MALCOLM PIRNIE

Pilot Study Report

Building 25 - HRC® Injection
Main Manufacturing Area
Watervliet Arsenal
Watervliet, New York

Baltimore Corps of Engineers
Baltimore, Maryland

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PILOT STUDY REPORT
BUILDING 25 - HRC® Injection
Watervliet Arsenal, Watervliet, New York

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
cells/mL	cells per milliliter
CVOCs	Chlorinated Volatile Organic Compounds
DCE	Dichloroethene
DHE	Dehalococcoides Ethanogenes
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
HRC®	Hydrogen Release Compound®
mg/L	milligram per liter
MMA	Main Manufacturing Area
MPI	Malcolm Pirnie
mV	millivolt
NYSDEC	New York State Department of Environmental Conservation
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethene
PLFA	Phospholipids fatty acids
psi	pounds per square inch
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SA	Siberia Area
SWMU	Solid Waste Management Unit
TCA	Trichloroethane
TCE	Trichloroethene
TDS	Total Dissolved Solids
µg/L	microgram per liter
USTAAC	United States Army Tank Automotive and Armaments Command
USEPA	United States Environmental Protection Agency
VC	Vinyl Chloride
VOCs	Volatile Organic Compounds
WVA	Watervliet Arsenal
Zebra	Zebra Environmental Corporation

1.0 Introduction and Background

1.1 Introduction

A Pilot Study was conducted to evaluate the effectiveness of using Hydrogen Release Compound (HRC®) for reducing the concentration of chlorinated volatile organic compounds (CVOCs) in the overburden and bedrock groundwater in the Building 25 area. This Pilot Study was conducted in accordance with the *Work Plan for Building 25 and Building 40 Pilot Studies, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Pilot Work Plan) (Malcolm Pirnie, 2001a). The goals of the Pilot Study were as follows:

- Evaluate the effectiveness of HRC® as a corrective measure for the overburden and bedrock groundwater near Building 25;
- Demonstrate that HRC® can be efficiently delivered and distributed into the overburden and bedrock treatment zones; and
- Reduce contaminant concentrations and mass in the affected area.

1.2 Site Description

The Watervliet Arsenal (WVA), a 140-acre government-owned installation under the command of the U.S. Army Tank Automotive and Armaments Command (USTAAC), is located in the City of Watervliet, New York (Figure 1-1). The WVA consists of two primary areas: the Main Manufacturing Area (MMA), encompassing approximately 125 acres, where manufacturing and administrative operations occur, and the Siberia Area (SA), primarily used for the storage of raw and hazardous materials, finished goods, and supplies brought from the MMA (Figure 1-2). Building 25, also known as the Minor Components Building, is located in the southeast corner of the MMA. The area around the building is currently paved; however, the area to the south and east of the building was not paved until the 1960s/1970s. Building 25 was identified as Solid Waste Management Unit (SWMU) #5 during the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) conducted at the WVA from 1995 to 1999 (Malcolm Pirnie, 1999).

1.3 Summary of Contamination at Building 25

Groundwater to the east and southeast of Building 25 has been shown to contain chlorinated volatile organic compounds (CVOCs) at concentrations greater than New York State Department of Environmental Conservation (NYSDEC) Class GA Standards. The CVOCs are primarily composed of chlorinated solvents, specifically, tetrachloroethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane (1,1,1-TCA) in the overburden, weathered bedrock, and bedrock groundwater. Based on the results of the RFI, the horizontal extent of contamination associated with solvent use at Building 25 is limited to an approximately 0.4-acre area in the vicinity of well cluster EM-SP-1B/AW-MW-47 to the south, and by the eastern edge of the former Erie Canal to the east. The highest concentrations of CVOCs detected in the overburden groundwater were at well WVA-AW-25-MW-3 (MW-3) and in the bedrock groundwater at well WVA-AW-25-MW-2 (MW-2).

2.0 Overview of Natural Attenuation

2.1 Natural Attenuation/Reductive Dechlorination Overview

Natural attenuation (NA) processes, such as biodegradation, hydrolysis, dispersion, dilution, sorption, and volatilization affect the fate and transport of organic contaminants in all hydrologic systems. Reductive dechlorination is the most important process in the natural biodegradation of chlorinated solvents (i.e., PCE and TCE). The process of reductive dechlorination is dependent on the geochemical conditions in the subsurface and the availability of microorganisms that are responsible for degradation. Under anaerobic conditions, reductive dechlorination results in the removal of chlorine atoms from the CVOCs such that PCE is dechlorinated to form TCE, which is subsequently dechlorinated to form dichloroethene (DCE), vinyl chloride (VC), and, ultimately, ethene. However, if the geochemical conditions and availability of the specific microorganisms are not ideal for reductive chlorination, the complete degradation process may terminate after removal of only some of the chlorine atoms. Figure 2-1 shows the reductive dechlorination pathways for various chlorinated solvents, including those present in the groundwater at Building 25.

For reductive dechlorination to occur, electron acceptors (CVOCs), electron donors (sulfate, nitrate, iron, and methane), a reducing environment (low redox conditions), a carbon source, and microbes are needed. During reductive dechlorination, the CVOCs act as the electron acceptor and are broken down by microbes to less chlorinated solvents. Through this degradation process, the PCE and TCE concentrations decrease, while the cDCE and VC concentrations initially increase. Over time, cDCE and VC are degraded and concentrations decrease to less than baseline concentrations. The products of the complete reductive dechlorination of CVOCs include chloride, carbon dioxide, ethane, and ethene, and are dependent on the chemical structure of the parent compound.

The primary driving force behind the reductive dechlorination process is the presence or absence of subsurface microbes. In anaerobic environments, there are microbes that use hydrogen primarily for methane production (methanogens) and there are microbes that can utilize hydrogen to dechlorinate VOCs (reductive dechlorinators). Studies have shown that when both are present, the methanogens and reductive dechlorinators compete for hydrogen, which is produced by microbial consumption of carbon in the subsurface. High concentrations of hydrogen favor the methanogens, whereas the reductive dechlorinators are better supported in relatively low hydrogen concentration environments. As a result, the reductive dechlorination process may be slowed in subsurface systems where both types of microorganisms are present, but where methanogens dominate.

Reductive dechlorination occurs naturally in anaerobic and reducing environments. An anaerobic environment is indicated when dissolved oxygen (DO) concentrations are less than 2.0 milligrams per liter (mg/L). Reductive dechlorination will proceed in a reducing environment in which hydrogen can be produced and utilized by subsurface microbes. A reducing environment is indicated by an oxidation-reduction potential (ORP) less than 50 millivolts (mV).

Ferric iron, nitrate, sulfate, and methane act as electron donors in the biodegradation process of CVOCs. Reductive dechlorination has been demonstrated under nitrate- and iron-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CVOCs occur under sulfate-reducing and methanogenic conditions (USEPA, 1998). As the CVOCs are biodegraded, concentrations of nitrate, sulfate, and methane decrease as these electron donors are utilized, while the concentrations of ferrous iron (the reduced product of ferric iron) increase.

2.1.1 Building 25

Based on the data collected during the RFI and long-term monitoring program prior to February 2002, aquifer conditions at Building 25 were generally favorable for the degradation of CVOCs in both the overburden and bedrock groundwater. Low concentrations of the intermediate CVOC breakdown product cDCE were present in the groundwater, indicating that reductive dechlorination was occurring, but at a slow rate. However, the average dissolved organic carbon (DOC) concentration was approximately 2 mg/L, indicating a lack of carbon, which was potentially limiting the microbial processes that result in complete reductive dechlorination.

2.2 HRC® Selection

HRC® was selected as the corrective measures technology to enhance the natural attenuation processes in the overburden and bedrock groundwater at Building 25 by adding carbon to the system, thereby promoting the reductive dechlorination of the CVOCs in the groundwater. According to its manufacturer (Regenesis), HRC® is a proprietary, environmentally safe, food quality, polylactate ester specially formulated for slow release of lactic acid (a source of carbon) upon hydration. The process by which HRC® operates is a complex series of chemical and biologically mediated reactions. Initially, when in contact with subsurface moisture, the HRC® slowly releases lactic acid. Indigenous anaerobic microbes, such as acetogens, metabolize the lactic acid producing consistent low concentrations of dissolved hydrogen. The resulting hydrogen is than used by reductive dechlorinators to strip the chlorinated VOC molecules of their chlorine atoms and allow for biological degradation.

The primary advantages of using HRC® over other carbon sources are listed below.

- **Long Reaction Time:** The HRC's patented time release feature allows a one-time application to treat an entire site.
- **Viscous Solid with Low Solubility:** HRC® stays in the area where it is injected and is not flushed away by groundwater flow.
- **Desorption of Chlorinated VOCs:** The continuous hydrogen source provided by HRC® can reduce dissolved phase chlorinated VOC concentrations. This creates a large concentration gradient, which in turn facilitates desorption of chlorinated VOCs from the soil or rock matrix. Thus, by applying HRC® to treat the source and increase the rate of chlorinated VOC desorption, treatment time may be reduced without increasing contaminant concentration in groundwater.

When compared to other remediation approaches, HRC® technology has the following advantages:

- **Low Capital Cost:** HRC® application requires low capital costs as it is relatively inexpensive and is generally applied to the subsurface through push-point type applications.
- **Low Operation and Maintenance Cost:** Unlike actively engineered systems, the use of HRC® requires no continuous mechanical operations, therefore operating and maintenance costs are eliminated.
- **Minimal Site Disturbance:** Treatment with HRC® is in-situ; thus, above ground disturbance is minimized.
- **Rapid Treatment:** By supplying a consistent low level of hydrogen over approximately one year's time, the dechlorination process is stimulated to increase in the subsurface by orders of magnitude. This results in a very rapid removal of the chlorinated VOC contamination when compared to natural attenuation approaches.

3.0 Monitoring and Injection Well Installation

3.1 Utility Clearance/Markout

A geophysical survey of utilities in the area near Building 25 was conducted during the RFI. Utilities in the vicinity of Building 25 include a storm sewer line, a water supply line running parallel to the east side of the building, approximately 40 to 50 feet east of the building, and an electrical line running parallel to the south side of the building, approximately 10 feet south of the building. Prior to performing any of the drilling or injection activities, Malcolm Pirnie (MPI) referred to the utility maps generated during the RFI, and coordinated with WVA personnel to ensure that utilities were not damaged during work.

3.2 Bedrock Injection and Monitoring Well Installations

The bedrock injection and monitoring wells that were installed as a part of the Pilot Study are discussed below in Sections 3.2.1 and 3.2.2. Hybrid monitoring well SP-1 was installed prior to the RFI. Bedrock and overburden monitoring wells MW-2, MW-3, and MW-53 were installed during the RFI. The details on the installation of these wells are not discussed as a part of this Pilot Study Report.

3.2.1 Bedrock Injection Well Installation

In December 2001, six bedrock injection wells, designated WVA-AW-25-IW-1 (IW-1) through WVA-AW-25-IW-6 (IW-6), were installed in the Building 25 area as part of the Pilot Study. Injection well IW-6 is located adjacent to bedrock monitoring well MW-2. The remaining five injection wells (IW-1 through IW-5) are located down gradient of MW-2 in a barrier configuration perpendicular to the direction of groundwater flow (see Figure 3-1). Competent bedrock was encountered approximately 13-14 feet below ground surface (bgs) in the bedrock injection wells. All injection wells were constructed as open borehole wells with open intervals between 20 feet bgs and 35 feet bgs. Boring logs for each of the bedrock injection wells are provided in Appendix A. Each injection well was installed and developed in accordance with the Pilot Work Plan.

3.2.2 Bedrock Monitoring Well Installation

In December 2001, one additional bedrock monitoring well, designated WVA-AW-25-

MW-7 (MW-7), was installed in the Building 25 area as part of the Pilot Study. The bedrock monitoring well was installed down gradient of bedrock injection wells IW-1 through IW-5 to monitor the effect of the HRC® injection on down gradient groundwater conditions. Competent bedrock was encountered at 13 feet bgs at MW-7. The bedrock monitoring well is open from 20 feet bgs to 35 feet bgs. The boring log for the bedrock monitoring well is provided in Appendix A. Monitoring well MW-7 was installed and developed in accordance with the Pilot Work Plan.

4.0 HRC® Injections

4.1 Overburden HRC® Injection

A direct-push drilling rig was used to inject HRC® into 35 temporary injection points at a depth of 15 to 17 feet bgs at Building 25 (Figure 4-1). The injections were conducted by Zebra Environmental Corporation (Zebra) of Albany, New York, between February 4 and 7, 2002. As discussed in Section 3.4.2 of the Pilot Work Plan, the injection points were located on a 50 feet by 75 feet grid pattern over the area of contaminated overburden groundwater in the vicinity of Building 25. All of the delivery points were spaced 10 feet on center between rows, and 10 feet on center within columns. HRC® was injected continuously throughout the saturated overburden from a depth of approximately eight feet bgs to the bottom of each temporary point at 15 to 17 feet bgs. Thirty-eight pounds of HRC® was injected into each delivery point, yielding a total volume of approximately 1,350 pounds of HRC® injected in the overburden. Once the injection was completed, the delivery points were backfilled with a bentonite/sand mix and capped with asphalt cold-patch.

4.2 Bedrock HRC® Injection

On February 8, 2004, the six bedrock injection wells (Figure 4-2) were filled with HRC® by American Auger from Syracuse, New York, (drilling company), with technical support from Zebra. HRC® can be injected into an open borehole using a single or straddle packer system under pressure or by filling the borehole without pressure. Due to the nature of the fractured bedrock encountered in the Building 25 area, it was proposed in the Pilot Work Plan to use a single packer and inject the HRC® under pressure to maximize the horizontal and vertical extent of contact between the bedrock aquifer and the HRC®. The HRC® was first injected under pressure into injection well IW-6. However, the HRC® did not flow into the formation, even at pressures as high as 2,000 pounds per square inch (psi). As a result, the HRC® was passively injected into the six bedrock injection wells by evacuating the groundwater in the injection wells and filling them to the ground surface with HRC®. Each injection well was filled with 420 to 450 pounds of HRC®, yielding a total injected volume of approximately 2,600 pounds of HRC®. All purge water resulting from the evacuation of the injection wells was containerized and disposed in accordance with state and federal guidelines.

5.0 Monitoring

The main purpose of the Pilot Study monitoring program was to evaluate the HRC® distribution in the overburden and fractured bedrock, and to confirm that the HRC® was reducing the concentrations of CVOCs and creating aquifer conditions conducive to biodegradation via reductive dechlorination. Five groundwater monitoring wells were selected to monitor the Pilot Study area. Monitoring wells MW-3 and SP-1, located in the center of the HRC® overburden injection point grid, were sampled to monitor the effectiveness of the treatment in the overburden groundwater. The bedrock monitoring wells MW-2 and MW-53, located up-gradient of the HRC® bedrock treatment barrier and down gradient of the bedrock injection point IW-6, and bedrock monitoring well MW-7, located down gradient of the HRC® bedrock treatment barrier, were sampled to monitor the effectiveness of the HRC® injection in the bedrock groundwater. Groundwater sampling at MW-53 was discontinued after the June 2002 sampling event as there was no appreciable change in the aquifer conditions in the months following the HRC® injection. During the Pilot Study, groundwater levels were also measured regularly at the five monitoring wells in the Building 25 area. Groundwater elevations at the Building 25 monitoring wells are included in Table 5-1.

There were two types of monitoring events during the Pilot Study, full and field monitoring events. Six full monitoring events were conducted between January 2002 and June 2004 (Table 5-2), during which samples from all five monitoring locations in the Pilot Study area were collected and analyzed for the parameters listed in Table 5-3. A full baseline monitoring event was conducted in January 2002, prior to the HRC® injection (February 2002), to evaluate pre-injection aquifer conditions and to establish a baseline for comparison of VOC concentrations and geochemical changes induced by the addition of HRC® to the aquifer.

Table 5-2. Dates of Field and Full Monitoring Events.

Date	Monitoring Event	
	Field	Full
January 29 - 31, 2002 (Baseline Event)	✓	✓
February 27, 2002	✓	
March 13, 2002	✓	
March 28, 2002	✓	
April 25 - 26, 2002	✓	✓
June 5, 2002	✓	
June 18 - 19, 2002	✓	✓
October 31, 2002	✓	✓
April 1, 2003	✓	✓
April 22, 2004	✓	✓

Nine field monitoring events, five of which occurred concurrently with the full monitoring events, were conducted between January 2002 and June 2004 (Table 5-2). During these events, samples collected from all five monitoring locations were analyzed for field parameters as listed in Table 5-3. The first field monitoring event was conducted within a month of the HRC® injection in February 2002.

Table 5-3. Analytical Parameters Tested During Each Monitoring Event.

Analytical Parameter	Monitoring Event	
	Field	Full
Volatile Organic Compounds (VOCs)		✓
Dissolved Gases		✓
Dissolved Organic Carbon (DOC)		✓
Total Dissolved Solids (TDS)		✓
*Alkalinity	✓	✓
*Chloride	✓	✓
*Ferrous Iron	✓	✓
*Nitrate/Nitrite	✓	✓
*Sulfate	✓	✓
**Dissolved Oxygen (DO)	✓	✓
**Oxidation Reduction Potential (ORP)	✓	✓
**pH	✓	✓
**Salinity	✓	✓
**Temperature	✓	✓
**Turbidity	✓	✓

* Analyzed in the field via test kit techniques
** Analyzed in the field via water quality instrumentation

In addition to the full and field monitoring events, groundwater samples were collected from the Building 25 monitoring wells as part of the Arsenal-wide long-term monitoring program in May 2002, May and October 2003, May 2004, and May and October 2005. The May and October 2005 sampling events are included in this Pilot Study Report to document groundwater conditions in the study area following the conclusion of the Pilot Study in June 2004. Data collected during the long-term monitoring program were validated by a third party data validator and have been included in this Pilot Study Report.

Groundwater samples from MW-2, MW-3, and MW-7 were collected in June, July, and October 2002 and April 2004 for the analysis of phospholipids fatty acids (PLFA), which is an analysis used to monitor microbial responses to their environment. In November 2003, a groundwater sample was collected from MW-7 to evaluate the presence or absence of dehalococcoides ethanogenes (DHE) which, when present, has been shown to fully degrade PCE and TCE to ethene under anaerobic conditions.

All wells were sampled in accordance with the procedures outlined in the United States Environmental Protection Agency (USEPA) protocol for Low Stress (Low Flow) Purging and Sampling (USEPA, 1998). Dedicated, permanently installed bladder pumps were used to collect groundwater samples at all of the monitoring wells, except for MW-53, in which a submersible pump was utilized. A flow-through cell was used to measure field parameters during well purging and after sample collection. The submersible pump and flow-through cell were decontaminated before and after use to prevent cross-contamination between wells. Purge logs for the field parameter results collected during the full and field monitoring events are included in Appendix B.

6.0 Pilot Study Results

The criteria by which the outcome of the Pilot Study was monitored and measured were as follows:

- Dissolved oxygen (DO) concentrations;
- Oxidation reduction potential (ORP);
- Trends in electron donor concentrations, including nitrate, sulfate, ferric iron, and methane;
- Trends in target chlorinated organic contaminant concentrations;
- Evidence of the presence of the HRC® in the subsurface; **and**
- Trends in dissolved gases (i.e. ethane, ethene, and methane) concentrations.

6.1 Aquifer Conditions

Groundwater samples for geochemical and microbial analyses were collected in accordance with the methods specified in the Pilot Study Work Plan. During the field and full monitoring events, DO and ORP were analyzed in the field by MPI using a Horiba U-22 water quality meter with a flow through cell. The geochemical parameters were monitored to compare the conditions of the aquifer prior to and after the HRC® injection, and to assess whether the chemical properties of the aquifer were adequate for reductive dechlorination to occur. The results of geochemical analyses from samples collected throughout the Pilot Study and the long-term monitoring program are tabulated in Table 6-2. Microbial Insights, Inc. performed the microbial analyses (PLFA and DHE). The Microbial Analysis Reports from Microbial Insights, Inc. is included in Appendix C.

6.2 Geochemical Conditions

6.2.1 Dissolved Oxygen (DO)

As discussed in Section 2.0, an aerobic environment (DO less than 2.0 milligrams per liter (mg/L)) is essential for reductive dechlorination to occur. As shown on Figure 6-1, the DO concentrations at all four monitoring wells varied during the first four months following the HRC® injection, but have been less than 1.5 mg/L since the June 2002 monitoring event. During the first two long-term monitoring events following the end of the Pilot Study in June 2004, the DO concentrations remained less than 1.5 mg/L, except at SP-1, which increased to 3.82 mg/L in

May 2005 and 9.51 mg/L in October 2005. However, the DO measurement of 9.51 mg/L is suspect and may have been associated with air bubbles in the sampling flow-through cell at the time of the measurement.

6.2.1.1 Oxidation Reduction Potential (ORP)

As discussed in Section 2.0, a reducing environment (ORP is less than 50 mV) is essential for reductive dechlorination to occur. As shown on Figure 6-2, the ORP levels at all four monitoring wells decreased during the first field monitoring event following the HRC® injection. During the course of the Pilot Study and up to the most recent long-term monitoring event (October 2005), the ORP levels remained below 50 mV at all four monitoring locations, confirming that the overburden and bedrock aquifers were under reducing conditions during the Pilot Study.

6.2.2 Microbial Analyses

6.2.2.1 Quantitative Dehalococcoides Ethanogenes (DHE)

A groundwater sample was collected from the bedrock monitoring well MW-7 in November 2003 to evaluate whether DHE was naturally present in the groundwater in the Building 25 area. It has been shown in various studies that when DHE is present, TCE can fully degrade to ethene under anaerobic conditions. In the sample collected from MW-7, DHE was present, but not at a quantifiable concentration. This result indicates that complete degradation of the CVOCs in the subsurface at Building 25 may be slowed by low microbial populations.

6.2.2.2 Phospholipids Fatty Acids

Groundwater samples were collected from monitoring wells, MW-2, MW-3, and MW-7 in June, July, and October 2002 and April 2004 to collect information on the microbial community in the groundwater in the Building 25 area. PLFA is a tool that can monitor the microbial responses to their environment. There are three different types of information that can be obtained from PLFA profiles: biomass, community structure, and physiological status.

<u>Biomass</u>

The viable microbial biomass in MW-3 (~10^4 cells per milliliter (cells/mL)) was much lower than the viable microbial biomasses in MW-2 and MW-7 (~ 10^6 cells/mL). In July 2002, the biomasses in all three samples decreased by one order of magnitude, and then increased in

October 2002. In comparison to the baseline biomass values collected in June 2002, the biomass values in April 2004 were approximately four times greater at MW-2 and MW-7 and 26 times less at MW-3.

Community Structure

The microbial community structures of samples MW-7 and MW-3 were similar, with the community structure of MW-3 being stable throughout the Pilot Study and MW-7 being variable. The microbial community structure of MW-2 differed from the community structures of MW-3 and MW-7, primarily in the proportion of "anaerobic" biomarkers. Gram negative proteobacteria (monoenoic PLFA) was the dominant community member for all three monitoring wells. Gram negative bacteria are particularly important for biodegradation since they are fast-growing bacteria that can utilize a wide range of carbon sources and adapt quickly to changes in their environment. In June 2002, Firmicutes (an "anaerobic" biomarker) was the dominant community member at MW-2. The proportion of Firmicutes decreased by 60 percent at MW-2 from June 2002 (46.3 percent) to April 2004 (18.3 percent). By April 2004, the proportion of Firmicutes were similar at all three monitoring locations (12.6 to 18.3 percent).

Physiological Status

Physiological status is an indicator of the presence of toxic compounds and changing environmental conditions that induce stress and starvation on microbes. The physiological stress biomarker (stress ratio) for adaptation to toxic exposure was slightly elevated during the October 2002 and April 2004 sampling events at all three locations. In comparison to the October 2002 stress ratios, the stress ratios at MW-3 and MW-7 in April 2004 were still elevated, but did not increase, while the stress ratio at MW-2 was four times greater, indicating the microbes at MW-2 were adapting and changing to a greater induced stress. The biomarker for starvation/toxic exposure increased in June 2002 at MW-3 and MW-7, but had decreased to nearly initial levels in April 2004. The starvation ratio at MW-2 was relatively low throughout the Pilot Study; however, the starvation ratio at MW-2 in April 2004 was approximately three times greater than in October 2002.

6.3 Chlorinated Volatile Organic Compounds (CVOCs)

Groundwater samples for CVOC analyses were collected in accordance with the methods specified in the Pilot Study Work Plan and analyzed by Severn Trent Laboratories of Shelton, Connecticut. Analytical laboratory data packages for the analyses conducted by Severn Trent are contained in the compact disc in Appendix D. CVOCs were analyzed during the full monitoring events only. Groundwater samples collected from the Building 25 monitoring wells were analyzed for CVOCs to observe the effect of the HRC® injection on the CVOCs concentrations and to monitor the progress of reductive dechlorination at each of these wells. The results of the CVOC analyses from samples collected throughout the Pilot Study and the long-term monitoring program are tabulated in Table 6-1. The analytical results from samples collected from the Pilot Study monitoring wells are discussed below based on the groundwater monitoring zone being sampled. For comparison purposes, SP-1, a hybrid monitoring well, is included and discussed in the overburden monitoring well section.

6.3.1 Overburden Monitoring Wells

6.3.1.1 WVA-AW-25-MW-3

Monitoring well MW-3 is located within the overburden injection grid. As shown on Table 6-1, prior to the HRC® injection in February 2002, the predominant CVOC at MW-3 was TCE. TCE, cDCE, and 1,1,1-TCA were present at concentrations greater than the corresponding NYSDEC Class GA Groundwater Standards (NYSDEC GA Standards). As shown on Figure 6-1, reductive dechlorination of TCE occurred concurrently with the production of cDCE after the HRC® injection. Within two months after the injection, the TCE concentration was reduced from 410 micrograms per liter (µg/L) in January 2002 to 330 µg/L in April 2002, while the cDCE concentration increased from 32 µg/L to 64 µg/L. Within four months of the injection, TCE concentrations were approximately 50 percent less than the baseline concentration and the cDCE concentrations were approximately 70 percent greater. At the end of the Pilot Study in May 2004, the TCE concentrations remained 59 percent less than the baseline TCE concentration, whereas the cDCE concentrations remained at 70 percent greater than the baseline cDCE concentration. Both the TCE and cDCE concentrations were relatively stable in May 2004. VC was not detected during the baseline sampling event. Beginning in October 2002, the VC concentrations increased to 51 µg/l and 61 µg/l (April 2003), but then decreased to 27 µg/l in May 2004, indicating that complete degradation was occurring. During 2005, the TCE concentrations decreased to 130 µg/l (68 percent less than the baseline concentration), while the cDCE concentrations gradually increased to 140 µg/l (77 percent more than the baseline concentration). The VC concentrations remained stable. The total CVOC concentrations at MW-3 decreased by 31 percent over the course of the Pilot Study and decreased by another three percent over the following year (2005).

6.3.1.2 83DM-SP-1

Monitoring well SP-1 monitors the overburden and weathered bedrock groundwater and is located within the overburden injection grid area, down gradient of the bedrock injection well IW-6. Prior to the HRC® injection, the predominant CVOC at SP-1 was TCE, which was the only VOC to exceed the NYSDEC GA Standards. PCE and cDCE were present at trace concentrations. Two months after the HRC® injection, the TCE concentration at SP-1 was unchanged; however, the cDCE concentration had increased from 2 µg/L in January 2002 to 26 µg/L in April 2002 (Figure 6-1). Within four months of the injection, TCE concentrations were approximately 90 percent greater than the baseline concentration and the cDCE concentrations were 98 percent greater. VC was not detected at SP-1 until October 2002. Since October 2002, VC has been detected at concentrations greater than 20 µg/L and has remained relatively stable at those concentrations. As described above, following the HRC® injection, there was an immediate production of cDCE and a delayed production of VC with subsequent consumption of both CVOCs, which is typical of the reductive dechlorination process. However, TCE concentrations increased along with the cDCE concentrations. The increase in cDCE and VC concentrations indicates that TCE degradation was occurring; however, the data also indicate that TCE was being replenished from an upgradient and/or adjacent source area. This replenishment may have been due to the desorption of the TCE from the overburden aquifer matrix as a result of the HRC® injection. However, the TCE, cDCE, VC, and overall CVOC concentrations decreased by at least 70 percent during 2005 and to concentrations similar to the CVOC concentrations during the baseline sampling event.

6.3.2 Bedrock Monitoring Wells

6.3.2.1 WVA-AW-25-MW-2

Monitoring well MW-2 is located adjacent to the bedrock injection point IW-6 and up-gradient of the bedrock HRC® injection barrier. As shown on Table 6-1, prior to the HRC® injection in February 2002, the predominant CVOC at MW-2 was TCE. TCE, cDCE, and 1,1,1-TCA were present at concentrations greater than the corresponding NYSDEC GA Standards. As shown on Figure 6-1, reductive dechlorination of TCE occurred at MW-2 after the HRC® injection concurrently with the production of cDCE. Within two months after the injection, the

TCE concentration was reduced from 170 µg/L in January 2002 to 49 µg/L in April 2002, while the cDCE concentration increased from 17 µg/L to 68 µg/L. During the April and May 2003 sampling events, PCE, TCE, cDCE, and VC were not detected. By May 2004, the TCE concentrations had steadily decreased to nearly non-detectable levels (9 µg/l) and the cDCE concentrations had decreased to pre-injection concentrations. VC was only detected at MW-2 in October 2002 (2 µg/l), May 2004 (6 µg/l), and May (3.2 µg/l) and October (7.8 µg/l) 2005. The total CVOC concentration at MW-2 at the end of the Pilot Study in May 2004 was 82 percent less than the total baseline CVOC concentration. In 2005, the CVOC concentrations remained relatively stable. The October 2005 overall CVOC concentration at MW-2 was 76 percent less than the overall baseline CVOC concentration.

6.3.2.2 WVA-AW-25-MW-7

Monitoring well MW-7 is located down gradient of the bedrock injection barrier. The predominant CVOC at MW-7 prior to the HRC® injection was PCE. PCE, TCE, and cDCE were present at concentrations greater than the corresponding NYSDEC GA Standards. As shown on Figure 6-1, reductive dechlorination of PCE and TCE occurred after the HRC® injection concurrently with the production of cDCE. Within two months after the HRC® injection, the PCE concentration was reduced by 93 percent and within four months was reduced to non-detectable levels (Figure 6-1). The TCE concentration was reduced to non-detectable concentrations in April 2002, while the cDCE concentration increased from 10 µg/L in January 2002 to 150 µg/L in April 2002. By June 2002, cDCE concentrations had returned to low levels. VC was only detected at MW-7 during the June 2002 sampling event (16 µg/L). During 2005, PCE and TCE were not detected for the first time since monitoring well MW-7 was installed. The cDCE concentration decreased to 1.6 µg/l (84 percent less than the baseline concentration) and was the only CVOC detected in 2005. The total CVOC concentrations at MW-7 decreased by 88 percent over the course of the Pilot Study and decreased another 11 percent over the following year (2005). It should be noted that HRC® was present in well MW-7 from the October 2002 monitoring event through the end of the Pilot Study. The presence of the HRC® is attributed to the injections at the upgradient barrier wells IW-1 through IW-5 and is indicative of HRC distribution downgradient of the HRC® barrier.

6.4 Indicator Parameters

Groundwater samples collected from the Building 25 Pilot Study monitoring wells for indicator parameter analyses were collected in accordance with the methods specified in the Pilot Study Work Plan. Severn Trent Laboratories performed the carbon dioxide, ethane, ethene, methane, and DOC analyses. Analytical data packages for these analyses are contained on the compact disc in Appendix D. All other indicator parameter analyses were conducted in the field by MPI. Ferrous iron, nitrate, sulfate, and alkalinity were measured using Hach® test kits. Field indictor parameters were analyzed during the field and full monitoring events. Carbon dioxide, ethane, ethene, methane, and DOC were analyzed only during the full monitoring events. These indicator parameters were monitored to compare the conditions of the aquifer prior to, and after the HRC® injection, and to assess whether the chemical properties of the aquifer were adequate for reductive dechlorination to occur. The dissolved gases were evaluated to assess the progress of reductive dechlorination at each monitoring well. As discussed in Section 2.0, carbon dioxide, ethane, and ethene are products of complete reductive dechlorination of CVOCs. The results of indicator parameters analyses from samples collected throughout the Pilot Study and the long-term monitoring program are tabulated on Table 6-2.

6.4.1 Carbon dioxide

Carbon dioxide was not detected at any of the Building 25 monitoring wells during the Pilot Study and within the first year following the end of the Pilot Study (May 2004), except in May 2005 at MW-2 (2,310 µg/l).

6.4.2 Ethane

Ethane, which is a byproduct of the complete degradation of 111 TCA, was only detected at MW-7 (4 µg/L) in October 2002.

6.4.3 Ethene

As shown on Figure 6-4, ethene, which is a product of the complete degradation of PCE and TCE, was first detected in October 2002 at monitoring wells, MW-3, MW-7, and SP-1. Ethene was not detected at MW-2 during the Pilot Study. At MW-3 and MW-7, the appearance of ethene coincided with the reduction of PCE and TCE, indicating that complete degradation of the CVOCs was occurring. Coincident with the ethene production was the production of VC. VC was at its highest concentrations at MW-3 and MW-7 during the sampling events in which ethene was present. As discussed in Section 6.2.1.2, it appears that TCE at SP-1 was consumed and subsequently replenished over the course of the Pilot Study, which is a trend typical of groundwater close to a contaminant source area. Unlike the other Building 25 Pilot Study monitoring wells, ethene concentrations at SP-1 exhibited the same trend (production and consumption) in concentrations as TCE. The ethene concentrations were the highest at MW-3 (8.9 µg/L and 20 µg/L) and were similar at MW-7 (3.0 µg/L) and SP-1 (4.2 to 4.4 µg/L). During the 2005 long-term monitoring program sampling events, ethene was not detected at any of the four Building 25 monitoring wells.

6.4.4 Methane

Prior to the HRC® injection, methane was detected at low concentrations at MW-2, MW-3, and MW-7 and was not detected at SP-1. The methane concentrations at all four monitoring wells slightly increased during the first full post-injection monitoring event in April 2002 (Figure 6-4). Methane concentrations in all monitoring wells increased by 99 percent between the April 2002 and April 2003 sampling events. In general, the methane concentrations at MW-2 continually increased between October 2002 and May 2004. In May 2005, the methane concentration was five times less than the May 2004 concentration. The maximum methane concentrations in monitoring wells MW-2, MW-3, and MW-7 were measured in May 2004 (5,800 µg/L, 1,800 µg/L, and 18,000, respectively). The methane concentrations at SP-1 peaked in October 2003 (600 µg/L) and then decreased to the May 2004 concentration of 280 µg/L. The elevated methane concentrations in April and October 2003 at SP-1 and in May 2004 at MW-2, MW-3, and MW-7 are likely due to microbial activity by methane producing bacteria (methanogens). As discussed in Section 6.1.2, the biomass at MW-2, MW-3, MW-7, and SP-1 during these sampling events may have been more conducive to methane production than reductive dechlorination. At the overburden wells MW-3 and SP-1, peaks in methane concentration were associated with smaller peaks in alkalinity concentrations, indicating that when microbes were active they favored the production of methane rather than the degradation of TCE. This is shown on Figure 6-3, where the TCE concentrations at MW-3 stabilize at 170 µg/L in May 2003 and remain at that concentration through the end of the Pilot Study.

Unlike the methane production at the overburden monitoring wells, the methane concentration peaks at MW-2 and MW-7 were not associated with alkalinity peaks, indicating that the methanogens were not utilizing all of the hydrogen. This is exemplified by the fact that reductive dechlorination occurred simultaneously with the methane production at these locations. The data also suggests that once the PCE, TCE, and cDCE were degraded, methane was produced at a much faster rate due to the lack of CVOC electron acceptors. In April 2004, the biomasses at MW-2 and MW-7 were four times greater than in June 2002. These peaks in biomass correlate with the May 2004 peaks in methane concentrations.

In May 2005, the methane concentrations at all four monitoring wells decreased by at least 50 percent. Concurrent with the decrease in methane concentrations, DOC concentrations decreased or remained low in the Building 25 area, indicating that the decrease in methane may be due to the lack of carbon versus an increase in reductive dechlorination of CVOCs by reductive dechlorinators. However, based on the decrease in CVOC concentrations at SP-1, MW-2, and MW-7 in 2005, the limited amount of microorganisms present in the subsurface in these areas may have been reductive dechlorinators instead of methanogens.

6.4.5 Dissolved Organic Carbon (DOC)

As discussed in Section 2.0, DOC is an indicator of the amount of carbon in an environment that is available for microbial growth and use. Prior to the HRC® injection, DOC measurements at all four monitoring wells were relatively low, with the greatest concentration at MW-7 (27 µg/L). As shown in Figure 6-5, during the first full monitoring event after the HRC® injection (April 2002), all of the monitoring wells except MW-3 exhibited increases in DOC concentrations of at least 98 percent as compared to the baseline concentrations. In April 2002, the DOC concentration at MW-3 was 9.4 µg/L, which was slightly less than the baseline concentration (10 µg/L).

The DOC concentrations at SP-1 and MW-7 peaked in April 2002 (190 µg/L and 1,800 µg/L, respectively) and decreased to pre-injection concentrations by June 2002 at both monitoring locations. This decrease in DOC concentrations corresponded with the increase of methane concentrations at these wells, which indicates that methanogens were most likely stimulated and utilized the carbon to produce methane (Figure 6-4). At MW-7, the DOC concentrations rebounded twice between October 2002 and May 2003, and October 2003 and April 2004. When the DOC concentrations were at their peak in April 2002, reductive dechlorination was taking place, indicating that reductive dechlorinators were utilizing the hydrogen produced from the HRC® in the aquifer to break down the CVOCs. The decrease in DOC concentrations following the peak at MW-7 correlates with the increase in the microbial starvation biomarker in July 2002.

The slight decrease in DOC concentrations between June and October 2002 at MW-2 correlates with the increase in the microbial starvation biomarker in July 2002. In October 2002, the DOC concentrations increased while the microbial starvation biomarker decreased. The presence of HRC® was not directly evident based on the DOC concentrations at MW-3, which did not change between the baseline and first post-injection field monitoring event and did not show a significant change in concentration during the Pilot Study.

6.4.6 Alkalinity

Alkalinity was used as an indicator of overall microbial activity as it has been shown that increased biological activity can produce increases in alkalinity concentrations (USEPA, 1998). Prior to the HRC® injection, alkalinity concentrations ranged from 179 mg/L at MW-2 to 292 mg/L at MW-7. During the first field monitoring event in February 2002, the alkalinity concentrations increased at MW-2 and MW-7 and slightly decreased at MW-3. Monitoring well SP-1 had not been sampled for alkalinity prior to the HRC® injection in February 2002. As shown on Figure 6-6, alkalinity concentrations at the bedrock wells (MW-3 and MW-7) varied after the HRC® injection. At MW-3, the alkalinity concentrations peaked in April 2003 (478 mg/L) and began to stabilize at concentrations greater than the pre-injection concentrations. The peaks in alkalinity concentrations correlate with the peaks in methane concentrations. Monitoring wells MW-2 and SP-1 exhibited rapid increases in alkalinity concentrations in March 2002 (10,000 mg/L) and in June 2002 (4,000 mg/L), respectively. Following these rapid increases in alkalinity concentrations, the concentrations rapidly decreased and remained at pre-injection concentrations for the duration of the Pilot Study. In 2005, the alkalinity concentrations at the bedrock monitoring wells (MW-2 and MW-7) decreased concurrently with the decrease in methane concentrations, while the alkalinity concentrations at the overburden monitoring wells (SP-1 and MW-3) increased.

6.4.7 Ferrous Iron

As discussed in Section 2.0, ferric iron (Fe^{3+}) can act as an electron donor in the reductive dechlorination process and, as a result, produce ferrous iron (Fe^{2+}). Prior to the HRC® injection, ferrous iron concentrations ranged from 0.01 mg/L at MW-3 to 0.09 mg/L at MW-7 (Figure 6-7). The ferrous iron concentration at SP-1 was not measured during the baseline sampling event in January 2002. At all four monitoring wells, except SP-1, ferrous iron concentrations increased to greater than 1.61 mg/L during the first field monitoring event (February 2002), indicating that ferric iron had been utilized as an electron donor for reductive dechlorination.

All of the monitoring wells exhibited a peak in ferrous iron concentrations during the February, March, or April 2002 field monitoring events. Monitoring wells MW-2, MW-3, and SP-1, exhibited rapid decreases in ferrous iron concentrations directly following these peaks, indicating the depletion of iron in the aquifer systems. However, the data suggests that the iron was replenished (through advective flow) and continued to be utilized throughout the Pilot Study since a majority of the post-injection samples show ferrous iron concentrations remaining greater than the baseline concentrations for the duration of the Pilot Study. The monitoring wells (MW-2 and MW-7) that had higher ferrous iron concentrations throughout the study, indicating the continuous reduction of ferric iron, were also the monitoring wells that had removed at least 80 percent of the total CVOCs during the Pilot Study. At the end of 2005, an iron-reducing environment remained at all four monitoring locations. However, the amount of ferrous iron being produced by the reduction of ferric iron at the bedrock monitoring wells MW-3 and SP-1 has continued to decrease over time.

6.4.8 Nitrate

Prior to the HRC® injection, nitrate concentrations varied from 0.53 mg/L at MW-2 to 0.92 mg/L at MW-3. The nitrate concentration at MW-7 was 0 mg/L. As shown on Figure 6-8, during the first post-injection field monitoring event in February 2002, nitrate concentrations decreased to less than 0.1 mg/L at all monitoring locations, except MW-7. These data indicate that nitrate was used as an electron donor for reductive dechlorination during the Pilot Study. Beginning in May 2003, the nitrate concentrations at all four monitoring wells began to slightly increase. In general, nitrate concentrations were increasing and were similar to pre-injection concentrations at the conclusion of the Pilot Study and during 2005. However, the decrease in nitrate concentrations at MW-7 and SP-1 in October 2005 suggests that nitrate is still being utilized as an electron donor.

6.4.9 Sulfate

As discussed in Section 2.0, CVOCs are most efficiently biodegraded under sulfate-reducing conditions. As shown on Figure 6-9, prior to the HRC® injection, sulfate concentrations were greater than the maximum concentration (80 mg/L) that could be measured by the Hach® test kit at all of the monitoring locations. Within two months of the HRC® injection, the sulfate concentrations at SP-1, MW-2, and MW-7 had decreased to less than 4 mg/L. The sulfate concentrations at MW-3 began to decrease in June 2002. These data indicate that sulfate was utilized as an electron donor for reductive dechlorination at all locations.

The sulfate concentrations at MW-3 continued to decrease until October 2002 (28 mg/L), then increased to pre-injection concentrations by October 2003. The sulfate concentrations at SP-1 gradually increased after March 2002 to pre-injection concentrations in April 2004. At MW-2 and MW-7, the sulfate concentrations did not show signs of rebound to the baseline concentrations and remained less than 20 mg/L throughout the Pilot study, indicating that CVOC degradation through sulfate reduction was ongoing at the conclusion of the Pilot Study. In 2005, the sulfate concentrations at MW-2 and MW-7 increased, but were still more than 60 mg/L less than the baseline concentrations.

7.0 Pilot Study Discussion

Based on the data collected during the Pilot Study, the injection of the HRC® successfully promoted reductive dechlorination of the CVOCs in both the overburden and bedrock groundwater in the Building 25 area. Figures 7-1, 7-2, 7-3, and 7-4 show a geologic cross-section of the Building 25 area along with CVOC concentrations at each well during the baseline sampling event (January 2002), a midpoint sampling event during the Pilot Study (April 2003), the last sampling event during the Pilot Study (May 2004), and the most recent sampling event (October 2005) conducted at the site. As shown on these figures, by the end of the Pilot Study in May 2004, the total sum of CVOCs decreased by 82 percent at MW-2, 31 percent at MW-3, 88 percent at MW-7, and increased by 92 percent at SP-1 in comparison to the baseline total sum of CVOCs. In addition, the relative proportion of the parent CVOC (i.e., PCE or TCE) decreased by more than 38 percent at all locations, including SP-1.

The overall decreasing or stable trend in the CVOCs concentrations at Building 25 continued into 2005. In October 2005, the total sum of CVOCs decreased by 76 percent at MW-2, 34 percent at MW-3, 99 percent at MW-7, and increased by 51 percent at SP-1 in comparison to the baseline total sum of CVOCs. In comparison to the May 2004 CVOCs concentrations, the total sum of concentrations in October 2005 at SP-1 decreased by 83 percent and were similar to the baseline CVOCs concentrations. At MW-7, cis-DCE was the only CVOC detected in October 2005. The overall decrease in the concentration of the parent CVOC (i.e., PCE or TCE) in all monitoring wells, except SP-1, decreased by more than 68 percent.

The data indicate that the HRC® provided the energy source needed for the reductive dechlorinators to breakdown CVOCs during the Pilot Study. An increase in microbial activity was indicated by the increase in alkalinity and dissolved gas concentrations after the HRC® injection, and by microbial population data. Overburden and bedrock aquifer conditions were also shown to be conducive to reductive dechlorination. ORP and DO levels in the groundwater in the treatment area were low and the electron donors (i.e. ferric iron, nitrate, sulfate, and methane) decreased in concentration, indicating that they were being used for the biodegradation of CVOCs. As shown on Figures 6-7, 6-8, and 6-9, there was always at least one electron donor available at each of the monitoring wells during the Pilot Study. At many of the monitoring wells, ferric iron, nitrate, and sulfate were present simultaneously. In general, following the end of the Pilot Study, the presence of electron donors and the geochemistry of the subsurface in the

Building 25 area was adequate for the reductive dechlorination of CVOCs to continue.

CVOC and dissolved gas data indicate that complete reductive dechlorination occurred at all monitoring wells. However, the rate of dechlorination was not sufficient to treat all the CVOCs during the time frame of the Pilot Study. Electron donor availability, carbon concentrations, and microbes were all likely limiting factors in the rate of biodegradation of CVOCs. As discussed earlier, carbon concentrations were adequate for the production of microbial activity in the Building 25 area, as indicated by the increase in alkalinity and DOC concentrations. Although the ferric iron, nitrate, and/or sulfate concentrations were reduced at various points during the study, there was always at least one electron donor available for use. However, the electron donor present may not have been the most efficient donor. The monitoring wells where ferric iron and sulfate were continually utilized (MW-2 and MW-7) had a rapid and more complete biodegradation of CVOCs than the monitoring wells that did not. Based on the data collected during this study, the type and quantity of microbes was also a limiting factor on the rate of biodegradation. At many of the monitoring wells methane was produced. Since methanogens compete with reductive dechlorinators for carbon, it is likely that the increased methanogenic activity restricted the rate of reductive dechlorination during the Pilot Study.

8.0 Pilot Study Conclusions

Based on the data collected during and after the Pilot Study, the injection of HRC$^{®}$ was successful in promoting the biodegradation of the PCE and TCE in both the overburden and bedrock groundwater through reductive dechlorination. This conclusion is supported by the following data.

- HRC$^{®}$ was successfully delivered and distributed into the overburden and bedrock groundwater as shown by the increase in DOC concentrations at three of the four monitoring wells studied during the Pilot Study and the detection of HRC$^{®}$ at MW-7.
- By the end of 2005, the HRC$^{®}$ reduced the total CVOC concentrations by 76 and 99 percent in the two bedrock monitoring wells (MW-2 and MW-7), and by 34 percent in overburden monitoring well MW-3.
- The CVOCs concentrations at MW-2, MW-3, and MW-7 are not showing signs of rebound and are remaining relatively stable or are decreasing more than three years after the HRC$^{®}$ injection.
- The geochemistry of the overburden and bedrock groundwater was conducive to the reductive dechlorination of PCE and TCE into its daughter products (i.e., cDCE, VC, and ethene).
- Trends in the concentration of daughter products and the concentrations of dissolved gases in the groundwater indicate that complete degradation of the CVOCs was occurring during the Pilot Study and is still occurring after the Pilot Study.
- Ferric iron, nitrate, sulfate, and methane were available as electron donors and were utilized as election donors for the reductive dechlorination of PCE, TCE, cDCE, and VC. Electron donor concentrations following the Pilot Study indicated that reductive dechlorination is still occurring in the groundwater.
- Concentrations of CVOCs in the monitoring well MW-7, located downgradient of the HRC barrier injection wells were significantly reduced to concentrations less than NYSDEC Class GA Groundwater Standards.

These results, combined with the fact that HRC$^{®}$ was still present in the subsurface at the conclusion of the three-year Pilot Study, and that concentration trends for CVOCs, geochemical parameters, and electron donors are indicative of ongoing reductive dechlorination, indicate that biodegradation of the CVOCs in the groundwater at Building 25 will continue in the future.

Since the CVOCs in the groundwater at Building 25 are localized to the Pilot Study Area and are not migrating beyond the WVA property boundary, long-term monitoring accompanied by the ongoing natural attenuation is recommended as the final corrective measure for the CVOCs in the Building 25 groundwater

9.0 References

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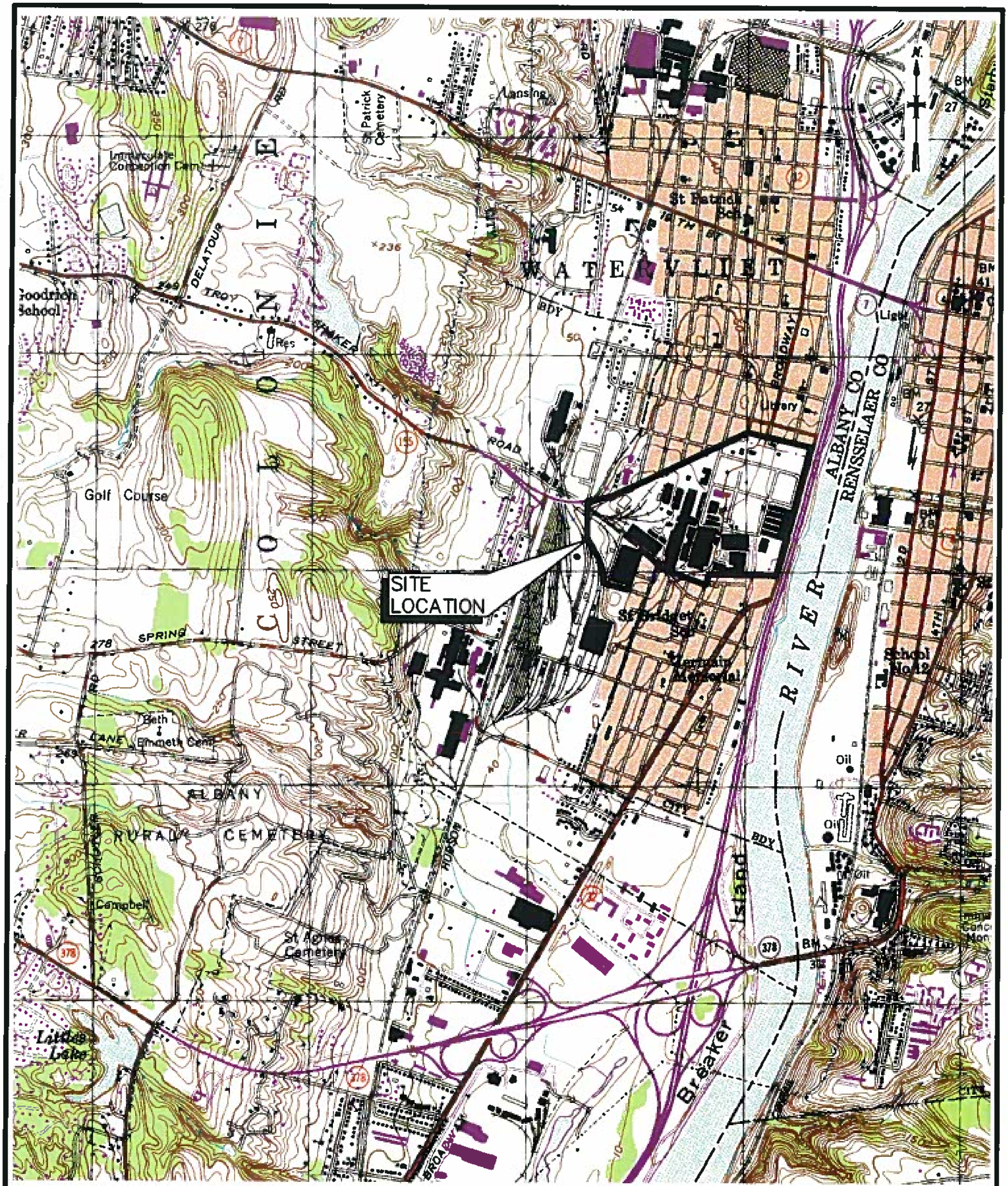
USEPA, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. EPA/600/R-98/128, September 1998.



SOURCE: NYSDOT TROY SOUTH
QUAD MAP, 1980

1,000' 0 2,000'

SCALE: 1" = 2,000'

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
SITE LOCATION

WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

MALCOLM PIRNIE, INC.

FIGURE 1-1

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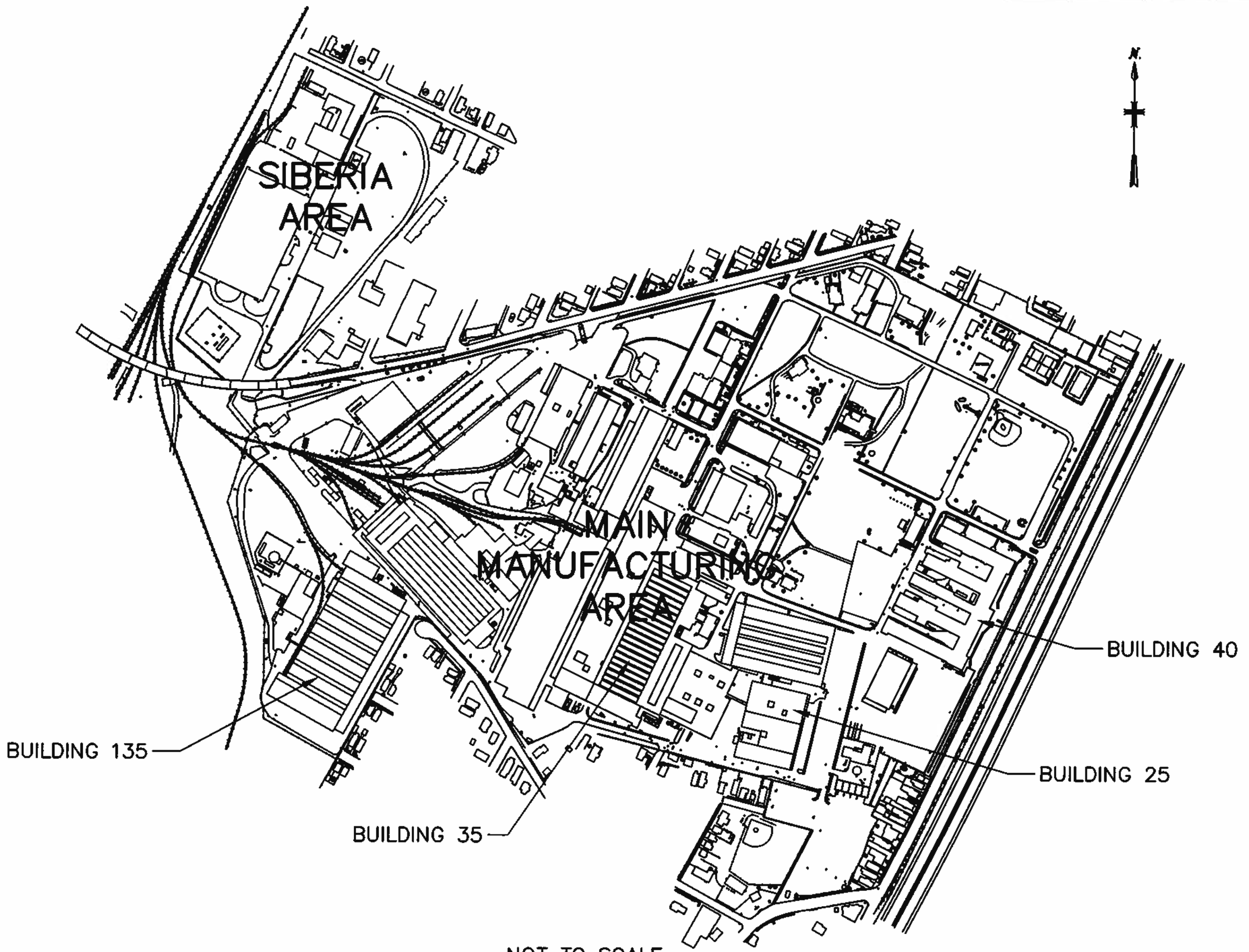


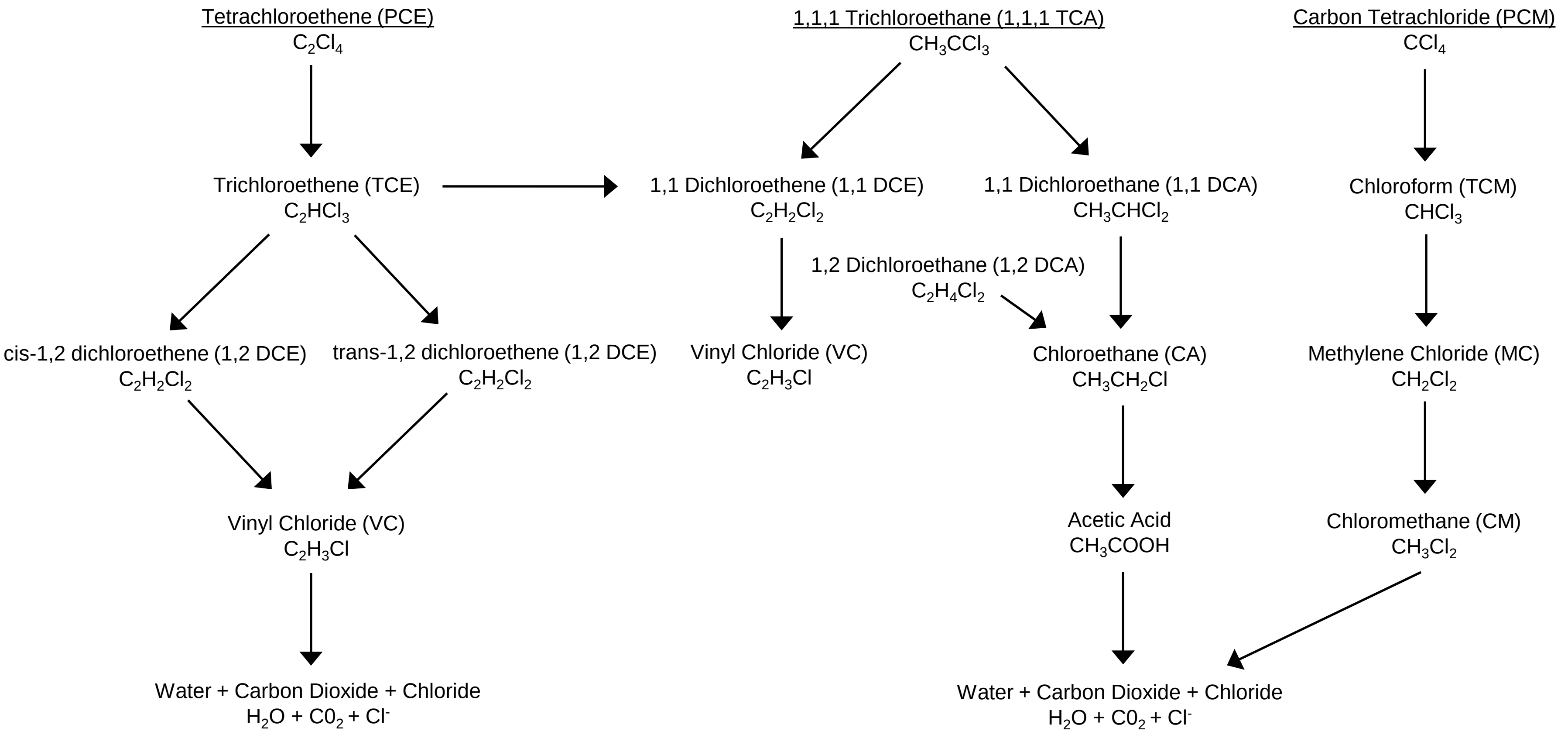
NOT TO SCALE

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
SITE PLAN
WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

MALCOLM PIRNIE, INC.

FIGURE 1–2



SOURCE: Morrison, R., *Environmental Forensics*, 2000

US Army Corps of Engineers
Baltimore District

REDUCTIVE DECHLORINATION PATHWAY FOR SELECTED CHLORINATED SOLVENTS

BUILDING 25 – HRC PILOT STUDY,
WATERVLIET ARSENAL, WATERVLIET, NEW YORK

FIGURE 2-1

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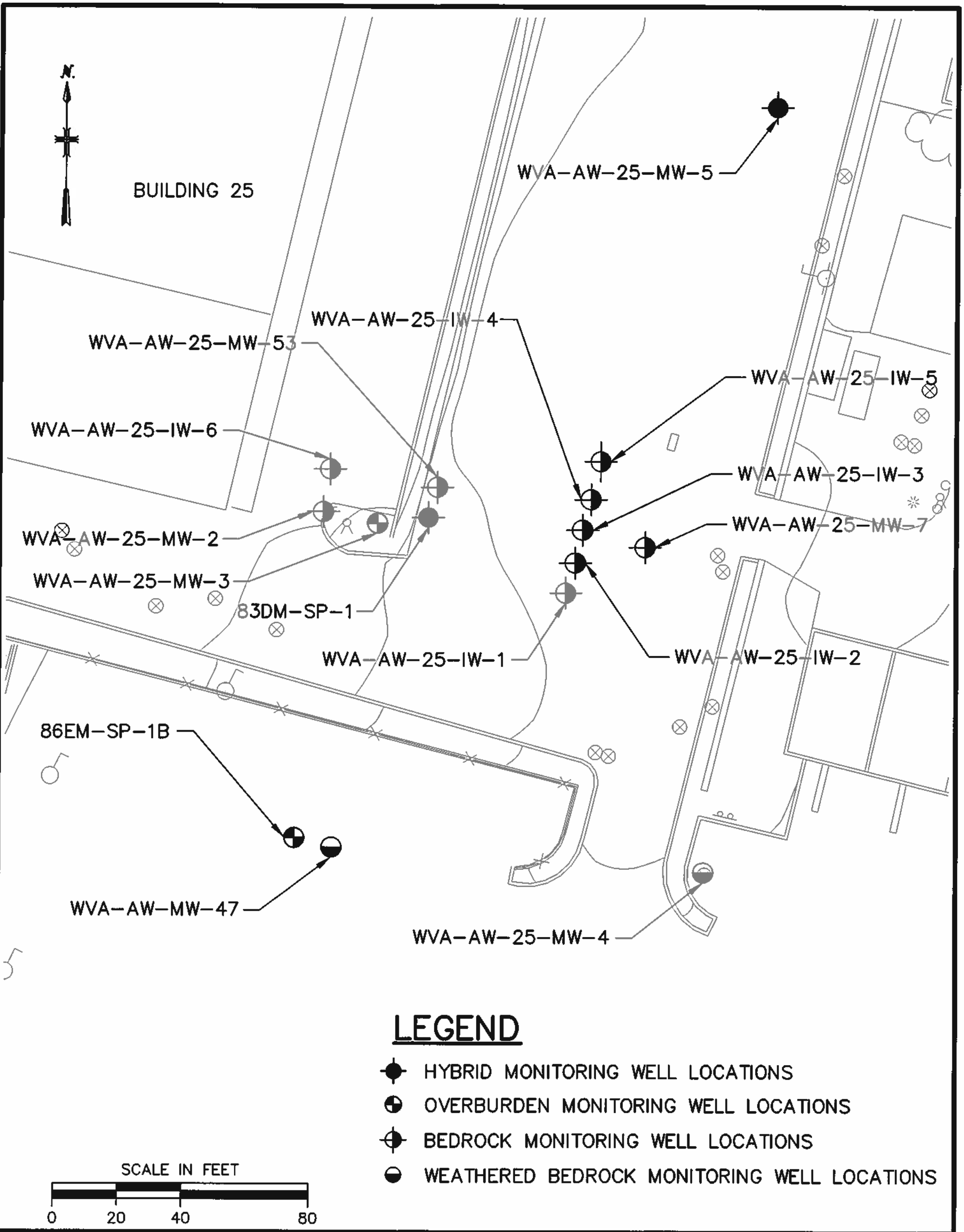

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
SAMPLING LOCATIONS

WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

MALCOLM PIRNIE, INC.

FIGURE 3-1

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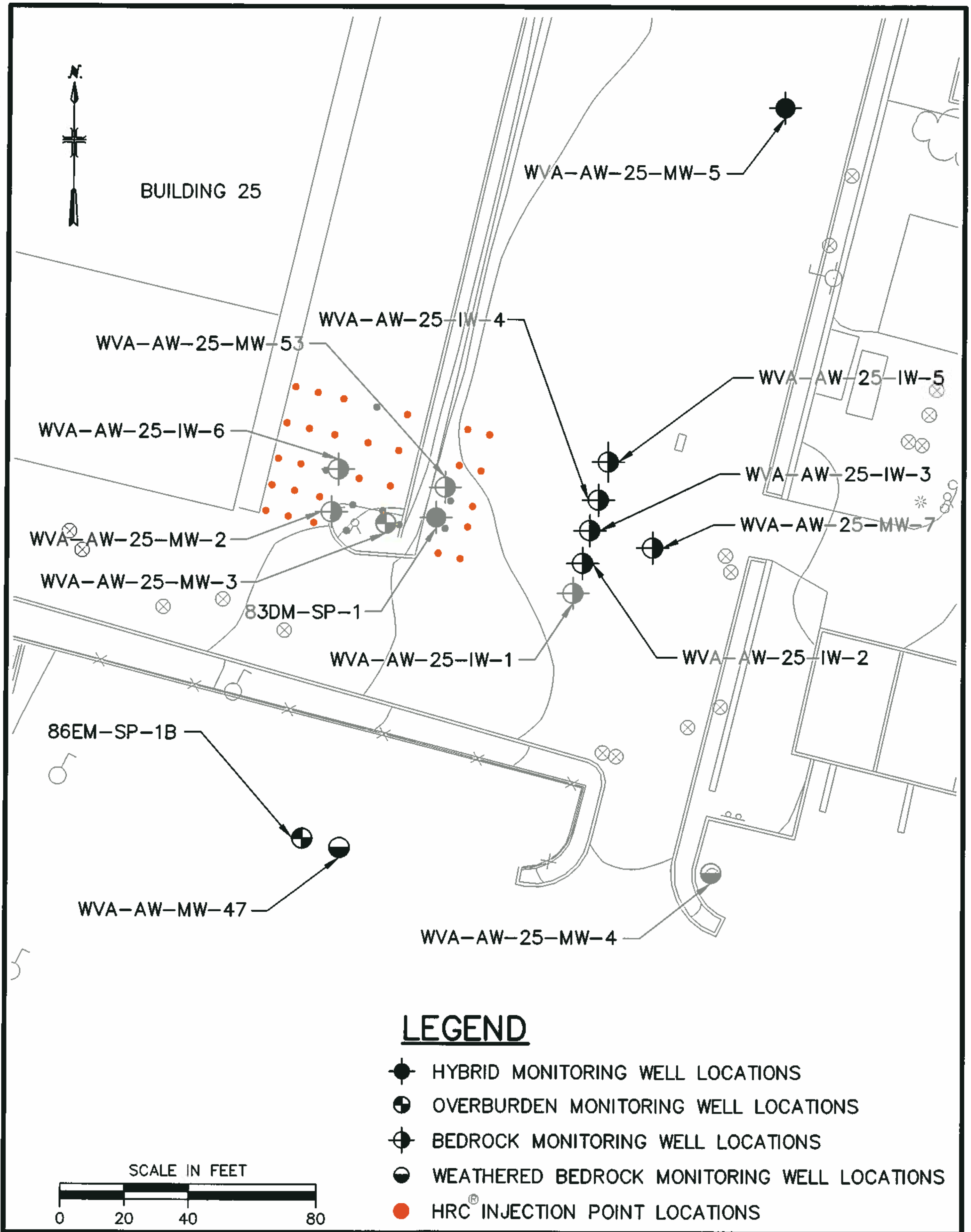


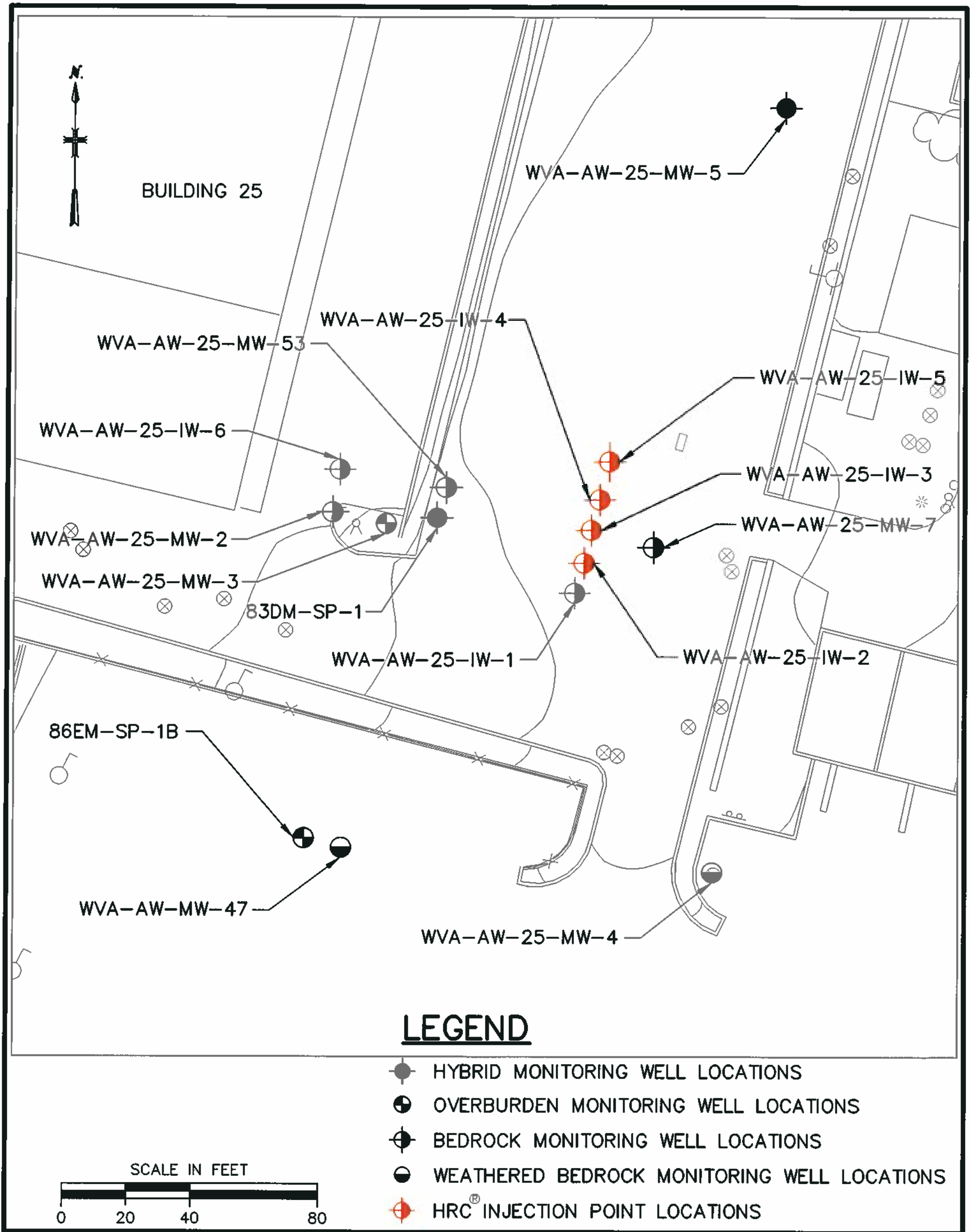
US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
OVERBURDEN HRC® INJECTION LOCATIONS

WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

MALCOLM PIRNIE, INC.

FIGURE 4-1



US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
BEDROCK HRC® INJECTION LOCATIONS

WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

MALCOLM PIRNIE, INC.

FIGURE 4-2

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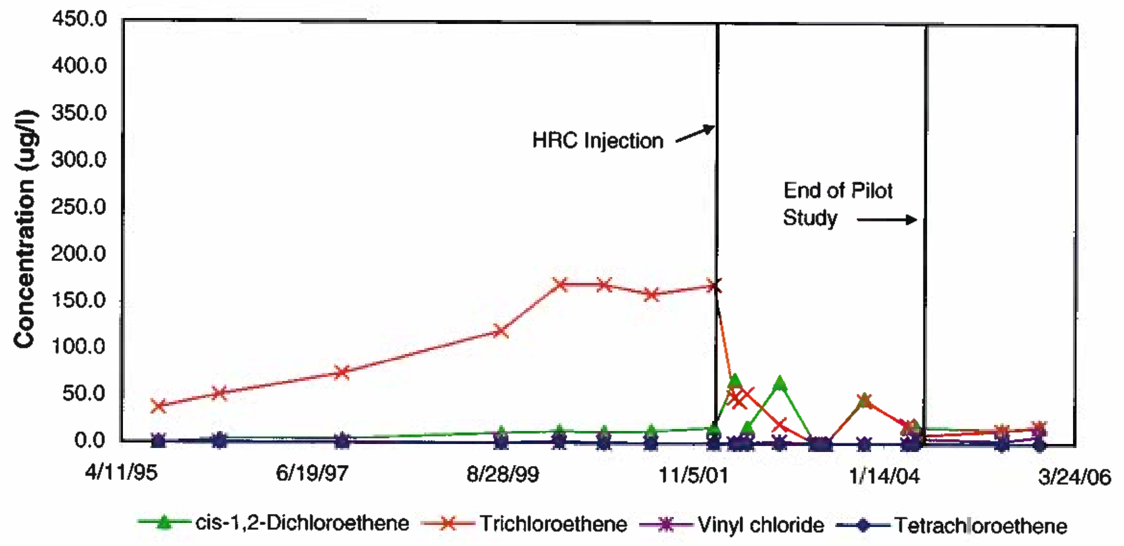

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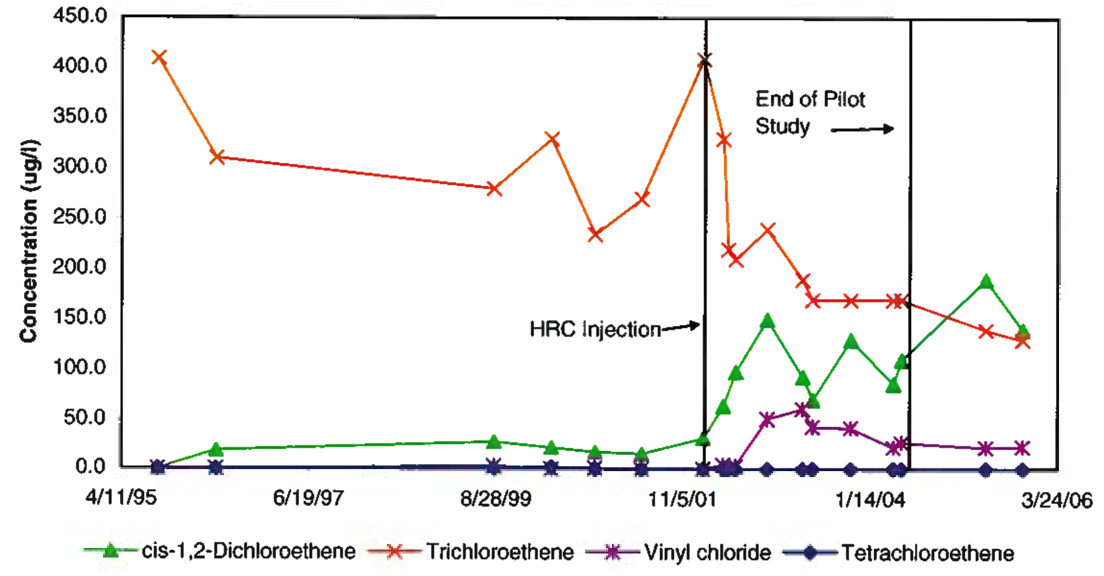
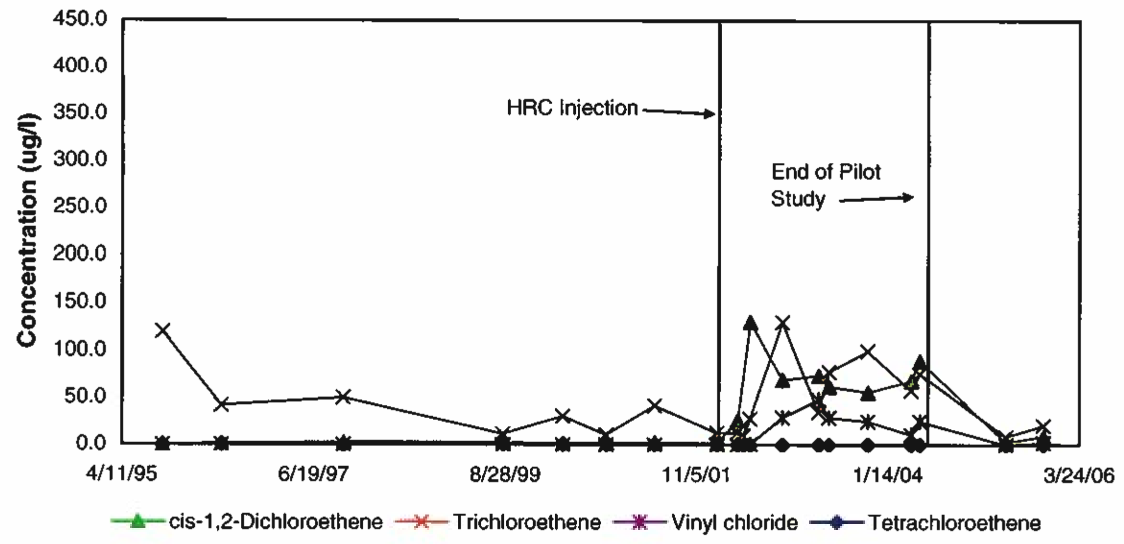


83DM-SP-1



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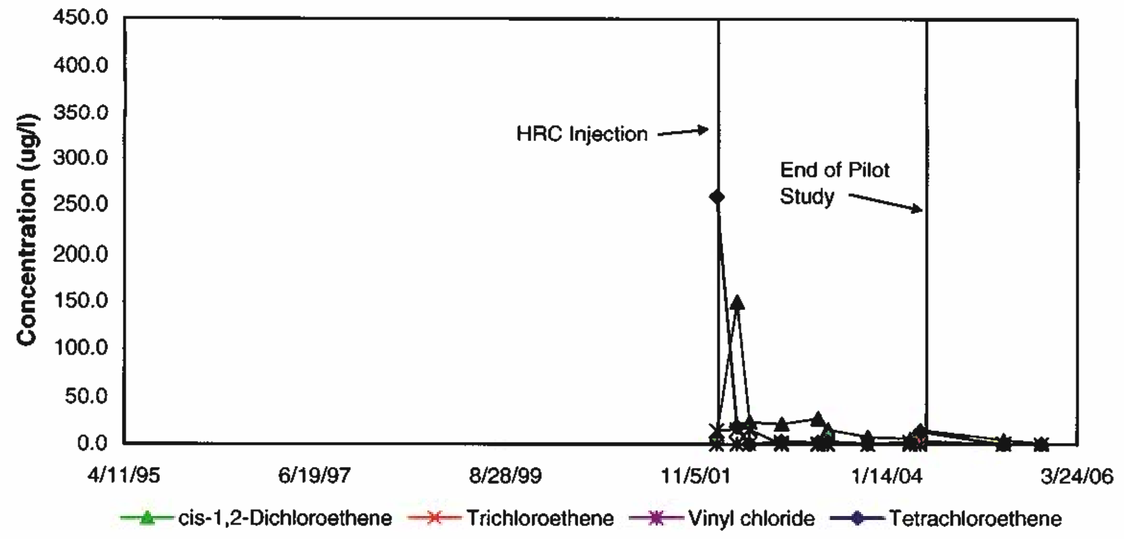


US Army Corps
of Engineers
Baltimore District

BUILDING 25 - HRC PILOT STUDY
WATERVLIET ARSENAL, WATERVLIET, NEW YORK
VOCs IN GROUNDWATER

FIGURE 6-1

Figure 6-2
Dissolved Oxygen Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

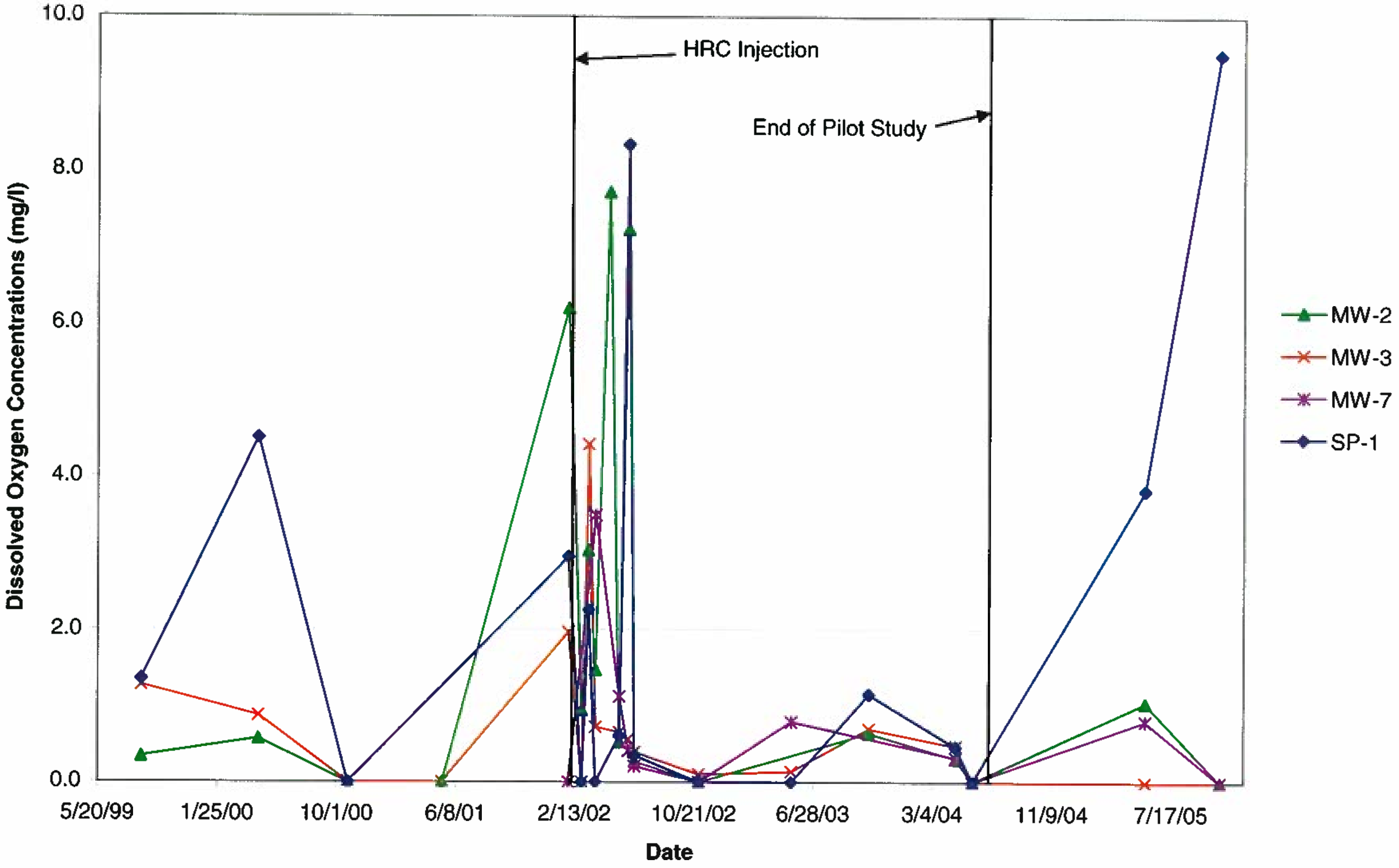
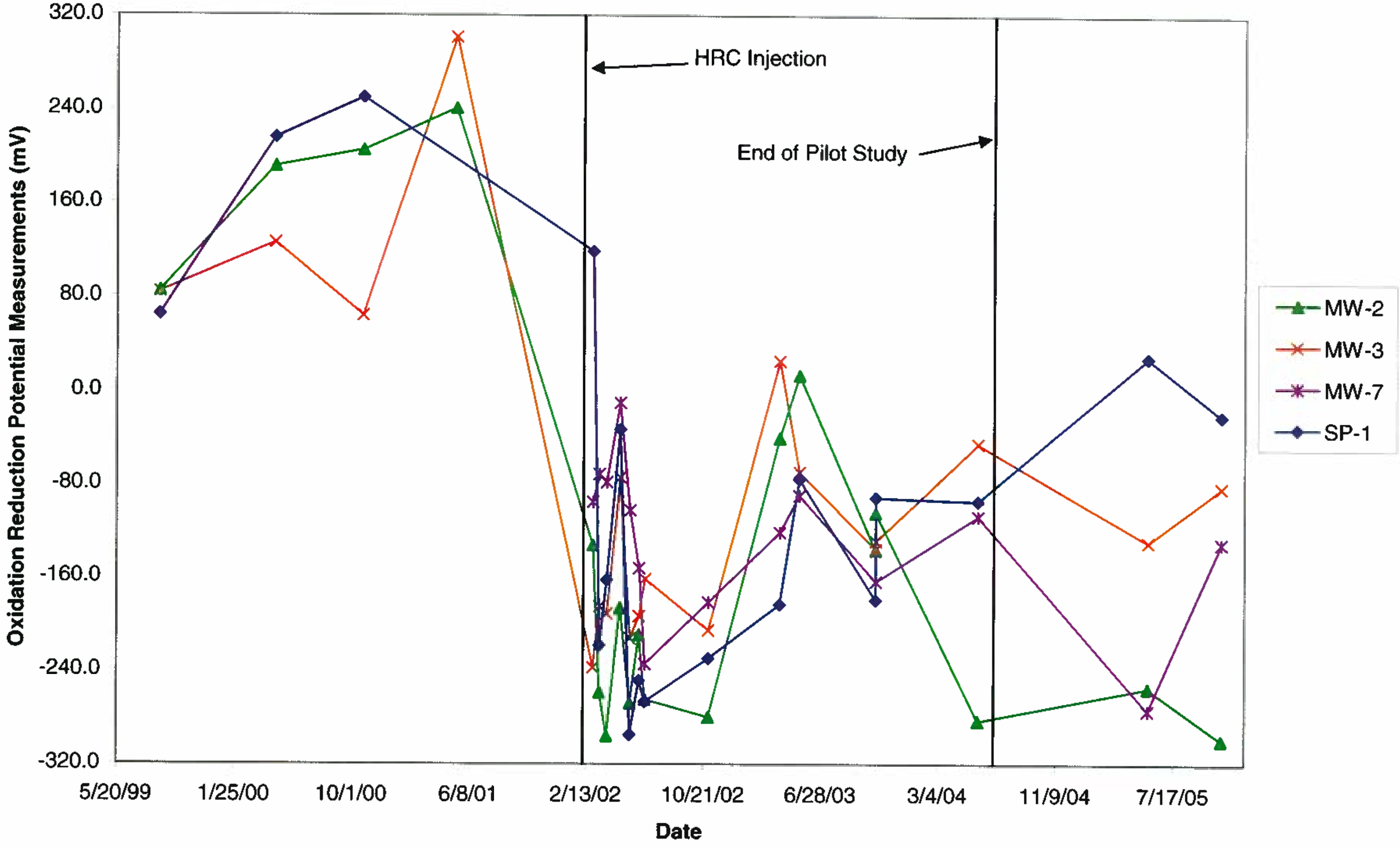
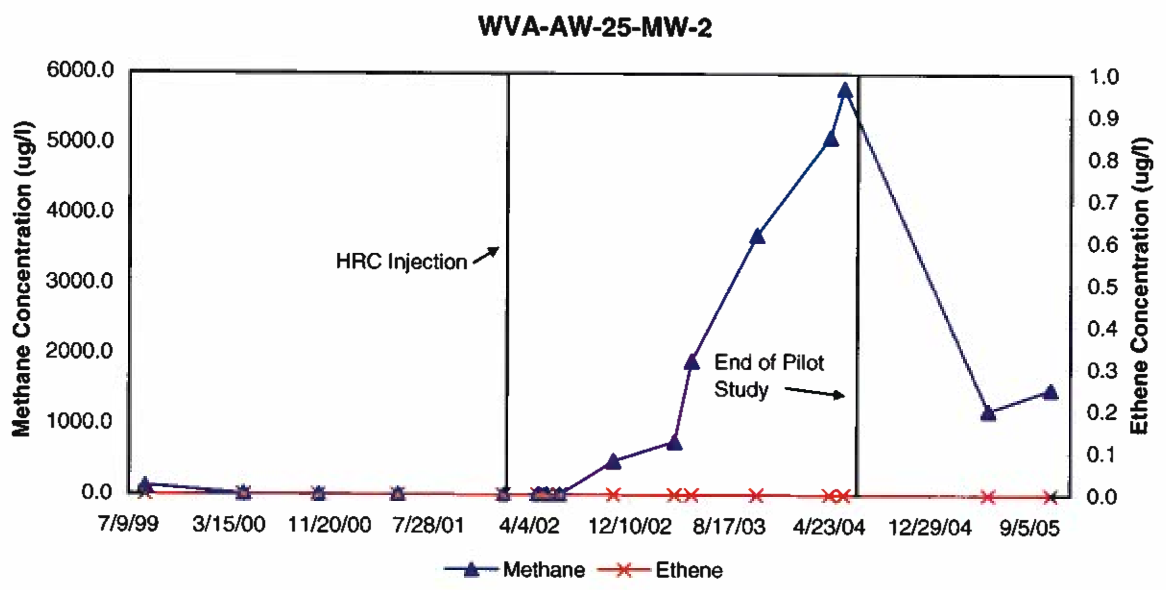


Figure 6-3
Oxidation Reduction Potential Measurements in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

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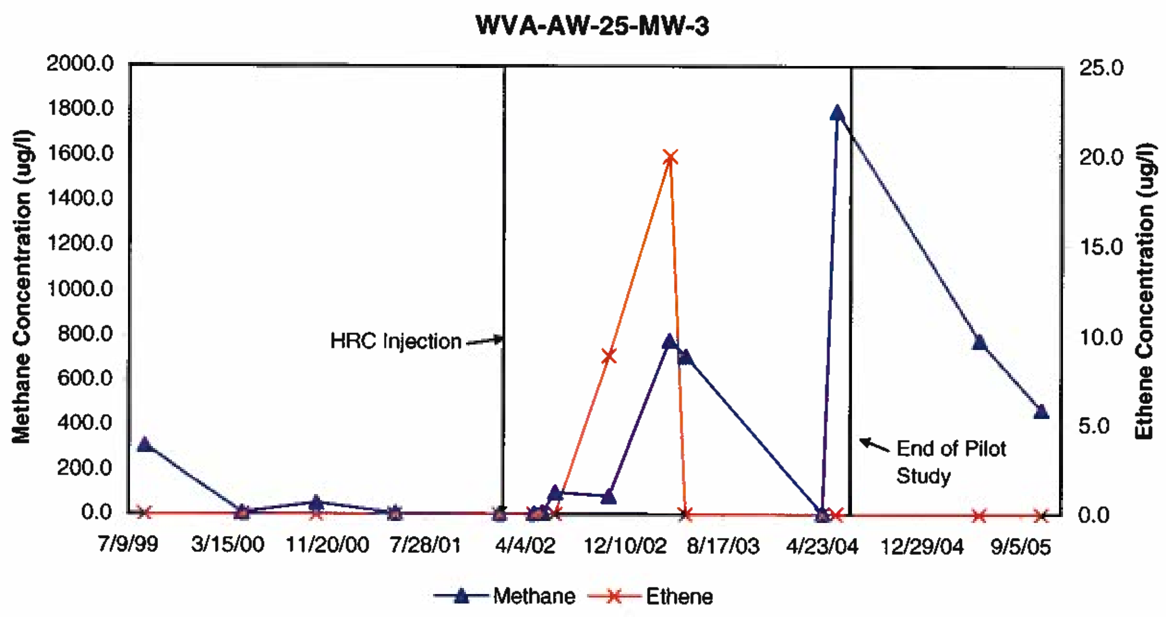
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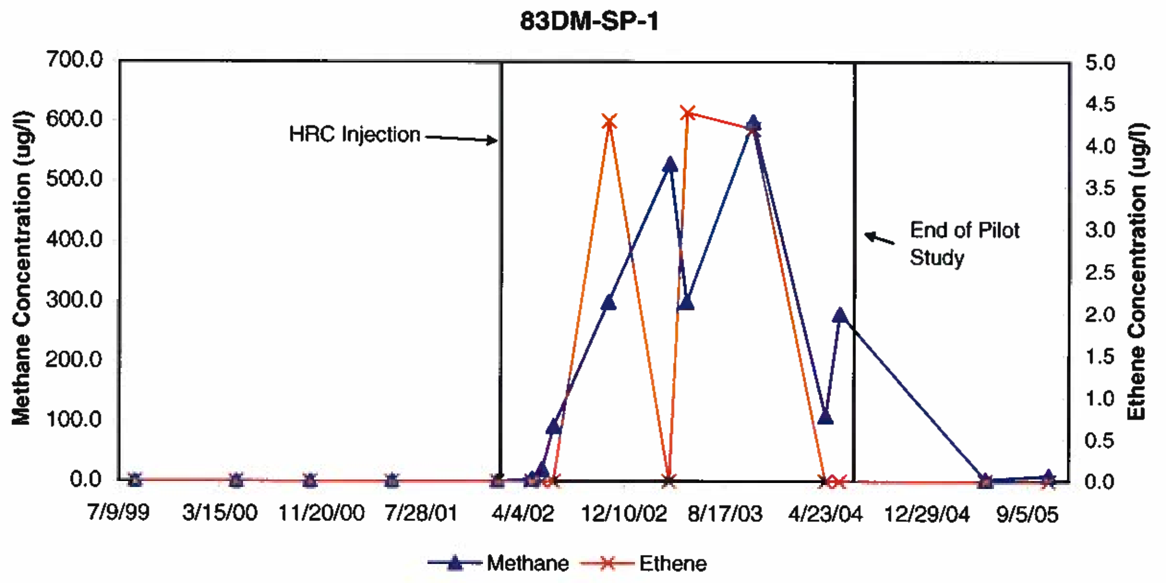
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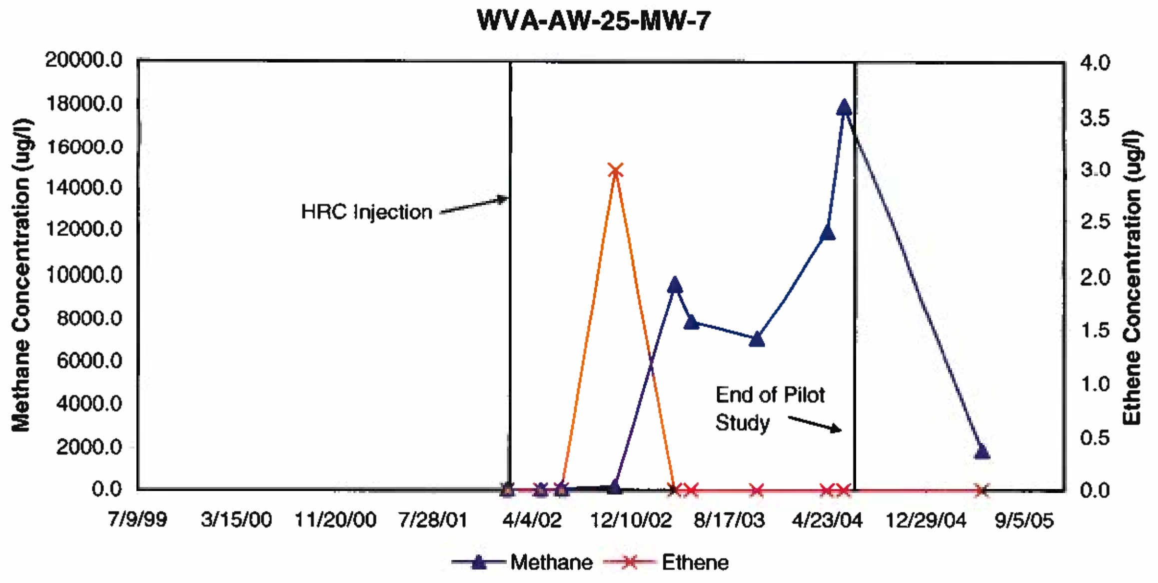
WVA-AW-25-MW-7

Note: Vertical scales are not the same.

US Army Corps
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BUILDING 25 - HRC PILOT STUDY
WATERVLIET ARSENAL, WATERVLIET, NEW YORK
DISSOLVED GASES IN GROUNDWATER

FIGURE 6-4

Figure 6-5
Dissolved Organic Carbon Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

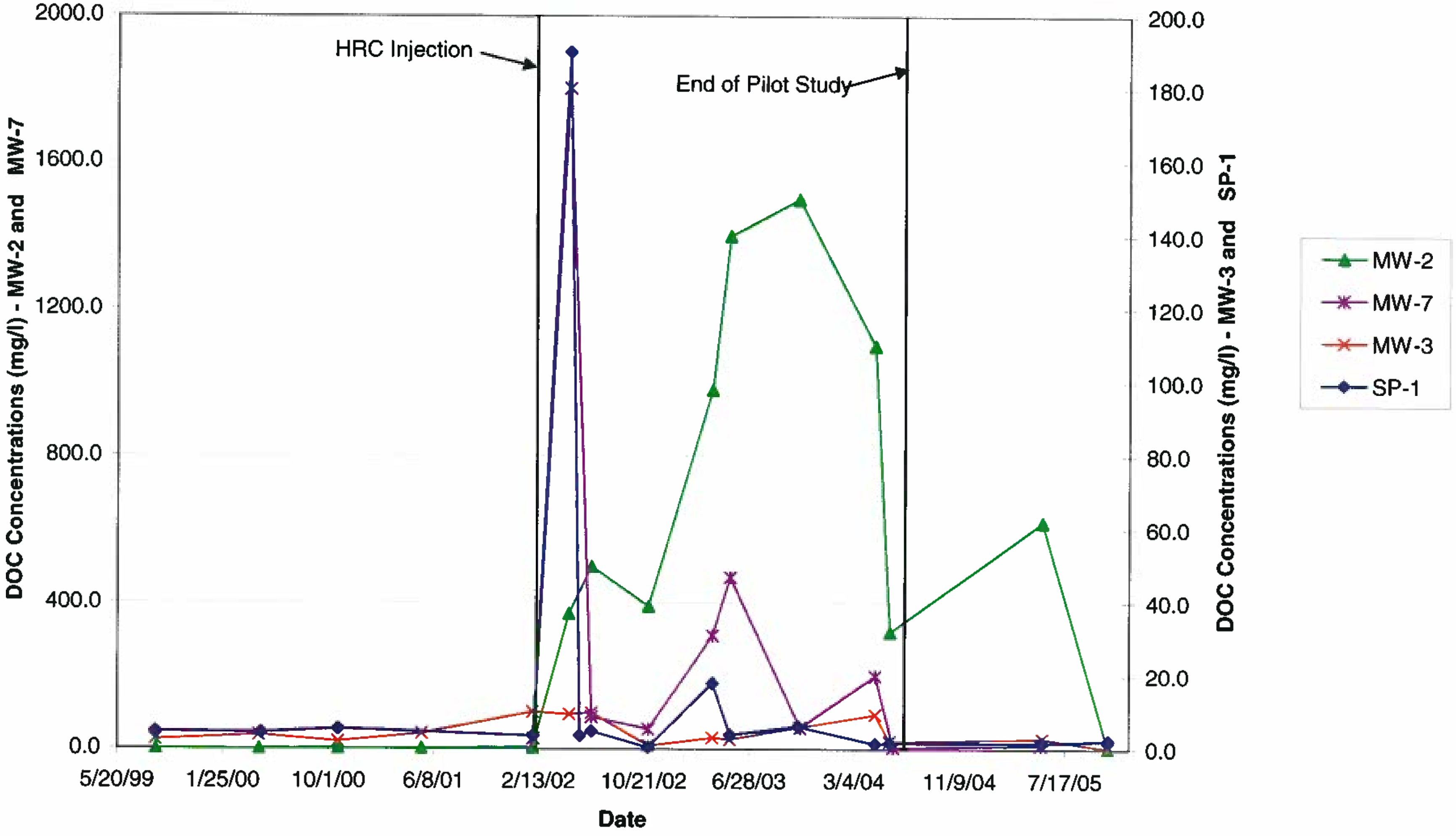


Figure 6-6
Alkalinity Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

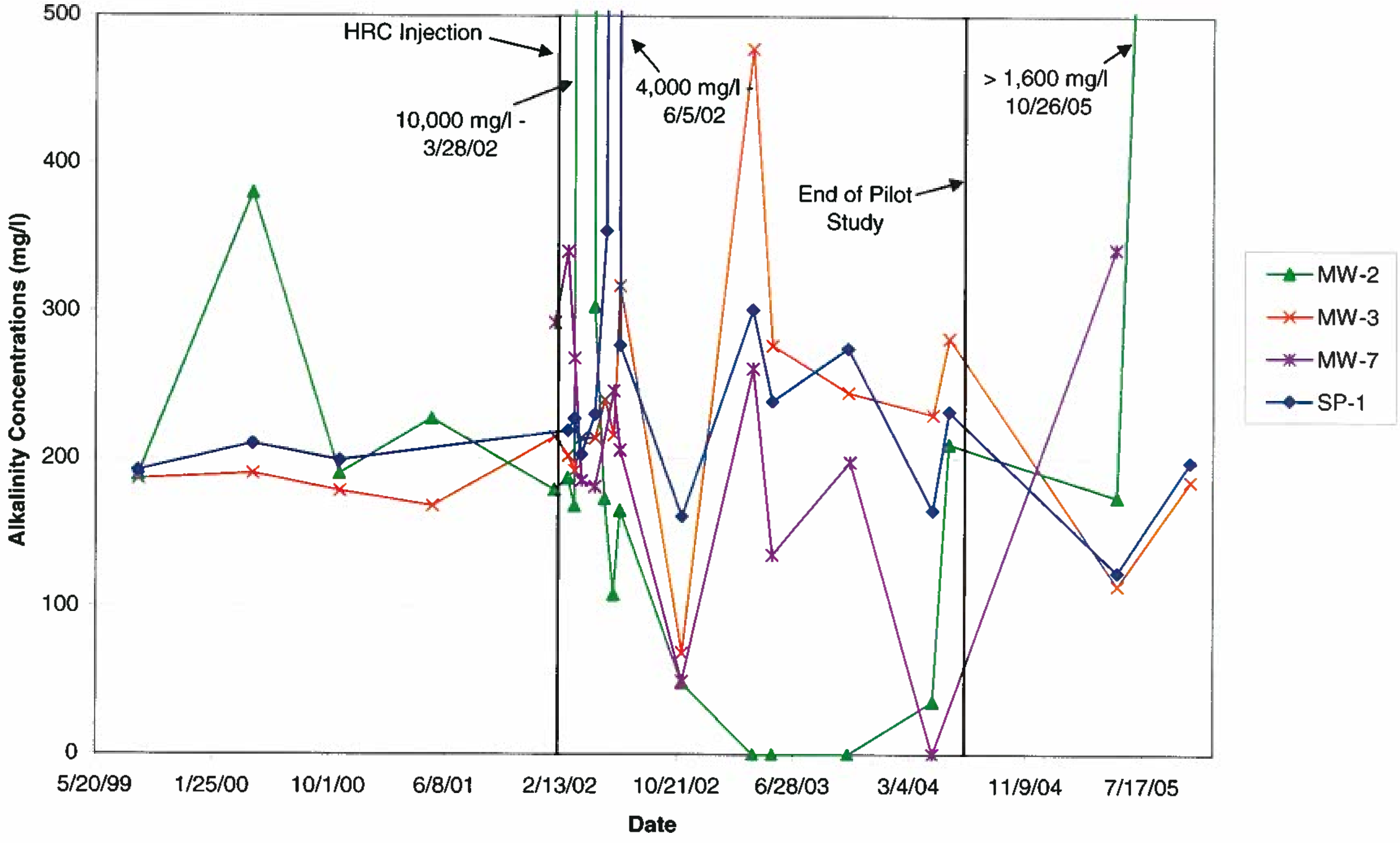
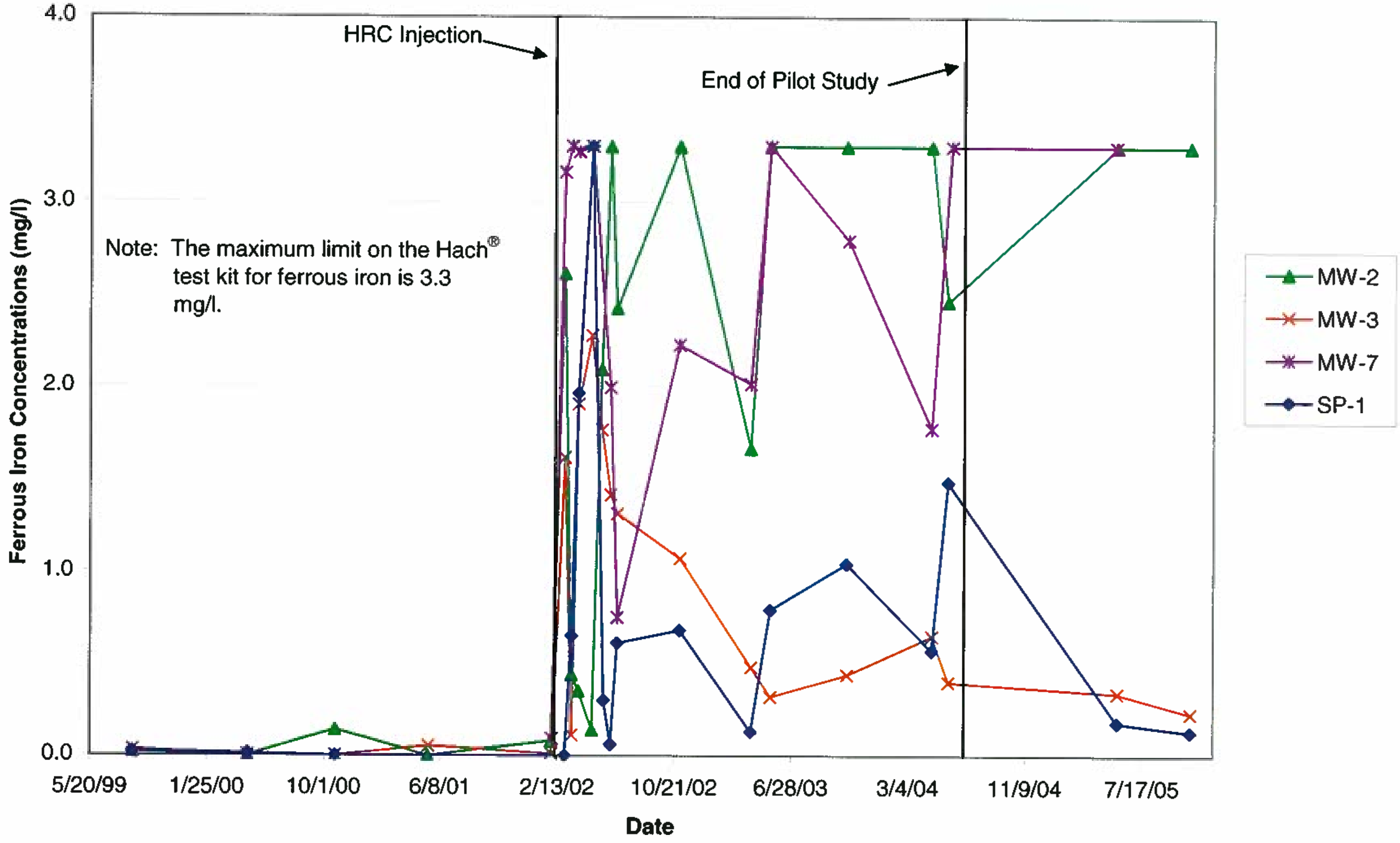


Figure 6-7
Ferrous Iron Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York



Note: The maximum limit on the Hach® test kit for ferrous iron is 3.3 mg/l.

Figure 6-8
Nitrate Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

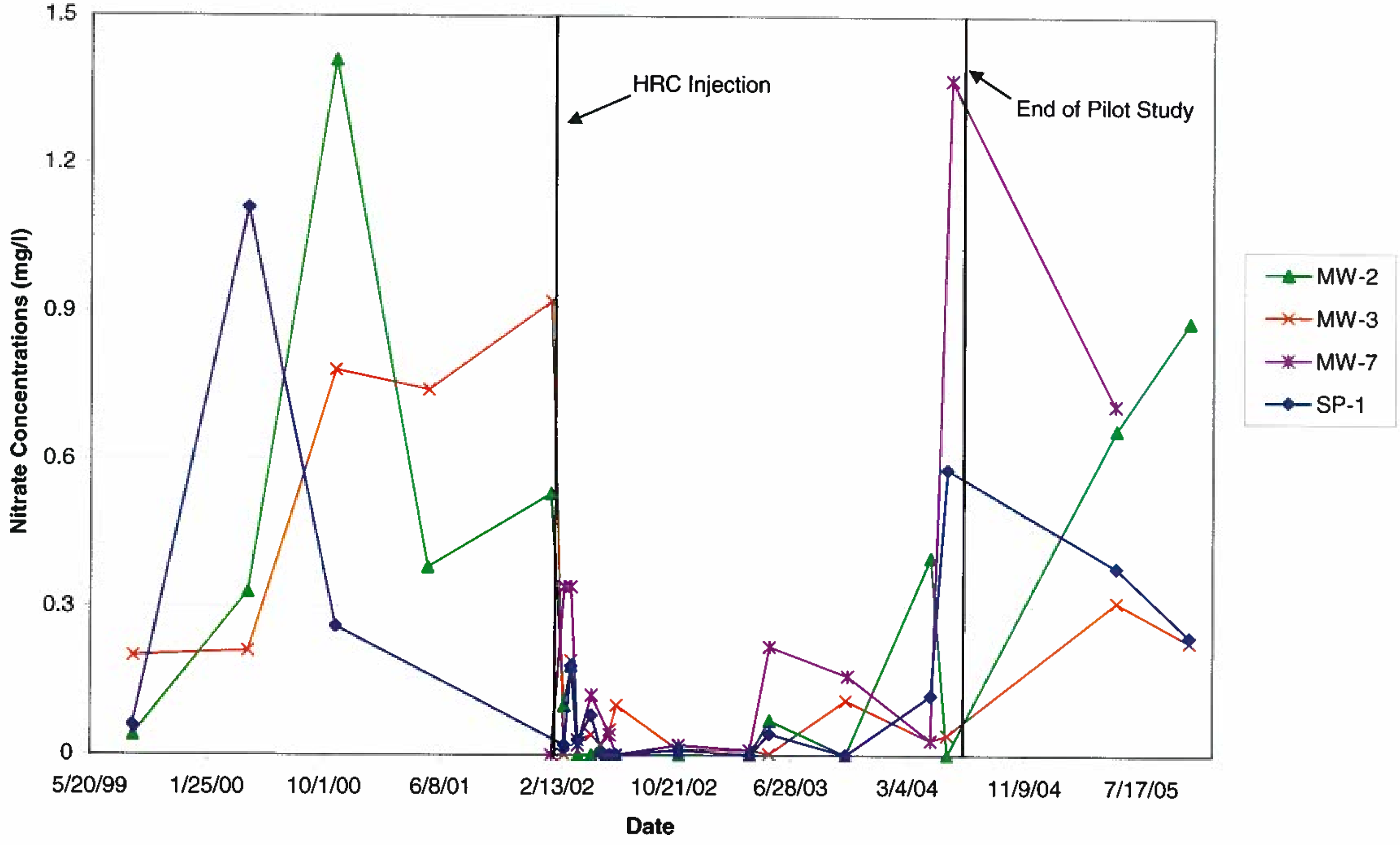
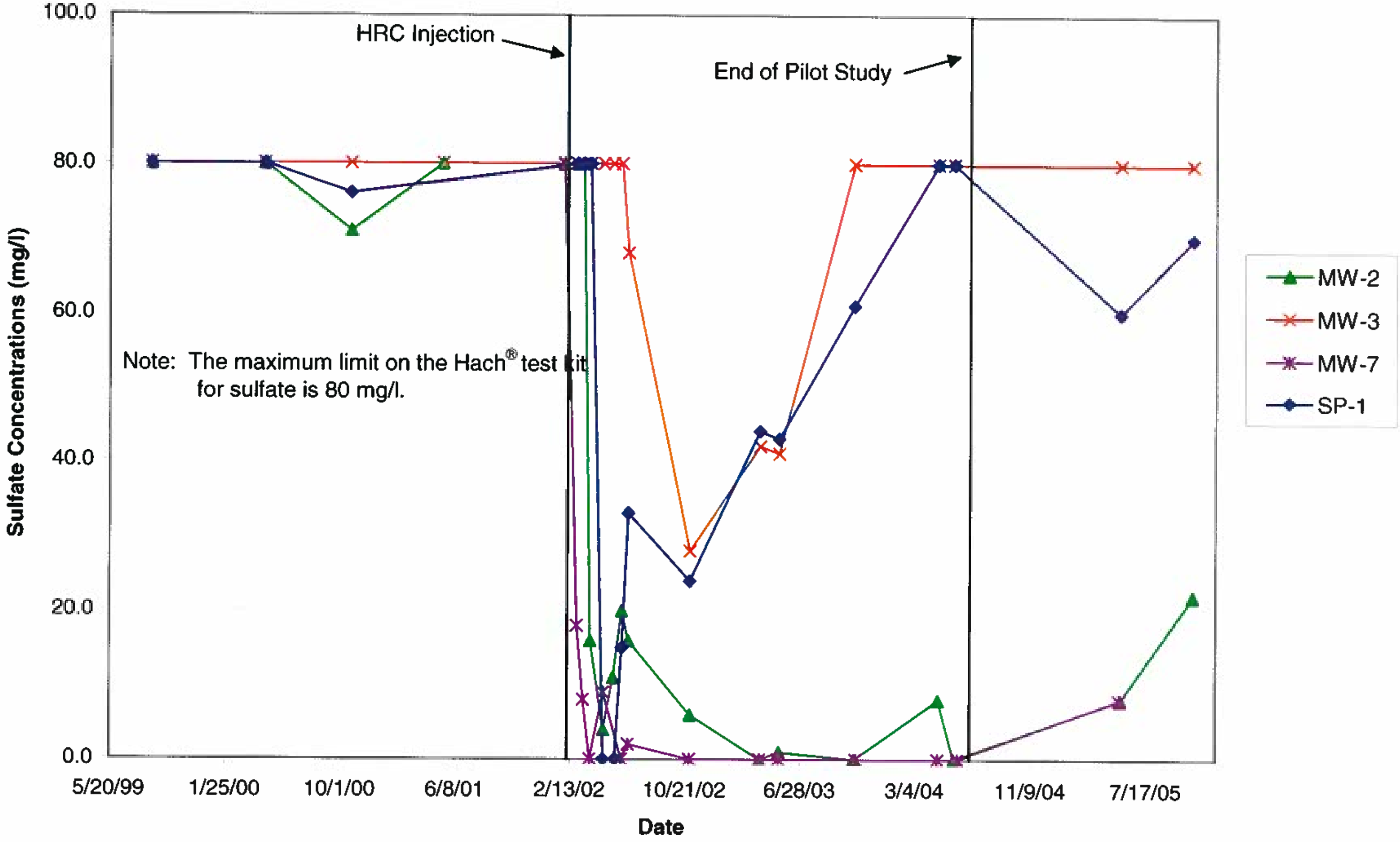
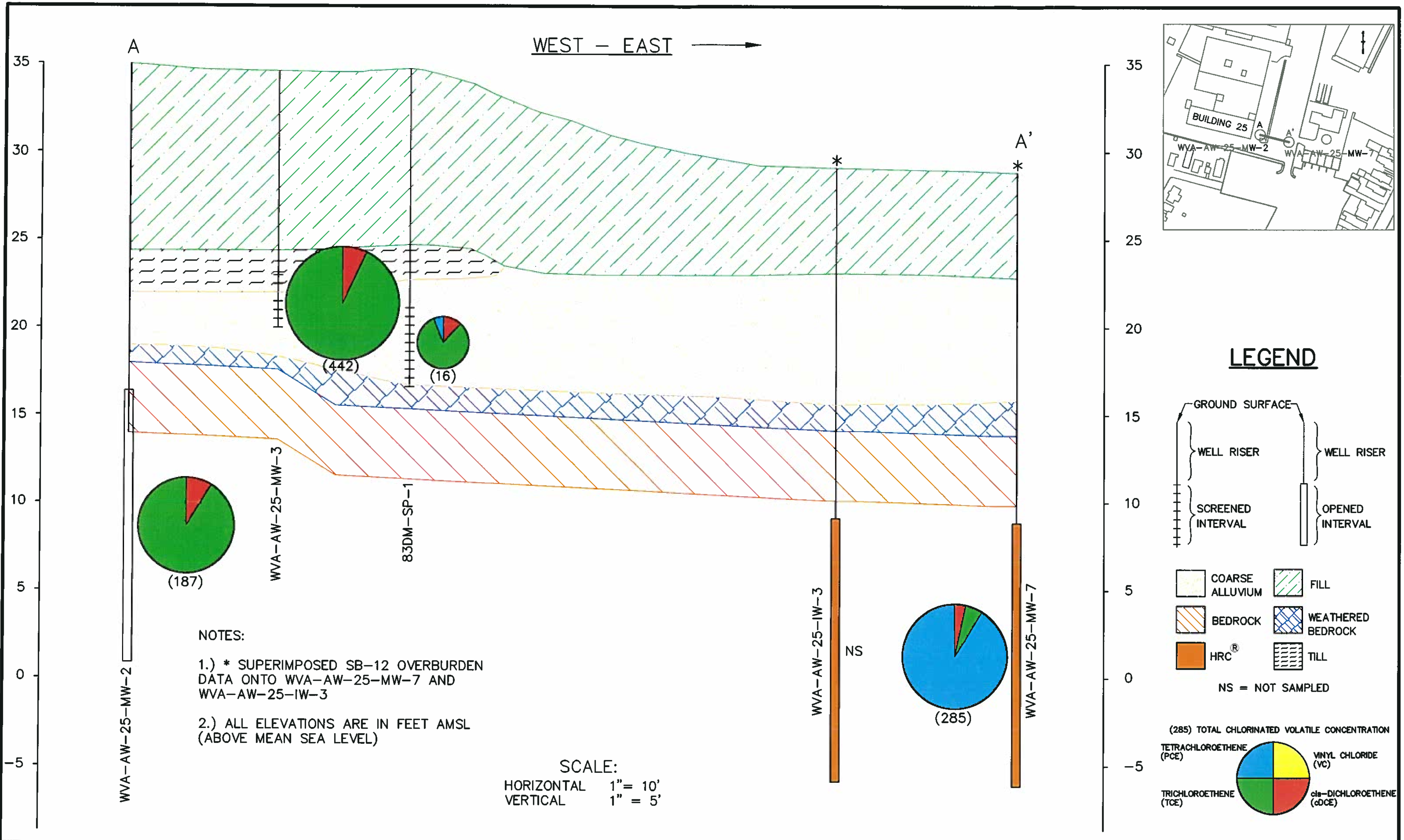


Figure 6-9
Sulfate Concentrations in Groundwater
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York



Note: The maximum limit on the Hach® test kit for sulfate is 80 mg/l.



NOTES:

1.) * SUPERIMPOSED SB-12 OVERBURDEN DATA ONTO WVA-AW-25-MW-7 AND WVA-AW-25-IW-3

2.) ALL ELEVATIONS ARE IN FEET AMSL (ABOVE MEAN SEA LEVEL)

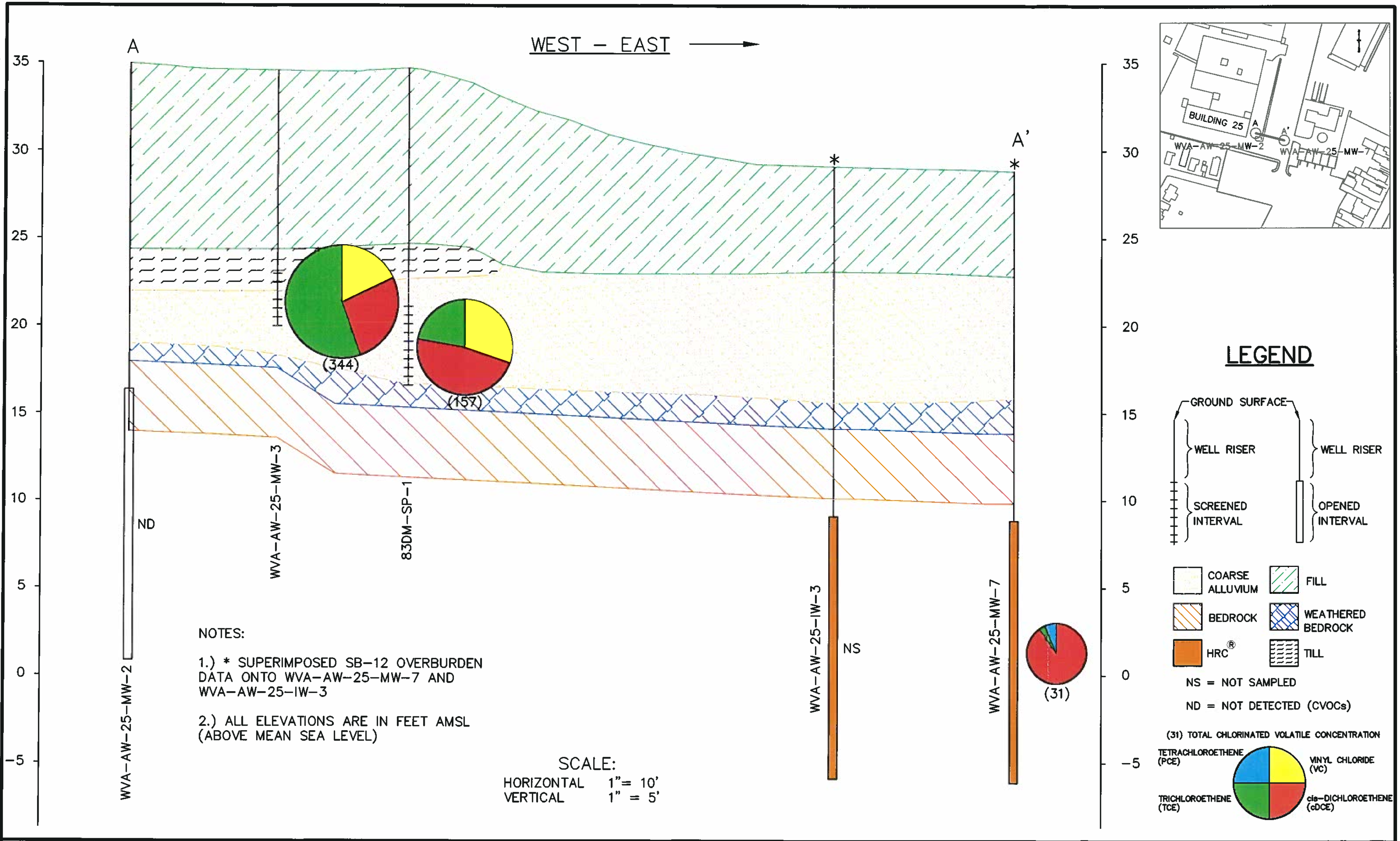
SCALE:
HORIZONTAL 1" = 10'
VERTICAL 1" = 5'

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
GEOLOGIC CROSS-SECTION A-A' (JANUARY 2002)
WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

FIGURE 7-1

XREFS: None IMAGES: None
User: fuller Spec: PIRNIE STANDARD? File: I:\ACAD\PROJ\0285\890\CROSS SECTION A-A' JAN-02.DWG Scale: 1:1 Date: 05/05/2005 Time: 14:18 Layout: Layout1



NOTES:

1.) * SUPERIMPOSED SB-12 OVERBURDEN DATA ONTO WVA-AW-25-MW-7 AND WVA-AW-25-IW-3

2.) ALL ELEVATIONS ARE IN FEET AMSL (ABOVE MEAN SEA LEVEL)

SCALE:

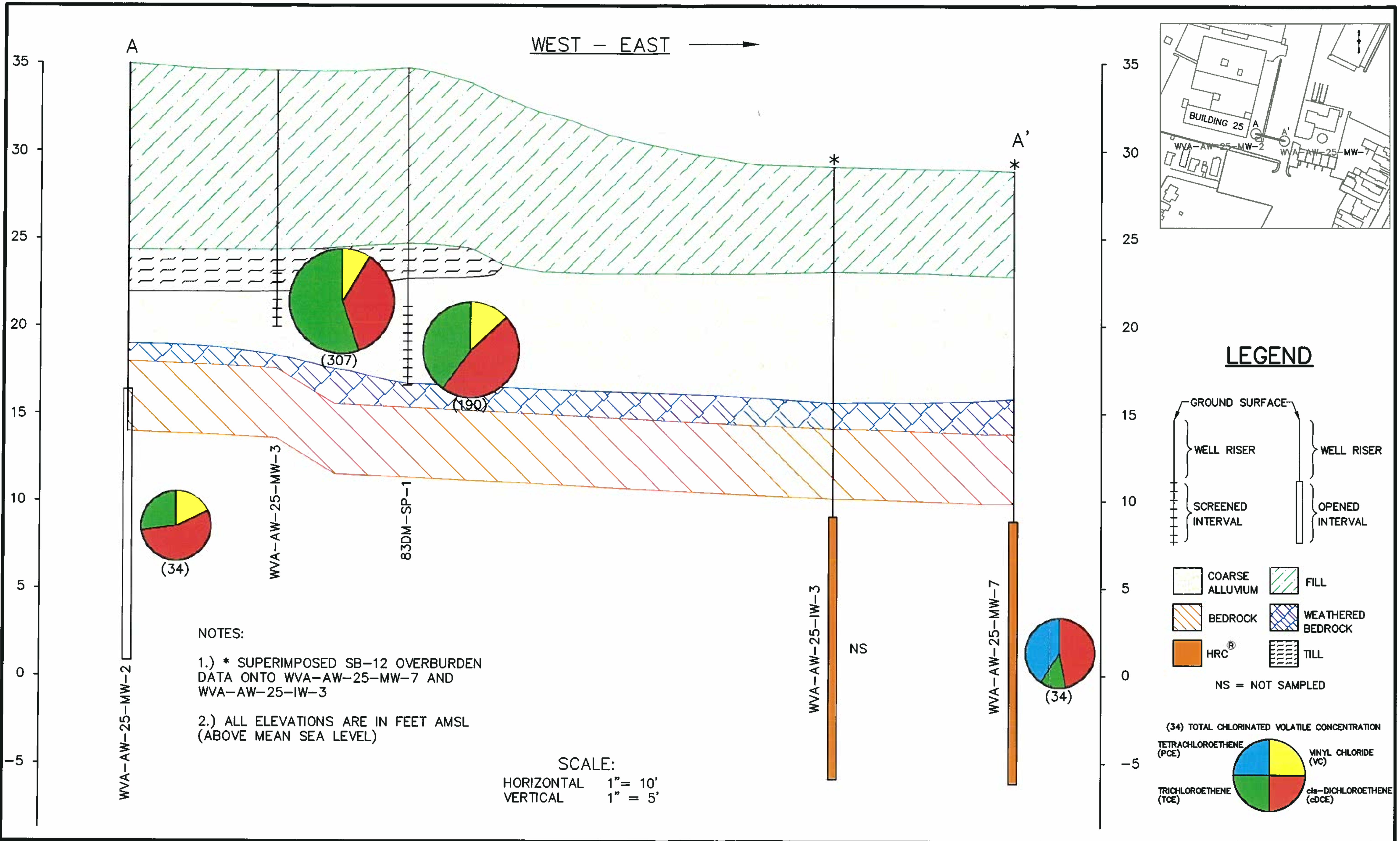
HORIZONTAL	1" = 10'
VERTICAL	1" = 5'

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
GEOLOGIC CROSS-SECTION A-A' (APRIL 2003)
WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31-94-D-0017

FIGURE 7-2

XREFS: None IMAGES: None
User: fuller Spec: PIRNIE STANDARD? File: I:\ACAD\PROJ\0285\890\CROSS SECTION A-A' APRIL 03.DWG Scale: 1:1 Date: 05/05/2005 Time: 14:18 Layout: Layout1



NOTES:

1.) * SUPERIMPOSED SB–12 OVERBURDEN DATA ONTO WVA–AW–25–MW–7 AND WVA–AW–25–IW–3

2.) ALL ELEVATIONS ARE IN FEET AMSL (ABOVE MEAN SEA LEVEL)

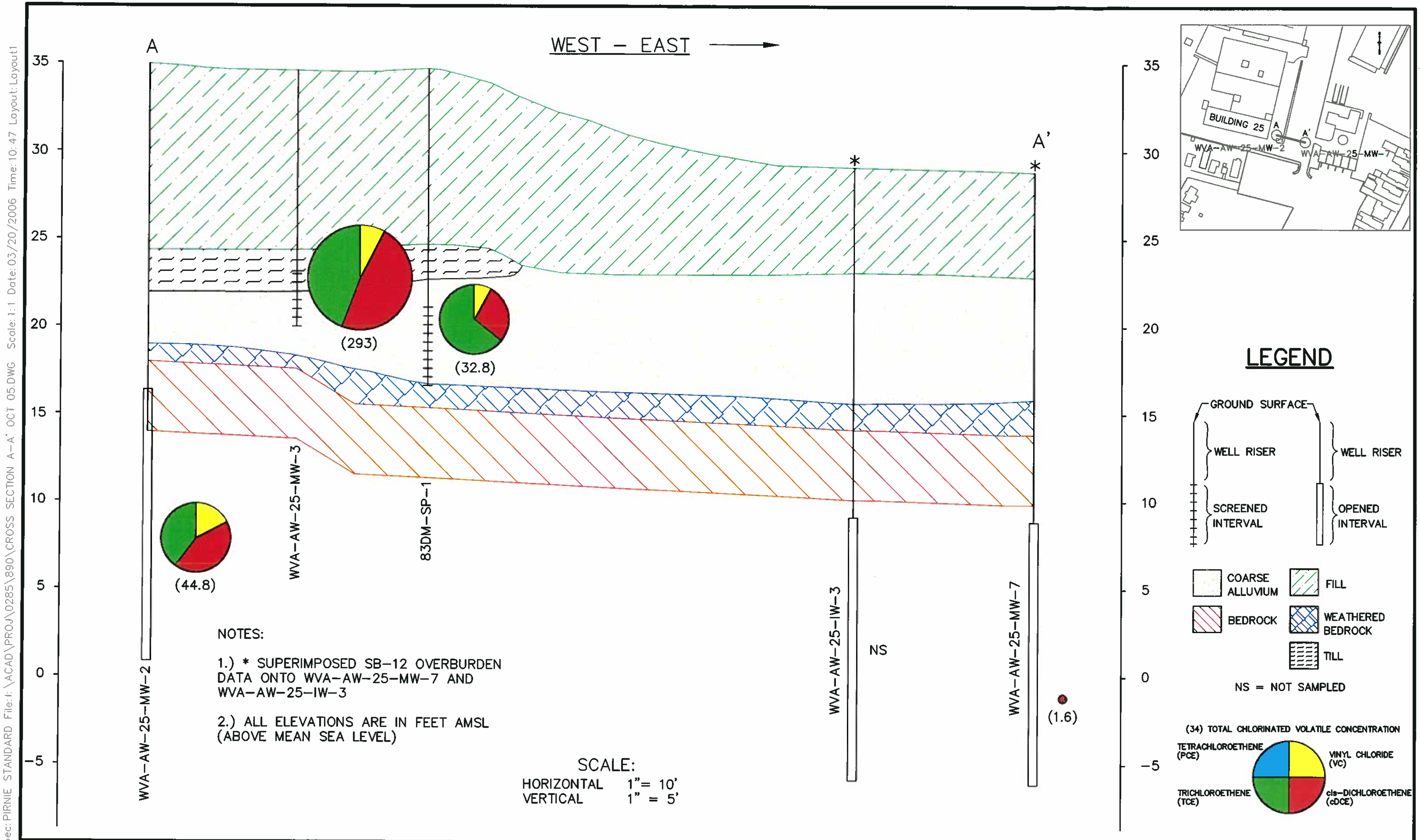
SCALE:
HORIZONTAL 1"= 10'
VERTICAL 1" = 5'

US Army Corps
of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
GEOLOGIC CROSS–SECTION A–A' (MAY 2004)
WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31–94–D–0017

FIGURE 7–3

XREFS: None IMAGES: None
User: fuller Spec: PIRNIE STANDARD? File: I:\ACAD\PROJ\0285\890\CROSS SECTION A–A' MAY 04.DWG Scale: 1:1 Date: 05/05/2005 Time: 14:18 Layout: Layout1



NOTES:

1.) * SUPERIMPOSED SB–12 OVERBURDEN DATA ONTO WVA–AW–25–MW–7 AND WVA–AW–25–IW–3

2.) ALL ELEVATIONS ARE IN FEET AMSL (ABOVE MEAN SEA LEVEL)

SCALE:
HORIZONTAL 1"= 10'
VERTICAL 1" = 5'

US Army Corps of Engineers

MAIN MANUFACTURING AREA
BUILDING 25
GEOLOGIC CROSS–SECTION A–A' (OCTOBER 2005)
WATERVLIET ARSENAL
USACE CONTRACT NO. DACA31–94–D–0017

FIGURE 7–4

Table 5-1
Summary of Groundwater Elevations
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

Well	Reference Elevation (feet AMSL)	1/30/2002		2/27/2002		3/13/2002		3/28/2002	
		DTW (feet)	Groundwater Elevation (feet) (a)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)
83DM-SP-1	37.79	13.37	24.42	13.40	24.39	13.40	24.39	12.70	25.09
WVA-AW-25-MW-2	34.66	12.12	22.54	12.20	22.46	12.40	22.26	11.48	23.18
WVA-AW-25-MW-3	34.34	10.49	23.85	10.35	23.99	10.30	24.04	10.10	24.24
WVA-AW-25-MW-7	28.53	17.35	11.18	8.55	19.98	11.20	17.33	10.00	18.53
WVA-AW-MW-53	29.83	9.53	20.30	8.70	21.13	8.95	20.88	8.95	20.88

Notes:

DTW-Depth to water

bgs - Below ground surface

AMSL - Above mean sea level

NM - Not measured

Table 5-1
Summary of Groundwater Elevations
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

Well	Reference Elevation (feet AMSL)	4/26/2002		6/5/2002		6/18/2002		10/31/2002	
		DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)
83DM-SP-1	37.79	13.45	24.34	13.18	24.61	13.00	24.79	13.26	24.53
WVA-AW-25-MW-2	34.66	12.20	22.46	11.65	23.01	11.40	23.26	10.98	23.68
WVA-AW-25-MW-3	34.34	10.70	23.64	10.19	24.15	10.00	24.34	10.26	24.08
WVA-AW-25-MW-7	28.53	12.59	15.94	12.26	16.27	16.35	12.18	5.30	23.23
WVA-AW-MW-53	29.83	9.60	20.23	9.45	20.38	9.00	20.83	NM	NM

Notes:

DTW-Depth to water

bgs - Below ground surface

AMSL - Above mean sea level

NM - Not measured

Table 5-1
Summary of Groundwater Elevations
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

Well	Reference Elevation (feet AMSL)	4/1/2003		4/22/2004		5/23/2005		10/26/2005	
		DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)	DTW (feet)	Groundwater Elevation (feet)
83DM-SP-1	37.79	13.18	24.61	14.06	23.73	13.39	24.40	12.64	25.15
WVA-AW-25-MW-2	34.66	10.60	24.06	10.83	23.83	11.21	23.45	10.10	24.56
WVA-AW-25-MW-3	34.34	10.13	24.21	10.42	23.92	10.68	23.66	10.16	24.18
WVA-AW-25-MW-7	28.53	7.54	20.99	7.05	21.48	2.78	25.75	10.42	18.11
WVA-AW-MW-53	29.83	NM	NM	NM	NM	NM	NM	NM	NM

Notes:

DTW-Depth to water

bgs - Below ground surface

AMSL - Above mean sea level

NM - Not measured

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	SP-1* 9/27/1995 (ug/l)	SP-1* 5/30/1996 (ug/l)	SP-1* 10/21/1997 (ug/l)	SP-1* 8/18/1999 (ug/l)	SP-1* 4/25/2000 (ug/l)	SP-1* 10/24/2000 (ug/l)	SP-1* 5/14/2001 (ug/l)
Acetone	50*	ND U						
Bromomethane	5.0				ND U	ND U	ND U	ND U
Carbon disulfide	---	ND U	ND U		ND U	ND U	1 J	ND U
Chloroform	7.0	7	ND U	1 J	ND U	ND U	ND U	ND U
Chloromethane	---				ND U	ND U	ND U	ND U
1,1-Dichloroethane	5.0	ND U	0.7 J	ND U	0.5 J	ND U	ND U	ND U
1,1-Dichloroethene	5.0	ND U	ND U	ND U	ND U	ND U	ND U	ND U
cis-1,2-Dichloroethene	5.0	ND U	2 J	3 J	3 J	2 J	2 J	3 J
trans-1,2-Dichloroethene	5.0	ND U	ND U	ND U	ND U	ND U	ND U	ND U
Methylene chloride	5.0	ND U	0.8 J	ND U	ND U	ND U	ND U	0.5 JB
2-Butanone	50*	ND U	ND U	ND U	2 J	ND U	ND U	ND U
4-Methyl-2-Pentanone	---				ND U	ND U	1 J	ND U
1,1,2,2-Tetrachloroethane	5.0				0.6 J	ND U	0.4 J	ND U
Tetrachloroethene	5.0	ND U	0.7 J	ND U	1 J	0.9 J	1 J	0.6 J
1,1,1-Trichloroethane	5.0	33	9	10	1 J	7	ND U	9
Trichloroethene	5.0	120	42	50	12	31	11	42
Vinyl chloride	2.0	ND U	ND U	ND U	ND U	ND U	ND U	ND U

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Program
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	SP-1 1/30/2002 (ug/l)	SP-1 4/26/2002 (ug/l)	SP-1* 5/21/2002 (ug/l)	SP-1 6/18/2002 (ug/l)	SP-1 10/31/2002 (ug/l)	SP-1 4/1/2003 (ug/l)	SP-1* 5/13/2003 (ug/l)
Acetone	50*	10 U	6 JB			10 U		
Bromomethane	5.0	5 U	5 U	2 U	3 J	5 U	5 U	3 U
Carbon disulfide	---	5 U	5 U	4 J	0.3 U	5 U	5 U	0.6 U
Chloroform	7.0	2 J	5 U	0.2 U	0.6 J	0.6 J	5 U	0.4 U
Chloromethane	---	5 U	5 U	0.9 U	2 J	5 U	5 U	1 U
1,1-Dichloroethane	5.0	5 U	2 J	6	4 J	5 J	14	9
1,1-Dichloroethene	5.0	5 U	5 U	1 J	1 J	2 J	0.8 J	0.8 J
cis-1,2-Dichloroethene	5.0	2 J	26		130	69	74	62
trans-1,2-Dichloroethene	5.0	5 U	5 U	0.6 J	0.7 J	5 U	0.7 J	0.6 J
Methylene chloride	5.0	0.7 J	5 U	0.5 J	0.2 UB	0.6 J	0.4 UB	0.4 UB
2-Butanone	50*	10 U	10 U	15 B	0.4 U	10 U	7 J	1 U
4-Methyl-2-Pentanone	---	10 U	10 U	0.4 U	0.4 U	10 U	10 U	0.5 U
1,1,2,2-Tetrachloroethane	5.0	5 U	8 J	0.3 U	0.3 U	5 U	5 U	0.7 U
Tetrachloroethene	5.0	1 J	5 U	0.3 U	0.3 U	5 U	5 U	0.4 U
1,1,1-Trichloroethane	5.0	5 U	5 U	27	26	28	21	20
Trichloroethene	5.0	13	13	10	28	130	35	78
Vinyl chloride	2.0	5 U	5 U	0.3 U	0.6 J	29	48	29

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Progran
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	SP-1* 10/23/2003 (ug/l)	SP-1 4/22/2004 (ug/l)	SP-1* 5/27/2004 (ug/l)	SP-1* 5/23/2005 (ug/l)	SP-1* 10/26/2005 (ug/l)
Acetone	50*					
Bromomethane	5.0	3 U	5 U	5 U	5 U	5 U
Carbon disulfide	---	2 U	5 U	5 U	5 U	5 U
Chloroform	7.0	2 U	5 U	5 U	5 U	5 U
Chloromethane	---	2 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5.0	7	11	14	5 U	1.8 JM
1,1-Dichloroethene	5.0	1 J	0.9 J	5 U	5 U	5 U
cis-1,2-Dichloroethene	5.0	56	68	89	2.6 J	9.3
trans-1,2-Dichloroethene	5.0	2 U	0.8 J	5 U	5 U	5 U
Methylene chloride	5.0	2 UB	5 U	5 U	5 U	5 UB
2-Butanone	50*	4 U	5 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	---	2 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	5.0	2 U	5 U	5 U	5 U	5 U
Tetrachloroethene	5.0	2 U	5 U	5 U	5 U	5 U
1,1,1-Trichloroethane	5.0	20	9	12	5 U	5.1
Trichloroethene	5.0	100	58	76	8.9	21
Vinyl chloride	2.0	25	11	25	5 U	2.5 J

Notes:

🟨 Concentration exceeds NYSDEC Class GA Standard

🟧 HRC present in well

Blank cells indicate parameter was not analyzed

* - Samples collected during the Long-Term Monitoring Progran

ND and U - Not detected at listed quantitation limit

J - Estimated value

B - Detected in blank

ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-2* 9/12/1995 (ug/l)	MW-2* 5/24/1996 (ug/l)	MW-2* 10/21/1997 (ug/l)	MW-2* 8/19/1999 (ug/l)	MW-2* 4/20/2000 (ug/l)	MW-2* 10/24/2000 (ug/l)	MW-2* 5/10/2001 (ug/l)
Acetone	50*	ND U						
Bromomethane	5.0				ND U	ND U	ND U	ND U
Carbon disulfide	---	ND U	ND U		ND U	ND U	0.8 J	ND U
Chloroform	7.0	ND U	ND U	ND U	2 J	ND U	1 J	0.8 J
Chloromethane	---				ND U	ND U	ND U	ND U
1,1-Dichloroethane	5.0	ND U	1 J	1 J	3 J	4 J	3 J	3 J
1,1-Dichloroethene	5.0	ND U	0.8 J		2 J	2 J	2 J	2 J
cis-1,2-Dichloroethene	5.0	ND U	4 J	4 J	11	13	12	13
trans-1,2-Dichloroethene	5.0	ND U	ND U	ND U	ND U	ND U	1 J	ND U
Methylene chloride	5.0	ND U	2 JB	2 JB	ND U	0.6 J	0.5 JB	ND U
2-Butanone	50*	ND U	ND U	ND U	ND U	ND U	4 JB	ND U
4-Methyl-2-Pentanone	---				ND U	ND U	ND U	ND U
1,1,2,2-Tetrachloroethane	5.0				ND U	ND U	ND U	ND U
Tetrachloroethene	5.0	ND U	ND U	ND U	ND U	2 J	ND U	ND U
1,1,1-Trichloroethane	5.0	21	20	19	49	51	51	43
Trichloroethene	5.0	37	51	74	120	170	170	160
Vinyl chloride	2.0	ND U	ND U	ND U	ND U	ND U	0.6 J	ND U

Notes:

🟨	Concentration exceeds NYSDEC Class GA Standard
🟧	HRC present in well

Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Progran
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-2 1/29/2002 (ug/l)	MW-2 4/25/2002 (ug/l)	MW-2* 5/17/2002 (ug/l)	MW-2 6/18/2002 (ug/l)	MW-2 10/31/2002 (ug/l)	MW-2 4/1/2003 (ug/l)	MW-2* 5/13/2003 (ug/l)
Acetone	50*	10 U	18		10 U	10 U		
Bromomethane	5.0	5 U	5 U	2 J	5 U	5 U	1000 U	310 U
Carbon disulfide	---	5 U	0.4 J	0.3 U	5 U	5 U	1000 U	60 U
Chloroform	7.0	0.9 J	0.7 J	0.4 J	0.6 J	5 U	1000 U	40 U
Chloromethane	---	5 U	5 U	0.9 U	5 U	5 U	1000 U	100 U
1,1-Dichloroethane	5.0	4 J	4 J	4 J	6	12	1000 U	60 U
1,1-Dichloroethene	5.0	2 J	1 J	1 J	1 J	0.8 J	1000 U	60 U
cis-1,2-Dichloroethene	5.0	17	68		53	66	1000 U	60 U
trans-1,2-Dichloroethene	5.0	5 U	5 U	0.3 J	5 U	5 U	1000 U	60 U
Methylene chloride	5.0	5 U	0.5 JB	0.4 J	5 U	0.4 J	330 JB	61 JB
2-Butanone	50*	10 U	10 U	0.4 U	17	14	22000	17000
4-Methyl-2-Pentanone	---	10 U	10 U	0.4 U	10 U	2 J	2000 U	50 U
1,1,2,2-Tetrachloroethane	5.0	5 U	5 U	0.3 U	5 U	5 U	1000 U	70 U
Tetrachloroethene	5.0	5 U	5 U	0.3 U	5 U	5 U	1000 U	40 U
1,1,1-Trichloroethane	5.0	49	32	26	23	5 U	1000 U	40 U
Trichloroethene	5.0	170	49	45	53	21	1000 U	70 U
Vinyl chloride	2.0	5 U	5 U	0.3 U	0.8 J	2 J	1000 U	100 U

Notes:

🟨 Concentration exceeds NYSDEC Class GA Standard

🟧 HRC present in well

Blank cells indicate parameter was not analyzed

* - Samples collected during the Long-Term Monitoring Progran

ND and U - Not detected at listed quantitation limit

J - Estimated value

B - Detected in blank

ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-2* 10/23/2003 (ug/l)	MW-2 4/22/2004 (ug/l)	MW-2* 5/27/2004 (ug/l)	MW-2* 5/23/2005 (ug/l)	MW-2* 10/26/2005 (ug/l)
Acetone	50*					
Bromomethane	5.0	62 U	5 U	5 U	5 U	5 U
Carbon disulfide	---	12 U	0.7 J	3 J	5 U	5 U
Chloroform	7.0	8 U	5 U	5 U	5 U	5 U
Chloromethane	---	20 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5.0	12 U	6	5	5.1	8.1 H
1,1-Dichloroethene	5.0	16 U	5 U	5 U	5 U	5 U
cis-1,2-Dichloroethene	5.0	48 J	18	18	15	19
trans-1,2-Dichloroethene	5.0	12 U	5 U	5 U	5 U	5 U
Methylene chloride	5.0	8 UB	5 U	5 U	5 U	5 UB
2-Butanone	50*	1600 J	120	10 U	19 U	19
4-Methyl-2-Pentanone	---	10 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	5.0	14 U	5 U	5 U	5 U	5 U
Tetrachloroethene	5.0	8 U	5 U	5 U	5 U	5 U
1,1,1-Trichloroethane	5.0	8 U	5 U	5 U	2.1 J	4.7 J
Trichloroethene	5.0	46 J	20	9	14	18
Vinyl chloride	2.0	20 U	5 U	6	3.2 J	7.8

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Progran
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-3* 9/13/1995 (ug/l)	MW-3* 5/19/1996 (ug/l)	MW-3* 8/19/1999 (ug/l)	MW-3* 4/20/2000 (ug/l)	MW-3* 10/24/2000 (ug/l)	MW-3* 5/11/2001 (ug/l)	MW-3 1/29/2002 (ug/l)
Acetone	50*	ND U						40 U
Bromomethane	5.0			ND U	ND U	ND U	ND U	20 U
Carbon disulfide	---	ND U	ND U	ND U	ND U	2 J	ND U	20 U
Chloroform	7.0	3 J	ND U	2 J	ND U	0.95 J	0.75 J	20 U
Chloromethane	---			ND U	ND U	ND U	ND U	20 U
1,1-Dichloroethane	5.0	4 J	4 J	6 J	4 J	3.5 J	3.5 J	20 U
1,1-Dichloroethene	5.0	3 J	2 J	2 J	3 J	2 J	2 J	20 U
cis-1,2-Dichloroethene	5.0	ND U	19	28	22	17.5	15.5	32
trans-1,2-Dichloroethene	5.0	ND U	ND U	ND U	ND U	1.9 J	ND U	20 U
Methylene chloride	5.0	ND U	ND U	1 J	5 J	3 J	2.5 JB	20 U
2-Butanone	50*	ND U	ND U	ND U	ND U	9.5 J	ND U	40 U
4-Methyl-2-Pentanone	---			ND U	ND U	ND U	ND U	40 U
1,1,2,2-Tetrachloroethane	5.0			ND U	ND U	ND U	ND U	20 U
Tetrachloroethene	5.0	ND U	ND U	0.7 J	ND U	ND U	ND U	20 U
1,1,1-Trichloroethane	5.0	100	82	49	51	44	38.5	66
Trichloroethene	5.0	410 D	310	280	330	235	270	410
Vinyl chloride	2.0	ND U	ND U	3 J	ND U	0.9 J	ND U	20 U

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Progran
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-3 4/26/2002 (ug/l)	MW-3* 5/17/2002 (ug/l)	MW-3 6/18/2002 (ug/l)	MW-3 10/31/2002 (ug/l)	MW-3 4/1/2003 (ug/l)	MW-3* 5/13/2003 (ug/l)	MW-3* 10/23/2003 (ug/l)
Acetone	50*	20 UB		20 U	20 U			
Bromomethane	5.0	10 U	3 U	10 U	10 U	10 U	3 U	3 U
Carbon disulfide	---	10 U	0.6 U	10 U	10 U	2 J	0.6 U	2 U
Chloroform	7.0	1 J	0.4 U	10 U	0.8 J	1 J	0.7 J	0.7 J
Chloromethane	---	10 U	2 U	10 U	10 U	10 U	1 U	2 U
1,1-Dichloroethane	5.0	8 J	6 J	6 J	8 J	8 J	6	9
1,1-Dichloroethene	5.0	2 J	2 J	2 J	2 J	3 J	2 J	2 J
cis-1,2-Dichloroethene	5.0	64		98	150	93	70	130
trans-1,2-Dichloroethene	5.0	10 U	0.6 U	10 U	10 U	10 U	0.6 U	0.8 J
Methylene chloride	5.0	1 J	0.4 U	10 U	1 J	1 JB	0.4 UB	2 UB
2-Butanone	50*	20 U	0.8 U	20 U	20 U	20 U	1 U	4 U
4-Methyl-2-Pentanone	---	20 U	0.8 U	20 U	20 U	20 U	0.5 U	2 U
1,1,2,2-Tetrachloroethane	5.0	10 U	0.6 U	10 U	10 U	10 U	0.7 U	2 U
Tetrachloroethene	5.0	10 U	0.6 U	10 U	10 U	10 U	0.4 U	2 U
1,1,1-Trichloroethane	5.0	53	43	36	47	40	36	40
Trichloroethene	5.0	330	220	210	240	190	170	170
Vinyl chloride	2.0	4 J	3 J	3 J	51	61	43	42

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
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ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-3 4/22/2004 (ug/l)	MW-3* 5/27/2004 (ug/l)	MW-3* 5/23/2005 (ug/l)	MW-3* 10/26/2005 (ug/l)
Acetone	50*				
Bromomethane	5.0	5 U	5 U	10 U	5 U
Carbon disulfide	---	0.7 J	5 U	10 u	5 U
Chloroform	7.0	5 U	5 U	10 U	5 U
Chloromethane	---	5 U	5 U	10 U	5 U
1,1-Dichloroethane	5.0	6	7	9.2 J	8 H
1,1-Dichloroethene	5.0	1 J	2 J	2.4 J	1.7 J
cis-1,2-Dichloroethene	5.0	86	110	190	140
trans-1,2-Dichloroethene	5.0	1 J	0.6 J	1.1 J	1.1 J
Methylene chloride	5.0	5 U	5 U	2.7 U	5 UB
2-Butanone	50*	10 U	10 U	20 U	10 U
4-Methyl-2-Pentanone	---	5 U	10 U	20 U	10 U
1,1,2,2-Tetrachloroethane	5.0	5 U	5 U	10 U	5 U
Tetrachloroethene	5.0	5 U	5 U	10 U	5 U
1,1,1-Trichloroethane	5.0	32	35	43	29
Trichloroethene	5.0	170	170	140	130
Vinyl chloride	2.0	22	27	22	23

Notes:

🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
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ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-7 1/31/2002 (ug/l)	MW-7 4/26/2002 (ug/l)	MW-7 6/18/2002 (ug/l)	MW-7 10/31/2002 (ug/l)	MW-7 4/1/2003 (ug/l)	MW-7* 5/13/2003 (ug/l)	MW-7* 10/27/2003 (ug/l)
Acetone	50*	20 U	280 B	10 U	18			
Bromomethane	5.0	10 U	100 U	5 U	5 U	5 U	3 U	3 U
Carbon disulfide	---	10 U	100 U	2 J	5 U	5 U	0.6 U	2 U
Chloroform	7.0	10 U	100 U	5 U	5 U	5 U	0.4 U	2 U
Chloromethane	---	10 U	100 U	1 J	5 U	5 U	1 U	2 U
1,1-Dichloroethane	5.0	10 U	100 U	5 U	5 U	5 U	0.6 U	2 U
1,1-Dichloroethene	5.0	10 U	100 U	5 U	5 U	5 U	0.8 U	2 U
cis-1,2-Dichloroethene	5.0	10 J	150	24	22	28	16	8
trans-1,2-Dichloroethene	5.0	10 U	200 U	5 U	5 U	5 U	0.6 U	2 U
Methylene chloride	5.0	10 U	10 J	5 U	0.7 J	0.7 JB	0.4 UB	2 UB
2-Butanone	50*	20 U	2800	190	10 U	60	1 U	29 J
4-Methyl-2-Pentanone	---	20 U	200 U	10 U	10 U	10 U	0.5 U	2 U
1,1,2,2-Tetrachloroethane	5.0	10 U	100 U	5 U	5 U	5 U	0.7 U	2 U
Tetrachloroethene	5.0	260	19 J	5 U	3 J	2 J	3 J	0.6 J
1,1,1-Trichloroethane	5.0	10 U	100 U	5 U	5 U	5 U	0.4 U	2 U
Trichloroethene	5.0	15	100 U	5 U	2 J	1 J	1 J	2 U
Vinyl chloride	2.0	10 U	100 U	16	5 U	5 U	1 U	2 U

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
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ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-7 4/22/2004 (ug/l)	MW-7* 6/4/2004 (ug/l)	MW-7* 5/20/2005 (ug/l)	MW-7* 10/25/2005 (ug/l)
Acetone	50*				
Bromomethane	5.0	5 U	11 UJ	5 U	5 U
Carbon disulfide	---	5 U	2 UJ	5 U	5 U
Chloroform	7.0	5 U	2 UJ	5 U	5 UJ
Chloromethane	---	5 U	6 UJ	5 U	5 U
1,1-Dichloroethane	5.0	5 U	2 UJ	5 U	5 U
1,1-Dichloroethene	5.0	5 U	3 UJ	5 U	5 U
cis-1,2-Dichloroethene	5.0	6	16 J	4.9 J	1.6 J
trans-1,2-Dichloroethene	5.0	5 U	2 UJ	5 U	5 U
Methylene chloride	5.0	5 U	20 U	5 UB	5 UB
2-Butanone	50*	69	340	2.3 J	10 U
4-Methyl-2-Pentanone	---	5 U	4 UJ	10 U	10 U
1,1,2,2-Tetrachloroethane	5.0	5 U	3 UJ	5 U	5 U
Tetrachloroethene	5.0	2 J	14 J	5 U	5 U
1,1,1-Trichloroethane	5.0	5 U	4 UJ	5 U	5 U
Trichloroethene	5.0	3 J	4 J	5 U	5 U
Vinyl chloride	2.0	5 U	2 UJ	1.1 J	5 U

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
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ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-1
Summary of CVOCs in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

ANALYTE	NYSDEC Class GA Groundwater Standard (ug/l)	MW-53* 10/21/1997 (ug/l)	MW-53 1/30/2002 (ug/l)	MW-53 4/25/2002 (ug/l)	MW-53 6/18/2002 (ug/l)
Acetone	50*		10 U	14	10
Bromomethane	5.0		5 U	5 U	5 U
Carbon disulfide	---		5 U	2 J	5 U
Chloroform	7.0	ND U	5 U	5 U	5 U
Chloromethane	---		5 U	5 U	5 U
1,1-Dichloroethane	5.0	ND U	5 U	5 U	5 U
1,1-Dichloroethene	5.0		5 U	5 U	5 U
cis-1,2-Dichloroethene	5.0	ND U	5 U	5 U	5 U
trans-1,2-Dichloroethene	5.0	ND U	5 U	5 U	5 U
Methylene chloride	5.0	ND U	5 U	5 UB	5 UB
2-Butanone	50*	ND U	10 U	10 U	10 U
4-Methyl-2-Pentanone	---		10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	5.0		5 U	5 U	5 U
Tetrachloroethene	5.0	ND U	5 U	5 U	5 U
1,1,1-Trichloroethane	5.0	ND U	5 U	5 U	5 U
Trichloroethene	5.0	ND U	5 U	5 U	5 U
Vinyl chloride	2.0	ND U	5 U	5 U	5 U

Notes:
🟨 Concentration exceeds NYSDEC Class GA Standard
🟧 HRC present in well
Blank cells indicate parameter was not analyzed
* - Samples collected during the Long-Term Monitoring Progran
ND and U - Not detected at listed quantitation limit
J - Estimated value
B - Detected in blank
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	SP-1* 8/18/1999	SP-1* 4/25/2000	SP-1* 10/24/2000	SP-1* 5/14/2001	SP-1 1/30/2002	SP-1 2/27/2002	SP-1 3/13/2002	SP-1 3/28/2002
Carbon dioxide (ug/l)	ND U	ND U	ND U	ND U	350 U			
Ethane (ug/l)	ND U	ND U	ND U	ND U	4 U			
Ethene (ug/l)	ND U	ND U	ND U	ND U	3 U			
Methane (ug/l)	ND U	ND U	ND U	ND U	2 U			
Dissolved Organic Carbon (mg/l)	4.65	4.34	5.36		3.5			
Alkalinity (mg/l)	192	210	199			219	227	203
Chloride (mg/l)	480	640	244			201	223	179
Ferrous Iron (mg/l)	0.02	0.01	0			0	0.65	1.96
Nitrate (mg/l)	0.06	1.11	0.26			0.02	0.18	0.03
Nitrite (mg/l)	0.016	0.028	0.004			0.006	0.001	0
Sulfate (mg/l)	80	80	76			80	80	80
Dissolved Oxygen (mg/l)	1.36	4.5	0		2.95	0	2.26	0
Oxidation-Reduction Potential (uS/cm)	64.1	216	250			118	-219	-163

Notes:
Blank cells indicate parameter was not analyzed
ND and U - Not detected at listed quantitation limit
* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	SP-1 4/26/2002	SP-1* 5/21/2002	SP-1 6/5/2002	SP-1 6/18/2002	SP-1 10/31/2002	SP-1 4/1/2003	SP-1* 5/13/2003	SP-1* 10/23/2003
Carbon dioxide (ug/l)	350 U	350 U		350 U	350 U	350 U	350 U	350 U
Ethane (ug/l)	4 U	4 U		4 U	4 U	8 U	4 U	4 U
Ethene (ug/l)	3 U	3 U		3 U	4.3	6 U	4.4	4.2
Methane (ug/l)	4.5	20		93	300	530	300	600 D
Dissolved Organic Carbon (mg/l)	190			4.8	0.35	18	3.8	6.1
Alkalinity (mg/l)	230	354	>4000	277	161	301	239	275
Chloride (mg/l)	176	58	220	235	21	22	27	258
Ferrous Iron (mg/l)	3.3	0.3	0.06	0.61	0.68	0.13	0.79	1.04
Nitrate (mg/l)	0.08	0	0	0	0.01	0	0.043	0
Nitrite (mg/l)	0.004	0	0.004	0	0	0.014	0.02	0
Sulfate (mg/l)	0	0	20	33	24	44	43	61
Dissolved Oxygen (mg/l)		0.61	7.23	0.35	0		0	1.15
Oxidation-Reduction Potential (uS/cm)	-34	-295	-210	-267	-230	-184	-76	-180

Notes:
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* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	SP-1 4/22/2004	SP-1* 5/27/2004	SP-1* 5/23/2005	SP-1* 10/26/2005
Carbon dioxide (ug/l)	500 U	500 U	500 U	
Ethane (ug/l)	4 U	20 U	4 U	4 U
Ethene (ug/l)	3 U	15 U	3 U	3 U
Methane (ug/l)	110	280 D	2.7	9.7
Dissolved Organic Carbon (mg/l)	1.4	1.7	1.7	2.3
Alkalinity (mg/l)	165	232	123	198
Chloride (mg/l)	390	409	318	194
Ferrous Iron (mg/l)	0.57	1.48	0.18	0.13
Nitrate (mg/l)	0.12	0.58	0.38	0.24
Nitrite (mg/l)	0.005	0.008	0.011	0.004
Sulfate (mg/l)	80	80	60	70
Dissolved Oxygen (mg/l)	0.46	0	3.82	9.51
Oxidation-Reduction Potential (uS/cm)	-92	-95	28	-22

Notes:
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Long-Term Monitoring Program
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J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-2* 8/19/1999	MW-2* 4/20/2000	MW-2* 10/24/2000	MW-2* 5/10/2001	MW-2 1/29/2002	MW-2 2/27/2002	MW-2 3/13/2002	MW-2 3/28/2002
Carbon dioxide (ug/l)	ND U	ND U	ND U	ND U	350 U			
Ethane (ug/l)	ND U	ND U	ND U	ND U	4 U			
Ethene (ug/l)	ND U	ND U	ND U	ND U	3 U			
Methane (ug/l)	130	12.8	5.2	10	2 U			
Dissolved Organic Carbon (mg/l)	ND U	ND U	1.54	1.46	4.2			
Alkalinity (mg/l)	189	380	190	227	179	187	168	10,000
Chloride (mg/l)	341	290	278	250	204	198	210	222
Ferrous Iron (mg/l)	0.02	0	0.14	0	0.08	2.61	0.44	0.35
Nitrate (mg/l)	0.04	0.33	1.41	0.38	0.53	0.1	0.18	0
Nitrite (mg/l)	0.019	0.047	0.004	0	0.014	0.006	0	0
Sulfate (mg/l)	80	80	71	80	80	80	80	16
Dissolved Oxygen (mg/l)	0.34	0.57	0	0	6.2	0.95	3.04	1.48
Oxidation-Reduction Potential (uS/cm)	84.6	191	205	241		-133	-259	-296

Notes:
Blank cells indicate parameter was not
ND and U - Not detected at listed quant
* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-2 4/25/2002	MW-2* 5/17/2002	MW-2 6/5/2002	MW-2 6/18/2002	MW-2 10/31/2002	MW-2 4/1/2003	MW-2* 5/13/2003	MW-2* 10/23/2003
Carbon dioxide (ug/l)	350 U	350 U		350 U	350 U	350 U	350 U	350 U
Ethane (ug/l)	4 U	4 U		4 U	4 U	40 U	40 U	4 U
Ethene (ug/l)	3 U	3 U		3 U	4 U	30 U	30 U	3 U
Methane (ug/l)	9	5.2		3.7	480 D	750	1900	3700 D
Dissolved Organic Carbon (mg/l)	370			500	390	980	1400	1500
Alkalinity (mg/l)	303	173	108	165	49	0	0	0
Chloride (mg/l)	138	107	214	158	28	109	83	103
Ferrous Iron (mg/l)	0.14	2.09	3.3	2.42	3.3	1.66	3.3	3.3
Nitrate (mg/l)	0	0.01	0	0	0	0	0.07	0
Nitrite (mg/l)	0	0	0.004	0	0	0	0	0.001
Sulfate (mg/l)	4	11	20	16	6	0	1	0
Dissolved Oxygen (mg/l)	7.71	0.53	7.23	0.27	0		13.25**	0.64
Oxidation-Reduction Potential (uS/cm)	-187	-268	-210	-265	-280	-184	13	-137

Notes:
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ND and U - Not detected at listed quant
* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-2 4/22/2004	MW-2* 5/27/2004	MW-2* 5/23/2005	MW-2* 10/26/2005
Carbon dioxide (ug/l)	500 U	500 U	2310	
Ethane (ug/l)	80 U	160 U	4 U	4 U
Ethene (ug/l)	60 U	120 U	3 U	3 U
Methane (ug/l)	5100	5800 D	1200 E	1500 E
Dissolved Organic Carbon (mg/l)	1100	320	620	1 U
Alkalinity (mg/l)	36	210	174	>1600
Chloride (mg/l)	160	265	276	220
Ferrous Iron (mg/l)	3.3	2.46	3.3	3.3
Nitrate (mg/l)	0.4	0	0.66	0.88
Nitrite (mg/l)	0.101	0	0.051	0.05
Sulfate (mg/l)	8	0	8	22
Dissolved Oxygen (mg/l)	0.31	0	1.04	0
Oxidation-Reduction Potential (uS/cm)	-105	-283	-255	-299

Notes:
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Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-3* 8/19/1999	MW-3* 4/20/2000	MW-3* 10/24/2000	MW-3* 5/11/2001	MW-3 1/29/2002	MW-3 2/27/2002	MW-3 3/13/2002	MW-3 3/28/2002
Carbon dioxide (ug/l)	ND U	ND U	ND U	ND U	350 U			
Ethane (ug/l)	ND U	ND U	ND U	ND U	4 U			
Ethene (ug/l)	ND U	ND U	ND U	ND U	3 U			
Methane (ug/l)	310	7.9	52	6.3	2.3			
Dissolved Organic Carbon (mg/l)	2.36	3.62	1.94	4.07	10			
Alkalinity (mg/l)	186	190	178	168	215	202	192	214
Chloride (mg/l)	409	400	380	396	284	224	268	220
Ferrous Iron (mg/l)	0.03	0	0	0.05	0.01	1.61	0.11	1.9
Nitrate (mg/l)	0.2	0.21	0.78	0.74	0.92	0	0.19	0.03
Nitrite (mg/l)	0.028	0.02	0.013	0.067	0.012	0	0	0.001
Sulfate (mg/l)	80	80	80	80	80	80	80	80
Dissolved Oxygen (mg/l)	1.27	0.87	0	0	1.97	0	4.41	0.72
Oxidation-Reduction Potential (uS/cm)	83	125	63	301		-238	-186	-192

Notes:
Blank cells indicate parameter was not :
ND and U - Not detected at listed quant
* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-3 4/26/2002	MW-3* 5/17/2002	MW-3 6/5/2002	MW-3 6/18/2002	MW-3 10/31/2002	MW-3 4/1/2003	MW-3* 5/13/2003	MW-3* 10/23/2003
Carbon dioxide (ug/l)	350 U	350 U		350 U	350 U	350 U	350 U	
Ethane (ug/l)	4 U	4 U		4 U	4 U	12 U	20 U	
Ethene (ug/l)	3 U	3 U		3 U	8.9	20	15 U	
Methane (ug/l)	3.8	8.3		7.5	63	780	710	
Dissolved Organic Carbon (mg/l)	9.4			9.8	0.79	3	2.6	
Alkalinity (mg/l)	214	240	216	317	69	478	277	245
Chloride (mg/l)	199	114	224	221	34	14	36	315
Ferrous Iron (mg/l)	2.27	1.76	1.41	1.31	1.07	0.48	0.32	0.44
Nitrate (mg/l)	0.04	0.02	0.05	0.1	0.01	0.01	0.002	0.11
Nitrite (mg/l)	0.002	0.003	0	0.002	0.001	0.005	0.07	0.004
Sulfate (mg/l)	80	80	80	68	28	42	41	80
Dissolved Oxygen (mg/l)		0.65	0.56	0.39	0.1		0.14	0.7
Oxidation-Reduction Potential (uS/cm)	-75	-213	-194	-162	-206	25	-70	-136

Notes:
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ND and U - Not detected at listed quant
* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-3 4/22/2004	MW-3* 5/27/2004	MW-3* 5/23/2005	MW-3* 10/26/2005
Carbon dioxide (ug/l)	500 U	500 U	500 U	
Ethane (ug/l)	80 U	80 U	4 U	4 U
Ethene (ug/l)	60 U	60 U	3 U	3 U
Methane (ug/l)	1700	1800 D	780 E	470
Dissolved Organic Carbon (mg/l)	9.4	1.9	2.8	0.18 B
Alkalinity (mg/l)	230	282	114	185
Chloride (mg/l)	360	452	464	505
Ferrous Iron (mg/l)	0.65	0.4	0.34	0.23
Nitrate (mg/l)	0.03	0.04	0.31	0.23
Nitrite (mg/l)	0.004	0	0.012	0.002
Sulfate (mg/l)	80	>80	80	80
Dissolved Oxygen (mg/l)	0.47	0	0	0
Oxidation-Reduction Potential (uS/cm)	-129	-46	-130	-83

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ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-7 1/31/2002	MW-7 2/27/2002	MW-7 3/13/2002	MW-7 3/28/2002	MW-7 4/26/2002	MW-7* 5/21/2002	MW-7 6/5/2002	MW-7 6/18/2002
Carbon dioxide (ug/l)	350 U				350 U			350 U
Ethane (ug/l)	4 U				4 U			4 U
Ethene (ug/l)	3 U				3 U			3 U
Methane (ug/l)	48				16			54
Dissolved Organic Carbon (mg/l)	27				1800			87
Alkalinity (mg/l)	292	340	268	185	181		246	206
Chloride (mg/l)	298	941	405	780	331		468	425
Ferrous Iron (mg/l)	0.09	3.16	3.3	3.27	3.3		1.99	0.75
Nitrate (mg/l)	0	0.34	0.34	0.02	0.12		0.04	0
Nitrite (mg/l)	0.066	0	0	0.002	0.03		0	0
Sulfate (mg/l)	80	18	8	0	9		0	2
Dissolved Oxygen (mg/l)	0	>20**	>20**	3.49		1.12	0.41	0.21
Oxidation-Reduction Potential (uS/cm)		-96	-72	-79	-11	-213	-153	-235

Notes:
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Long-Term Monitoring Program
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J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-7 10/31/2002	MW-7 4/1/2003	MW-7* 5/13/2003	MW-7* 10/27/2003	MW-7 4/22/2004	MW-7* 6/4/2004	MW-7* 5/20/2005	MW-7* 10/25/2005
Carbon dioxide (ug/l)	350 U	350 U	350 U	350 U	500 U	500 U	0	
Ethane (ug/l)	4	180 U	160 U	4 U	160 U	320 U	4 U	
Ethene (ug/l)	3	130 U	120 U	3 U	120 U	240 U	3 U	
Methane (ug/l)	160	9700	7900	7100 D	12000	18000	1900 E	
Dissolved Organic Carbon (mg/l)	53	310	470	57	200	3.8	10	
Alkalinity (mg/l)	50	261	135	198	0		342	
Chloride (mg/l)	24	1105	>2500	515	0		>3000	
Ferrous Iron (mg/l)	2.22	2.01	3.3	2.79	1.77	>3.3	3.3	
Nitrate (mg/l)	0.02	0.01	0.22	0.16	0.03	1.37	0.71	
Nitrite (mg/l)	0.072	0	0.009 U	0	0	0.351	0.044	
Sulfate (mg/l)	0	0	0 U	0	0	0	8	
Dissolved Oxygen (mg/l)	0		0.79		0.32	0	0.8	0
Oxidation-Reduction Potential (uS/cm)	-182	-122	-90		-164	-108	-274	-131

Notes:
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Long-Term Monitoring Program
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J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter

Table 6-2
Summary of Indicator Parameters in Groundwater Samples
Building 25 - HRC Pilot Study
Watervliet Arsenal, Watervliet, New York

PARAMETER	MW-53 1/30/2002	MW-53 2/27/2002	MW-53 3/14/2002	MW-53 3/28/2002	MW-53 4/25/2002	MW-53 6/5/2002	MW-53 6/18/2002
Carbon dioxide (ug/l)	350 U				350 U		350 U
Ethane (ug/l)	4 U				4 U		4 U
Ethene (ug/l)	3 U				3 U		3 U
Methane (ug/l)	1100 E				1300 D		1400 E
Dissolved Organic Carbon (mg/l)	10				3.3		0.4 B
Alkalinity (mg/l)	649	202	174	165	155	123	222
Chloride (mg/l)	230	133	162	152	155	140	195
Ferrous Iron (mg/l)	0.02	0.59	0	0.01	0.07	0.02	0
Nitrate (mg/l)	0	0.32	0.16	0	0	0	0.06
Nitrite (mg/l)	0	0.004	0	0	0.001 U	0	0.003
Sulfate (mg/l)	0	80	6	0	0 U	0	0
Dissolved Oxygen (mg/l)	0	0	1.38	2.69		0.39	0.28
Oxidation-Reduction Potential (uS/cm)		-350	-333	-292	-222	-318	-317

Notes:
Blank cells indicate parameter was not
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* - Samples collected during the
Long-Term Monitoring Program
** - DO sensor not properly functioning
J - Estimated value
B - Detected in blank
mg/l - milligrams per liter
ug/l - micrograms per liter