primary contaminants within these areas include TCA and TCE.
- A third source, containing TCA, TCE and a different suite of VOCs, was also delineated on the northeast side of the building. Contaminants unique to this area include 1,2,4-TMB and 1,3,5-TMB, which suggest an origin from a different source as compared to the two areas on the south side of the building. Floating free-phase LNAPL has also been observed in two monitor wells within this area (ERT-1S and MW-F).
- The shallow unconsolidated soils at the Site include fill material and fine sand and silt alluvium (having low hydraulic conductivities) down to an average depth of approximately 20 feet. Glaciofluvial sand and gravel deposits (with higher hydraulic conductivities) occur beneath the alluvial deposits, having an average thickness of approximately 20 feet beneath the Site.
- The average depth to the piezometric surface (water table) is approximately 11 feet bgs. The water table occurs in the fill/fine sand and silt alluvium. The bottom 6 feet of alluvial deposits is saturated with groundwater. The vertical hydraulic conductivity has been estimated to range from 2.3x10-6 to 7.9x10-7 cm/sec based on hydraulic testing of Shelby Tubes.
- Groundwater in the coarse-grained sand and gravel aquifer is likely semi-confined below the fill/fine sand and silt alluvium. Groundwater generally flows in a west/northwest direction across the Site toward Vestal Well 1-1 and Well 1-1A and the Susquehanna River. The average horizontal hydraulic conductivity has been estimated to be 110 feet per day based on an aquifer test. The average vertical hydraulic conductivity has been estimated to be 0.3 feet per day based on Shelby Tube testing. The vertical anisotropy has been estimated to be 370. There is insufficient data to estimate the vertical leakance of groundwater from the fill/fine sand and silt alluvium to the glaciofluvial sand and gravel.
- Soil and groundwater analytical results show the primary COCs at the Site are TCA, TCE, cis-1,2-DCE, 1,2,4-TMB and 1,3,5-TMB.

- NAPL occurs on the northeast side of the building and appears to be restricted to a relatively small area that encompasses wells ERT-1S and MW-F. Nearby wells that surround the wells do not contain LNAPL, which suggests minimal LNAPL mobility.
- The fill/fine sand and silt alluvium in Area 3 contained COCs above the screening criteria as shown on Figure 4-11. The glaciofluvial sand and gravel in Area 3 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 35 feet bgs (PSB-201/202) in the glaciofluvial sand and gravel as shown on Figure 4-12. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.
- PCBs were detected in the fill/fine sand alluvium above the screening criteria as shown on Figure 4-13.
- The fill/fine sand and silt alluvium in Area 4-1 contained COCs above the screening criteria as shown on Figure 4-14. The glaciofluvial sand and gravel in Area 4-1 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 33 feet bgs (PSB-217) in the glaciofluvial sand and gravel as shown on Figure 4-15 and 4-16. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.
- The fill/fine sand and silt alluvium in Area 4-2 contained COCs above the screening criteria as shown on Figure 4-17. The glaciofluvial sand and gravel in Area 4-2 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 32.5 feet bgs (PSB-211) in the glaciofluvial sand and gravel as shown on Figure 4-18 and 4-19. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.
- The extent of COCs above the screening criteria has not been defined in Area 4-2. Soil samples collected from ASB-1 (20-24 feet bgs), located in the southwestern portion of Area 4-2 contains COCs above the screening criteria. These data show the horizontal extent of COCs has not been defined to the southwest of ASB-1.
- The extent of COCs above the screening criteria has not been defined in Area 4-2B. Soil samples collected from ASB-7 (17-17.5 feet bgs), located in the southwestern portion of Area 4-2B, contains COCs above the screening criteria. These data show the horizontal extent of COCs has not been defined to the southwest of ASB-7.

6 Conclusions

- The shallow unconsolidated soils at the Site include fill material and fine sand and silt alluvium down to an average depth of approximately 20 feet. Glaciofluvial sand and gravel deposits occur beneath the alluvial deposits, having an average thickness of approximately 20 feet beneath the Site.
- The average depth to the piezometric surface (water table) is approximately 11 feet bgs. The water table occurs in the fill/fine sand and silt alluvium. The bottom 6 feet of alluvial deposits is saturated with groundwater. The vertical hydraulic conductivity has been estimated to range from 2.3x10-6 to 7.9x10-7 cm/sec based on hydraulic testing of Shelby Tubes.
- Groundwater in the coarse-grained sand and gravel aquifer is likely semi-confined below the fill/fine sand and silt alluvium. Groundwater generally flows in a west/northwest direction across the Site toward Vestal Well 1-1 and Well 1-1A and the Susquehanna River. The average horizontal hydraulic conductivity has been estimated to be 110 feet per day based on an aquifer test. The average vertical hydraulic conductivity has been estimated to be 0.3 feet per day based on Shelby Tube testing. The vertical anisotropy has been estimated to be 370. There is insufficient data to estimate the vertical leakance of groundwater from the fill/fine sand and silt alluvium to the glaciofluvial sand and gravel.
- Soil and groundwater analytical results show the primary COCs at the Site are TCA, TCE, cis-1,2-DCE, 1,2,4-TMB and 1,3,5-TMB.
- NAPL occurs on the northeast side of the building and appears to be restricted to a relatively small area that encompasses wells ERT-1S and MW-F. Nearby wells that surround the wells do not contain LNAPL, which suggests minimal LNAPL mobility.
- The fill/fine sand and silt alluvium in Area 3 contained COCs above the screening criteria as shown on Figure 4-11. The glaciofluvial sand and gravel in Area 3 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 35 feet bgs (PSB-201/202) in the glaciofluvial sand and gravel as shown on Figure 4-12. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.
- PCBs were detected in the fill/fine sand alluvium above the screening criteria as shown on Figure 4-13.
- The fill/fine sand and silt alluvium in Area 4-1 contained COCs above the screening criteria as shown on Figure 4-14. The glaciofluvial sand and gravel in Area 4-1 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 33 feet bgs (PSB-217) in the glaciofluvial sand and gravel as shown on Figure 4-15 and 4-16. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.

- The fill/fine sand and silt alluvium in Area 4-2 contained COCs above the screening criteria as shown on Figure 4-17. The glaciofluvial sand and gravel in Area 4-2 also contains COCs above the screening criteria. COCs were detected above the screening criteria to 32.5 feet bgs (PSB-211) in the glaciofluvial sand and gravel as shown on Figure 4-18 and 4-19. The maximum depth of COCs in the glaciofluvial sand and gravel has not been defined.
- The extent of COCs above the screening criteria has not been defined in Area 4-2 and Area 4-2B. Soil samples collected from ASB-7 (17-17.5 feet bgs), located in the southwestern portion of Area 4-2B, contains COCs above the screening criteria. Soil samples collected from ASB-1 (20-24 feet bgs), located in the southwestern portion of Area 4-2 contains COCs above the screening criteria. These data show the horizontal extent of COCs above the screening criteria has not been defined in these areas.
- The hydraulic conductivity of the saturated portion of the fill/fine sand and silt alluvium ranged between 0 and 25 feet per day. The hydraulic conductivity of the glaciofluvial sand and gravel ranges from 75 to 100 feet per day or more. The results of the HPT borings also showed the following:
    - Area 3: The top of the aquifer is from 22 and 24 feet bgs and the bottom is from 45 and 48.5 feet bgs.
    - Area 4-1: The top of the aquifer is from 16 and 16.5 feet bgs and the bottom is from 35.5 and 40 feet bgs.
    - Area 4-2: The top of the aquifer ranges from 18 to 20.5 feet bgs and the bottom is from 39.5 and 41.5 feet bgs.
    - Area 4-2B: The top of the aquifer ranges from 18 to 20 feet bgs and the bottom is from 42.5 to 45 feet bgs.
- The results of the geotechnical borings show:
    - Soil resistivity testing results for samples collected from the shallow (generally 5-20 feet bgs) fill/fine sand and silt alluvium and the deeper glaciofluvial sand and gravel (generally 25-35 feet bgs) yielded a relatively small range in soil resistivity values (in the range of 3,000-11,000 ohm-cm). The measured resistivity values for the soil samples tested fall well within this range, supporting the potential for ERH to be considered as an optional alternative to TCH for the planned ISTR remedial action.
    - The vertical soil permeability testing results for the two samples collected from the fill/fine sand and silt alluvium at GEO-001 and GEO-002B, yielded vertical soil permeability values of 2.3E-06 and 7.9E-07 cm/sec. Soil permeability testing results for samples collected from the glaciofluvial sand and gravel at GEO-001 and GEO-002B, yielded vertical soil permeability values of 1.6E-04 and 5.6E-05 cm/sec, respectively. Combining the vertical hydraulic conductivity (average = 0.3 ft/day) with the horizontal hydraulic

conductivity (average = 110 ft/day) from the slug tests and aquifer pump test shows the vertical anisotropy is roughly 370.

    - Soil unconfined compressive strength testing results for samples collected from the shallower (generally 5 to 20 ft bgs) fine-grained soils at GEO-001 and GEO-002B, yielded 957 and 1,357 pounds per square foot or roughly 0.5 tons per square foot. These results do not represent significant challenges relative to the anticipated ISTR installation, as soil loading/surcharges from the ISTR installation are expected to be minimal.

- Four groundwater samples were collected during the PDI investigation. Groundwater samples were collected from one monitoring well in the glaciofluvial sand and gravel and from one monitoring well in the fluvial fine sand and silt installed in each of Areas 3, 4-1 and 4-2 to characterize the current groundwater quality in these areas.

    - Area 3: PCE, TCE, cis-1,2-DCE and trans-1,2-DCE, vinyl chloride, TCA and 1,1,2-TCA, 1,1-DCA and 1,1,2-trichloro-1,2,2-trifluoroethane were detected in the groundwater sample collected from ERT-1S. Cis-1,2-DCE was detected at the highest concentration of 150,000 µg/l. Cis-1,2-DCE and trans-1,2-DCE, TCA, 1,1-DCE, TCE and vinyl chloride were all present at concentrations above the National Primary Drinking Water Screening Criteria and New York State Ambient Water Quality Screening Criteria. The groundwater sample collected from ERT-1I contained chlorinated compounds. Cis-1,2-DCE, TCA, TCE, 1,1-DCA were detected at concentrations that exceed either the state and federal regulatory limits. Metals and PCB were not detected in the groundwater sample collected from ERT-1I.

    - Area 4-1: Groundwater sample collected from ERT-4S and ERT-4D contained chlorinated compounds and metals. Concentrations of TCA and 1,1,2-Trichloroethane, 1,1-DCE, carbon tetrachloride, methylene chloride, PCE, TCE and vinyl chloride exceeded both state and federal regulatory limits in the sample from ERT-3S. Chromium and lead were also detected in groundwater samples collected from ERT-4S. Total concentrations of these substances exceeded both state and federal regulatory limits. Dissolved concentrations were below regulatory limits. Groundwater collected from ERT-4D contained chlorinated solvents. TCA, 1,1-DCE and TCE were detected at concentrations that exceeded both state and federal regulatory limits. Cis-1,2-DCE was also detected at a concentration that exceeded NYS Ambient Water Quality Screening criteria. Arsenic was detected in the groundwater sample collected from ERT-4I at a concentration that exceeded its federal MCL. No metals were detected at concentrations that exceeded NYS Ambient Water Quality Screening criteria.

    - Area 4-2: Groundwater sample collected from ERT-3S and ERT-3I contained chlorinated compounds. Groundwater collected from ERT-3S contained TCA, 1,1-DCA, TCE, cis-1,2-DCE and 1,1-DCE at concentrations that exceed NYS Ambient Water Quality Screening criteria. 1,1-DCE was detected at a concentration (35 J µg/l) that exceeded the National Primary Drinking Water Standards. Groundwater collected from ERT-3I contained chlorinated compounds and metals. Groundwater collected from ERT-3I contained TCA, 1,1-DCA, TCE, 1,1-DCE at concentrations that exceed the NYS Ambient Water Quality Screening criteria. 1,1-DCE and TCE were detected at concentrations that exceed the National Primary Drinking Water Standards. Chromium was detected and a low concentration (14 µg/l) that is below state or federal criteria. PCBs were not detected.

  - 1,4-dioxane was detected in the groundwater sample collected from ERT-4S at 13.9 µg/l. 1,4-dioxane was not detected in any other groundwater sample collected during this PDI.

- A topographic survey was completed and included in Appendix D.

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