Watervliet Arsenal

Watervliet, New York

Focused Corrective Measures Study

Main Manufacturing Area
Watervliet Arsenal
Watervliet, New York

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Report Prepared By:

Malcolm Pirnie, Inc.

43 British American Blvd.
Latham, New York 12110

Report Prepared For:

U.S. Army Corps of Engineers

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1. Introduction

1.1. Purpose of Report

A Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted at the Main Manufacturing Area (MMA) of the Watervliet Arsenal (WVA) in Watervliet, New York from 1995 through 2001. The RFI was conducted in accordance with an Administrative Order on Consent between the WVA, the New York State Department of Environmental Conservation (NYSDEC), and the United States Environmental Protection Agency (USEPA) Region 2. The results of the RFI were presented in the *Final RCRA Facility Investigation Report, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated November 2000 (Final RFI Report) (Malcolm Pirnie 2000a).

Subsequent to the completion of the RFI, a corrective measures screening process was initiated by the WVA to identify, evaluate, develop, and recommend remedial alternatives for the areas of the MMA requiring corrective measures. As a preliminary step in the screening process, additional investigations were conducted after the completion of the RFI to further understand the nature and extent of contamination. These investigations included:

- Soil, groundwater, soil vapor, and indoor air investigations at Building 40.
- Soil, groundwater, soil vapor, and indoor air investigations at Building 25.
- A soil vapor and indoor investigation of 25 buildings within the MMA and three off-site residential buildings adjacent to the MMA.

Following these investigations, bench, field-scale, and full-scale pilot studies were performed to evaluate corrective measures for these areas. Interim corrective measures (ICMs) were also performed for groundwater and indoor air at Building 40 and for indoor air at eight other MMA buildings.

The purpose of this Corrective Measures Study (CMS) report is to present the results of the preliminary screening of corrective measures technologies identified, and the proposed final corrective measures developed, for the Solid Waste Management Units (SWMUs) located in the MMA. This report also addresses the proposed final corrective measures for the unnamed SWMU for vapor degreaser units (SWMU - Vapor Degreaser Units), which includes the vapor degreasers formerly located at Buildings 20, 25, 40, 110, 120, and 130, as well as vapor intrusion into MMA buildings, which was a new requirement after completion of the RFI.

The major overburden unit identified in the MMA has been described as fill, consisting of brown or dark gray silty sand with angular gravel. The fill material is the only unit consistently found throughout the site, with the thickest amount of fill being in the eastern portion of the MMA. Underlying the fill are the following native overburden units: a fine grained alluvium, a coarser alluvium, and glacial till. These units are not present in all areas of the site.

The bedrock underlying the site is a black, medium-hard laminated shale, showing some characteristics of minor metamorphism. This shale has been identified as part of the Snake Hill Formation. The Snake Hill Formation has been described as heavily folded, and the effects of this have been noted during rock coring, as the shale displayed bedding planes at angles as high as 70 degrees. During coring, nearly vertical fractures were often encountered. The bedrock can be described in three ways based on the degree of weathering observed. The first is an extremely weathered zone approximately four feet thick. This extremely weathered bedrock unit is encountered at depths ranging from near ground surface to approximately 20 feet below ground surface (bgs). Beneath this extremely weathered bedrock is a zone of less weathered shale showing minimal competency. Competent bedrock is generally encountered at depths ranging from approximately 1.5 feet bgs on the bedrock divide to approximately 20 feet bgs on the eastern property boundary. Typically, competent bedrock was encountered at shallower depths and at higher elevations in the western portion of the MMA.

A borehole geophysical survey was conducted in 17 monitoring wells across the MMA to characterize the extent, orientation and magnitude of linear features (i.e., bedding and fractures) which intersect each of the well boreholes investigated. As part of the survey, Borehole Image Processing System (BIPS) high resolution panoramic video logging and standard video logging were used to identify fracture and or bedding plane magnitude and orientation. In addition, standard temperature and fluid resistivity logging were used to identify areas where groundwater recharge was occurring into the borehole. The primary direction of all linear features encountered in the well boreholes was to the east at an average dip direction of 100 to 110 degrees. These data corresponded to the direction of groundwater flow as delineated from water level measurements and discussed further below.

1.3.2. Hydrogeology

The majority of the MMA is relatively impervious to rainfall except at the residential and recreational areas of the northeastern portion of the WVA. Due to the shallow depth of bedrock and the limited amount of overburden in several areas of WVA, groundwater may be encountered within different geologic units (overburden, weathered bedrock, or bedrock) depending on the drilling location. For instance, groundwater is encountered in the bedrock at the western end of WVA (topographic high and local recharge area);

progressing eastward towards the Hudson River, groundwater is encountered in the weathered bedrock and then in the overburden deposits.

Groundwater flow in bedrock in the MMA is primarily controlled by the degree of fracturing within the bedrock itself and the local recharge area which is coincident with the topographic high. The most prominent feature on the potentiometric surface is a groundwater divide trending approximately north to south through Buildings 135 and 130. This feature appears to mirror a bedrock ridge. The primary discharge area for groundwater from the Main Manufacturing Area is to the Hudson River which is located to the east of WVA. For the area surrounding Building 25, groundwater in each of the hydrostratigraphic units flows from west to east towards the Hudson River, with a component of flow to the northeast. West of the groundwater divide, shallow groundwater flow discharges towards the Kromma Kill. Groundwater recharge occurs in the area of the bedrock ridge, resulting in consistently downward vertical gradients in this area. Groundwater flow in the eastern portion of the WVA, near the Hudson River discharge, exhibits generally upward vertical gradients.

The proposed final corrective measures were selected based on an evaluation of technical, environmental, human health and institutional concerns, as well as the results of bench and field/full-scale pilot studies and interim corrective measures.

1.2. Site Location and Background

The WVA is a 140-acre government-owned installation under the command of the U.S. Army Tank-Automotive and Armaments Command (TACOM). Located in the City of Watervliet, New York, the WVA is situated on the western shore of the Hudson River five miles north of the City of Albany, as shown on Figure 1-1. The WVA is a national registered historic landmark, which was established in 1813 with the purchase of 12 acres of land by the U.S. War Department. It currently consists of two primary areas: the MMA (125 acres), where manufacturing and administrative operations occur, and the Siberia Area (15 acres), which is primarily used for the storage of raw and hazardous materials, finished goods, and supplies brought from the MMA. These areas, as well as Buildings 20, 25, 40, 110, and 121, are shown on Figure 1-2. The WVA currently manufactures large caliber cannons and mortars.

The MMA is bounded on the east by Broadway Street (Route 32) and a six-lane highway (I-787), which separate the WVA from the Hudson River. Residential/light commercial properties are located along the northern and southern site boundaries. To the west of the MMA are: residential properties; the Siberia Area of WVA, which extends into the Town of Colonie; commercial properties; lands formerly owned by the Delaware and Hudson Railroad; and Canadian Pacific railroad tracks.

1.3. Physical Setting

The physical setting of the MMA is discussed in detail in the RFI Report (Malcolm Pirnie 2000a) and summarized below.

1.3.1. Geology

Surface soils at the MMA have been mapped by the National Cooperative Soil Survey (NCSS) as one of three distinct units. Surface soils in the southern and western portion of the site, the area where the majority of manufacturing activities occur, have been classified as “Ur”, or “urban land”. The northeastern portion of the MMA, containing the majority of residences, the golf course, swimming pool area, and a softball field is classified as “NaB”, or “Nassau channery silt loam, undulating.” The bedrock beneath these soils is very shallow, typically at a depth of sixteen inches. A small natural area in the block between AW-MW-22 and AW-MM-25 has been classified as “NaC”, or “Nassau channery silt loam rolling”. This soil is very similar to NaB and the only obvious difference is that it is typically found on slopes of up to 15 percent, while “NaB” is typically found on slopes of three to eight percent.

2. Nature and Extent of Contamination

The nature and extent of contamination at the MMA is discussed fully in the RFI Report and is summarized below. Areas and media not discussed in the RFI Report are also summarized below, with reference to reports developed after the RFI was complete.

2.1. Summary of Solid Waste Management Units (SWMUs)

There are 24 named and additional unnamed SWMUs within the MMA. A summary of each SWMU is provided below. Corrective measures presented in this Focused CMS Report are related to SWMU No. 5 (Building 25), SWMU – Vapor Degreaser Units, and soil vapor intrusion, which is not a listed SWMU as it was a new requirement after the RFI was completed. A summary of all SWMUs is provided in Table and Figure 2-1.

2.1.1. SWMU No. 1: Sludge Drying Beds

There are five sludge drying beds at the industrial wastewater treatment plant, which was built in 1970 (Building 36) (Figure 2-1). In 1975, one of the beds was converted to an emergency holding tank that was determined to be a surface impoundment as stated in 40 CFR Part 260.10. Hazardous waste was stored in this bed for periods greater than 90 days, which necessitated the application for a Part B Permit upon the enactment of the RCRA regulations. WVA formally closed the bed in October 1987. Changes in the closure rules required additional soil removal for clean closure. WVA performed this additional work in January 1994. The NYSDEC accepted the clean closure in a letter dated May 3, 1994 and no further action was required.

2.1.2. SWMU No. 4: Demolished Cyanide Treatment Facility

The cyanide treatment facility (Building 110A) (Figure 2-1) was constructed in 1969 and put on-line in 1978. Cyanide treatment operations were relocated to the wastewater treatment plant, and the cyanide treatment facility was demolished, in 1981 during the Renovation of Armament Manufacturing (REARM) project. There were no known releases from the treatment tanks, and waste transfer lines, along with all of the building materials and cyanide treatment units, were shipped to a hazardous waste disposal facility upon demolition of the structure. Analytical results from soil and groundwater samples collected during the RFI indicated that elevated levels of cyanide were not present in the vicinity of the former facility. This SWMU was identified as not being a source of contamination and therefore no further actions were required.

2.1.3. SWMU No. 5: Building 25

A self-contained vapor degreaser unit located in the southeast quadrant of Building 25 (Minor Components Building) (Figure 2-1) was installed around 1970 and ceased operation in 1982. The original degreaser used for cleaning small metal components in Building 25 was tetrachloroethene (PCE), which was eventually replaced by trichloroethene (TCE) and 1,1,1-trichloroethane (1,1,1-TCA). Potential releases of these chlorinated solvents to the soil and groundwater at Building 25 could have been through vents in the exhaust system, spills, and disposal of spent solvents. Chlorinated volatile organic compounds (CVOCs), including PCE, TCE, and 1,1,1-TCA were discovered in downgradient groundwater monitoring wells in 1986 and also in soil and groundwater samples collected during the RFI. Previous investigations at Building 25 are summarized in the RFI. A Pilot Study for treating groundwater containing elevated PCE and TCE concentrations east of Building 25 was conducted from 2001 to 2004. Details of this study are included in the *Pilot Study Report, Building 25 – HRC® Injection, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Building 25 Pilot Study) (Malcolm Pirnie, 2006a) and summarized in Section 4.0 of this report. No further remedial activity was required for this SWMU for soil and groundwater. Vapor intrusion mitigation for this SWMU is discussed separately in Section 5.

2.1.4. SWMU No. 6: Wastewater Treatment Plant

An on-site treatment facility (Building 36) (Figure 2-1) that treats mainly acid rinse waters (acidic chromium metal plating wastes) and soluble waste oil was constructed in 1969 and put on-line in 1970. In accordance with a RCRA exemption de-listing the waste, the sludge generated from the facility is dewatered and disposed in an industrial non-hazardous waste landfill. Treated effluent is discharged into the Hudson River (outfall 002) in accordance with a State Pollutant Discharge Elimination System (SPDES) permit. In January 1996, there was evidence of a leak in the underground single-walled transfer line from the indoor clarifiers to the outside sludge drying beds. Remedial actions included soil removals. In 1996, the broken transfer line was replaced with a 12,000 gallon waste soluble oil underground storage tank (UST). Analytical results from soil and groundwater samples collected during prior investigations indicated that RCRA-listed metals (i.e., chromium) were not present in the vicinity of the former facility. An extensive groundwater monitoring program is in place for the facility. No further remedial activity is required for this SWMU.

2.1.5. SWMUs Nos. 7 - 14: Underground Waste Oil Storage Tanks

Eight USTs in the MMA were designated for waste oil storage, but were reportedly used to store hydraulic oil, lubricants, non-chlorinated degreasing solvents, chlorinated solvents, and skim oil, which were produced during various manufacturing activities that took place at WVA. Since September 1987, all eight USTs were removed and/or replaced. The USTs removed under SWMUs 11 and 12 were leaking upon removal. However, no significant residual contamination remained after removal and/or replacement of any of the USTs. No further action is required for these SWMUs. The location of the eight USTs is shown in Figure 2-1 and is provided below:

- SWMU 7 – Building 141 (Northwest Quadrant of the Siberia Area)
- SWMU 8 – Building 135 (along north wall)
- SWMU 9 – Building 115 (along south wall)
- SWMU 10 – Building 110, South (along west wall)
- SWMU 11 – Building 110, North (along west wall)
- SWMU 12 – Building 44 (along south wall)
- SWMU 13 – Building 35, South (along south wall)
- SWMU 14 – Building 25 (along northwest wall)

2.1.6. SWMU No. 15 - 17: Underground Waste Oil Storage Tanks

2.1.6.1. SWMU 15

SWMU 15 (UST 13) is the former location of a leaking 1,000-gallon underground waste oil storage tank located east of Building 15 (Figure 2-1). The UST was removed and replaced in 1995. A new tank and piping were installed once the WVA deemed the excavated pit to be satisfactorily clean based on the results of the soil, sediment, and groundwater/accumulated rainwater samples collected in the pit. The site was closed clean by the NYSDEC in February 1995. No further action is required for this SWMU.

2.1.6.2. SWMU 16

SWMU 16 (UST 23) is the former location of a 1,000-gallon waste oil storage tank in the west central portion of Building 35 (Figure 2-1). The UST was removed in 1994 and replaced with a new tank and piping. Composite soil samples that were collected from the excavation pit showed no reportable detections for VOCs and semi-volatile organic compounds (SVOCs). The excavated pit was backfilled with clean sand. No further action is required for this SWMU.

2.1.6.3. SWMU 17

SWMU 17 (UST 25) is a 5,000-gallon waste oil storage tank located east of Building 36 (Figure 2-1). The line and the tank were certified as being free of any leaks based upon two tightness tests conducted on January 10, 1995 and February 22, 1996. No further action is require for this SWMU.

2.1.7. SWMU No. 19: Outfall No. 003

Outfall 003 is the main WVA outfall to the Hudson River. This outfall includes the effluent from the industrial wastewater treatment plant (IWTP) that flows through Outfall 002. As shown on Figure 2-2, Outfall 003 is located east of Building 40. Prior to the construction of the IWTP in 1970 and the cyanide treatment plant in 1978, waste was discharged directly to the Hudson River via this outfall. This outfall is monitored in accordance with the WVA's SPDES permit. According to site personnel, exceedances of permitted discharge limits for temperature, total suspended solids, and pH have been noted periodically in the past. However, these exceedances were considered “minor” and have never been repeated with any frequency. No leaks or breaks in the pipe have been documented and, according to the *RCRA Facility Assessment (RFA) Report, Watervliet Arsenal, Watervliet, New York* (RFA Report) (NYSDEC, 1992); it is unlikely that any traces of hazardous material remains in this outfall. No further action is required for this SWMU.

2.1.8. SWMU No. 20: Industrial Sewers

There are three types of waste lines that convey waste material to the on-site treatment plant in separate industrial sewers: acid rinse water, soluble waste oil, and cyanide rinse water. The acid and soluble sewers are constructed of both clay tile or plastic (polyethylene, polyvinyl chloride (PVC), and chlorinated polyvinyl chloride (CPVC)), depending on the section, and were installed in the early 1970s. Portions of the sewers have been upgraded since that time where necessary. The cyanide sewers were constructed of ductile iron pipe and were installed in the late 1970s. Use of these sewers was discontinued in 1994 when cyanide plating operations were phased out.

In 1992, Empire Soils Investigations, Inc. (Empire) conducted an investigation of leaks from the Manhole 34D of chromic acid line. The investigation revealed iron and manganese concentrations that exceeded NYSDEC Glass GA Standards and Guidance Values in the eight groundwater monitoring wells installed along the line (Empire, 1993a). During a video survey of the line conducted by Empire in 1992, twenty-three defects were noted. These defects were repaired and the line was re-sleeved in 1992 following the survey (Empire, 1993b).

In May 1993, during preventive maintenance, a number of potential leaking points were detected on the chromic acid rinse water line that conveys the waste to the onsite treatment plant (Building 36). The spill was reported to the NYSDEC, which resulted in the issuance of a consent order. Extensive line repair, soil removal, and groundwater extraction and monitoring were subsequently performed. All of the waste lines were upgraded in 1993 and 1994. Additional RFI activities, which included groundwater sampling, were initiated in 2000 to evaluate whether additional releases had occurred in the past. The contaminants of concern (COCs); RCRA-listed metals, polyaromatic hydrocarbons (PAHs), and cyanide, were not detected in the groundwater. No further remedial activity is required for this SWMU.

2.1.9. SWMU No. 21: Building 132 Incinerator

Building 132 was built in 1944 and is located at the western edge of the MMA near the gate leading to the Siberia Area (Figure 2-1). The incinerator was put on-line in 1945 and disposed of non-hazardous waste, primarily consisting of waste paper and office trash until 1975. Subsequently, Building 132 was used for the storage of pesticides and insecticides. This practice was ended in the late mid-1990s when the WVA switched to the use of an outside contractor for pest and weed control services. The building is currently used for the storage of non-manufacturing recycling materials (i.e., paper) before shipment off-site. Based upon RFI groundwater and soil results that did not indicate the presence of contamination at concentrations greater than guidance levels, no further action is required for this SWMU.

2.1.10. SWMU No. 25: Erie Canal

The Erie Canal passed through the eastern portion of MMA (Figure 2-1), flowing in a north/south direction. The Canal was built between 1817 and 1824 and was filled in with dirt, brick, portions of the canal, and other unknown fill materials around 1940 during the World War II expansion at the WVA. When present, the canal provided transportation, power, and water for fire protection for the WVA until the canal was relocated to Waterford in 1922.

In 1993, WVA personnel observed machining coolant oil seeping into an excavation in the area of the waste oil line at Manhole 43, which is located within the area of the former Erie Canal. Approximately 15 to 30 yards of soil were excavated and a soil sample was collected, showing no evidence of contamination at concentrations greater than guidance values. Soil borings were completed in the former canal during the 1990 and 1997 hydrogeological investigations of the MMA. These samples indicated that the canal fill materials were predominantly silt and clay in nature. Analysis of a soil sample collected from 20 feet under pavement revealed petroleum and lead contamination at concentrations greater than guidance values. However, contamination was not encountered outside of the canal fill area or in groundwater samples downgradient of the canal. Based on these data, no further remedial activity is required for this SWMU. Long term groundwater monitoring will continue as part of the WVA LTM Program.

2.1.11. SWMU No. 26: Building 35 Process Pit

Building 35, or the Heat Treat and Metal Processing Building, was constructed in 1918 along the southern property boundary of the MMA (Figure 2-1). In 1942 and during the mid to late 1970s (REARM project), Building 35 was extended and expanded into the current floor plan of 17 bays. Manufacturing activities conducted at Building 35 include chrome plating, cadmium-cyanide plating (discontinued in 1994), magnaflux testing, heat treatment, and cannon tube machining. The main waste types generated at Building 35 include water soluble cutting oil, combustible waste oil, metal chips, magnaflux testing oil, and process water from the chrome plating operations.

Four process pits were installed and used primarily for chrome plating of 155 mm guns, 8-inch guns, and equipment in Building 35. Today, two of the process pits are used for the chrome plating of cannon tubes. During the late 1980s, one of the original pits, the West pit, was converted to a furnace pit to be used for heat treatment of cannon tubes and is still currently being used for this purpose. In 1987, during the conversion of the chrome plating pit to the furnace pit, petroleum, oils, and lubricants (POLs) was observed to be seeping through cracks in the concrete walls and accumulating in the furnace pit.

Various investigations have been conducted to assess the soil and water contamination from POLs due to the manufacturing processes at Building 35. In 1990 and 1991, Clough, Harbour and Associates (CHA) conducted and prepared a *Phase I Subsurface Contamination Investigation of the Chrome and Shrink Pit Areas in Buildings 35 and 135 of the Watervliet Arsenal, Albany* (Phase I Investigation) (CHA, 1991) report. As a result of the investigation, the petroleum in Building 35 was identified as containing compounds characteristic of kerosene and that the source of the oil found in the furnace pit was probably a result of POLs leaking from the machinery in Buildings 35 and 110. A passive recovery pump was installed in January 1999 to test the viability of Light Non-Aqueous Phase Liquid (LNAPL) (POLs) recovery. LNAPL recovery was found to be minimal with no effect on the presence or distribution of the LNAPL. Based upon groundwater and soil results that do not indicate the presence of contamination at concentrations greater than guidance levels, and that the distribution of LNAPL is stable, no further remedial activity is required for this SWMU.

2.1.12. SWMU No. 27: Building 135 Process Pit

Building 135 was constructed in 1943 in the southwest corner of the MMA (Figure 2-1). The main shop floor area of the building is divided into five bays. A High Bay section is located at the south end of Building 135, rising approximately 50 feet above the rest of the building to facilitate lifting cannon tubes into and out of three pits: the Cold Works Pit, the Furnace Pit, and the Shrink Pit to WVA personnel. A Rotary Forge machine, considered the largest rotary forge in the world at the time, was installed in June 1975.

Manufacturing operations conducted at Building 135 include the delivery of raw steel billets; the forging of the billets into rough cannon tubes; the machining of the outside of the tubes; the lead plating and rifling of the inner bore; heat treatment, various quality control and strength tests on the partially completed cannon tubes prior to shipment to other buildings at the WVA. The main waste types generated at Building 135 include water soluble cutting oil, combustible waste oil, and metal chips from milling operations. Capacitors in the building that had contained polychlorinated biphenyls (PCBs) have been removed and replaced. Machines containing hydraulic oil with PCBs have been drained, flushed, and refilled with hydraulic oil containing less than 50 milligrams per liter (mg/l) PCBs.

The main focus of the Building 135 investigation was the Shrink Pit, which is located in the southeast corner of the building and is constructed of shale bedrock. The Shrink Pit houses three furnaces, an elevator, a metal stair case for access, a wet pit (commonly referred to as the "Blue Lagoon") and a dry pit at the bottom. The Shrink Pit was used to shrink a part of the gun tube, known as the hoop, onto the gun barrel. At its deepest point, the Shrink Pit is 100 feet deep and at its widest point is 51.5 by 40.5 feet wide (at the shop floor level). Drainage chases were installed around the perimeter wall of the Shrink Pit to collect groundwater for use in the shrinking process and were connected to the wet pit by a network of pipes. Groundwater that accumulates in the wet pit is pumped and discharged through Outfall 004 (Figure 2-2) to the storm sewer at the southern side of the building. This discharge is monitored by the NYSDEC under the WVA SPDES Permit.

Various investigations have been conducted to assess the soil and water contamination from POLs due to the manufacturing processes at Building 135. As mentioned previously, CHA conducted a Phase I investigation of the chrome and shrink pit areas in Buildings 35 and 135 in 1990 and 1991. As a result of the investigation, the petroleum in Building 135 was identified as containing compounds characteristic of refined petroleum lubricating oil and that the presence of LNAPL in the Blue Lagoon is most likely from POLs leaking from the machinery in Building 135. Based upon groundwater and soil results that did not indicate the presence of contamination at concentrations greater than guidance levels, and the lack of LNAPL in surrounding wells, no further action is required for this SWMU.

2.1.13. SMWU: Vapor Degreaser Units

Six vapor degreaser units were designated as part of the SWMU – Vapor Degreaser Units in the RFI Report. These vapor degreaser units, which were located in Buildings 20, 25, 40, 110, 120, and 130, were used for removing protective oil coatings from the surfaces of metal parts. The vapor degreaser units were exhausted to the atmosphere and were shut down periodically to remove accumulated sludges and oils. The units used chlorinated solvents, including PCE, TCE, and/or 1,1,1-TCA. Based on the results of the RFI, no further action is required for the vapor degreaser units at Buildings 20, 110, 120, and 130. The six buildings in which the vapor degreaser units are located are shown on Figure 2-1 and are discussed below:

- **Building 20**: The installation date of this vapor degreaser is unknown. The unit was idle from 1976 until its removal circa 1978.
- **Building 25**: See Sections 4 and 5.
- **Building 40**: See Sections 5 and 6.
- **Building 110**: The installation dates of the two degreasers known to have been present in this building are unknown. Both units were removed around 1976. According to WVA personnel, one of the units had been located in a section of the building called 110A, which was demolished in the early 1980s as part of Project REARM and is currently the location of the expanded Building 35.

- **Building 120**: The installation date of this vapor degreaser unit is unknown. The unit was removed around 1981. Approximately 250 feet south of the former location of this unit is a recovery well (RW-2), which was installed in 1993 as a result of an underground diesel fuel oil line leak. Groundwater samples collected during various monthly and quarterly sampling events from RW-2 have contained halogenated organics and other aromatics, including PCE and TCE at concentrations greater than guidance levels. Bedrock monitoring wells MW-8 and MW-64 are also located in the area of RW-2 and contain PCE and TCE at concentrations greater than guidance values. Based on the results of the RFI, the contamination at this location is not migrating and, therefore, no further remedial activity is required for this area.
- **Building 130**: The installation date of this degreaser is unknown. The unit is presumed to have been removed in 1981.

2.1.14. Chip Handling Facility Areas

Two chip handling facilities, the Building 132 South Chip Handling Area and the Building 123 Chip Handling Area (area currently surrounded by Buildings 121, 122, and 123), were designated as SWMUs in the RFI Report and are shown on Figure 2-1. The exact dates of operation for both chip handling areas is unknown, but the chip handling area at Building 132 is believed to have been operational in the mid to late 1950s. The storage capacity of both areas is estimated to have been up to 80 tons, or approximately 40 cubic yards. Waste metal gun steel chips were generated and placed in these areas directly on the ground. Various cutting oils coated the chips, which according to WVA, “dripped off or washed off during storm events.”

Various investigations have been conducted in these areas to assess the soil and water contamination due to the chip handling facility activities, as well as the environmental effects of an 8,000-gallon fuel oil release near Building 121. In November 1992, Lockwood Greene Engineers, Inc. (LGE) completed a Preliminary Assessment Screening Report and, in June 1993, Huntingdon-Empire Soils (HES) completed a soils characterization report for the Building 132 South Chip Handling Facility. Both reports confirmed that soils in this area were contaminated with total petroleum hydrocarbons. As a result of a natural gas line being installed to the WVA’s boiler plant (January to March 1994), the contaminated soils were excavated, removed, and disposed of at a nearby landfill.

No intrusive investigations had been completed for the SWMU in the Building 123 Chip Handling Area. However, piezometers and test holes were completed as part of a study conducted by William F. Cosulich Associates, P.C. (WFCA) in 1978. According to the Oil Pollution Source Elimination Study (WFCA, 1980), the Building 123 Chip Handling Facility was operated between the late 1950s and 1960s and then up until approximately 1976 was used “as a wash rack area for cleaning oil from metal.” The processes occurring in Building 121, the diesel oil spill (8,000-gallon release) at Building 116, and the Building 123 Chip Handling Facility, were all listed as sources of groundwater and soil contamination in this area. As a result of the presence of LNAPL observed in wells, piezometers, and test pits installed in this area, two interceptor trenches were installed in 1975 and 1976 to limit migration of oil from the source area. The one trench is located on the north side of Building 121 and the other trench was installed alongside the railroad track that runs northwest of Building 121. Details in regards to the installation of the interceptor trench and the removal of oil impacted soil to an off-site disposal site were included in the Update of the Initial Installation Assessment of Watervliet Arsenal report prepared by Environmental Science and Engineering, Inc. (ESE) in July 1987 (ESE, 1987). No further actions are required for this SWMU.

2.1.15. Chrome Plating Pit Areas

The basic function of the Chrome Plating Pits is to collect spillage and drainage from the chromium plating, anodizing, cadmium cyanide (use of this compound was discontinued in 1994), and manganese phosphate lines which contain caustic cleaners, electro-polishing, rinse water, and plating/coating solutions. The sump liquid and cyanide spillage and drainage is separately pumped and delivered to the industrial waste treatment plant. Waste placed into these pits include chromic acid and other plating fluids, such as caustic cleaners; sulfuric and phosphoric acids; cadmium, nickel, copper, manganese phosphate plating/coating solutions and rinse waters. The Chrome Plating Areas are located in Building 35 and, formerly, in Building 110, which are shown on Figure 2-1 and discussed separately below. No further actions are required for this SWMU.

- **Building 35 Minor Plating Area**: The plating area operations began in 1983 and are on-going. This pit consists of four adjacent plating/coating lines in a 135 x 56 foot area in the east-central side of Building 35. Many of the processing tanks in this area are approximately 700 gallons, but range in size up to 2,200 gallons. In July 1993, Empire Soils collected groundwater samples from monitoring wells 100 to 200 feet downgradient of the sump area, which showed that no RCRA-listed metals other than lead exceeded the applicable guidance values (Empire, 1993b).
- **Building 35 Major Plating Area**: This plating area consists of four adjacent pits in the southwest corner of Building 35 and are identified from west to east as the 120 mm cannon pit, the 155 mm furnace pit, the 8-inch cannon pit, and the new medium tube (NMT) pit. The 155 mm furnace pit operated from 1952 to 1987 when the pit was converted to an electric oven heat treatment facility. The 8-inch cannon pit, NMT pit, and 120 mm cannon pit began operating in 1976, 1980, and 1987, respectively. The 8-inch pit and NMT pit have been abandoned and are no longer used. The chrome plating tanks have a capacity of 12,760 gallons of fluid, while the associated tanks, which are used for rinsing, electropolishing, and cleaning, hold approximately 2,800 gallons of fluid.
- **Building 110 LC Plating Area**: The liquid chrome (LC) plating area was a pit divided equally into two sections, a shallow (approximately 40 feet deep) section and a deep (approximately 70 feet deep) section, with small individual holding tanks. The plating area was located in the center of Building 110. The shallow section was in

operation since the 1940s and was renovated from 1982 to 1984. Use of both sections of the pit was discontinued in 1991 and the pit was permanently abandoned in 2009 by backfilling with flowable fill.

2.1.16. Chrome Plating Scrubbers

Air exhaust scrubbers are used to remove contaminants entrained in the exhaust air from chrome plating operations, prior to discharge to the atmosphere. The scrubbers are located at Buildings 35 and 114 (used for laboratory testing only). The water used to remove the contaminants from the air stream is automatically discharged to the wastewater treatment plant. No further actions are required for this SWMU.

2.2. Areas of Concern

The areas of concern (AOCs) identified in the MMA are summarized below and in Table 2-2. All of the AOCs are categorized within the Vapor Degreaser Units SWMU.

2.2.1. Groundwater

Groundwater samples were collected during the RFI, the Long-Term Monitoring (LTM) program, and the various CMS studies. The nature of the groundwater contamination in the MMA is primarily related to the presence of CVOCs, which were used prior to 1982 in vapor degreasing operations. Groundwater containing CVOCs at concentrations greater than guidance values is found in the following general areas:

- Building 40
- Building 25
- Building 114 area

2.2.1.1. Building 25

Groundwater contamination is primarily located east and southeast of Building 25, coincident with the groundwater flow direction in this area of the MMA. The contamination primarily consists of PCE, TCE, vinyl chloride (VC), 1,1-dichloroethane (1,1-DCA), and 1,1,1-TCA, which exceed the corresponding NYSDEC Class GA Standards in the overburden, weathered bedrock, and bedrock groundwater.

Based on the results of the RFI, the horizontal extent of groundwater CVOC contamination is limited to an approximately 0.4-acre area in the vicinity of well cluster 86EM-SP-1B (SP-1B)/WVA-AW-MW-47 (MW-47) to the south, and by the eastern edge of the former Erie Canal to the east (Figure 2-3). This area is adjacent to, and downgradient from, the location of a vapor degreaser formerly located in the southeast corner of Building 25. The highest concentrations of chlorinated VOCs detected in the overburden were at well WVA-AW-25-MW-3 (MW-3) and in the bedrock were at well WVA-AW-25-MW-2 (MW-2) (Figure 2-3). Based on downgradient monitoring, the CVOCs are not migrating beyond the former Erie Canal or the WVA property boundary.

2.2.1.2. Building 40

Groundwater contamination at Building 40 primarily consists of PCE and cis-1,2-dichloroethene (cDCE), with a lesser percentage of TCE and VC. All of these contaminants are found in the bedrock groundwater. Overburden groundwater is not impacted. Based on the results of the RFI, LTM program, and the various CMS studies, the horizontal extent of bedrock groundwater contamination is limited to the area that extends southeast from monitoring well WVA-AW-MW-79 (MW-79) and WVA-AW-MW-88 (MW-88) (west of Building 40) to the eastern site boundary and, presumably, beyond the site boundary to the Hudson River (Figure 2-4). As discussed herein, the majority of the CVOC mass is entrained in the bedrock matrix. The exact source of the CVOCs in the groundwater at Building 40 is not known. However, there are no known continuing surface sources of CVOCs in the groundwater in the Building 40 area.

2.2.2. Soil Vapor

2.2.2.1. MMA

In accordance with the directive by the NYSDEC and the New York State Department of Health (NYSDOH), the WVA performed vapor intrusion investigations within, and adjacent to, the MMA from 2007 through 2008. The purpose of the investigation was to assess whether CVOCs were present in the sub-slab soil vapor beneath, and the indoor air within, buildings located in the MMA, including those that once contained degreasing operations, as well as three off-site private residences along the southeastern WVA property boundary. The evaluation also assessed whether soil vapor at the WVA southern property boundary contained CVOCs. A total of 25 buildings in the MMA were sampled during at least one of the two investigation phases. Based on the results of the investigations, no further action is required at the off-site residences, the WVA property boundary, and at Buildings 9, 18, 19, 23, 24, 35, 38, 44, 108, 110, 112, 115, 116, 123, 124, and 126. Corrective measures were found to be required for Buildings 20, 21, 22, 25, 114, 120, 121, and 130 due to the presence of CVOCs in soil vapor and/or indoor air at concentrations greater than guidance values (Figure 2-5).

2.2.2.2. Building 40

Due to the presence of CVOCs in the bedrock groundwater to the east of Building 40, the extent and concentration of VOCs in the indoor air within and the soil gas beneath Building 40 was investigated in a separate investigation. The investigation found that CVOCs were present in the soil vapor and indoor at concentrations greater than guidance values and corrective measures were required.

3. Corrective Action Objectives and Technology Screening

3.1. Groundwater Corrective Action Objectives

3.1.1. Building 25

The Corrective Action Objectives (CAOs) for groundwater in the Building 25 area of the MMA are the NYSDEC Class GA groundwater standards and/or guidance values, which are presented in Table 3-1. Compliance with the groundwater CAOs is measured at the monitoring wells immediately downgradient (east) of Building 25.

3.1.2. Building 40

The CAOs for groundwater in the Building 40 area of the MMA are the NYSDEC Class GA groundwater standards and/or guidance values listed in Table 3-1 or the approved alternate concentration limits (ACLs). However, given the likely presence of DNAPL in the fractured bedrock at the site, and the presence of CVOCs in the bedrock matrix, it is recognized that the achievement of the CAO may take a very long time or may not be achievable using currently available technologies. The compliance points for the Building 40 groundwater are the multi-level groundwater monitoring wells installed at the eastern WVA property boundary. Building 40 bedrock groundwater corrective measures and CAOs are discussed in greater detail in Section 6 of this report.

3.2. Soil Vapor Intrusion Corrective Action Objectives

The CAOs for soil vapor and indoor air are the action levels listed in the *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* (NYSDOH 2006).

3.3. Groundwater Technology Screening Summary

Various remedial technologies were evaluated to determine the potential of achieving site remedial objectives using both conventional and innovative remedial alternatives. The following programs/information resources were utilized to identify and review technologies for remediation of CVOCs in groundwater that may be potentially applicable to the Building 40 and Building 25 groundwater:

- United States Environmental Protection Agency (USEPA) Superfund Technology Innovation Program (TIP) (formerly the Technology Innovation Office (TIO);
- USEPA Cleanup Information (CLU-IN) Website (www.clu-in.org);
- Federal Remediation Technologies Roundtable;
- Environmental Security Technology Certification Program (ESTCP);

- Strategic Environmental Research and Development Program (SERDP);
- Interstate Technology and Regulatory Council (ITRC);
- Air Force Center for Engineering and the Environment (AFCEE);
- Naval Facilities Engineering Command (NAVFAC);
- National Groundwater Association – Groundwater On-line Database;
- University of New Hampshire Bedrock Bioremediation Center; and
- U.S. Geological Survey (USGS) Toxic Substances Hydrology Program.

In addition, the following publications were reviewed:

- Federal Remediation Technologies Roundtable. 2009. *Treatment Technologies Screening Matrix*.
- Interstate Technology Regulatory Council (ITRC). 2008. *In Situ Bioremediation of Chlorinated Ethene DNAPL Source Zones*. June 2008.
- LaChance, John (TerrraTherm) and Pierre Lacombe (USGS). 2009. *Thermal Treatment of DNAPL in Fractured Bedrock Using Thermal Conduction Heating*. Presentation for 2009 Fractured Rock Technology Seminar and Guided Site Tour, Naval Air Warfare Center, West Trenton, New Jersey. June 2009.
- McDade, James M., Travis McGuire, Charles Newell. 2005. *Analysis of DNAPL Source-Depletion Costs at 36 Field Sites*. Spring 2005.
- National Groundwater Association. *Fractured Rock: State of the Science and Measuring Success in Remediation*. September 2005.
- National Research Council (NRC). 2005. *Contaminants in the Subsurface, Source Zone Assessment and Remediation*.
- Sale, Tom, Charles Newell, Hans Stroo, Robert Hinchee, and Paul Johnson (ESTCP). 2008. *Frequently Asked Questions Regarding Management of Chlorinated Solvents in Soils and Groundwater*. July 2008.
- Strategic Environmental Research and Development Program. 2007. *Project Fact Sheet: A Comparison of Pump-and-Treat Natural Attenuation, and Enhanced Biodegradation to Remediate Chlorinated Ethene-Contaminated Fractured Rock Aquifers*, Naval Air Warfare Center, West Trenton, New Jersey. October 2007.
- United States Environmental Protection Agency. 2005. *Steam Enhanced Remediation Research for DNAPL in Fractured Rock, Loring Air Force Base, Limestone, Maine*. National Risk Management Research Laboratory, Cincinnati, Ohio. August 2005.

The technology-specific information is presented in the following subsections. The applications of potential remedial alternatives were screened according to geologic and hydrogeologic conditions, the nature of contamination, engineering requirements, and implementability. Final selected technologies were based on the ability to achieve the

CAOs, the physical constraints of the impacted areas, and the limitations imposed by operations at the MMA.

3.3.1. Bedrock Matrix and Groundwater

Corrective measures technologies were chosen for groundwater that could potentially meet the CAOs. Some of the corrective measures technologies are general in nature, describing broad categories of potential remedies, while other technologies are specific remedial options for the site. The following corrective measures technologies were retained for consideration for the Building 25 and Building 40 bedrock matrix and/or groundwater.

1. Monitored Natural Attenuation (MNA);
2. Containment;
3. In-Situ Treatment;
4. In-Situ Thermal Remediation (ISTR); and
5. No Action.

3.3.2. Monitored Natural Attenuation (MNA)

Natural attenuation may be considered for remediation of contaminants in groundwater and saturated soils if site-specific factors support its use. The factors include:

- Protection of potential receptors during attenuation;
- Favorable geological and geochemical conditions;
- Documented reduction of degradable contaminant mass in a reasonable time frame in the surface and subsurface soils;
- Confirmation in microcosm studies of contaminant cleanup; and
- For the persistent or conserved contaminants, ensured containment during and after natural attenuation.

Target contaminants for natural attenuation are VOCs, SVOCs, and fuel hydrocarbons. Fuel and halogenated VOCs (chlorinated solvents) are so far the most commonly evaluated for natural attenuation. Pesticides also can be allowed to naturally attenuate, but the process may be less effective and may be applicable to only some compounds within the group.

Factors that may limit the applicability and effectiveness of the process include:

- Extensive site characterization with modeling and long-term monitoring may be more costly than active remediation.
- Toxicity of degradation and transformation products may exceed that of the original contaminants.

- Risks occur at sites where geological characteristics such as fractured bedrock make contaminant assessment and hydraulic control difficult.
- Contaminants may migrate past site boundary before they are fully degraded or transformed.
- The source must be removed so there is no continuous release to groundwater.

MNA would involve the degradation of CVOCs in the overburden and bedrock groundwater by naturally occurring processes (i.e. biodegradation). Such degradation is monitored over time under a long-term monitoring program at both Building 25 and Building 40. The presence of PCE breakdown products, TCE, cDCE, and VC indicates natural attenuation is ongoing in the overburden and bedrock groundwater at Building 25 and in the bedrock groundwater at Building 40. In addition, the presence of the organism *dehalococcoides ethegenes* (DHE), which is capable of completely degrading CVOCs, has been confirmed in bedrock groundwater samples collected from the Building 25 and Building 40 areas.

Even though natural attenuation of CVOCs in groundwater at Building 25 and Building 40 is occurring, by itself, the process has not significantly reduced the concentration of CVOCs in the groundwater, although it has likely limited its lateral extent. However, through bedrock matrix diffusion, the migration of CVOCs in the groundwater has been attenuated. Even though the natural attenuation processes have served to reduce the mass and extent of CVOCs in the overburden and bedrock groundwater and could potentially result in the achievement of CAOs, the rate at which they currently occur is slow and would not result in a measurable decrease in contaminant mass or groundwater concentration in the near future. Given this, MNA, by itself, was eliminated from further consideration. MNA coupled with a more effective source treatment technology, however, was retained for further consideration.

3.3.3. Containment

Containment includes in-situ and ex-situ treatments, such as extraction and barrier technology (i.e., slurry wall/vertical barrier and permeable barrier walls) that would be employed to prevent contaminants from entering adjacent properties and essentially “contain” the contaminant plume. The most widely used containment method is groundwater extraction and treatment. Groundwater extraction and treatment technologies, commonly referred to as a “pump and treat” systems, have been widely used for two decades, growing in prominence in the early to mid-1980s.

Target contaminants for containment via groundwater extraction and treatment, are VOCs, SVOCs, fuel hydrocarbons, unexploded ordnance (UXO) (i.e., explosive compounds) and dissolved metals. Fuel and halogenated VOCs (chlorinated solvents) are the most commonly evaluated contaminants for groundwater extraction and treatment remedial systems.

Factors that may limit the applicability and effectiveness of the process include:

- Site geology and contaminant characteristics/distribution.
- Treatment may take a very long time (i.e., greater than 100 years) to meet the NYSDEC Class GA groundwater standards and/or guidance values.
- Desorption and/or back-diffusion of contaminants from the soil or bedrock matrix once groundwater extraction ceases and groundwater level rises creating a potential increase, essentially a rebound, in contaminant concentrations in the groundwater.
- Combination with complementary technologies (e.g., bioremediation, air sparging, dual phase extraction, and soil flushing) may be required to lower contaminant concentrations.

Groundwater extraction would involve the use of one or more wells to intercept and remove groundwater containing CVOCs from the subsurface. Groundwater extracted from the subsurface would then be treated at the surface and discharged under the appropriate discharge permit. Groundwater extraction would be accompanied by long-term groundwater monitoring to evaluate the degree to which CVOCs are removed from the subsurface and to evaluate the rebound in CVOC concentrations after the cessation of pumping.

Similar to MNA, the use of containment technologies, such as groundwater extraction and treatment, by itself, would result in a reduction in groundwater CVOC concentrations at the property boundary and prevent migration of the groundwater plume to adjacent properties, but would do little to reduce CVOC mass in the shale bedrock matrix. As such, groundwater concentrations would be expected to rebound to near their pre-remediation concentrations upon shut down of the containment remedy since CVOC source concentrations in the shale bedrock aquifer would be relatively unaffected by extraction of the groundwater.

A USEPA study of 28 sites at which groundwater containment remedies have been implemented found that, while 21 of 25 sites have met plume containment goals, only two of 28 sites have met their aquifer restoration goals (USEPA 1999). In fact, the study stated that the “EPA has concluded that one of the most effective means of remediating a site at which contaminated groundwater is present is to remove, or at least isolate, the source material from the groundwater.” These data indicate that, while containment remedies are viable remedies to eliminate potential exposure pathways, they are not effective source treatment technologies and are not suitable at sites where the source of the contamination has not been remedied. Therefore, the use of containment technologies (i.e. groundwater extraction and treatment) for Buildings 25 and 40 bedrock groundwater was eliminated from consideration.

3.3.3.1. In-Situ Treatment – Enhanced Bioremediation, Hydrogen Release Compound

In-situ treatments involve the addition of amendments to destroy or promote the enhanced degradation of, CVOCs. These technologies typically require long-term groundwater monitoring to verify the degradation of the CVOCs and to evaluate when or if additional injections are required. Enhanced bioremediation is one typical in-situ treatment in which indigenous or inoculated microorganisms (e.g., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in groundwater, converting them to innocuous end products. Nutrients (e.g., carbon, oxygen, nitrates) or other amendments may be used to promote and accelerate the ongoing bioremediation and contaminant desorption from subsurface materials.

Bioremediation can take place under aerobic or anaerobic conditions. In the presence of sufficient oxygen (aerobic conditions), microorganisms use atmospheric oxygen to function and can convert many organic contaminants to carbon dioxide, water, and microbial cell mass. In the absence of oxygen (anaerobic conditions), the organic contaminants are ultimately metabolized to methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas by microorganisms. Sometimes contaminants may be degraded to intermediate or final products that may be less, equally, or more hazardous than the original contaminant. For example, TCE anaerobically biodegrades to the more toxic VC. VC can be degraded further if the proper conditions are created.

There are four major processes that enhance bioremediation; nutrient injection, oxygen enhancement with hydrogen peroxide, nitrate enhancement, and bio-augmentation. At the MMA, nutrient injection was considered as a possible remedial technology for Building 25, specifically, the injection of hydrogen release compound (HRC®) into the subsurface. Hydrogen release compound is an environmentally safe polylactate ester that supplies additional carbon to the subsurface to be used by anaerobic microorganisms. These organisms release hydrogen and accelerate reductive dechlorination reactions (substitute carbon with hydrogen in chlorinated VOCs) that convert CVOCs into ultimately ethanes or ethenes (i.e., PCE → TCE → cDCE → VC → ethene).

When HRC® becomes hydrated, lactic acid is slowly released to the subsurface, which begins various biochemical reactions. In anaerobic environments, microorganisms, such as acetogens, metabolize the lactic acid provided by the HRC®, producing low concentrations of dissolved hydrogen. The hydrogen is then used by other subsurface organisms (reductive dehalogenators) to strip CVOCs of their chlorine atoms and allow for biological degradation. Nutrient injection can be injected either in the source area to remove contaminant mass or as a barrier to prevent ongoing migration of a contaminant plume.

Bioremediation techniques have been successfully used to remediate soils, sludges, and groundwater contaminated with petroleum hydrocarbons, solvents, pesticides, wood preservatives, and other organic chemicals. Bench- and pilot-scale studies have demonstrated the effectiveness of anaerobic and aerobic microbial degradation of halogenated and non-halogenated organic compounds in groundwater. Bioremediation is especially effective for remediating low level residual contamination in conjunction with source removal. While bioremediation (nor any other remediation technology) cannot degrade inorganic contaminants, bioremediation can be used to change the valence state of inorganics and cause adsorption, immobilization onto soil particulates, precipitation, uptake, accumulation, and concentration of inorganics in micro or macroorganisms.

Factors that may limit the applicability and effectiveness of the process include:

- Preferential colonization by microbes may occur causing clogging of nutrient injection wells, limiting adequate contamination and microorganism contact throughout the contaminant zone.
- Fluctuations in the water table may impact the effectiveness of this technology in the "smear zone."
- Preferential flow paths may severely decrease contact between injected fluids and contaminants throughout the contaminated zones. Engineered controls should be implemented for clay, highly layered, or heterogenous subsurface environments because of oxygen (or other electron acceptor) transfer limitations.
- High concentrations of heavy metals, highly chlorinated compounds, long chain hydrocarbons, or inorganic salts are likely to be toxic to microorganisms.
- Bioremediation is not preferred for soils with low permeabilites (i.e., fine clays).
- Bioremediation slows at low temperatures.
- Contaminant mobility may increase with the use of a water-based solution through soil, requiring the use of another remediation technology to remove contaminants from the groundwater or prevent expansion of the contaminant plume.
- Under anaerobic conditions, contaminants may be degraded to a product that is more hazardous than the original contaminant.

However, many of the these factors can be controlled with a properly designed remediation program.

Enhanced biodegradation would accelerate the degradation of the CVOCs in the overburden and bedrock groundwater, however, similar to MNA, many of the enhanced biodegradation technologies are applicable only to the CVOCs present in the groundwater. The use of most enhanced bioremediation technologies create a greater reverse diffusion gradient by which CVOCs in the overburden and bedrock matrix would be drawn into the groundwater more quickly. However, the rate at which this would occur may not result in a measurable decrease in overall contaminant mass in the near future (i.e., greater than 100 years). Overall, the advantages of using HRC® versus other carbon sources and enhanced bioremediation technologies include the following:

- Long Reaction Time: The compound's patented time release feature allows a one-time application to treat an entire site, thus it may not have to be reapplied repeatedly as with other carbon sources, such as molasses or common sugar solutions.
- Viscous Solid with Low Solubility: HRC® stays in place where it is injected and generates hydrogen.
- Desorption of Chlorinated VOCs: The continuous hydrogen source provided by HRC® can reduce dissolved phase chlorinated VOC concentrations by creating a larger concentration gradient, which in turn facilitates desorption of CVOCs 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.
- Low Capital Cost: HRC® application required 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 operation, 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 CVOC contamination when compared to natural attenuation approaches.

Based upon the longevity, implementability, and lower cost of injecting HRC® in the subsurface, use of HRC®, accompanied by long-term MNA was selected as the preferred technology for the treatment of CVOCs in the Building 25 groundwater.

3.3.3.2. In-Situ Treatment – Chemical Oxidation, Fenton's Reagent

The in-situ chemical oxidation (ISCO) treatments involve the delivery and distribution of oxidants and other amendments (e.g., catalysts) into the subsurface to chemically transform organic contaminants of concern into innocuous end products such as carbon dioxide (CO_2), water, and inorganic compounds which are more stable, less mobile, and/or inert. The primary advantages of ISCO technologies are their relatively lower capital cost and shorter treatment times than extraction technologies. Since the reaction is near immediate, treatment is also far more rapid than biological techniques.

Hydrogen peroxide-based Fenton's reagent is a well documented and effective in-situ chemical oxidation treatment. Fenton's reagent is a solution that is formed on-site by mixing hydrogen peroxide (H_2O_2) and a ferrous iron (Fe^{+2}) catalyst together to produce hydroxyl radicals (OH•), which is a very powerful nonspecific oxidizing agent, second only to fluorine in oxidizing power. Because hydrogen peroxide degrades rapidly in the environment, excess oxidant in the subsurface does not represent an environmental impact. However, the complete oxidation of contaminants requires sufficient time so that residual compounds are completely removed from the contaminant stream. Therefore, Fenton's reagent is most effective for dissolved phase contamination in groundwater.

Many reactions can occur during the oxidation of a contaminant. A contaminant, such as a halogenated organic compound (i.e., TCE), will react with hydrogen peroxide and ferrous iron (as a catalyst) to ideally produce carbon dioxide, water, hydrogen, and chloride ions, which are non-toxic. The hydrogen peroxide, catalyst, buffering solution (if needed), and water, which is used for dilution (solution is typically 5 to 20 percent hydrogen peroxide concentration), can be applied to saturated and unsaturated soil and bedrock by gravity feed or pressure through preexisting or newly installed monitoring wells and injection points screened at the targeted zone for the most effective remediation of the groundwater plume.

Fenton's reagent can be used to treat a wide variety of organic and inorganic contaminants in soil and groundwater, including chlorinated solvents, petroleum hydrocarbons, PAHs, SVOCs, pesticides, PCBs, phenolics, wood preservatives, and ordnance compounds.

When DNAPLs are oxidized within the soil interface, organic contaminants become desorbed from the soil, or essentially enter the aqueous phase. Oxidation continues to oxidize the contaminants within the interstitial groundwater. As a result of the oxidation process, aerobic biodegradation of contaminants can benefit from the presence of oxygen released during the decomposition of hydrogen peroxide.

Factors that may limit the applicability and effectiveness of the process include:

- Subsurface heterogeneity can cause uneven distribution of oxidants. Once injected into the subsurface, there is no control over the movement of the oxidant.
- Because the cost of ISCO injections is related to the depth and quantity of DNAPL, the number and pattern of injection and extraction wells (if necessary) and monitoring wells must be designed to ensure maximum coverage of the treatment zone.
- ISCO with Fenton's reagent often requires more than one application of oxidant to address rebound effects. Subsequent injection events may be hindered by the decrease in porosity of the subsurface due to the formation of metal oxide precipitates.
- With ISCO systems using Fenton's reagent, reduction of pH to levels between three and six standard units (S.U.) is required because at natural groundwater pH conditions

(six to seven S.U.), a ferrous catalyst will precipitate as its oxidized form (ferric iron), resulting in localized hydroxyl radical generation and a limited area treated by the reagent.

- Hydroxyl radicals generated can react with common inorganic species in groundwater, such as carbonate and bicarbonate, which can result in less hydroxyl radicals available to break down the contaminants. However, carbonate may act as a pH buffer and prevent the reduction in pH level necessary for the Fenton's reagent reaction to occur.
- Large quantities of Fenton's reagent are required for treatment of DNAPLs. Typically, Fenton's reagent is not applicable at sites where more than six inches of contaminant free product is present.
- Cost of using Fenton's reagent can increase in the presence of native organic matter which exerts a larger demand for oxidants.
- Lack of proper site characterization, calculation of injection variables (i.e., injection pressure and reagent concentration), and/or monitoring of injection operations may result in adverse effects, such as the development of carbon dioxide and/or oxygen off-gas, which can mobilize vapors and contaminants within the subsurface that may cause explosions in an inappropriate environment.

Rapid reaction times and high destruction efficiencies can be achieved with hydrogen peroxide, resulting in significantly reducing concentration at source areas and reducing remediation costs over the life of the project. Based on the stoichiometry of the oxidation of TCE by hydrogen peroxide, it would take 0.8 pounds of oxidant to fully oxidize one pound of TCE.

Hydrogen peroxide can be used to treat DNAPL sources within both the saturated and unsaturated zones of soil and bedrock. Since the Fenton's reagent is applied in-situ directly to the contaminant, the reagent should not cause vertical movement of the contaminant, which is often a concern with other remediation technologies. Typically, extensive geophysical logging, packer testing, and discrete sampling are conducted to evaluate fracturing and hydraulic properties of the soil and bedrock to appropriately design the full scale injection treatment. The use of Fenton's reagent in fractured bedrock has been limited, but when used during field studies the oxidant has been successful. However, the use of fast-reacting chemical oxidants, such as Fenton's reagent, at the MMA, would have an effect similar to that of groundwater extraction, in that the CVOCs in the bedrock fractures and overburden would be removed, but there would be little treatment of the CVOC mass in the shale bedrock matrix source. Given this, the use of Fenton's reagent was eliminated from consideration.

3.3.3.3. In-Situ Treatment – Chemical Oxidation, Potassium and Sodium Permanganate

Another well-documented and effective in-situ chemical oxidation treatment is to inject potassium and/or sodium permanganate into the area of concern. Potassium permanganate is a solid and is typically mixed with water to create a 2 to 5 percent solution on-site, while sodium permanganate is a 40 percent solution that is sent to the site containerized in a 55-gallon drum. Typical concentrations for sodium permanganate solutions injected into the subsurface are 5 to 20 percent, depending on the site characteristics. Potassium and sodium permanganate have the same oxidative capabilities, but sodium permanganate is 10 times more soluble than potassium permanganate and is more concentrated. Permanganate is a weaker oxidizer than hydroxyl radicals, but is more stable in the subsurface and has been shown to remain active in the subsurface for months after injection.

Potassium and sodium permanganate can completely oxidize certain chlorinated hydrocarbons in-situ, including those commonly found at DNAPL sites (e.g., PCE and TCE) without the production of toxic daughter products. Hazardous intermediate compounds may be formed due to incomplete oxidation caused by insufficient quantity of either oxidant or catalyst, the presence of interfering compounds (e.g., natural organic-rich media, iron, manganese, magnesium, and calcium) that consume the reagents, and/or inadequate mixing or contact time between contaminant and oxidizing agent. The primary products of the reaction between permanganate and PCE and/or TCE are hydrochloric acid (HCl), CO_2, and manganese dioxide (MnO_2). These products are generally not considered harmful in the groundwater environment. However, it is important to understand the fate of the primary by-products in order to minimize adverse impacts to the treatment zone.

- CO_2 – Carbon dioxide will combine with water to form the carbonate series and lower the pH of the groundwater.
- HCl – Hydrochloric acid is highly reactive and unpredictable, and is typically neutralized in the groundwater environments.
- MnO_2 – Manganese dioxide will precipitate out of solution and coat soil and bedrock pore spaces and bedrock fractures. The buildup of manganese dioxide, and other manganese oxides, may reduce aquifer permeability over time, thereby hindering delivery of oxidant to contaminated zones.

Chemical oxidation, via potassium and sodium permanganate, occurs at both the soil interface and free-phase interface (for NAPL situations) and within the interstitial pore spaces in saturated subsurface (for dissolved compounds). Organic compounds that contain carbon-carbon double bonds (alkenes) are more readily oxidized by permanganate than compounds having single carbon-carbon bonds (alkanes). Thus, permanganate is more effective at remediating chlorinated VOCs containing PCE and/or TCE rather than 1,1,1-TCA.

Factors that may limit the applicability and effectiveness of the process include:

- Subsurface heterogeneity can cause uneven distribution of oxidants. Once injected into the subsurface, there is no control over the movement of the oxidant.
- Because the cost of ISCO injections is related to the depth and quantity of DNAPL, the number and pattern of injection and extraction wells (if necessary) and monitoring wells must be designed to ensure maximum coverage of the treatment zone.
- ISCO with permanganate often requires more than one application of oxidant to address rebound effects. Subsequent injection events may be hindered by the decrease in porosity of the subsurface due to the formation of metal oxide precipitates.
- The potential to alter subsurface biogeochemistry and locally mobilize co-contaminants (e.g., redox sensitive metals such as chromium).
- The process may not be cost-effective for high contaminant concentrations in a large surface area because of the large amounts of oxidizing agent required.
- Incomplete oxidation or formation of toxic intermediate contaminants may occur.
- Large quantities of permanganate are required for treatment of DNAPLs.

Rapid reaction times and high destruction efficiencies can be achieved with potassium and sodium permanganate, resulting in significantly reducing concentration at source areas and reducing remediation costs over the life of the project.

Since potassium and sodium permanganate are relatively stable and can remain active in the subsurface for months after injection, they can diffuse into media with low permeabilities (i.e., clay and porous rock) over time, further enhancing oxidant/contaminant contact and destroying CVOC mass in the matrix. Application of excess potassium and sodium permanganate can allow for diffusion of permanganate into the matrix at the same time as contamination is diffusing out of the matrix (i.e., the reactants will be moving toward each other) adding to the treatment of the CVOC mass in the rock matrix. Since the permanganate is applied in-situ directly to the contaminant, the oxidant should not cause vertical movement of the contaminant, which is often a concern with other remediation technologies. Pilot studies utilizing permanganate in fractured bedrock have been limited due to the inherent complications of injecting into fractured bedrock. However, based upon the stability and longevity of permanganate in the subsurface, use of permanganate, accompanied by long-term MNA was selected as the preferred technology for the CVOCs in the Building 40 groundwater.

3.3.3.4. In-Situ Treatment – Iron Injection, Zero-Valent Iron and Nanoscale Zero-Valent Iron

Zero-valent iron (ZVI) has been used and well studied in permeable reactive barriers (PRBs) for groundwater treatment for almost 20 years. PRBs were not considered as a viable remediation technology for the groundwater at Building 25 and Building 40 because a majority of the CVOC contamination is located in the bedrock. For a PRB to be successful, the contact between the barrier and the contaminant is critical for remediation. Because the groundwater flow in bedrock fractures is unpredictable, contact with the groundwater plume may be limited and an unknown volume of the plume may pass by the barrier, resulting in some of the contaminant not being treated. Thus, trenching and constructing a PRB would not be cost effective or the best remedy for the treatment of this particular groundwater contaminant plume.

ZVI and nanoscale zero-valent iron (NZVI) colloids can be utilized in the Building 25 and Building 40 overburden areas, but as injected materials, not as a PRB. ZVI and NZVI are injected in the source area or down gradient of the flow path of a contaminant plume, allowing the water portion of the source area or plume to passively move through the injected material while the contaminants react with the colloids within the slurry. Once the contaminants come in contact with the ZVI or NZVI slurry, the reactions that occur break the contaminant down into harmless products or immobilize the contaminants by precipitation or sorption. Based on size, NZVI colloids react with the contaminants and flow with the groundwater, but settle over time, while the ZVI colloids are designed to settle when injected and react with groundwater passing through. The material injected is intended for long-term operation to control migration of contaminants in groundwater.

The two chemical agents considered for the ICM at Building 25 and CMS at Building 40 were ZVI (i.e., Ferox™) and NZVI (i.e., bimetallic nanoscale particle [BNP]). ZVI, or elemental iron (Fe0), is a strong reducing agent that supplies electrons from the iron surfaces in the slurry to an adsorbed halogenated compound (i.e., chlorinated solvents – PCE and TCE). As a result, when chlorinated organic contaminants react with the iron colloids, the contaminant is dechlorinated (i.e., the chlorine atoms are removed) to non-toxic by-products.

Ferox™ (provided by ARS Technologies) consists of micron-sized ZVI particles (approximately 80 micrometer size powder) that are injected as a slurry or as a dry material by either using an open borehole approach or directly into the fractures within the bedrock at a site. Both of these procedures use nitrogen gas as the carrier fluid. Hydrogen gas is generated by the anaerobic corrosion of the metallic iron by water, in which the hydrogen is then used to react with a halogenated hydrocarbon. The metallic iron may act as a catalyst for this reaction between the hydrogen and halogenated hydrocarbon. Impurities in the iron or surface defects may act as that catalyst as well.

Bimetallic nanoscale particles (provided by PARS Environmental) consists of submicron-sized (<10-6 meter) particles of ZVI with a trace coating of noble metal catalyst (typically palladium or platinum). The noble metal catalyst improves the reactivity of the iron by creating a second metal, in addition to the metallic iron, to catalyze the dehalogenation reactions. BNPs can rapidly destruct recalcitrant contaminants in-situ or ex-situ through the reduction-oxidation (redox) process, in which the contaminant serves as the electron acceptor. Typically, BNPs are injected via gravity feed (into monitoring wells) or pressure injection (into monitoring wells or by geoprobe) into the subsurface as a slurry at a low concentration (0.1 percent) of the total volume of injected slurry, which helps minimize the potential for clogging of a water-bearing zone. The use of BNPs can also stimulate the growth of an anaerobic microbial community capable of enhanced degradation of certain recalcitrant contaminants by creating strong negative redox conditions within the injection zone.

Target contaminant groups for Ferox™ and BNPs are CVOCs and leachable heavy metals (e.g., chromium and arsenic). BNPs have also been used to remediate groundwater contaminant plumes containing halogenated herbicides and pesticides, perchlorate, PCBs, and nitroaromatics. There have been many field demonstrations and pilot studies conducted in the overburden and bedrock at manufacturing and military sites that have showed decreases in high concentrations of halogenated aliphatics (i.e., PCE, TCE, DCE, and VC) in the groundwater by using ZVI and NZVI technologies. Of the halogenated aliphatics, cDCE and VC react relatively slowly in the presence of ZVI.

Factors that may limit the applicability and effectiveness of the process include:

- Production and accumulation of chlorinated byproducts due to the low reactivity of iron powders toward lightly chlorinated hydrocarbons (i.e., cDCE and VC).
- Iron colloids may lose their reactive capacity due to the precipitation of metal hydroxides and metal carbonates on the surface of the iron colloids, requiring re-injection of the iron periodically.
- Site-specific factors (e.g., carbonate, oxyanions, chloride, dissolved oxygen, alkalinity, and nitrate concentrations) of groundwater can affect the long-term life of the iron filings and iron reactivity during dehalogenation reactions.
- Duration of remediation of the entire plume may be long depending on the speed of the natural flow of the contaminant plume passing through the slurry.
- Iron filing slurries will treat contaminated groundwater in the overburden and in bedrock fractures, but not in the pore spaces of the bedrock matrix.
- Subsurface characteristics (e.g., soil type, grain sizes, permeability, subsurface obstructions, depth of groundwater, depth to bedrock, etc.) may all hinder the contact time between the contaminant and the iron colloids and slow down the rate of contaminant plume remediation.
- The injections must be designed to intersect the preferential groundwater flow paths because the remediation of the contaminant plume is dependent on the contact between the iron filings and the contaminants.
- Contaminants may be degraded to a product that is more hazardous than the original contaminant (i.e., byproducts of TCE, which includes cDCE and VC).

At both Building 25 and Building 40 at the MMA, most or all of the CVOC contamination is located in the bedrock. Therefore, the most appropriate remedy to successfully treat the contaminated plume in the bedrock would need to address the VOC mass in fractures as well as the VOCs in the rock matrix. ZVI and NZVI are not well suited for treating CVOCs concentration in the bedrock matrix. Given this, the use of iron injections was eliminated from consideration.

3.3.3.5. No Action

A no action response would include no remedial measures or monitoring. There are no inherent costs associated with a no action remedial response for a contaminated groundwater plume. The no action alternative would be the same as MNA, without monitoring, to demonstrate reductions in CVOC concentration. As such, a no-action response was not considered further.

3.3.3.6. Evaluation Criteria

Based on the evaluation of the above-mentioned technologies for the treatment of CVOCs in the groundwater at Buildings 25 and 40, data collected during pilot studies, and discussions with the NYSDEC, USEPA, and NYSDOH, the most beneficial and cost-effective in-situ remedial technologies for corrective measures were enhanced bioremediation through the injection of HRC® into the overburden and bedrock at Building 25 and ISCO through the injection of potassium and sodium permanganate into the bedrock at Building 40. Both remedial technologies were selected in conjunction with subsequent monitored natural attenuation of the CVOCs in groundwater. The remaining technologies were eliminated from consideration for the reasons summarized below. In general, these remedial technologies were eliminated based on their inability decrease the CVOC concentrations in the bedrock matrix (source area).

- Containment: May prevent off-site migration, but treatment time not acceptable (typically on the order of hundreds of years for bedrock sites) and the lack of impacted downgradient receptors.
- Fenton’s Reagent (ISCO Treatment): Oxidant is fast-reacting and does not remain in the subsurface for long periods of time.
- Iron Injection: Not capable of treating bedrock matrix contamination.
- No Action: Impacted areas where contamination remains must be monitored to ensure that potential receptors are not affected.

3.3.4. Vapor Intrusion

The following corrective measures technologies were retained for consideration for buildings impacted by soil vapor intrusion of the chlorinated VOCs.

1. Subsurface Depressurization;
2. Positive Pressure; and

3. Air Filtration.

3.3.4.1. Subsurface Depressurization

Subsurface depressurization systems (also commonly referred to as sub-slab depressurization systems) are the most common remedy for vapor intrusion mitigation. Buildings typically have a lower air pressure than the surrounding soil, particularly in the basement, creating a pressure gradient into the building that allows vapor intrusion to occur. A subsurface depressurization system prevents vapors from entering a building by creating a negative pressure field beneath the building, thereby preventing flow of vapors into the building. Subsurface depressurization systems can either be passive or active. An active system achieves lower subsurface air pressure by using a fan to draw air up from below the slab, while a passive system achieves lower subsurface air pressure by using only the convective flow of air created by connecting the sub-slab environment directly to the atmosphere.

Both active and passive systems have to be checked and maintained regularly to make sure they are performing as designed, although maintenance of active systems is more involved than that of passive systems. The period of performance for these systems is indefinite unless the source of the vapors is completely eliminated.

Subsurface depressurization systems were considered to applicable to Buildings 20, 21, 22, 25, 114, 120, 121, and 130 as these buildings were built with relatively modern foundations that included concrete slabs. However, subsurface depressurization was not considered to be applicable to Building 40 as it has an early 1800s field-stone foundation and earthen floors – most of which are no longer accessible due to modifications to the building over the last 200 years.

3.3.4.2. Positive Pressure

Heating, Ventilation, and Air Conditioning (HVAC) system modifications may be implemented to maintain adequate positive pressure within at least the lowest level of a structure (and all levels in contact with soil) to mitigate vapor intrusion. Older structures, however, rarely exhibit the requisite air tightness to make this approach cost effective. If sufficient positive pressure within the structure can be consistently maintained, then advective flow from the subsurface into the structure can be effectively eliminated. Most forced air heating and cooling systems only operate as needed. To implement positive-pressure vapor intrusion mitigation, the HVAC systems would require modification to run continuously to maintain a constant pressure within the structure.

Due to the age of the affected building in the MMA, which is greater than 50 years at a minimum, as well as the lack of forced air HVAC systems in most of the building, positive pressure mitigation was not considered to be applicable.

3.3.4.3. Air Filtration

The term air filtration is used as a general term to incorporate all remedial technologies in which air is passed through a filter (typically particulate filters or granular activated carbon and/or reactive media) to remove contaminants prior to discharge back into the space. In buildings, the filters can be incorporated as modules into an existing HVAC system or be installed within stand-alone air filtration units that recirculate air within the building.

Integrating activated carbon filtration modules into a preexisting or new HVAC system will be dependent on construction of the system, capacity of the air handling units to handle the pressure-drop across the filtration media, the size of the area being treated, accessibility to the components of the system, piping required, structural requirements and limitations, and the size and type of filtration media.

Indoor air filtration was considered to be applicable for the mitigation of vapor intrusion in Building 40 since the use of subsurface depressurization and/or HVAC modification were not considered to be applicable to the building. However, modification of the existing HVAC systems in the building to include filters was not possible due to limitation on the capacity of the air handlers and the distribution of the system in affected areas of the building. Therefore, the installation of stand-alone air filtration units placed in, and/or ducted to, the affected areas of the building, was selected as the corrective measure for vapor intrusion mitigation in Building 40.

4. Building 25 Groundwater (SWMU 5 and Vapor Degreasers)

4.1. Background

As discussed in Section 2.0, the results of groundwater sampling conducted during the RFI, site-wide LTM program, and the various CMS studies at the MMA indicate that VOC contamination in groundwater at Building 25 is primarily located east and southeast of the building (Figure 2-3), coincident with the groundwater flow direction in this area of the MMA. The contamination primarily consists of chlorinated solvents, such as PCE, TCE, VC, 1,1-DCA, and 1,1,1-TCA, which exceed the corresponding NYSDEC Class GA Standards in the overburden, weathered bedrock, and bedrock groundwater. To address the CVOCs in groundwater, HRC® was injected into the overburden and bedrock in the area east of Building 25 in February 2004. The 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,* dated December 2001 (Malcolm Pirnie 2001a) (Building 25 Pilot Study Work Plan).

Reductive dechlorination is the most important process in the natural biodegradation of chlorinated solvents (i.e., PCE and TCE). For reductive dechlorination to completely degrade CVOCs, such as PCE and TCE to ethene in anaerobic (oxygen depleted) environments, the geochemical conditions in the subsurface must be ideal and the availability of microorganisms that are responsible for degradation must be present. Figure 4-1 shows the reductive dechlorination pathways for various chlorinated solvents, including those present in the groundwater at Building 25. The products of the intermediate (TCE, cDCE, 1,1-DCA, chloroform, and methylene chloride) and complete (chloride, carbon dioxide, ethane, ethene, and water) reductive dechlorination of CVOCs are dependent on the chemical structure of the parent compound.

Electron acceptors (CVOCs), electron donors (sulfate, nitrate, ferric iron, and methane), a reducing environment (oxidation reduction potential [ORP] less than 50 millivolts [mV]), an anaerobic environment (dissolved oxygen [DO] less than 2.0 mg/L), carbon source, and microbes (reductive dechlorinators) are all needed for reductive dechlorination to occur. The most important of these prerequisites is the presence of microbes that utilize hydrogen to dechlorinate VOCs (reductive dechlorinators) in anaerobic environments. However, another type of microbe, methanogens, competes with reductive dechlorinators in anaerobic environments for hydrogen, which is produced by the microbial consumption of carbon in the subsurface.

Based on data collected during the RFI and LTM program, aquifer conditions at Building 25 were generally favorable for the degradation of CVOCs in both the overburden and bedrock groundwater, except for the low concentrations (2 mg/L) of dissolved organic carbon (DOC) in the groundwater samples. A lack of carbon in the subsurface could potentially limit the microbial processes that result in complete reductive dechlorination. HRC® was selected as an interim corrective measure, for the reasons listed in Section 3.0, 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. An overview of natural attenuation and reductive dechlorination as well as the specific details regarding the Pilot Study are presented in the Building 25 Pilot Study Work Plan.

4.2. Pilot Study Implementation

The Building 25 Pilot Study was conducted to:

- Assess the degree to which CVOCs were present in the overburden and bedrock groundwater;
- Evaluate the effectiveness of HRC® as an interim corrective measure for the overburden and bedrock groundwater;
- Demonstrate that HRC® can be efficiently delivered and distributed into the overburden and bedrock treatment zones;
- Reduce contaminant concentrations and mass in the affected areas; and
- Assess the geochemical and biological conditions of the subsurface to gage whether or not reductive dechlorination of CVOCs could continue in this environment long-term.

In general, the Pilot Study consisted of one HRC® injection, in which HRC® was applied directly to the overburden and bedrock groundwater zones. The purpose of this injection event was to demonstrate that HRC® could effectively be injected into the subsurface and stimulate the reduction of CVOC concentrations in the groundwater.

4.2.1. HRC® Injections

4.2.1.1. 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 2-3). The injections were conducted by Zebra Environmental Corporation (Zebra) between February 4 and 7, 2002. The injection points were located on a 50 foot by 75 foot grid pattern over the area of contaminated overburden groundwater in the vicinity of Building 25. 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.

4.2.1.2. Bedrock HRC® Injection

On February 8, 2002, six bedrock injection wells (Figure 2-3) were filled with 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®.

4.3. Pilot Study Results

Details of the Building 25 Pilot Study results are presented in the *Pilot Study Report – Building 25 – HRC Injection, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated March 2006 (Malcolm Pirnie 2006). The Pilot Study was monitored and measured by the following criteria:

- 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 HRC® in the subsurface; and
- Trends in dissolved gases (i.e., ethane, ethene, and methane) concentrations.

4.4. Post-Pilot Study Results

As part of the site-wide LTM program, groundwater samples have been collected from the four Building 25 Pilot Study monitoring wells from the end of study through the present. These samples were analyzed for VOCs, geochemical parameters, and indicator parameters. The pilot study found that the geochemistry and presence of electron donors in the groundwater at Building 25 after the completion of the Pilot Study were adequate for reductive dechlorination of CVOCs to continue.

As shown on Figure 4-3, the concentrations of PCE, TCE, cDCE, and VC have continued to decrease or have remained stable at the concentrations measured during the last Pilot Study monitoring event in May 2004. By the end of the Pilot Study, the total sum of CVOCs decreased by 31 to 99 percent, depending on the sampling location. In addition, the relative proportion of the parent CVOC (i.e., PCE or TCE) decreased by more than 38 percent at all locations.

4.5. 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, the most downgradient bedrock well.
- 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 CVOC concentrations at MW-2, MW-3, and MW-7 have not shown significant rebounding and are remaining relatively stable, over six 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.
- 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. This conclusion has been supported by groundwater results from LTM monitoring events conducted from 2006 through 2010. 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 proposed final corrective measure for the CVOCs in the Building 25 groundwater.

5. Vapor Intrusion

5.1. MMA-Wide

As discussed in Section 2.2.2, the WVA performed a vapor intrusion investigation within, and adjacent to, the MMA and adjacent to the Siberia Area of the WVA. This work was performed in two phases: November 2007 (preliminary testing) and February 2008 (full scale investigation). The results of the investigations were presented in the *Data Summary Report – 2007 Vapor Intrusion Evaluation, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated December 2007 (Malcolm Pirnie 2007), and the *Vapor Intrusion Investigation Report, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated August 2008 (Malcolm Pirnie 2008). A total of 25 buildings in the MMA were sampled during at least one of the two investigation phases. Samples collected during the 2008 investigation are listed below.

Building	Current Use	No. Sub-slab Samples	No. Indoor Air Samples
9	Quarters	1	1
15	Motor Pool/Offices	2	2
18	Quarters	1	1
19	Quarters	2	2
20	Manufacturing/Office	12	
21	Cafeteria/Meetings/Quarters	2	2
23	Office	2	3
24	Office	2	3
25	Manufacturing/Office/Lab	17	12
35	Manufacturing	5	
38	Museum	2	2
44	Office (Arsenal Partnership)	1	1
108	Mail Room	1	1
110	Manufacturing	6	
112	Laboratory/Office	1	1
114	Laboratory/Office	1	1
116	Unoccupied	1	1
120	Lab/DPW/Office	2	8
121	Laboratory	2	1
122	Laboratory		1
123	Paint Booths	1	
124	National Guard	1	1
126	Storage	1	1
130	Storage	2	1
	Off-Site Residences	4	4

MMA	Property Boundary Soil Vapor	3	
SA	Property Boundary Soil Vapor	3	

Sub-slab soil vapor concentrations of the seven chlorinated VOCs currently regulated by the NYSDOH were compared to decision matrices defined in the NYSDOH Guidance and subsequent revisions (NYSDOH, 2006). These matrices utilize the relationship between indoor air and sub-slab soil vapor concentrations to define the recommended action (e.g., no further action, monitor, mitigate). Indoor air concentrations of TCE and

PCE were compared to the air guideline values defined in Table 3.1 in the NYSDOH Guidance.

Based on the results of the investigations, no further action was required at the off-site residences, the WVA property boundary, and at Buildings 9, 18, 19, 23, 24, 35, 38, 44, 108, 110, 112, 115, 124, and 126. A summary of the investigation results and conclusions at each building is provided below. Summary tables listing the results of the 2008 investigation are contained in Appendix A.

5.2. Building 9

Concentrations of chloromethane and carbon tetrachloride were detected in the indoor air sample. Carbon tetrachloride, TCA, TCE, and PCE were detected in the sub-slab sample at concentrations that, based on the indoor air sample results and corresponding NYSDOH matrices, did not require any further actions at this location.

5.3. Building 15

Two indoor air samples were collected in Building 15. Both samples contained similar low level concentrations of chloromethane and carbon tetrachloride that were less than the guideline values. Sub-slab sample results for TCE and PCE placed the building in the monitor/mitigate category in the NYSDOH matrices. Based on these data, and in consultation with the NYSDEC and NYSDOH, the WVA elected to monitor Building 15 as the majority of the building is used as a automobile repair shop.

5.4. Building 18

Concentrations of chloromethane and carbon tetrachloride were detected in the indoor air sample collected in Building 18, which is used as a garage. At the time of sampling, the overhead door was closed. Carbon tetrachloride, TCE, and PCE were detected in sub-slab samples at concentrations that, based on the indoor air sample results and corresponding NYSDOH matrices, did not require any further actions at this location.

5.5. Building 19

Indoor air samples contained concentrations of chloromethane, carbon tetrachloride, cDCE, and PCE. Carbon tetrachloride, cDCE, TCE, and PCE were detected in sub-slab samples at concentrations that, based on the indoor air sample results and corresponding NYSDOH matrices, did not require any further actions at this location.

5.6. Building 20

Indoor air samples collected from the second floor office spaces of Building 20 in 2007 contained chlorinated VOCs at low concentrations that, by themselves, did not require mitigation based on the NYSDOH matrices. Twelve sub-slab samples were collected in

Building 20. Carbon tetrachloride, cDCE, and TCE were detected in at least 50 percent of the samples, while TCA and PCE were detected in all 12 samples. In accordance with the NYSDOH matrices, mitigation was recommended based on the sub-slab sample concentrations.

5.7. Building 21

Indoor air samples contained concentrations of chloromethane, carbon tetrachloride, and 1,2-dichloroethane that, by themselves, did not require mitigation based on the NYSDOH matrices. However, sub-slab samples contained TCE at concentrations that required mitigation in accordance with the NYSDOH matrices.

5.8. Building 23

Indoor air samples contained TCA, TCE, PCE, chloromethane, chlorobenzene, trans-DCE, and carbon tetrachloride. Sub-slab samples contained TCE at concentrations that, based on the indoor air sample results and corresponding NYSDOH matrices, did not require any further actions at this location.

5.9. Building 24

Indoor air samples contained chloromethane, carbon tetrachloride, 1,1-dichloroethane, 1,1-dichloroethene, PCE, and TCA. Concentrations of TCA, TCE, chloromethane, PCE, vinyl chloride, and carbon tetrachloride were detected in sub-slab samples. Based on the indoor air sample results and corresponding NYSDOH matrices, no further actions were required at this location.

5.10. Building 25

Carbon tetrachloride, chloromethane, TCE, PCE, carbon tetrachloride and chloromethane were detected in the indoor air samples. The concentration of TCE in two indoor air samples exceeded the mitigate guidance level in the NYSDOH matrix. Carbon tetrachloride, 1,1-dichloroethene, TCE, PCE, TCA, chloromethane, 1,1-dichloroethane, cDCE, and vinyl chloride were also detected in at least one of the sub-slab samples in Building 25. Concentrations of TCE, PCE, and TCA in the sub-slab samples exceeded the mitigate guidance concentrations in the NYSDOH matrices. Based on these data, mitigation was recommended.

5.11. Building 35

In accordance with the work plan, there were no indoor air samples collected in Building 35 as this building is used for manufacturing only. Carbon tetrachloride, chloromethane, 1,1-dichloroethene, cDCE, TCA, TCE, and PCE were detected in the sub-slab samples at varying concentrations. Based on the NYSDOH matrices, monitoring or mitigation would have been recommended based on the sub-slab sample concentrations. However, since Building 35 is currently used for large-scale manufacturing operations, no further action was recommended.

5.12. Building 38

Concentrations of chloromethane, carbon tetrachloride, and TCA were detected in the indoor air samples. Chloromethane and carbon tetrachloride were detected in sub-slab samples. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.13. Building 44

Concentrations of chloromethane, carbon tetrachloride, PCE, and TCE were detected in the indoor air sample collected in Building 44. Chloromethane, carbon tetrachloride, PCE, and TCE were detected in the sub-slab sample. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.14. Building 108

Concentrations of chloromethane, carbon tetrachloride, PCE, and TCE were detected at low levels in the indoor air sample collected from Building 108. TCA, 1,1,2,2,-tetrachloroethane, chloromethane, TCE, PCE and carbon tetrachloride were detected in the sub-slab sample. Based on the NYSDOH matrices and the indoor air sample results, no further actions are required at this location.

5.15. Building 110

In accordance with the work plan, there were no indoor air samples collected in Building 110 as this building is used for manufacturing purposes only. Carbon tetrachloride, chloromethane, chlorobenzene, chloroethane, tDCE, 1,1-dichloroethene 1,1,2,2-tetrachloroethane, TCE, PCE, cDCE, TCA, and vinyl chloride were detected in the sub-slab samples. In accordance with the NYSDOH matrices, monitoring or mitigation would have been recommended based on the sub-slab sample concentrations. However, since Building 110 is currently used for large-scale manufacturing activities, no further action was recommended.

5.16. Building 112

Concentrations of chloromethane, carbon tetrachloride, and TCA were detected in the indoor air sample. Chloromethane, carbon tetrachloride, TCE, PCE, 1,1,2,2-tetrachloroethane, and TCA were detected in the sub-slab sample. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.17. Building 114

Chloromethane, carbon tetrachloride, cDCE, TCE, and PCE were detected in the indoor air sample collected from Building 114. The TCE concentration in the indoor air sample exceeded the NYSDOH indoor air guideline mitigate value. TCE and PCE were detected in the sub-slab sample at concentrations that exceeded the NYSDOH sub-slab guideline value. Based on these data, mitigation was recommended.

5.18. Building 116

Concentrations of chloromethane, carbon tetrachloride, cDCE, TCE, and PCE were detected in the indoor air sample. TCE and PCE were detected in the sub-slab sample. In accordance with the NYSDOH matrices, monitoring or mitigation would have been recommended based on the indoor air and sub-slab sample concentrations. However, no further action was recommended at this location as the building is locked and unoccupied (used for storage only), and there are no plans to use the building in the future.

5.19. Building 120

Carbon tetrachloride, TCE, chloromethane, TCA, PCE, and 1,1-dichloroethene were detected in the indoor air samples. TCA, TCE, PCE, carbon tetrachloride, and 1,1-dichloroethene were detected in the sub-slab samples. In accordance with the NYSDOH matrices, monitoring was recommended based on the use of the building for office space and the indoor air and sub-slab sample concentrations. However, the WVA chose to mitigate based on the building use.

5.20. Building 121

Chloromethane, carbon tetrachloride, PCE, 1,1-dichloroethene, and TCA were detected in the indoor air samples. Chloromethane, carbon tetrachloride, cDCE, TCA, TCE, and PCE were detected in the sub-slab samples. In accordance with the NYSDOH matrices, monitoring would have been recommended based on the indoor air and sub-slab sample concentrations. However, based on the presence of CVOCs in the groundwater beneath the building, the WVA chose to mitigate.

5.21. Building 123

In accordance with the work plan, there were no indoor air samples collected in Building 123. PCE, TCE, carbon tetrachloride, chloromethane, and TCA were detected in the sub-slab samples. In accordance with the NYSDOH matrices, monitoring or mitigation would have been recommended based on sub-slab sample concentrations. However, in consultation with the NYSDEC and NYSDOH, no further action was recommended since the building is currently only periodically used for spray painting of small parts and this use is expected to continue in the immediate future.

5.22. Building 124

Chloromethane, chloroethane, and carbon tetrachloride were detected in the indoor air sample. Chloromethane, 1,1-dichloroethene, carbon tetrachloride, TCA, TCE, and PCE were detected in the sub-slab sample. Based on the NYSDOH matrices and the indoor air sample results, no further action was required at this location.

5.23. Building 126

Concentrations of chloromethane and carbon tetrachloride were detected in the indoor air sample. Chloromethane, PCE, TCE, cDCE, chloroethane, 111-TCA, and carbon tetrachloride were detected in the sub-slab samples. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.24. Building 130

Chloromethane, carbon tetrachloride, TCE, and PCE were detected in the Building 130 indoor air sample. TCA, TCE, chloromethane, chloroethane, cDCE, and PCE were detected in the sub-slab samples. In accordance with the NYSDOH matrices, mitigation was recommended based on the sub-slab concentration of TCE.

5.25. Off-Site Residences

5.25.1. 307 9th Street

Carbon tetrachloride, chloromethane, and PCE were detected in the indoor air sample. Similar concentrations of carbon tetrachloride and chloromethane were detected in the sub-slab sample collected from the basement. The PCE concentration was slightly greater than the concentration in the indoor air sample. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.25.2. 319 9th Street

Chloromethane, carbon tetrachloride, and 1,2-dichloroethane were detected in the indoor air sample. The sub-slab sample contained chloromethane, TCA, TCE and PCE. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.25.3. 411 9th Street

Chloromethane and carbon tetrachloride were detected in the indoor air sample. Similar concentrations of carbon tetrachloride and chloromethane were detected in the sub-slab sample. Based on the NYSDOH matrices and the indoor air sample results, no further actions were required at this location.

5.26. Summary

As discussed above, eight buildings were found to require mitigation. These buildings are summarized in Table 5-1 below.

Table 5-1 – Buildings Requiring Soil Vapor Mitigation

Building	Impacted Media	Target Chlorinated VOCs
20	Sub-Slab Soil Vapor	PCE, TCE, TCA
21	Sub-Slab Soil Vapor	TCE
22	Sub-Slab Soil Vapor	TCE
25	Indoor Air, Sub-Slab Soil Vapor	TCE, TCA
114	Indoor Air, Sub-Slab Soil Vapor	PCE, TCE
120	Sub-Slab Soil Vapor	PCE, Carbon Tetrachloride
121	Sub-Slab Soil Vapor	TCE
130	Sub-Slab Soil Vapor	TCE

As discussed in Section 3, the corrective measures for these buildings consisted of the installation and operation of subsurface depressurization systems (SSDSs) at each of the eight buildings identified in Table 5-1. Due to the large differences in the size, layout, and use of the buildings, the type of, and operational parameters for, the SSDSs varied from building to building.

The design of each SSDS was based on the results of pilot testing conducted in 2008. These tests utilized a single extraction point in each building to evaluate the SSDS design parameters, which were:

- Flow rate;
- Vacuum pressure;
- Radius of influence; and
- Effluent chlorinated VOC concentrations.

A mobile extraction and treatment system was used to conduct the testing. The flow rate and vacuum pressures were varied to evaluate the resulting changes in radius of influence, which was determined by measuring vacuum pressures in sub-slab monitoring points installed at varying distances from the extraction point. These results were then used to determine the optimal design (i.e., number and location of extraction points) for the treatment areas, the sizing of the system, and the resulting piping layouts. Effluent chlorinated VOC concentrations were used to assess whether off-gas treatment would be required in the SSDS designs.

The results of the pilot testing, as well as the design of the SSDSs and the operations and maintenance requirements, are presented in the *Vapor Intrusion Interim Corrective*

Measures Work Plan, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York, dated July 2009 (Vapor Intrusion ICM Work Plan) (Malcolm Pirnie 2009).

The SSDSs in the eight buildings were installed in and activated in 2010. The results of the installation and the associated startup testing are presented in *Vapor Intrusion Interim Corrective Measures Construction Certification Report, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated September 2010 (Malcolm Pirnie 2010). As discussed in the certification report, the systems are operating as designed and are successfully mitigating vapor intrusion into the buildings. Based on this information, SSDSs are recommended as the proposed final corrective measure for vapor intrusion in Buildings 20, 21, 22, 25, 114, 120, 121, and 130. Monitoring and maintenance of the systems will be continued in accordance with the Vapor Intrusion ICM Work Plan.

5.27. Building 40

5.27.1. Background

Between February 2003 and February 2006, investigations were conducted to assess whether CVOCs associated with the bedrock groundwater contamination in the vicinity of Building 40 were present in the soil vapor and indoor air beneath and/or within the building. The results of these investigations were submitted to the NYSDEC, USEPA, and NYSDOH in the following documents:

- *Work Plan for Ambient Air Sampling and Basement Ventilation Testing, Building 40, Watervliet Arsenal, Watervliet, New York*, dated August 2003 (Malcolm Pirnie, 2003c);
- *Revised Work Plan, Indoor Air and Soil Gas Testing, Building 40, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated January 2004 (Malcolm Pirnie, 2004c);
- *Additional Indoor Air Sampling, Building 40, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated August 2004 (Malcolm Pirnie, 2004d);
- *Additional Soil Gas Testing and Soil Sampling, Building 40, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated April 2004 (Malcolm Pirnie, 2004e)

A summary of these investigations is provided below.

5.27.2. Initial Investigation

This investigation was conducted to initially assess whether CVOCs associated with the bedrock groundwater contamination in the vicinity of Building 40 were present, and to what extent, in the indoor air and/or soil gas in the Building 40 basement area. Low concentrations (i.e., less than 3.0 micrograms per cubic meter [$\mu g/m^3$]) of VC, cDCE, TCE, and PCE, as well as BTEX were detected in the basement indoor air samples.

5.27.3. Additional Investigations

Additional indoor air and soil gas investigations were conducted in September 2003, February/March 2004, April/August 2004, and February 2006 to further assess whether CVOCs associated with the bedrock groundwater contamination in the vicinity of Building 40 were present, and to what extent, in the soil vapor and indoor at Building 40. As part of these investigations, the following activities were performed:

- A confounding source survey was conducted to identify any potential or possible sources of CVOCs or petroleum compounds in the vicinity of the investigation area.
- Sixty-four indoor air samples were collected.
- Thirty soil gas collection points were installed at locations around Building 40 and sampled.
- A basement ventilation test was conducted.
- Three air samples were collected from three of the eight sealed openings along the eastern foundation wall of Building 40.
- Five air samples were collected from two vents on the west wall and three vents on the east wall (wall facing Interstate 787).
- Nine vents were inspected by video for total depths and structural information.

5.27.3.1. Indoor Air Sampling

Sixty-four indoor air samples were collected in Building 40 during the various investigations. TCE concentrations in indoor air samples greater than the NYSDOH action level of 5.0 µg/m^3 were measured in the following locations (Figure 5-1):

- First floor south conference room;
- First floor Unit 6;
- Second floor south section; and
- Second floor Unit 2.

5.27.3.2. Soil Gas Sampling

Thirty soil gas points were installed and sampled around Building 40. Each point was constructed with a “shallow” soil gas point constructed approximately five feet bgs and a “deep” soil gas point constructed approximately 10 feet bgs. In general, CVOC detections in the soil gas were localized in nature and coincided with areas of elevated TCE and PCE concentrations in groundwater (Figure 5-2).

5.27.3.3. Foundation Sampling

There were eight locations noted (Figure 5-2) along the eastern foundation walls of Building 40 where apparent former openings to the area below the current first floor exist. These former openings have been sealed with brick. Three of the sealed openings were penetrated to evaluate the nature of the space below the first floor. While penetrating the sealed openings it was found that the area behind the sealed openings had been backfilled. As a result, the soil gas behind the foundation wall was sampled by installing a horizontal soil gas point into the backfill material behind the wall. The soil gas points were sealed to the foundation and sampled. No CVOCs were detected in any of the foundation opening samples.

5.27.4. Corrective Measures

As discussed previously, due to the construction and age of the Building 40 foundation, the use of subsurface depressurization was not considered to applicable. Therefore, indoor air filtration was utilized as the mitigation measure for the Building 40 indoor air. The mitigation measure consisted of the installation of eight air filtration units (AFUs) in the impacted areas of the building as follows:

- **Unit 6 Body Forge Exercise Area**: Two, 2,000 cubic feet per minute (CFM) capacity, stand-alone Circul-Air AFUs equipped with granular activated carbon/permanganate filter media for CVOC treatment.
- **Unit 6 Turret Lab**: Two, 2,000 cubic feet per minute (CFM) capacity, stand-alone Circul-Air AFUs equipped with granular activated carbon/permanganate filter media for CVOC treatment.
- **South Conference Room**: One, 1,000 cubic feet per minute (CFM) capacity, Circul-Air AFU equipped with granular activated carbon/permanganate filter media for CVOC treatment and connected to the conference room via dedicated supply and return air ducts.
- **Unit 2 Second Floor**: Three, 2,000 cubic feet per minute (CFM) capacity, Circul-Air AFUs equipped with granular activated carbon/permanganate filter media for CVOC treatment and connected to the Unit 2 office areas via dedicated supply and return air ducts.

The locations of the AFUs are also shown on Figure 5-1. The AFUs were installed in 2006 and were activated in January 2007. The WVA monitors the operation of the units during monthly inspections and during semi-annual filter media testing. Filter media is replaced based on the results of the testing. Based on the performance of the systems to date and the impracticability of installing subsurface depressurization systems, the indoor air filtration units are the recommended proposed final corrective measure for vapor intrusion at Building 40.

6. Building 40 Bedrock Groundwater (SWMU Vapor Degreasers)

6.1. Background

Chlorinated volatile organic compounds, composed primarily of PCE, trichloroethene TCE, cDCE, and, to a lesser extent, VC, were detected in the bedrock aquifer in the vicinity of Building 40 during the RFI. As a preliminary step in the CMS process, an additional investigation was conducted in the Building 40 area to further define the extent of CVOC contamination in the bedrock aquifer. The results of this investigation are contained in the *Corrective Measures Data Gap Study Summary Report, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Malcolm Pirnie 2001) (Data Gap Study Report).

In 2001 and 2002, an in-situ chemical oxidation pilot study (Pilot Study) was performed in the Building 40 area to evaluate the degree to which the CVOCs in the bedrock groundwater could be treated using potassium permanganate (KMnO4). The Pilot Study was performed in accordance with the *Work Plan for Building 25 and Building 40 Pilot Studies, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Malcolm Pirnie, 2001a). The Pilot Study included multi-level monitoring well installation, rock core sampling, several phases of potassium permanganate (KMnO4) injection, and monitoring to evaluate both the distribution of potassium permanganate and CVOC destruction in the bedrock groundwater.

A Human Health and Ecological Exposure Assessment (Exposure Assessment) was performed for the MMA in conjunction with the CMS Data Gap and Pilot Studies. The results of the Exposure Assessment have been provided to the NYSDEC and USEPA in the *Draft Exposure Assessment, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Malcolm Pirnie, 2003). Based on the information in the draft Exposure Assessment, there is no identified risk to human health or the environment associated with contact, ingestion, or discharge of the groundwater. However, as discussed previously, an exposure pathway related to CVOC vapor intrusion into the indoor air of Building 40 was identified and mitigated.

Studies of the ambient air quality inside Building 40, and the soil gas quality around the building, were conducted to evaluate possible vapor intrusion pathways. The studies showed an area of elevated CVOC concentrations in the shallow soil gas in the courtyard adjacent to Unit 6 of Building 40. Historical information indicates the former presence of a vapor degreaser in Unit 6. Based on these data, it is suspected that the source of the CVOCs in the subsurface in the Building 40 area originated in the Unit 6 area.

Extensive hydrogeologic characterization studies were performed in the bedrock aquifer in the Building 40 area during the RFI and Data Gap Study. These studies included discrete zone packer testing, down-hole geophysical profiling, video and acoustic televiewer profiling, and intra- and cross-borehole flow testing. The results of these studies are detailed in the *United States Geological Survey (USGS) Open-File Report entitled Characterization of Fractures and Flow Zones in a Contaminated Shale at the Watervliet Arsenal, Albany County, New York: USGS Open File Report 01-385* (Williams and Paillet, 2002) and in the Data Gap Study Report. Based on the results of the hydrogeologic studies, groundwater in the bedrock aquifer in the Building 40 area flows along discrete, generally interconnected, fracture pathways. The results of the cross-borehole flow testing indicate that a highly transmissive fracture or series of fractures connects several of the wells in the Building 40 area. More than 80 discrete fractures were identified during the testing. However, the testing also demonstrated that other, less direct, connections exist between the monitoring wells installed in the Building 40 Area.

During the CMS investigations, rock core samples were collected from monitoring wells located in the central portion of the CVOC-impacted area. These samples were analyzed for rock matrix pore water VOC content by the University of Waterloo (UW). The analysis revealed that matrix pore water CVOC concentrations, some approaching aqueous solubility, were present in the rock cores from approximately 25 to 150 feet bgs.

6.2. Site Conceptual Model

The conceptual model for the bedrock groundwater in the Building 40 area is as follows.

CVOCs are present in the bedrock aquifer in the Building 40 area. Dissolved-phase CVOC concentrations indicating the potential presence of dense non-aqueous phase liquid (DNAPL), have been detected in the bedrock groundwater. Advective transport of the CVOCs in the bedrock aquifer takes place through a well connected fracture network that extends to a depth of approximately 150 to 200 feet bgs. This depth has been confirmed by both fracture groundwater and rock matrix CVOC analysis. Based on field observations, groundwater below approximately 150 feet is also affected by the presence of naturally-occurring hydrogen sulfide and methane gas. The original source of the CVOCs in the bedrock groundwater is presumed to be located in the northeastern portion of the building, between Units 5 and 6. Since significant CVOC concentrations were not detected in the overburden soil in this area, it is possible that the release occurred through a subsurface storm sewer that was once connected to floor drains in Unit 6 of Building 40.

Although fractures provide the only pathway for advective transport of groundwater and CVOCs through the bedrock aquifer, the ratio of the void space due to the presence of fractures to the bulk rock volume ("fracture porosity") is several orders of magnitude less than the matrix porosity of the rock itself – meaning that the capacity of the rock matrix to store CVOCs is orders of magnitude greater than the storage capacity in the fractures. This matrix storage capacity creates a diffusive gradient by which CVOCs present at high concentrations in the fractures can diffuse into the bedrock pore spaces. Thus, although DNAPL may still exist in some fractures, the majority of the DNAPL that was initially present in the fractures has likely dissipated due to dissolution and diffusive mass transfer to the rock matrix -- causing nearly all the VOC mass to now reside in the rock matrix and not in the bedrock fractures. This concept has been confirmed by the presence of high concentrations of CVOCs in bedrock core samples obtained during the pilot and CMS studies. Given these data, and the lack of any current surficial sources, it is presumed that the shale bedrock itself is the continuing source of the CVOCs in the groundwater

This site conceptualization indicates that the only truly effective remediation technologies for the fractured bedrock aquifer are those that will treat the CVOC mass in the rock matrix in addition to treating the CVOC mass in the fractures. Failure to treat the CVOC mass in the matrix (i.e., the source area) will result in a continuous diffusive transfer of CVOCs out of the bedrock into the groundwater in the fractures.

6.3. Pilot Study

Details for the Building 40 bedrock groundwater in-situ chemical oxidation pilot study (Pilot Study) are presented in the *Work Plan for Building 25 and Building 40 Pilot Studies, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York* (Malcolm Pirnie, 2001a) and the *Building 40 In-Situ Chemical Oxidation Pilot Study Report, Watervliet Arsenal, Watervliet, New York, dated April 2004* (Malcolm Pirnie, 2004) (Building 40 Pilot Study Report). A summary of the Pilot Study is presented below.

The objectives of the Building 40 bedrock groundwater corrective measures pilot study were to:

- Evaluate whether potassium permanganate could be effectively delivered and distributed through the bedrock treatment area;
- Confirm that CVOCs in the bedrock groundwater could be oxidized by the permanganate;
- Assess the persistence of the permanganate in the subsurface; and
- Estimate the degree and rate of diffusion of permanganate into the shale bedrock matrix.

In general, the Pilot Study consisted of two phases of potassium permanganate (KMnO4) solution application. The purpose of the first phase was to evaluate whether the KMnO4 solution could be efficiently injected into a major transmissive zone and effectively distributed along this zone in a relatively short period of time. The second phase was a longer-term permanganate delivery designed to flood certain areas with sufficient permanganate to allow for diffusion into the rock matrix.

6.3.1. Permanganate Distribution and CVOC Destruction

Single-point injections of potassium permanganate in the affected area resulted in distribution of permanganate both laterally and vertically throughout the bedrock aquifer in the Pilot Study area. CVOC concentrations in the bedrock groundwater were reduced in monitoring zones where permanganate was present. Based on rebound monitoring conducted after the completion of injections, permanganate residence time in the fractures was approximately two to three months.

6.3.2. Permanganate Matrix Invasion

Laboratory testing was conducted to measure the rate of permanganate invasion into the shale bedrock. This was accomplished by submerging rock core samples in KMnO4 solution for a period of time during which diffusion into the core would take place. Preliminary analysis indicates that the permanganate has successfully invaded the shale bedrock matrix, but that the invasion distances into the shale during the six month test period were less than100 microns.

6.3.3. Pilot Study Conclusions

The results of the Pilot Study indicated the following.

1. The vast majority of the CVOC mass in the bedrock aquifer in the Building 40 area is entrained in the shale bedrock matrix pore spaces.
2. Permanganate could be distributed both vertically and horizontally throughout the treatment area using a small number of injection points.
3. Permanganate reduced the concentration of CVOCs in the bedrock groundwater in the short term.

Based on the data collected during the Pilot Study, permanganate was selected as the corrective measures technology for treating the CVOC contamination in the Building 40 bedrock groundwater.

6.4. Corrective Measures

Details of the Building 40 Bedrock Groundwater Corrective Measures (CM) are presented in the following documents. The scope and results of the CM are summarized herein.

- *Corrective Measures Work Plan, Building 40 Bedrock Groundwater, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated June 2004 (Malcolm Pirnie, 2004) (CM Work Plan);

- *Corrective Measures Monitoring Program, Building 40 Bedrock Groundwater, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated August 2004 (Malcolm Pirnie, 2004a) (CMMP);
- *Corrective Measures Installation and Startup Report, Building 40 Bedrock Groundwater, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated August 2006 (Malcolm Pirnie, 2006) (CM Startup Report); and
- *Corrective Measures Performance Evaluation Report, Building 40 Bedrock Groundwater Corrective Measures, Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York*, dated December 2008, revised September 2009 (Malcolm Pirnie 2008 & 2009)(CM Performance Evaluation Report).

6.4.1. Corrective Measures Summary

The CM treatment program included injections of sodium permanganate (herein referred to as permanganate) and groundwater sampling at the WVA property line compliance boundary.

In accordance with the approved CM Work Plan, the Corrective Action Objective (CAO) for the CM Program was to reduce the concentration of hazardous constituents in groundwater migrating from the site to New York State and Federal groundwater standards, or approved alternate concentration limits (ACLs) developed for the site. However, given the likely presence of DNAPL in the fractured rock at the site, it was recognized by all parties that the achievement of the CAO may require an extensive time period and may not be achievable using currently available technologies. Accordingly, the CM program was subject to the following Performance Criteria, through which the CAO may be achieved over the long-term as a result of source reduction:

1. Permanganate Distribution: The permanganate must be well distributed to and within the boundary monitoring wells within one year after the initiation of full scale injections.
2. Permanganate Residence Time: The permanganate must persist for at least 30 days after injection in the boundary monitoring wells within two years after the initiation of full scale injections.

If these performance criteria were not met, the WVA was required to perform an evaluation as to whether the permanganate corrective measures, or any other potential corrective measures, are feasible for the site.

The corrective measures were initiated in September 2004 with injections on the west side (upgradient) of Building 40. Full scale injections into all five injection wells were initiated in August 2005. The maximum permanganate distribution in the compliance boundary monitoring wells was achieved during the first full-scale injection event in August 2005 when permanganate was delivered to nine of the 18 compliance monitoring zones. Beginning with the November 2005 injection event, and in subsequent injection events, injection well clogging limited the amount and/or rate of oxidant that could be delivered to injection wells IW-2 and IW-3. Clogging in these wells, which are located in the central portion of the treatment area, was accompanied by a decrease in permanganate distribution in the compliance monitoring zones. As of the last injection event in September 2006, permanganate residence time was less than 30 days in 16 of the 18 monitoring zones.

Injection well IW-3 was reamed with a roller bit in August 2006 to clear the remains of a partially disintegrated FLUTe™ liner and to attempt to redevelop the well. In September 2006, well IW-2 was mechanically cleaned using a drilling rig equipped with a wire brushing device, and redeveloped using a combination of surging and pumping. Specific capacity testing performed before and after the redevelopment/cleaning indicated that the flow conditions in these wells had not improved significantly. A subsequent injection event in September 2006 confirmed this finding as injections into well IW-2 and IW-3 were limited due to lack of flow and the resulting permanganate distribution was the lowest since full-scale injections were initiated. Temperature and pressure data collected during the injection indicated that the permanganate injections were not influencing all portions of the treatment area. Further attempts to rehabilitate injection well IW-2 in March 2007 using AirBurst® technology did not result in significant increases in specific capacity.

6.4.2. Corrective Measures Evaluation

Based on the failure of the permanganate treatment to meet the CAOs, and in accordance with the CM Work Plan, the WVA evaluated whether any additional technologies were capable of meeting the corrective measures metrics. An evaluation of the VOC mass discharge from the compliance boundary (property boundary) was also conducted. Details of these evaluations are presented in Attachments A and B, respectively, of the CM Performance Evaluation Report (Malcolm Pirnie 2009a).

6.4.2.1. Technology Evaluation

The following corrective measures technologies were screened in Section 5 of the Building 40 CM Work Plan (Malcolm Pirnie 2004b) for their potential effectiveness at meeting the CAO prior to the implementation of the permanganate corrective measures.

1. Monitored Natural Attenuation (MNA)
2. Containment
3. In-situ Enhanced Bioremediation (ISB)
4. In-situ Chemical Oxidation (ISCO)
5. No Action

Of these, in-situ chemical oxidation (ISCO) using permanganate was chosen as the only alternative that was potentially capable of meeting the CAO over the long term through source treatment of the bedrock matrix. Upon the failure of the permanganate corrective measures to meet corrective measures performance metrics, the WVA conducted a technology screening to confirm that there were no new applicable corrective measures technologies that have become available since the initial screening documented in the CM Work Plan evaluations. This evaluation included in-situ thermal remediation (ISTR) technologies, which had been developed at the time of the initial screening, but were not included in the Work Plan. The evaluation concluded that there were no currently available technologies, including ISTR, that were capable of meeting the CAOs under the site conditions.

6.4.2.2. Mass Discharge Evaluation

The purpose of the mass discharge evaluation was to assess the changes in VOC mass discharge across the compliance boundary since the discontinuation of permanganate injections, and the effect of new hydraulic conductivity estimates on the VOC mass discharge due to clogging associated with the precipitation of manganese dioxide particulates from the injection solution.

Compliance boundary VOC mass discharge estimates utilized during the corrective measures program and in the CM Performance Evaluation were estimated for each compliance monitoring zone using the hydraulic conductivity (K) values calculated for fractures that had detectable flow during the July 2004 geophysical testing. The K values utilized for the VOC mass discharge calculations were the sum of the individual K values for fractures with detectable flow that intersected each compliance monitoring zone at the time of the geophysical testing in 2004. Mass discharge estimates were calculated using the following assumptions:

- Discharge Zone Thickness: Set as the thickness of the screened interval in each compliance monitoring zone.
- Hydraulic Gradient: Set at 0.003 ft/ft based on the hydraulic gradient in the Building 40 area calculated from WVA-wide water table groundwater elevations.
- Horizontal Length of Discharge Zone: Set as the distance between compliance monitoring wells.
- VOC Concentration: Set at the total VOC concentration in each compliance monitoring zone during each monitoring event.

Table 6-1, below, presents changes from baseline in the estimated compliance boundary VOC mass discharge after each injection event. As shown in the table, the estimated compliance boundary VOC mass discharge in June 2010 was approximately 66 percent of the baseline using the 2004 K estimates and the was the lowest mass discharge estimate measured during the CM program.

	Table 6-1: Compliance Boundary VOC Mass Discharge									
	Baseline	**Jan. 2005**	**May 2005**	**Aug. 2005**	**Nov. 2005**	**Mar. 2006**	**Sept. 2006**	**Sept. 2007**	**May 2009**	**June 2010**
Total VOC Mass Discharge (lb/yr)	10.0	10.0	11.5	10.0	6.6	10.6	18.0	13.1	8.5	6.6
% of Baseline VOC Mass Discharge	---	*100%*	*115%*	*100%*	*66%*	*106%*	*180%*	*131%*	*85%*	*66%*

Notes:
lb/yr – pound per year

6.4.2.3. 2009 Hydraulic Conductivity Estimates

It was not possible to re-evaluate fracture / monitoring zone K in the compliance monitoring wells using the geophysical methods employed in 2004 due to the presence of multi-level monitoring wells in the boreholes. Accordingly, standard slug tests were performed in each monitoring zone in October 2007 to estimate the K after three years of permanganate injections. It is important to note that slug tests are not directly comparable to the geophysical testing and may not be appropriate for use in bedrock; however, given the limitations imposed by the presence of the multi-level wells, slug tests were utilized to gain an understanding of the potential changes in K resulting from the generation of manganese dioxide precipitates.

The results of the assessment indicated that the estimated K values in 2007 were generally less than 50 percent of the baseline values measured in 2004. However, several of the 2007 estimated K values were similar in magnitude to, or greater than, the 2004 estimates, which indicates that the slug test results were likely not biased low as compared to the 2004 estimates. These data, recognizing the potential limitations described above, support the conclusion that clogging due to manganese dioxide precipitation has reduced the capacity of the bedrock fractures to transport groundwater through the compliance boundary. This, and (presumably) the CVOC mass reduction accomplished by the permanganate treatment has resulted in a decrease in the VOC mass discharge across the compliance boundary, which was evidenced by the May 2009 and June 2010 sampling results.

6.5. Conclusions

The results of the testing, monitoring, and evaluations support the following conclusions for the Building 40 bedrock groundwater.

1. The permanganate injections conducted to date have not decreased groundwater VOC concentrations at the compliance boundary to less than NYSDEC Class GA standards/guidance values. Testing conducted in 2006 also showed that rock core VOC pore water concentrations have not decreased after two years of injections. However, based on subsequent monitoring, the injections may have reduced the mass discharge of CVOCs at the compliance boundary.
2. The persistent clogging problems indicate that a large portion of the injected permanganate mass was oxidized to insoluble precipitates through interaction with the rock matrix, specifically the reduced sulfur (i.e., pyrite), present in the rock. This interaction with the rock greatly limited the effectiveness of the permanganate injections. Rock core, water level, pressure, and temperature monitoring has shown that the injections are influencing only a portion of the treatment area due to clogging.
3. The CM program failed to achieve the CM Performance Criteria and, therefore, cannot achieve the overall CAO of reduction of VOC concentrations in groundwater to state or federal standards.

Based on these data, and the lack of any other potentially effective remedial technology, achievement of the CAO is not technically feasible using currently available technologies. In accordance with the provisions of the CM Work Plan, the CM Program was discontinued and a proposed final corrective measure of monitored natural attenuation was recommended for the site.

7. Evaluation of Proposed Final Corrective Measures

As stated in the USEPA Fact Sheet #3: Final Remedy Selection for Results-Based RCRA Corrective Action (USEPA, 2000), final remedies for RCRA Corrective Action facilities should achieve the following three performance standards:

1. Protection of human health and the environment based on reasonably anticipated land use(s) (current and future).
2. Achieve corrective action objectives appropriate to the anticipated land use.
3. Remediate the source of releases.

Within these performance standards, the USEPA has developed evaluation criteria by which each proposed final corrective measure should be judged as acceptable or unacceptable. These evaluation criteria are:

1. Long-term effectiveness
2. Reduction of toxicity, mobility, and volume
3. Short-term effectiveness
4. Implementability
5. Cost
6. Community acceptance
7. State acceptance

An evaluation of each of the proposed final corrective measures with regard to both the performance standards and the first five USEPA evaluation criteria is provided below. USEPA Criteria 5, cost, is not applicable to the WVA as all of the recommended corrective measures have already been implemented as full-scale pilot studies or ICMs. Criteria 6 and 7 are also not evaluated in this report and will be addressed through the preparation and review of the Statement of Basis for the Main Manufacturing Area. A summary of the corrective measures with regard to AOCs is presented in Table 8-1.

7.1. Building 25 Groundwater

Summary

SWMU: Building 25 (SWMU 5) and Vapor Degreaser Units
Corrective Measure: Monitored natural attenuation
Contaminants Treated: CVOCs

7.1.1. Description

Based upon 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, it is probable that biodegradation of CVOCs in the groundwater to concentrations less than the CAOs at Building 25 will occur over time. 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, the proposed final corrective measure for the CVOCs in the Building 25 groundwater is long-term monitoring through the site-wide long-term monitoring program, accompanied by ongoing natural attenuation.

7.1.2. Comparison to Performance Standards

7.1.2.1. Protection of Human Health and the Environment

The Building 25 groundwater corrective measure will protect human health and the environment by monitoring CVOC concentrations greater than the CAOs in the groundwater limited to the small area east and southeast of Building 25 to ensure that VOCs do not migrate to potential receptors beyond the WVA property boundary. The corrective measure will reduce concentrations of CVOCs in the groundwater and prevent further migration of CVOCs in the groundwater offsite.

7.1.2.2. Achievement of Corrective Action Objectives

This corrective measure will achieve the CAOs by continuing to degrade PCE and TCE through natural attenuation processes to non-toxic byproducts (i.e., carbon dioxide and ethene), ultimately reducing both the concentration and mass of the contaminants in the groundwater.

7.1.2.3. Source Remediation

As stated above, this corrective measure will reduce the concentrations and mass of CVOCs in the overburden and bedrock groundwater in the Building 25 area. The CVOCs in the groundwater are most likely a product of a vapor degreaser that was located in Building 25. This vapor degreaser has been removed and has not been a contributing source of CVOCs to the groundwater for some time.

7.1.3. Comparison to Evaluation Criteria

7.1.3.1. Long-term Effectiveness

This corrective measure will be effective over the long term since there is no longer a contributing source of CVOCs to the subsurface in the Building 25 area and CVOC concentrations greater than the CAOs will continue to decrease through natural attenuation. Long-term monitoring will document the progress of CVOC reduction to concentrations less than CAOs.

7.1.3.2. Reduction of Toxicity, Mobility, and Volume

This corrective measure will reduce the toxicity, mobility, and volume of the CVOCs in the overburden and bedrock aquifers by reducing the CVOC mass, and subsequently reducing concentrations in the groundwater.

7.1.3.3. Short-term Effectiveness

This corrective measure was effective in the short-term in reducing many of the groundwater concentrations to less than CAOs during the Pilot Study and will continue to be effective in sustaining these concentrations.

7.1.3.4. Implementability

The in-situ treatment conducted during the Pilot Study and subsequent long term groundwater monitoring demonstrated that an environment conducive to the natural attenuation of CVOCs is present in the Building 25 area and that CVOC concentrations are decreasing over time.

7.2. Building 40 Vapor Intrusion

Summary
SWMU: Vapor Degreaser Units
Corrective Measure: Stand-alone indoor air filtration units.
Contaminants Treated: VOCs, specifically TCE

7.2.1. Description

As discussed previously, due to the construction and age of the Building 40 foundation, the use of subsurface depressurization was not considered to applicable to address vapor intrusion into the building. Therefore, eight air filtration units (AFUs) were installed in the impacted areas of the building. The AFUs were installed in 2006 and were activated in January 2007. The WVA monitors the operation of the units during monthly inspections and during semi-annual filter media testing. Filter media is replaced based on the results of the testing.

7.2.2. Comparison to Performance Standards

7.2.2.1. Protection of Human Health and the Environment

The Building 40 indoor air and soil gas corrective measures will protect human health and the environment by removing VOCs that migrate to the indoor air from the subsurface.

7.2.2.2. Achievement of Corrective Action Objectives

The CAOs will be achieved by removing VOCs that migrate to the indoor air from the subsurface.

7.2.2.3. Source Remediation

Source remediation will be accomplished in the long term through the natural attenuation of the CVOCs in the underlying bedrock groundwater.

7.2.3. Comparison to Evaluation Criteria

7.2.3.1. Long-term Effectiveness

The corrective measure will be effective over the long term through continuous operation of the AFUs, as documented by the ongoing operations and monitoring program.

7.2.3.2. Reduction of Toxicity, Mobility, and Volume

The corrective measure will reduce the toxicity and mobility of the CVOCs by removing them from the indoor air, thereby preventing exposure.

7.2.3.3. Short-term Effectiveness

This corrective measure has been effective in the short-term by removing the CVOCs from the indoor air.

7.2.3.4. Implementability

The AFUs have already been installed and are currently operating.

7.3. Building 40 Groundwater

Summary
SWMU: Vapor Degreaser Units
Corrective Measure: Monitored natural attenuation.
Contaminants Treated: CVOCs

7.3.1. Description

The USEPA Natural Attenuation Protocol Table 2.3 (USEPA 1998b) contains a screening process to evaluate the potential for reductive dechlorination based on site monitoring data. Using data from groundwater samples collected from monitoring well MW-51 (located in the center of the impacted area) during the RFI and LTM program through 2003 (before the initiation of the permanganate corrective measures) resulted in a screening score of 23, which, according to the protocol, is indicative of strong evidence for anaerobic biodegradation of the chlorinated solvents present in the bedrock groundwater. These data included:

- The presence of relatively high concentrations (greater than 0.1 milligrams per liter [mg/l]) of the dissolved gases ethene and ethane, which are the final end products of the complete degradation of PCE and TCE.
- Low dissolved oxygen levels (less than 1 mg/l) and reducing conditions (reduction-oxidation potential less than 0 mV).

- Low nitrate and sulfate concentrations, which are indicative of the use of the nitrogen and sulfur as electron donors and which are potentially competing electron acceptors at high concentrations.
- Detectable concentrations of ferrous iron, which is indicative of both reducing conditions and the use of ferric iron as an electron donor.

Last, a groundwater sample collected from MW-51 in November 2003 showed the presence of DHC, which, as discussed above, can complete the reductive dechlorination process by converting vinyl chloride to ethene. Based on this information, it is anticipated that concentrations of chlorinated VOCs in the bedrock groundwater will decrease over time through natural attenuation processes.

Monitoring Plan

It is proposed that all zones in compliance boundary monitoring wells MW-82R, MW-83, MW-84R, MW-85R, and MW-86R be sampled for VOCs on an annual basis. Due to the presence of chlorinated VOCs (CVOCs) in the compliance boundary monitoring wells in the Building 40 area, a contingency monitoring plan has been developed in the event that anomalous CVOC concentrations are detected in these wells in the future.

Statistical Trigger

The proposed contingency evaluation protocol utilizes a well and contaminant-specific statistical “trigger” concentration that initiates a contingency evaluation in the event groundwater monitoring data indicates a potential changes in site conditions. This method is currently utilized by the NYSDEC for solid waste landfill monitoring programs to evaluate if a statistically significant release from a landfill has occurred [6 NYCRR Part 360-2.11(c)(5)(i)]. The statistical trigger will be calculated as follows:

1. The results for the COCs in each of the wells from the period of the spring of 2004 through the spring of 2009 were averaged to determine the mean “background concentration”. The standard deviation of the “background” data set was also established. The “background” mean and standard deviation will be the basis for all future comparisons.

2. Trigger values were established for each COC in each well as the sum of the background mean plus three times the background standard deviation. This test is commonly used to identify outlying data that fall outside the expected range of values based on a given baseline data set.

3. Monitoring events during which permanganate was present in the Building 40 compliance boundary wells (i.e., assumed zero concentrations) were not included in the calculations.

4. Monitoring events during which the compound was not detected were included as one half of the laboratory reporting limit for that compound.

Contingency Monitoring

Upon receipt of analytical data, the result for each of the COCs will be compared against the statistical trigger concentration. If the data for the COCs in a given well exceed the statistical trigger concentrations the NYSDEC will be notified of the condition within 15 days and potential follow up actions will be determined in consultation with the NYSDEC. If samples from three or more of the Building 40 compliance boundary wells contain COCs at concentrations greater than the corresponding statistical trigger concentrations, verification sampling consisting of quarterly sampling for one year will be conducted, with sampling results provided to the NYSDEC each quarter. The objective of the verification sampling will be to evaluate the potential causes of the increase in COC concentrations; to assess whether changes to the monitoring program are required; and, if necessary, to perform a risk evaluation and technology screening to evaluate potential corrective measures technologies that may be applicable to the site. Based on the results of the verification sampling, potential follow up actions will be determined in consultation with the NYSDEC. Significant increases in the levels of COCs will be discussed in the annual monitoring report and recommendations made for further actions, if necessary.

7.3.2. Comparison to Performance Standards

7.3.2.1. Protection of Human Health and the Environment

The Building 40 groundwater corrective measure will protect human health and the environment by monitoring CVOC concentrations greater than the CAOs to ensure that VOCs do not migrate beyond their current extent and/or increase in magnitude. The corrective measure will reduce concentrations of CVOCs in the groundwater and prevent further migration of CVOCs in the groundwater offsite. Other than diffuse discharge to the Hudson River. There are no known off-site receptors of groundwater from the Building 40 area.

7.3.2.2. Achievement of Corrective Action Objectives

This corrective measure will achieve the CAOs by continuing to degrade PCE and TCE through natural attenuation processes to non-toxic byproducts (i.e., carbon dioxide and ethene), ultimately reducing both the concentration and mass of the contaminants in the groundwater.

7.3.2.3. Source Remediation

Limited source remediation (to the extent practicable and feasible) was accomplished through the implementation of the permanganate corrective measures. However, the bedrock matrix will continue to act as source of contamination to the bedrock groundwater. The monitored natural attenuation remedy will further remediate the source by degrading CVOCs as they back-diffuse to the groundwater from the bedrock matrix.

7.3.3. Comparison to Evaluation Criteria

7.3.3.1. Long-term Effectiveness

The corrective measure will be effective over the long term in that CVOC source concentrations will be reduced, thereby reducing the concentration of CVOCs in the groundwater over the long-term

7.3.3.2. Reduction of Toxicity, Mobility, and Volume

The corrective measure will reduce the toxicity, mobility, and volume of the CVOCs in the bedrock aquifer by reducing the CVOC mass in the shale bedrock matrix and, subsequently, in the bedrock groundwater.

7.3.3.3. Short-term Effectiveness

The corrective measure will have limited effectiveness in the short-term, but will be able to document any changes in groundwater conditions.

7.3.3.4. Implementability

Long-term monitoring is already underway.

8. Proposed Final Corrective Measures

8.1. Building 25 Groundwater

A combination of long-term monitoring accompanied by the ongoing natural attenuation is the proposed final corrective measure for the groundwater in the Building 25 Pilot Study area. Based on the results and conclusions presented in the Building 25 Pilot Study, the proper geochemistry and nutrient supply necessary for sustaining natural attenuation of CVOCs is present. The CVOCs in the groundwater at Building 25 are also localized to the Pilot Study Area and are not migrating beyond the WVA property; therefore, the proposed final corrective measure should achieve CAOs for the groundwater at Building 25 over the long term.

8.2. Building 40

8.2.1. Vapor Intrusion

The proposed final corrective measure chosen for indoor air in portions of Building 40 that contain TCE concentrations that are greater than the current NYSDOH/NYSDEC action level of 5.0 $\mu g/m^3$ is to continue to treat the indoor air in these areas through the indoor air filtration units installed in 2006 and 2007.

8.2.2. Groundwater

As discussed in Section 6, achievement of the CAO for the Building 40 bedrock groundwater is not technically feasible using currently available technologies. It is therefore recommended that monitored natural attenuation documented through long-term groundwater monitoring be selected as the final corrective measure for the Building 40 bedrock groundwater.

8.3. Vapor Intrusion

Continued operation and monitoring of the subsurface depressurization systems (SSDSs) are recommended as the final corrective measure for vapor intrusion in Buildings 20, 21, 22, 25, 114, 120, 121, and 130.

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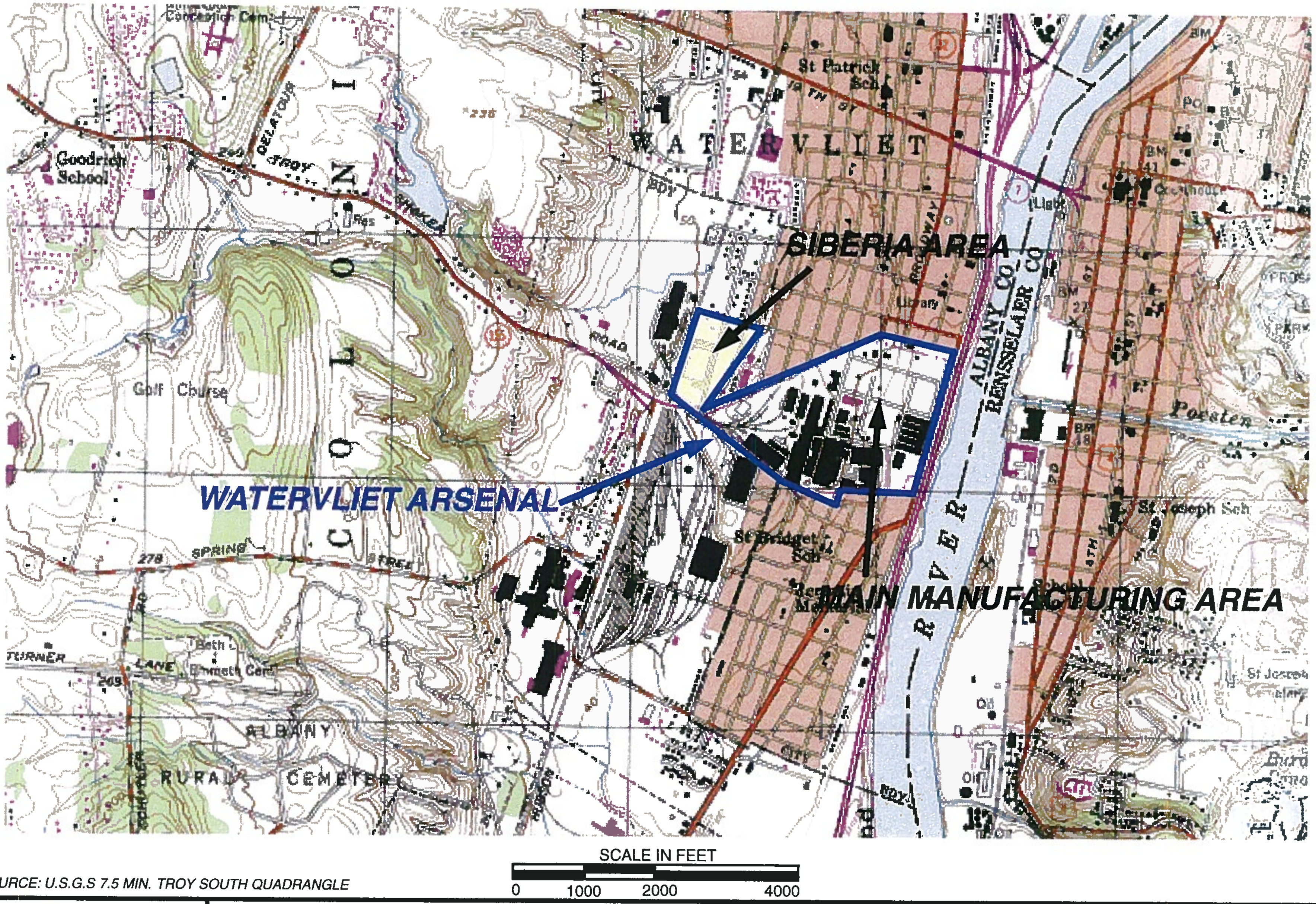
Watervliet Arsenal
Main Manufacturing Area Focused Corrective Measures Study

Figures

MALCOLM
PIRNIE



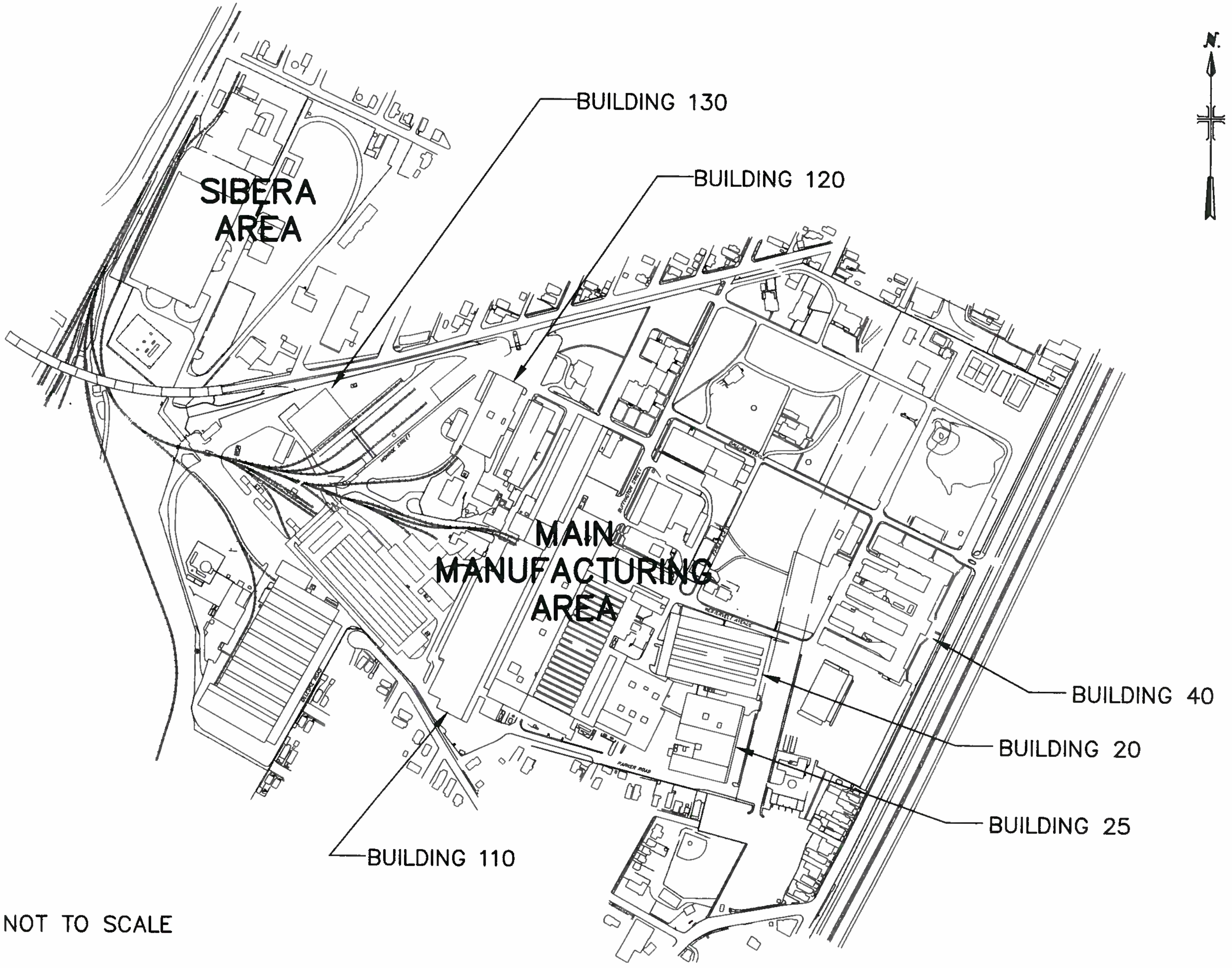
SOURCE: U.S.G.S 7.5 MIN. TROY SOUTH QUADRANGLE

US Army Corps
of Engineers
Baltimore District

CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA, WATERVLIET ARSENAL,WATERVLIET, NEW YORK

SITE LOCATION

FIGURE 1-1



NOT TO SCALE

MALCOLM PIRNIE

CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA
WATERVLIET ARSENAL, WATERVLIET, NEW YORK

SITE
MAP

MALCOLM PIRNIE, INC.

FIGURE 1–2

MMA SWMUs

Building 15: 15

Buildings 20, 120, and 130: Vapor Degreaser Units

Building 25: 5, 14, and Vapor Degreaser Units

Building 35: 13, 16, 26, Chrome Plating Pit Areas, and Chrome Plating Scrubbers

Building 36: 1, 6 and 17

Building 40: 19** and Vapor Degreaser Units

Building 44: 12

Building 110: 4*, 10, 11, Vapor Degreaser Units, Chrome Plating Pit Areas, and Chrome Plating Scrubbers

Building 114: Chrome Plating Scrubbers

Building 115: 9

Building 123: Chip Handling Facility Areas

Building 132: 21 and Chip Handling Facility Areas

Building 135: 8 and 27

Former Erie Canal Area: 25

Notes:

* Building 110A was demolished as part of the REARM project and no longer exists.

** SWMU 19 is for outfall 003, which is located east of Building 40.

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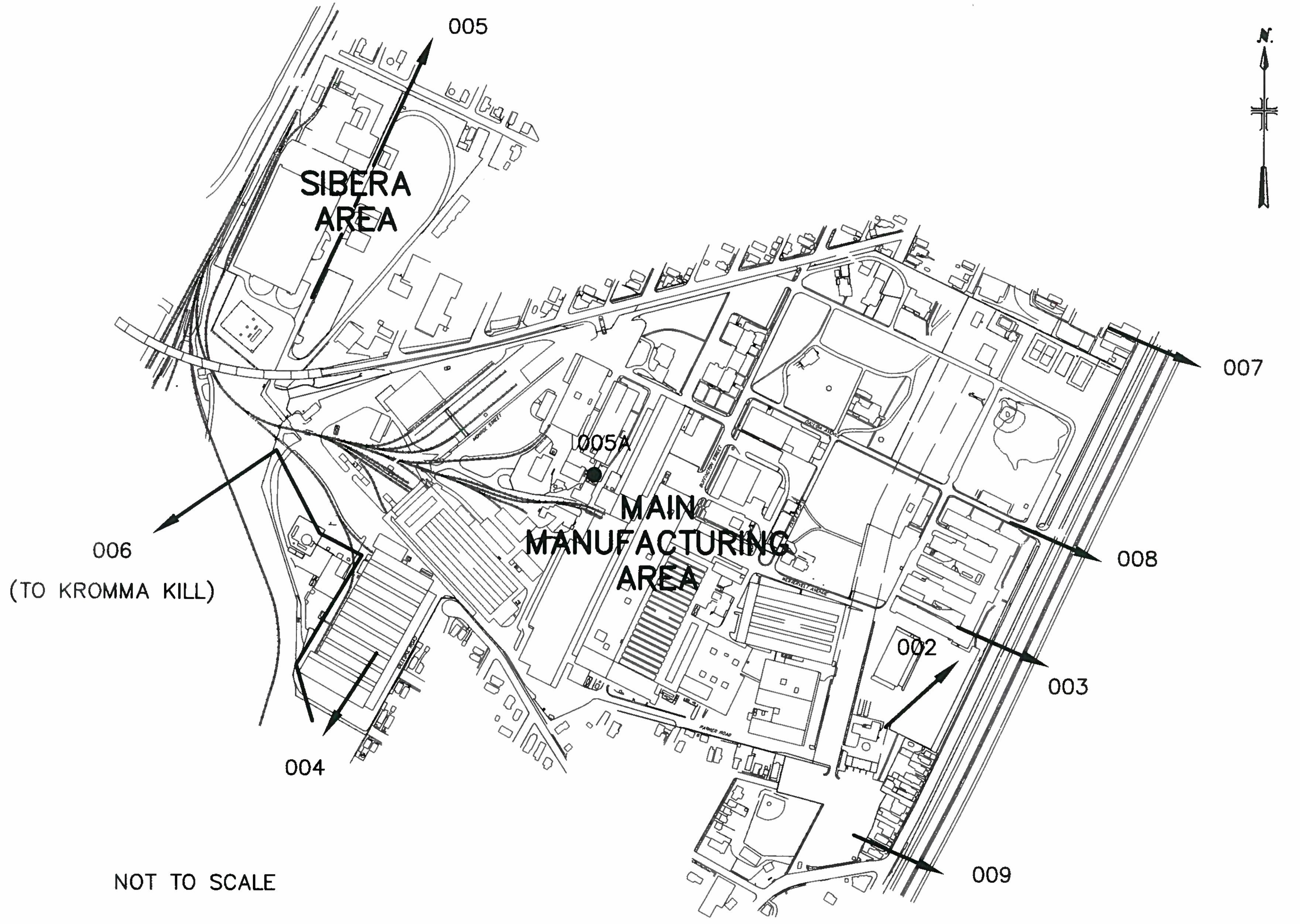
CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA, WATERVLIET ARSENAL, WATERVLIET, NEW YORK

SOLID WASTE MANAGEMENT UNIT (SWMU) LOCATIONS

FIGURE 2-1



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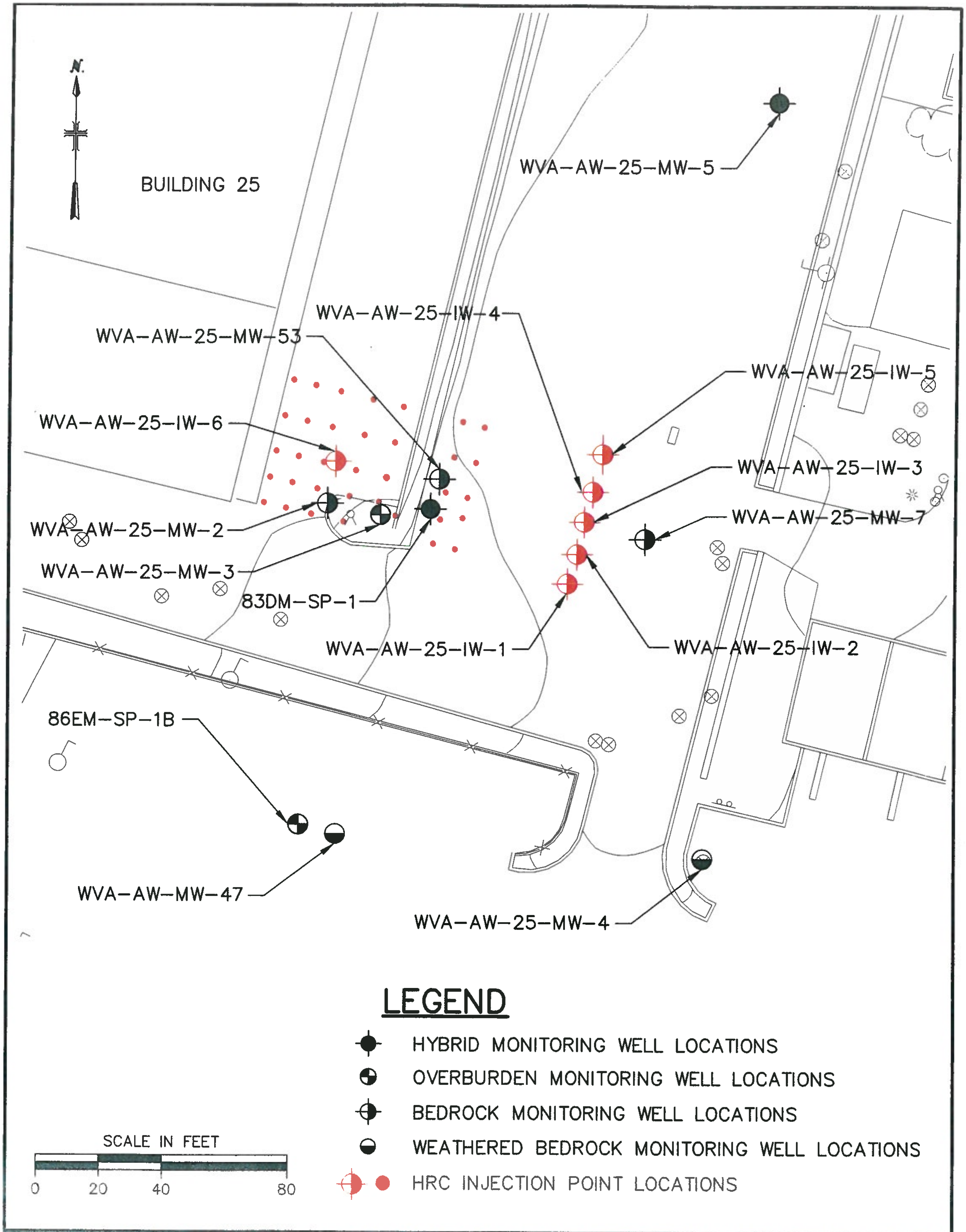
CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA
WATERVLIET ARSENAL, WATERVLIET, NEW YORK

OUTFALL
MAP

MALCOLM PIRNIE, INC.

FIGURE 2–2



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CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA
WATERVLIET ARSENAL, WATERVLIET, NEW YORK

OVERBURDEN AND BEDROCK HRC INJECTION LOCATIONS

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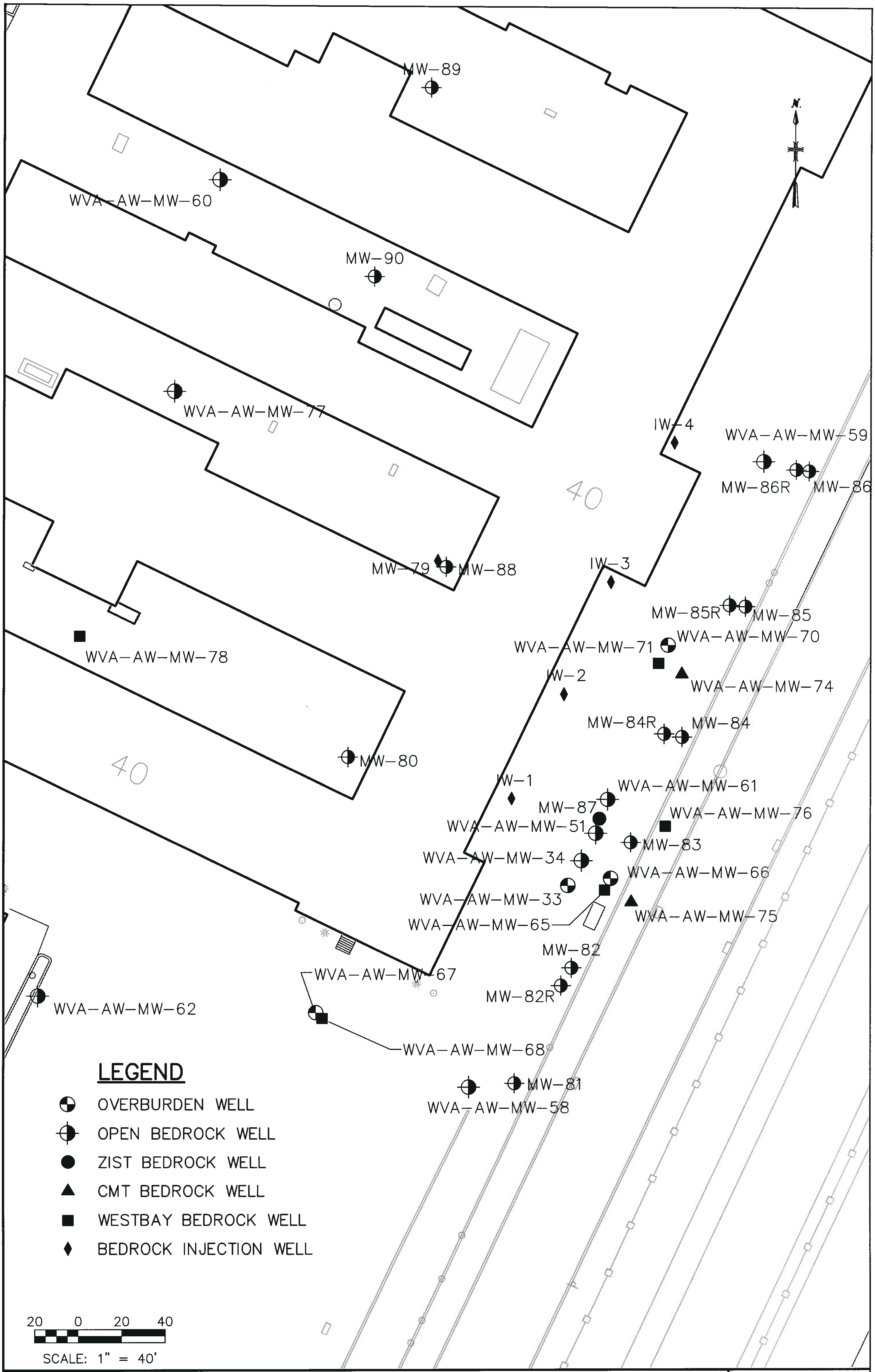
FIGURE 2-3



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WATERVLIET ARSENAL
MAIN MANUFACTURING AREA

MONITORING AND INJECTION WELL LOCATIONS (BUILDING 40)

MALCOLM PIRNIE, INC.

FIGURE 2-4

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User:LaPlante Spec:PIRNIE STANDARD File:I:\ACAD\PROJ\0285\939\FIGURE 1-3.DWG Scale:1:1 Date:10/17/2008 Time:14:47 Layout:Layout1

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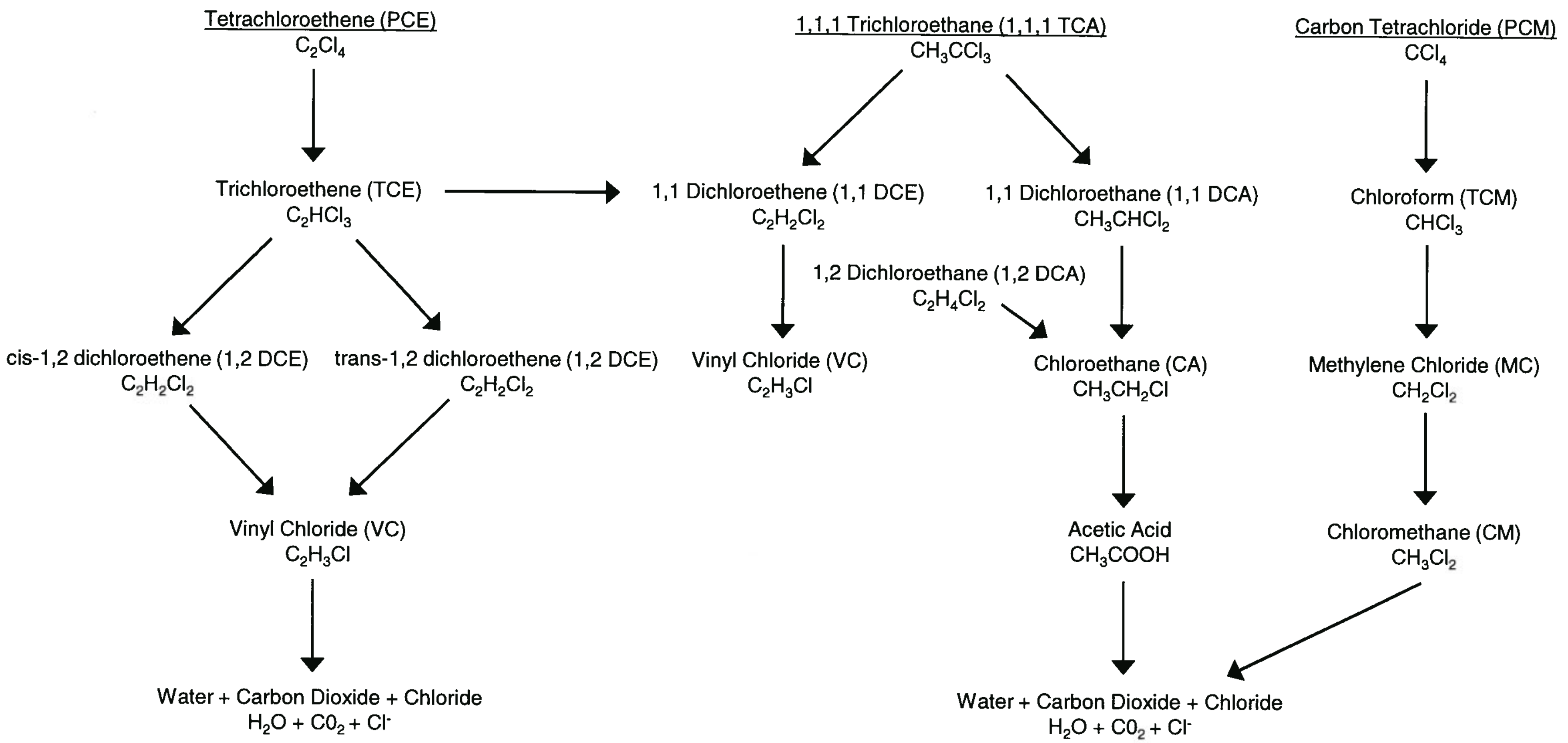
WATERVLIET ARSENAL MAIN MANUFACTURING AREA
WATERVLIET, NEW YORK
VAPOR INTRUSION CORRECTIVE MEASURES LOCATIONS

MALCOLM PIRNIE, INC.

FIGURE 2-5



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

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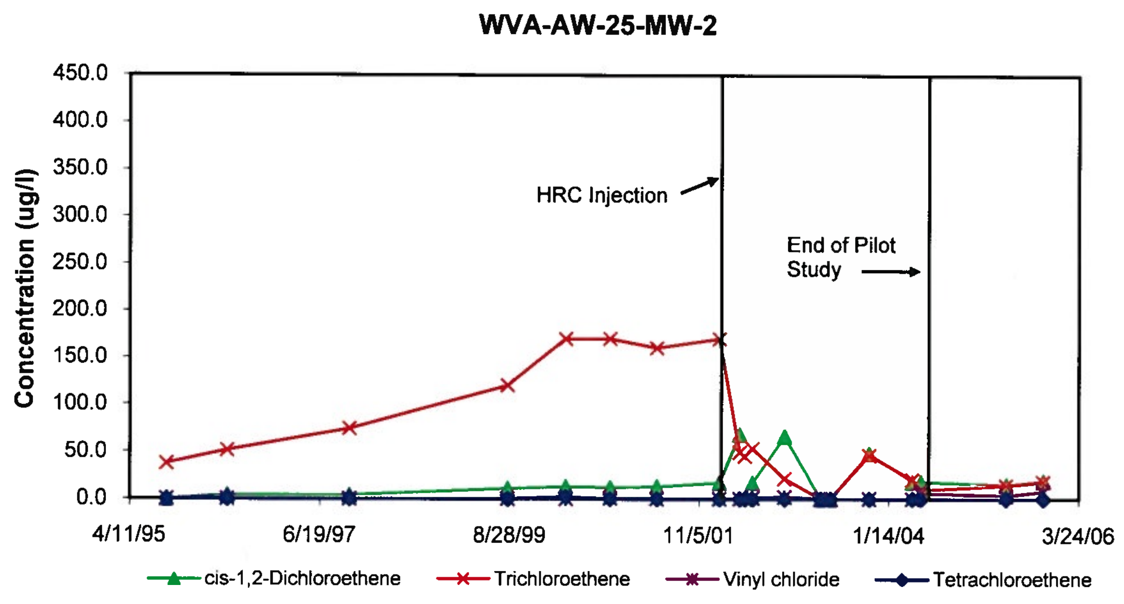
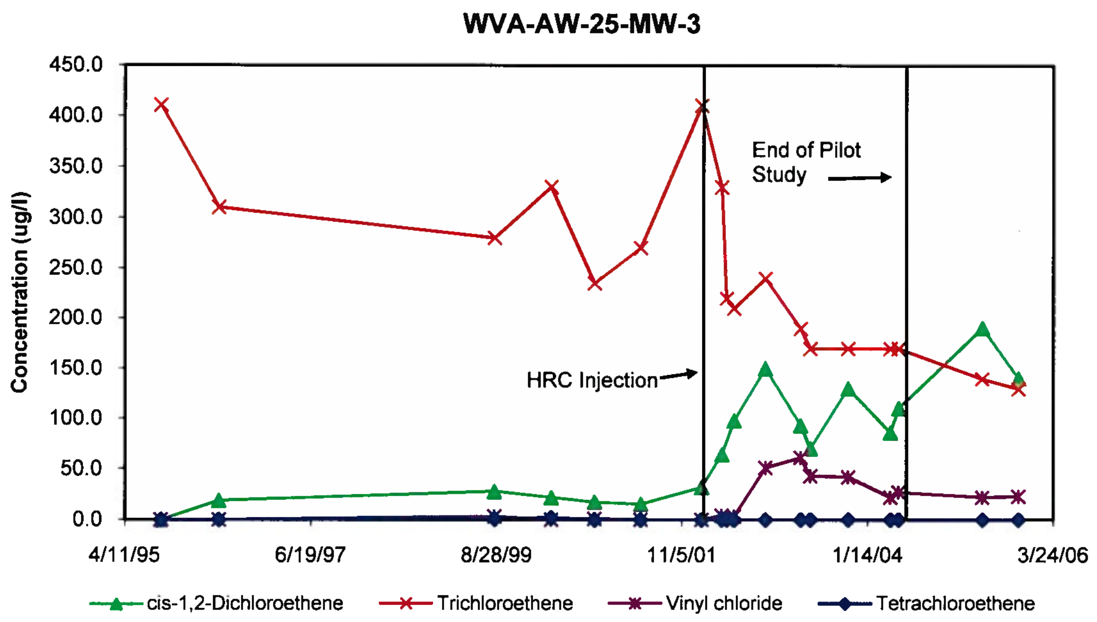
Baltimore District

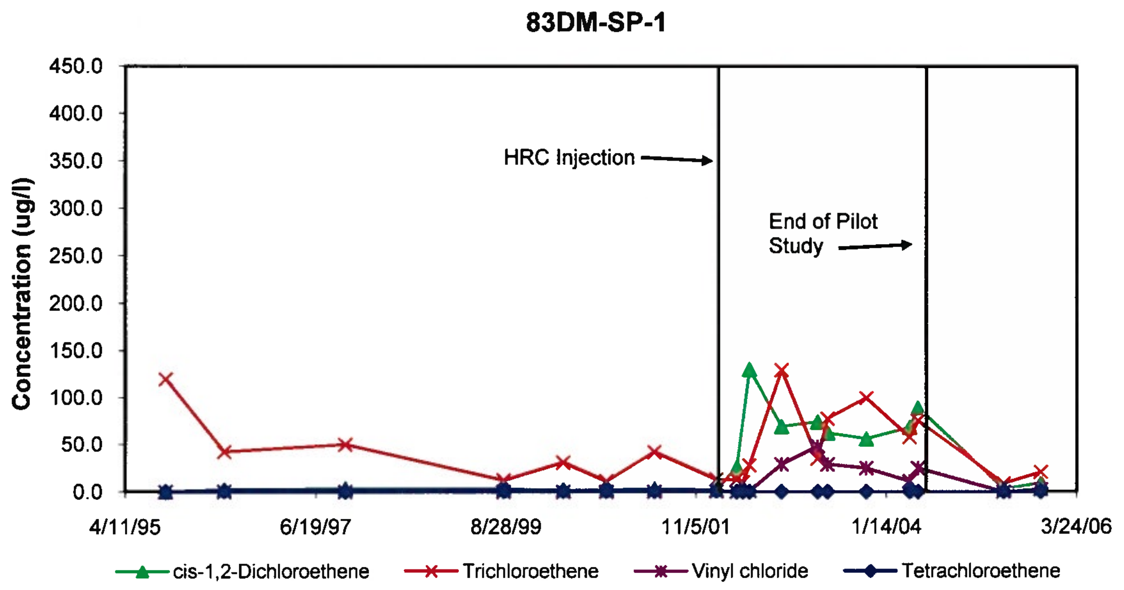
BUILDING 25 – CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA, WATERVLIET ARSENAL, WATERVLIET, NEW YORK

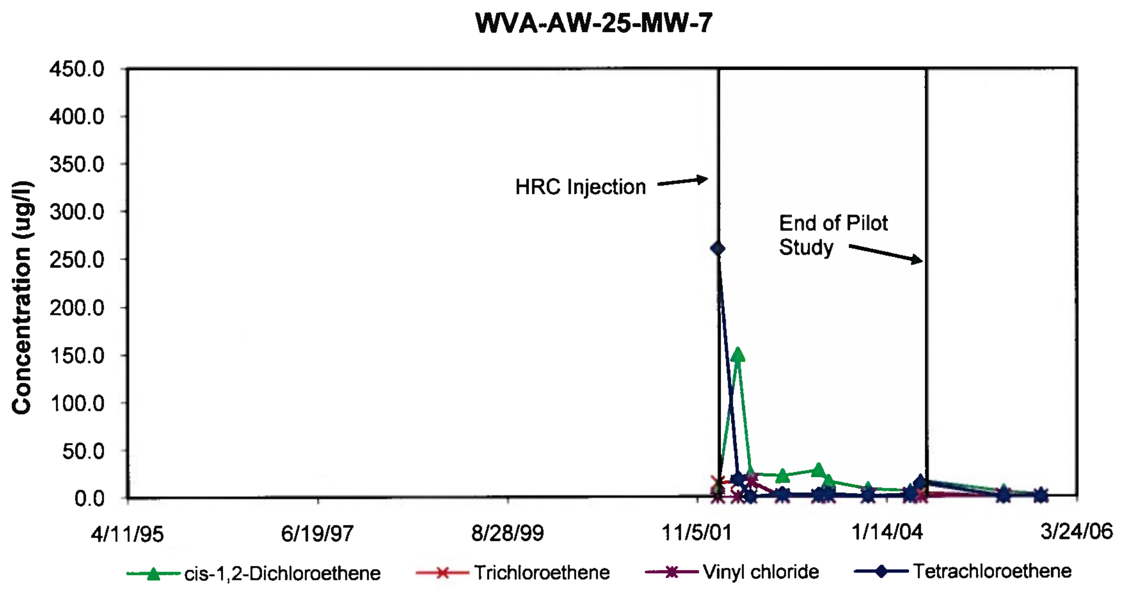
REDUCTIVE DECHLORINATION PATHWAY FOR SELECTED CHLORINATED SOLVENTS

FIGURE 4-1









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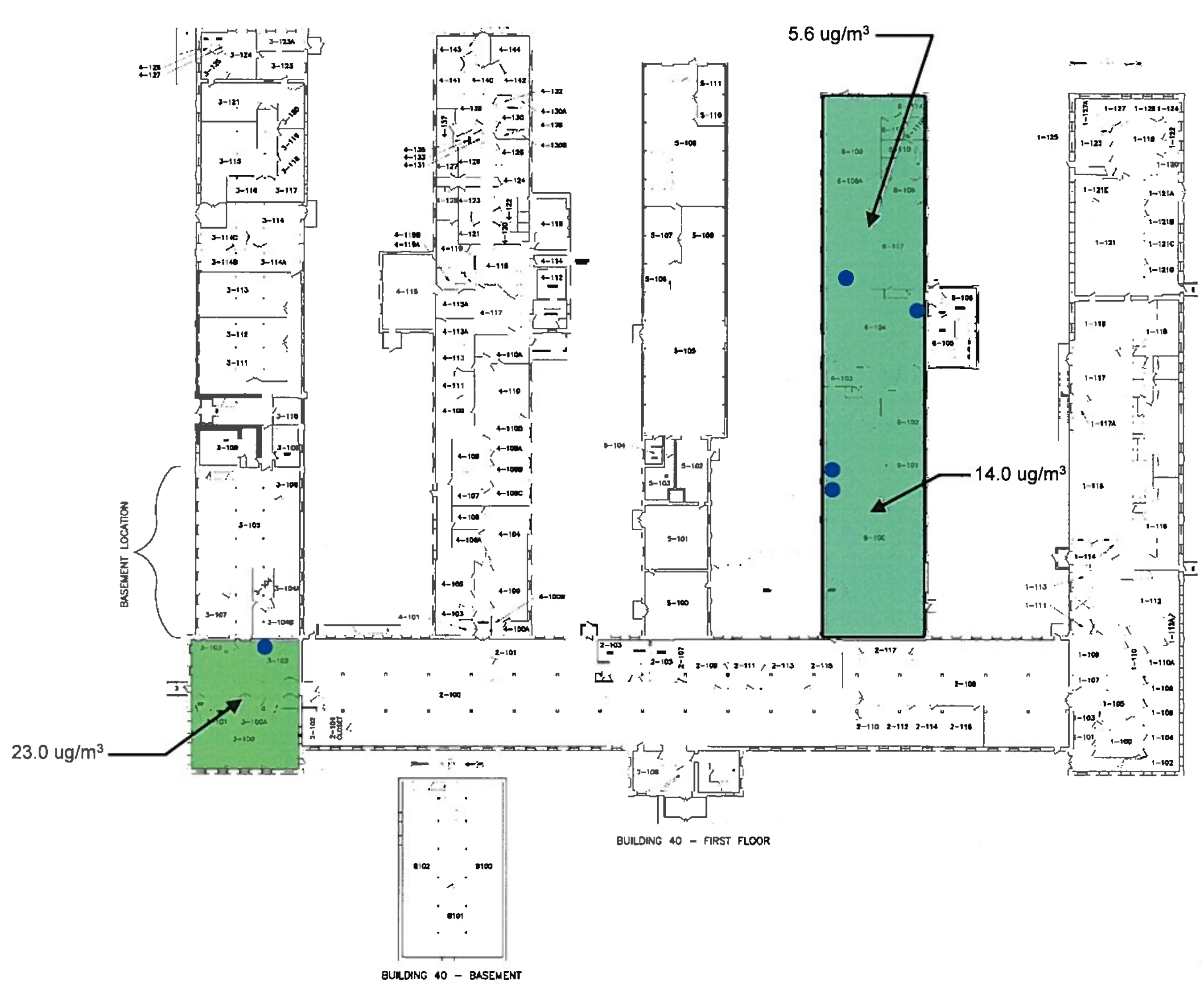
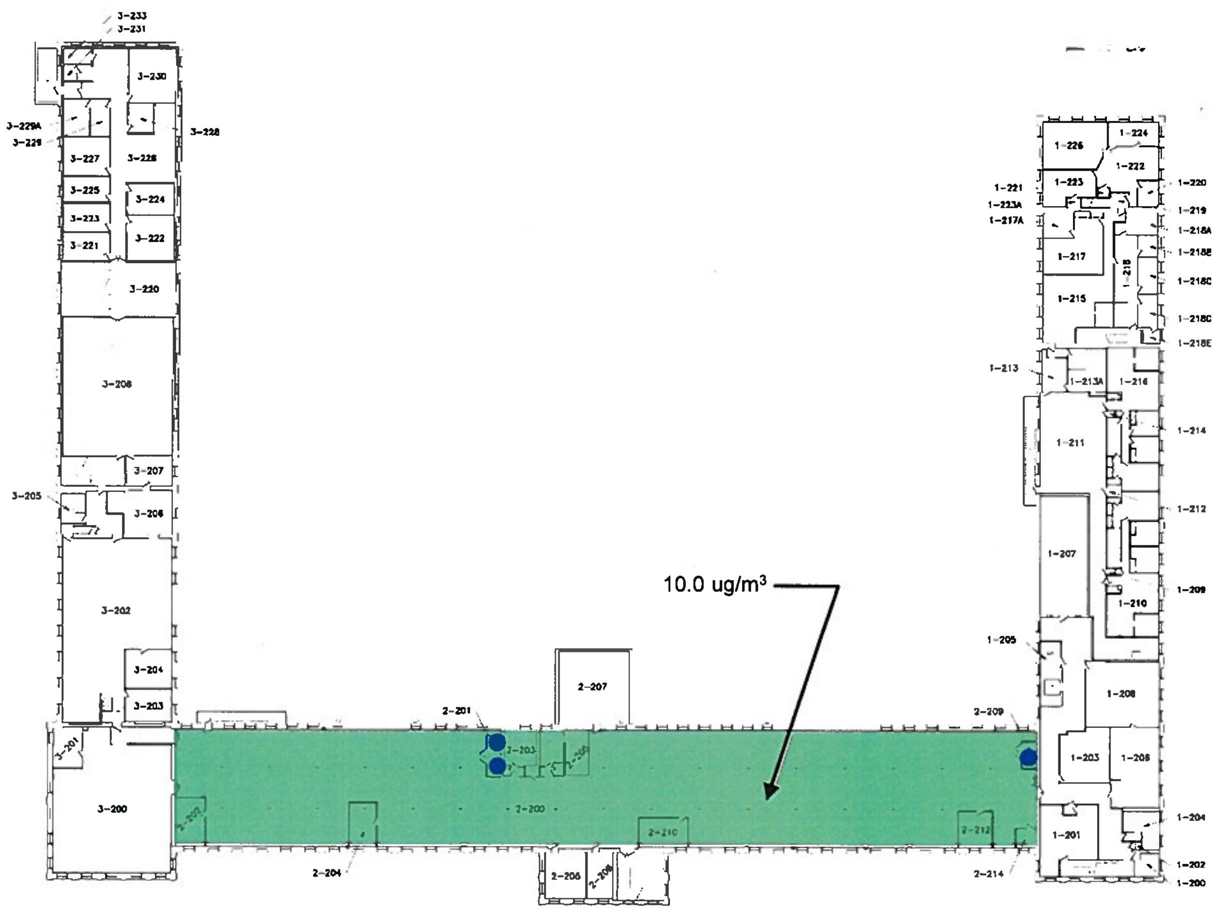
BUILDING 25 - CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA, WATERVLIET ARSENAL, WATERVLIET, NEW YORK
VOCs IN GROUNDWATER

FIGURE 4-2

FIRST FLOOR



SECOND FLOOR



LEGEND

- ● AIR FILTRATION UNIT (DUCT CONNECTIONS NOT SHOWN)
- 🟩 AREA OF CONCERN
- 23.0 ug/m^3 MAXIMUM DETECTED INDOOR AIR TCE CONCENTRATION DURING INVESTIGATIONS

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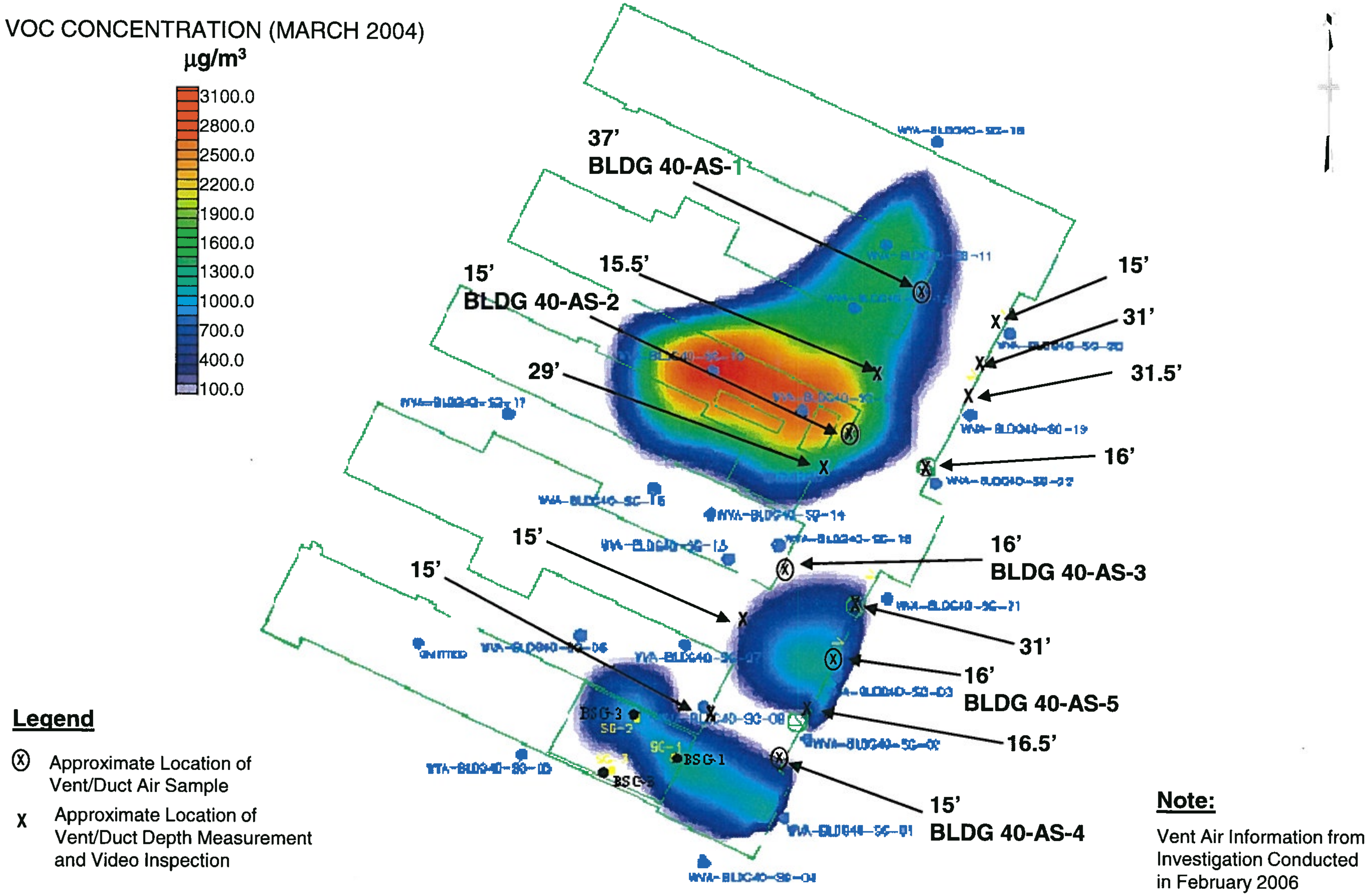
CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA
WATERVLIET ARSENAL, WATERVLIET , NEW YORK

BUILDING 40 INDOOR AIR AREAS OF CONCERN

FIGURE 5-1



Legend

Ⓧ Approximate Location of Vent/Duct Air Sample

X Approximate Location of Vent/Duct Depth Measurement and Video Inspection

Note:

Vent Air Information from Investigation Conducted in February 2006

\\ALBANY\Data\PROJECT\0285939\FILE\Air and Soil Gas Sampling\Feb 06 Attic\Bldg 40 Attic(Feb 2006).ppt

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BUILDING 40 – CORRECTIVE MEASURES STUDY
MAIN MANUFACTURING AREA, WATERVLIET ARSENAL, WATERVLIET, NEW YORK

SOIL GAS SAMPLING SUMMARY

FIGURE 5-2

Watervliet Arsenal

Main Manufacturing Area Focused Corrective Measures Study

Tables

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Table 2-1
Summary of Solid Waste Management Units (SWMUs)
Corrective Measures Study
Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York

SWMU Number	Location (Building)	Specific Area Addressed	Media of Concern	Contaminants of Concern	Status	Proposed Corrective Measure
1	36	Sludge Drying Beds	Groundwater	Trace Metals, Organics	NFA (Clean Closure May 1994)	None
4	110A	Cyanide Treatment Facility	Groundwater	Heavy Metals	NFA (RFI)	None
5 (also Vapor Degreasers)	25	Vapor Degreaser Unit	Groundwater Soil Vapor	Chlorinated Solvents	Corrective Measures	GW - MNA Soil Vapor - SSDS
6	36	Wastewater Treatment Plant	Groundwater	RCRA Metals	NFA	None
7	141	UST	Groundwater	POLs	NFA	None
8	135	UST	Groundwater	POLs	NFA	None
9	115	UST	Groundwater	POLs	NFA	None
10	110, South	UST	Groundwater	POLs	NFA	None
11	110, North	UST	Groundwater	POLs	NFA	None
12	44	UST	Groundwater	POLs	NFA	None
13	35, South	UST	Groundwater	POLs	NFA	None
14	25	UST	Groundwater	POLs	NFA	None
15	15	UST	Groundwater	POLs	NFA (Clean Closure February 1995)	None
16	35	UST	Groundwater	POLs	NFA (pre-RFI)	None
17	36	UST	Groundwater	POLs	NFA (pre-RFI)	None
19	East of 40	Outfall No. 003	Groundwater	None	NFA (pre-RFI)	None (SPDES Permit)
20	36	Industrial Waste Sewer Lines	Groundwater	Heavy Metals, PAHs, Cyanide	NFA	LTM
21	132	Incinerator	Groundwater	PAHs	NFA (RFI)	None
25	East of 20 and 25	Former Erie Canal Area	Groundwater	POLs, Lead	NFA	LTM
26	35	Process Pits	Groundwater	POLs	NFA (RFI)	LTM
27	135	Process Pit ("Shrink Pit")	Groundwater	POLs	NFA (RFI)	None
Vapor Degreaser Units	20, 25, 40, 110, 120, and 130	Vapor Degreaser Units	Groundwater	Chlorinated Solvents	Corrective Measures	GW: Bldgs.110, 120, 130 - NFA GW: Bldg. 25 - MNA GW: Bldg. 40 - MNA
			Soil Vapor	Chlorinated Solvents	Corrective Measures	Soil Vapor: Bldgs: 20, 25, 120, 130 - SSDS Soil Vapor Bldg. 40 - Indoor Air Filtration Soil Vapor: Bldg. 110 - NFA
Chip Handling Facility Areas	121, 122, 123, and 132	Two Chip Handling Facilities	Groundwater	POLs	NFA	None
Chrome Plating Pit Areas	35 and 110	Three Chrome Plating Pits	Groundwater	Heavy Metals, Cyanide	NFA (RFI)	None
Chrome Plating Scrubbers	35, 110, and 114	Six Chrome Plating Scrubbers	Groundwater	Heavy Metals	NFA (RFI)	None

Notes:

NFA - No Further Action
UST - Underground Storage Tank
LTM - Long Term Monitoring
SPDES - State Pollutant Discharge Elimination System
POLs - Petroleum, Oil, and Lubricants
PAHs - Polyaromatic Hydrocarbons
MNA - Monitored Natural Attenuation
LNAPL - Light Non-aqueous Phase Liquids
SSDS - Sub-slab Depressurization System

Table 2-2
Summary of Areas of Concern (AOCs)
Solid Waste Management Unit (SWMU) - Vapor Degreaser Units
Corrective Measures Study
Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York

AOC	Contaminant	Description
Groundwater		
Building 25	VOCs	Overburden/Weathered Bedrock Groundwater
		(South/Southeast of Building 25)
Building 40	VOCs	Bedrock Groundwater
		(East of Building 40)
Soil Vapor		
Buildings 20, 21, 22, 25, 40, 114, 120, 121, 123, 130	VOCs	Soil Vapor Intrusion (sub-slab and indoor air)

Table 3-1
Corrective Action Objectives (CAOs) for Groundwater
Buildings 25 and 40
Main Manufacturing Area
Watervliet Arsenal, Watervliet, New York

Analyte	**Corrective Action Objective (ug/l)**
Organic Compounds	
1,1-Dichloroethane	5.0
1,1-Dichloroethene	5.0
cis-1,2-Dichloroethene	5.0
trans-1,2-Dichloroethene	5.0
Methylene chloride	5.0
2-Butanone	50*
1,1,2,2-Tetrachloroethane	5.0
Tetrachloroethene	5.0
1,1,1-Trichloroethane	5.0
Trichloroethene	5.0
Vinyl chloride	2.0

Notes:
CAOs = NYSDEC Class GA groundwater standards
* NYSDEC Class GA groundwater guidance values

Table 8-1
Summary of Recommended Final Corrective Measures
Solid Waste Management Unit (SWMU) - 5 and Vapor Degreaser Units
Corrective Measures Study
Main Manufacturing Area, Watervliet Arsenal, Watervliet, New York

SWMU	Building	Contaminants	Media	Corrective Measure
5	25	VOCs	Groundwater	MNA
		VOCs	Soil Vapor	SSDS
Vapor Desgreasers	25	VOCs	See SWMU 5	
	40	VOCs	Groundwater	MNA
		VOCs	Soil Vapor	Air Filtration
	20	VOCs	Soil Vapor	SSDS
	110	VOCs	None	NFA
	120	VOCs	Soil Vapor	SSDS
	130	VOCs	Soil Vapor	SSDS

Watervliet Arsenal
Main Manufacturing Area Focused Corrective Measures Study

Appendix A:

2008 Vapor Intrusion Investigation Summary Tables

Tables 4 through 27

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Table 4
Building 9 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B9-A1 2/11/08
	COMPOUND	UNIT	
INDOOR AIR	Vinyl chloride	µg/m^3	0.044 U
	1,1-Dichloroethene	µg/m^3	0.068 U
	1,1-Dichloroethane	µg/m^3	0.14 U
	cis-1,2-Dichloroethene	µg/m^3	0.14 U
	1,1,1-Trichloroethane	µg/m^3	0.19 U
	1,2-Dichloroethane	µg/m^3	0.14 U
	Trichloroethene	µg/m^3	0.18 U
	1,1,2-Trichloroethane	µg/m^3	0.19 U
	Tetrachloroethene	µg/m^3	0.23 U
	1,1,2,2-Tetrachloroethane	µg/m^3	0.23 U
	trans-1,2-Dichloroethene	µg/m^3	0.68 U
	Chloromethane	µg/m^3	1.10
	Chloroethane	µg/m^3	0.22 U
	Chlorobenzene	µg/m^3	0.16 U
	Carbon Tetrachloride	µg/m^3	0.57

		Sample ID Sample Date	B9-SS1 2/20/08
	COMPOUND	UNIT	
SUB-SLAB	Vinyl chloride	µg/m^3	0.040 U
	1,1-Dichloroethene	µg/m^3	0.063 U
	1,1-Dichloroethane	µg/m^3	0.13 U
	cis-1,2-Dichloroethene	µg/m^3	0.12 U
	1,1,1-Trichloroethane	µg/m^3	0.30
	1,2-Dichloroethane	µg/m^3	0.13 U
	Trichloroethene	µg/m^3	0.64
	1,1,2-Trichloroethane	µg/m^3	0.17 U
	Tetrachloroethene	µg/m^3	4.90
	1,1,2,2-Tetrachloroethane	µg/m^3	0.22 U
	trans-1,2-Dichloroethene	µg/m^3	0.63 U
	Chloromethane	µg/m^3	0.16 U
	Chloroethane	µg/m^3	0.21 U
	Chlorobenzene	µg/m^3	0.14 U
	Carbon Tetrachloride	µg/m^3	0.35

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 5
Building 15 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID **Sample Date**	**B15-A1** **2/20/08**	**B15-A2b** **2/19/08**
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m³	0.040 U	0.045 U
	1,1-Dichloroethene	µg/m³	0.063 U	0.069 U
	1,1-Dichloroethane	µg/m³	0.13 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.12 U	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.17 U	0.19 U
	1,2-Dichloroethane	µg/m³	0.13 U	0.14 U
	Trichloroethene	µg/m³	2.10	0.53
	1,1,2-Trichloroethane	µg/m³	0.17 U	0.19 U
	Tetrachloroethene	µg/m³	6.30	3.50
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.24 U
	trans-1,2-Dichloroethene	µg/m³	0.63 U	0.69 U
	Chloromethane	µg/m³	1.20	1.20
	Chloroethane	µg/m³	0.21 U	0.23 U
	Chlorobenzene	µg/m³	0.14 U	0.16 U
	Carbon Tetrachloride	µg/m³	0.49	0.55

		Sample ID **Sample Date**	**B15-SS2** **2/20/08**	**SS-1** **(B15-SS2 Dup.)** **2/20/08**
	COMPOUND	**UNIT**		
SUB-SLAB	Vinyl chloride	µg/m³	0.073 U	0.11 U
	1,1-Dichloroethene	µg/m³	0.11 U	0.17 U
	1,1-Dichloroethane	µg/m³	0.23 U	0.34 U
	cis-1,2-Dichloroethene	µg/m³	0.22 U	0.33 U
	1,1,1-Trichloroethane	µg/m³	5.00	5.10
	1,2-Dichloroethane	µg/m³	0.23 U	0.34 U
	Trichloroethene	µg/m³	**26.0**	**26.0**
	1,1,2-Trichloroethane	µg/m³	0.31 U	0.46 U
	Tetrachloroethene	µg/m³	**300**	**300**
	1,1,2,2-Tetrachloroethane	µg/m³	0.39 U	0.58 U
	trans-1,2-Dichloroethene	µg/m³	1.10 U	1.70 U
	Chloromethane	µg/m³	0.29 U	0.43 U
	Chloroethane	µg/m³	0.38 U	0.55 U
	Chlorobenzene	µg/m³	0.26 U	0.39 U
	Carbon Tetrachloride	µg/m³	1.60	1.70

Legend:

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2
🟧 - Mitigate and/or Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2
U - Not detectred at or greater than the Reporting Limit (RL)

Table 6
Building 18 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B18-A1 2/11/08	
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m^3	0.039	U
	1,1-Dichloroethene	µg/m^3	0.06	U
	1,1-Dichloroethane	µg/m^3	0.12	U
	cis-1,2-Dichloroethene	µg/m^3	0.12	U
	1,1,1-Trichloroethane	µg/m^3	0.16	U
	1,2-Dichloroethane	µg/m^3	0.12	U
	Trichloroethene	µg/m^3	0.16	U
	1,1,2-Trichloroethane	µg/m^3	0.16	U
	Tetrachloroethene	µg/m^3	0.21	U
	1,1,2,2-Tetrachloroethane	µg/m^3	0.21	U
	trans-1,2-Dichloroethene	µg/m^3	0.60	U
	Chloromethane	µg/m^3	1.30	
	Chloroethane	µg/m^3	0.20	U
	Chlorobenzene	µg/m^3	0.14	U
	Carbon Tetrachloride	µg/m^3	0.54	

		Sample ID Sample Date	B18-SS1 2/20/08	
	COMPOUND	**UNIT**		
SUB-SLAB	Vinyl chloride	µg/m^3	0.037	U
	1,1-Dichloroethene	µg/m^3	0.058	U
	1,1-Dichloroethane	µg/m^3	0.12	U
	cis-1,2-Dichloroethene	µg/m^3	0.12	U
	1,1,1-Trichloroethane	µg/m^3	0.16	U
	1,2-Dichloroethane	µg/m^3	0.12	U
	Trichloroethene	µg/m^3	0.51	
	1,1,2-Trichloroethane	µg/m^3	0.16	U
	Tetrachloroethene	µg/m^3	14.0	
	1,1,2,2-Tetrachloroethane	µg/m^3	0.20	U
	trans-1,2-Dichloroethene	µg/m^3	0.58	U
	Chloromethane	µg/m^3	0.15	U
	Chloroethane	µg/m^3	0.19	UJ
	Chlorobenzene	µg/m^3	0.13	U
	Carbon Tetrachloride	µg/m^3	0.38	

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 7
Building 19 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

	Sample ID Sample Date		B19-A1 2/11/08	B19-A2 2/11/08
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m³	0.045 U	0.041 U
	1,1-Dichloroethene	µg/m³	0.069 U	0.064 U
	1,1-Dichloroethane	µg/m³	0.14 U	0.13 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U	0.13 U
	1,1,1-Trichloroethane	µg/m³	0.19 U	0.18 U
	1,2-Dichloroethane	µg/m³	0.17	0.13 U
	Trichloroethene	µg/m³	0.19 U	0.17 U
	1,1,2-Trichloroethane	µg/m³	0.19 U	0.18 U
	Tetrachloroethene	µg/m³	0.24 U	0.24
	1,1,2,2-Tetrachloroethane	µg/m³	0.24 U	0.22 U
	trans-1,2-Dichloroethene	µg/m³	0.69 U	0.64 U
	Chloromethane	µg/m³	1.30	1.20
	Chloroethane	µg/m³	0.23 U	0.21 U
	Chlorobenzene	µg/m³	0.16 U	0.15 U
	Carbon Tetrachloride	µg/m³	0.60	0.54

	Sample ID Sample Date		B19-SS1 2/20/08
	COMPOUND	**UNIT**	
SUB-SLAB	Vinyl chloride	µg/m³	0.042 U
	1,1-Dichloroethene	µg/m³	0.065 U
	1,1-Dichloroethane	µg/m³	0.13 U
	cis-1,2-Dichloroethene	µg/m³	0.25
	1,1,1-Trichloroethane	µg/m³	0.18 U
	1,2-Dichloroethane	µg/m³	0.13 U
	Trichloroethene	µg/m³	15.0
	1,1,2-Trichloroethane	µg/m³	0.18 U
	Tetrachloroethene	µg/m³	38.0
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U
	trans-1,2-Dichloroethene	µg/m³	0.65 U
	Chloromethane	µg/m³	0.54
	Chloroethane	µg/m³	0.22 UJ
	Chlorobenzene	µg/m³	0.15 U
	Carbon Tetrachloride	µg/m³	0.64

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 8
Building 20 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

	Sample ID Sample Date		**B20-SS1 2/28/08**	**B20-SS2 2/28/08**	**SS-2 (B20-SS2 Dup.) 2/28/08**	**B20-SS3 2/28/08**	**B20-SS4 2/28/08**	**B20-SS5 2/28/08**	**B20-SS6 2/28/08**	**B20-SS7 2/28/08**	**B20-SS8 2/28/08**
	COMPOUND	**UNIT**									
SUB-SLAB	Vinyl chloride	µg/m^3	0.43 U	0.054 U	0.034 U	0.042 U	0.80	0.043 U	0.042 U	0.037 U	0.51 U
	1,1-Dichloroethene	µg/m^3	0.67 U	0.13	0.053 U	0.20	0.83	0.068	0.065 U	0.058	87
	1,1-Dichloroethane	µg/m^3	1.4 U	0.23	0.11 U	0.13 U	1.8	0.14 U	0.13 U	0.12 U	1.6 U
	cis-1,2-Dichloroethene	µg/m^3	1.3 U	0.17 U	0.11 U	0.13 U	0.13 U	0.13 U	0.13 U	0.12 U	1.6 U
	1,1,1-Trichloroethane	µg/m^3	36	7.9 J	0.79 J	14	34	3.4	2.4	1.5	**930**
	1,2-Dichloroethane	µg/m^3	1.4 U	0.17 U	0.11 U	0.13 U	0.16	0.14 U	0.13 U	0.12 U	1.6 U
	Trichloroethene	µg/m^3	**1,100**	**40 J**	**5.3**	**82**	1.4	0.18 U	0.70	2.0	**200**
	1,1,2-Trichloroethane	µg/m^3	1.8 U	0.23 U	0.15 U	0.18 U	0.18 U	0.18 U	0.18 U	0.16 U	2.2 U
	Tetrachloroethene	µg/m^3	**150**	8.0 J	0.69	26	1.1	2.3	0.58	1.1	50
	1,1,2,2-Tetrachloroethane	µg/m^3	2.3 U	0.29 U	0.18 U	0.22 U	0.23 U	0.23 U	0.22 U	0.20 U	2.8 U
	trans-1,2-Dichloroethene	µg/m^3	6.7 U	0.84 U	0.53 U	0.65 U	0.67 U	0.67 U	0.65 U	0.58 U	8.0 U
	Chloromethane	µg/m^3	1.7 U	0.89 J	1.2 J	0.35	2.2	0.17 U	0.68	2.2	2.1 U
	Chloroethane	µg/m^3	2.2 U	0.28 U	0.18 U	0.22 U	1.4	0.22 U	0.22 U	0.31	2.6 U
	Chlorobenzene	µg/m^3	1.5 U	0.20 U	0.12 U	0.15 U	0.15 U	0.15 U	0.15 U	0.13 U	1.8 U
	Carbon Tetrachloride	µg/m^3	2.1 U	0.31	0.50	0.51	0.21 U	0.39	0.23	0.36	2.5 U

Legend:

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

🟧 - Mitigate and/or Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

🟩 - No further action, Mitigate, and/or Monitor according to Soil Vapor/Indoor Air Matrices

U - Not detrected at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

B20-SS9 2/28/08	**B20-SS10 2/28/08**	**B20-SS11 2/28/08**	**B20-SS12 3/5/08**
0.041 U	0.043 U	0.041 U	0.045 U
0.064 U	0.067 U	0.064 U	1.0
0.13 U	0.14 U	0.13 U	0.14 U
0.13 U	0.13 U	0.13 U	0.14 U
2.3	2.1	3.7	16
0.13 U	0.14 U	0.13 U	0.14 U
3.7	1.5	0.17 U	0.19 U
0.18 U	0.18 U	0.18 U	0.19 U
0.80	2.2	3.1	4.0
0.22 U	0.23 U	0.22 U	0.24 U
0.70	0.67 U	0.64 U	0.69 U
0.19	0.17 U	0.17 U	0.18 U
0.21 U	0.22 U	0.21 U	0.23 U
0.15 U	0.15 U	0.15 U	0.16 U
0.45	0.48	0.34	0.22 U

Table 9
Building 21 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B21-A1 2/11/08	B21-A2 2/12/08
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m³	0.036 U	0.044 U
	1,1-Dichloroethene	µg/m³	0.055 U	0.068 U
	1,1-Dichloroethane	µg/m³	0.11 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.11 U	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.15 U	0.19 U
	1,2-Dichloroethane	µg/m³	0.19	0.14 U
	Trichloroethene	µg/m³	0.15 U	0.18 U
	1,1,2-Trichloroethane	µg/m³	0.15 U	0.19 U
	Tetrachloroethene	µg/m³	0.19 U	0.23 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.19 U	0.23 U
	trans-1,2-Dichloroethene	µg/m³	0.55 U	0.68 U
	Chloromethane	µg/m³	1.30	1.60
	Chloroethane	µg/m³	0.18 U	0.22 U
	Chlorobenzene	µg/m³	0.13 U	0.16 U
	Carbon Tetrachloride	µg/m³	0.48	0.60

		Sample ID Sample Date	B21-SS1 2/19/08	B21-SS2 2/19/08
	COMPOUND	**UNIT**		
SUB-SLAB	Vinyl chloride	µg/m³	33 UJ	0.099 U
	1,1-Dichloroethene	µg/m³	10 UJ	0.17
	1,1-Dichloroethane	µg/m³	11 UJ	0.31 U
	cis-1,2-Dichloroethene	µg/m³	16 UJ	0.30 J
	1,1,1-Trichloroethane	µg/m³	16 UJ	0.93
	1,2-Dichloroethane	µg/m³	16 UJ	0.31 U
	Trichloroethene	µg/m³	🟥 **2,500 J**	🟥 **300**
	1,1,2-Trichloroethane	µg/m³	22 UJ	0.42 U
	Tetrachloroethene	µg/m³	25 UJ	35
	1,1,2,2-Tetrachloroethane	µg/m³	16 UJ	0.53 U
	trans-1,2-Dichloroethene	µg/m³	5,700 J	1.50 U
	Chloromethane	µg/m³	22	0.40 U
	Chloroethane	µg/m³	290 J	0.51 U
	Chlorobenzene	µg/m³	18 UJ	0.36 U
	Carbon Tetrachloride	µg/m³	28 UJ	0.70

Legend:

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 10
Building 23 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B23-A1	B23-A2	B23-A3
		Sample Date	2/5/08	2/5/08	2/5/08
	COMPOUND	UNIT			
INDOOR AIR	Vinyl chloride	µg/m^3	0.044 U	0.042 U	0.044 U
	1,1-Dichloroethene	µg/m^3	0.068 U	0.065 U	0.068 U
	1,1-Dichloroethane	µg/m^3	0.14 U	0.13 U	0.14 U
	cis-1,2-Dichloroethene	µg/m^3	0.14 U	0.13 U	0.14 U
	1,1,1-Trichloroethane	µg/m^3	1.40	1.70	3.60
	1,2-Dichloroethane	µg/m^3	0.14 U	0.13 U	0.14 U
	Trichloroethene	µg/m^3	0.75	1.60	1.00
	1,1,2-Trichloroethane	µg/m^3	0.19 U	0.18 U	0.19 U
	Tetrachloroethene	µg/m^3	0.42	0.39	0.40
	1,1,2,2-Tetrachloroethane	µg/m^3	0.23 U	0.22 U	0.23 U
	trans-1,2-Dichloroethene	µg/m^3	0.87	0.65 U	1.70
	Chloromethane	µg/m^3	1.80	1.20	1.40
	Chloroethane	µg/m^3	0.22 U	0.22 U	0.22 U
	Chlorobenzene	µg/m^3	0.17	0.15 U	0.16 U
	Carbon Tetrachloride	µg/m^3	0.59	0.56	0.61

		Sample ID	B23-SS1
		Sample Date	2/8/08
	COMPOUND	UNIT	
SUB-SLAB	Vinyl chloride	µg/m^3	0.066 U
	1,1-Dichloroethene	µg/m^3	0.10 U
	1,1-Dichloroethane	µg/m^3	0.21 U
	cis-1,2-Dichloroethene	µg/m^3	0.20 U
	1,1,1-Trichloroethane	µg/m^3	2.50
	1,2-Dichloroethane	µg/m^3	0.21 U
	Trichloroethene	µg/m^3	🟨 **17.0**
	1,1,2-Trichloroethane	µg/m^3	0.28 U
	Tetrachloroethene	µg/m^3	29.0
	1,1,2,2-Tetrachloroethane	µg/m^3	0.36 U
	trans-1,2-Dichloroethene	µg/m^3	3.40
	Chloromethane	µg/m^3	1.30
	Chloroethane	µg/m^3	0.34 U
	Chlorobenzene	µg/m^3	0.24 U
	Carbon Tetrachloride	µg/m^3	0.55

Legend:

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

U - Not detectred at or greater than the Reporting Limit (RL)

Table 11
Building 24 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B24-A1	B24-A2	B24-A3
		Sample Date	2/6/08	2/6/08	2/6/08
	COMPOUND	UNIT			
INDOOR AIR	Vinyl chloride	µg/m³	0.044 U	0.043 U	0.040 U
	1,1-Dichloroethene	µg/m³	0.068 U	0.067 U	0.16
	1,1-Dichloroethane	µg/m³	0.14 U	0.14 U	2.20
	cis-1,2-Dichloroethene	µg/m³	0.14 U	0.13 U	0.12 U
	1,1,1-Trichloroethane	µg/m³	0.19 U	0.18 U	2.00
	1,2-Dichloroethane	µg/m³	0.14 U	0.14 U	0.13 U
	Trichloroethene	µg/m³	0.18 U	0.18 U	0.17 U
	1,1,2-Trichloroethane	µg/m³	0.19 U	0.18 U	0.17 U
	Tetrachloroethene	µg/m³	0.23 U	0.23 U	0.71
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U	0.23 U	0.22 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U	0.67 U	0.63 U
	Chloromethane	µg/m³	1.40	1.30	1.60
	Chloroethane	µg/m³	0.22 U	0.22 U	0.21 U
	Chlorobenzene	µg/m³	0.16 U	0.15 U	0.14 U
	Carbon Tetrachloride	µg/m³	0.52	0.56	0.56

		Sample ID	B24-SS1	B24-SS2
		Sample Date	2/11/08	2/11/08
	COMPOUND	UNIT		
SUB-SLAB	Vinyl chloride	µg/m³	0.044 U	0.063
	1,1-Dichloroethene	µg/m³	0.068 U	0.067 U
	1,1-Dichloroethane	µg/m³	0.14 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U	0.13 U
	1,1,1-Trichloroethane	µg/m³	0.37	0.34
	1,2-Dichloroethane	µg/m³	0.14 U	0.14 U
	Trichloroethene	µg/m³	0.33	0.25
	1,1,2-Trichloroethane	µg/m³	0.19 U	0.18 U
	Tetrachloroethene	µg/m³	0.23 U	0.63
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U	0.23 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U	0.67 U
	Chloromethane	µg/m³	0.69	0.71
	Chloroethane	µg/m³	0.22 U	0.22 U
	Chlorobenzene	µg/m³	0.16 U	0.15 U
	Carbon Tetrachloride	µg/m³	0.57	0.61

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 12
Building 25 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

	Sample ID **Sample Date**		**B25-A1** **2/5/08**	**B25-A2** **2/5/08**	**B25-A3** **2/5/08**	**B25-A4** **2/5/08**	**B25-A5** **2/5/08**	**B25-A6** **2/8/08**	**B25-A7** **2/5/08**	**B25-A8** **2/6/08**	**B25-A9** **2/5/08**	**B25-A10** **2/5/08**	**B25-A11** **2/6/08**	**B25-A12** **2/5/08**
	COMPOUND	**UNIT**												
INDOOR AIR	Vinyl chloride	µg/m³	0.047	0.044 U	0.042 U	0.075	0.043 U	0.096	0.045 U	0.077	0.04 U	0.044 U	0.043 U	0.045 U
	1,1-Dichloroethene	µg/m³	0.068 U	0.068 U	0.065 U	0.065 U	0.067 U	0.065 U	0.069 U	0.067 U	0.07 U	0.068 U	0.067 U	0.069 U
	1,1-Dichloroethane	µg/m³	0.14 U	0.14 U	0.13 U	0.13 U	0.14 U	0.13 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U	0.14 U	0.13 U	0.13 U	0.13 U	0.13 U	0.14 U	0.13 U	0.14 U	0.14 U	0.13 U	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.19 U	0.19 U	0.18 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.19 U	0.19 U	0.18 U	0.19 U
	1,2-Dichloroethane	µg/m³	0.14 U	0.14 U	0.13 U	0.13 U	0.14 U	0.13 U	0.14 U	0.14	0.14 U	0.14 U	0.14 U	0.14 U
	Trichloroethene	µg/m³	0.19 U	0.39	0.18 U	0.85	0.31	3.60	0.2 U	**8.40**	0.61	0.18 U	4.40	0.19 U
	1,1,2-Trichloroethane	µg/m³	0.19 U	0.19 U	0.18 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.19 U	0.19 U	0.18 U	0.19 U
	Tetrachloroethene	µg/m³	0.44	0.42	0.41	0.41	0.48	0.22 U	0.41	0.23 U	0.53	0.47	0.23 U	0.42
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U	0.23 U	0.22 U	0.22 U	0.23 U	0.22 U	0.24 U	0.23 U	0.23 U	0.23 U	0.23 U	0.24 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U	0.68 U	0.65 U	0.65 U	0.67 U	0.65 U	0.69 U	0.67 U	0.68 U	0.68 U	0.67 U	0.69 U
	Chloromethane	µg/m³	1.20	1.20	1.10	1.10	1.10	1.20	1.10	1.20	1.20	0.80	1.20	4.50
	Chloroethane	µg/m³	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.23 U	0.22 U	0.22 U	0.22 U	0.22 U	3.20
	Chlorobenzene	µg/m³	0.16 U	0.16 U	0.15 U	0.15 U	0.15 U	0.15 U	0.16 U	0.15 U	0.16 U	0.16 U	0.15 U	0.16 U
	Carbon Tetrachloride	µg/m³	0.55	0.55	0.52	0.57	0.58	0.54	0.54	0.60	0.57	0.56	0.58	0.58

	Sample ID **Sample Date**		**B25-SS1** **2/28/08**	**B25-SS2** **2/28/08**	**B25-SS3** **2/28/08**	**B25-SS4** **3/4/08**	**B25-SS5** **3/4/08**	**B25-SS6** **3/4/08**	**B25-SS7** **3/4/08**	**B25-SS8** **3/4/08**	**B25-SS9** **3/4/08**	**B25-SS10** **3/4/08**
	COMPOUND	**UNIT**										
SUB-SLAB	Vinyl chloride	µg/m³	200 U	18 U	0.37 U	0.041 U	0.044 U	0.27 U	0.73 U	0.61	8.6 U	14 U
	1,1-Dichloroethene	µg/m³	**340**	45	58	1.4	0.71	8.7	1.1 U	0.44	13 U	23 U
	1,1-Dichloroethane	µg/m³	320 U	45	2.0	0.13 U	0.14 U	0.87 U	2.30 U	0.18	14 U	23 U
	cis-1,2-Dichloroethene	µg/m³	310 U	27 U	1.1 U	0.13 U	0.14 U	0.85 U	16	7.0	13 U	22 U
	1,1,1-Trichloroethane	µg/m³	**12,000**	**2,600**	**580**	8.1	3.0	98	3.2	2.0	21	31
	1,2-Dichloroethane	µg/m³	320 U	28 U	1.2 U	0.13 U	0.14 U	0.87 U	2.30 U	0.12 U	14 U	23 U
	Trichloroethene	µg/m³	**94,000**	**7,900**	**250**	2.3	0.84	**780**	**1,300**	**30**	**5,400**	**9,700 J**
	1,1,2-Trichloroethane	µg/m³	430 U	37 U	1.6 U	0.18 U	0.19 U	1.2 U	3.1 U	0.16 U	18 U	31 U
	Tetrachloroethene	µg/m³	540 U	46 U	21	3.4	4.4	10	**170**	19	**120**	**270 J**
	1,1,2,2-Tetrachloroethane	µg/m³	540 U	47 U	2.0 U	0.22 U	0.23 U	1.5 U	3.9 U	0.21 U	23 U	39 U
	trans-1,2-Dichloroethene	µg/m³	310 U	27 U	5.7 U	0.64 U	0.68 U	4.2 U	11 U	0.60 U	13 U	22 U
	Chloromethane	µg/m³	650 U	56 U	1.5 U	0.59	0.56	1.1 U	2.9 U	0.48	28 U	47 U
	Chloroethane	µg/m³	210 U	18 U	1.9 U	0.21 U	0.22 U	1.4 U	3.8 U	0.20 U	8.9 U	15.0 U
	Chlorobenzene	µg/m³	360 U	32 U	1.3 U	0.15 U	0.16 U	0.98 U	3 U	0.14 U	15 U	26 U
	Carbon Tetrachloride	µg/m³	500 U	43 U	1.8 U	1.1	0.48	1.3 U	3.6 U	0.32	21 U	36 U

	Sample ID **Sample Date**		**SS-3** **(B25-SS10 Dup.)** **3/4/08**	**B25-SS11** **3/4/08**	**B25-SS12** **3/4/08**	**B25-SS13** **3/4/08**	**B25-SS14** **3/4/08**	**B25-SS15** **3/4/08**	**B25-SS16** **3/4/08**	**B25-SS17** **3/4/08**	**B25-SS18** **3/4/08**	**B25-SS19** **3/4/08**	**B25-SS20** **3/4/08**
	COMPOUND	**UNIT**											
SUB-SLAB	Vinyl chloride	µg/m³	13 U	0.087 U	0.054 U	0.047 U	0.15 U	0.073 U	0.087 U	0.042 U	0.21 U	0.043 U	0.20 U
	1,1-Dichloroethene	µg/m³	20 U	3.2	1.0	2.8	3.7	22	22	11	6.2	1.9	1.1
	1,1-Dichloroethane	µg/m³	20 U	0.28 U	0.17 U	0.15 U	0.48 U	0.23 U	0.28 U	0.13 U	0.68	0.26	0.63 U
	cis-1,2-Dichloroethene	µg/m³	20 U	0.27 U	0.17 U	0.14 U	1.2	0.23 U	0.27 U	2.6	0.65 U	0.22	0.61 U
	1,1,1-Trichloroethane	µg/m³	28 U	35	9.7	18	29	**240**	**200**	**110**	77	11	18
	1,2-Dichloroethane	µg/m³	20 U	0.28 U	0.17 U	0.15 U	0.48 U	0.23 U	0.28 U	0.13 U	0.66 U	0.14 U	0.63 U
	Trichloroethene	µg/m³	**7,000 J**	**220**	**97**	0.20 U	**260**	**22**	**67**	12	**670**	**99**	11
	1,1,2-Trichloroethane	µg/m³	28 U	0.37 U	0.23 U	0.20 U	0.65 U	0.31 U	0.37 U	0.18 U	0.89 U	0.18 U	0.84 U
	Tetrachloroethene	µg/m³	**190 J**	3.0	0.58	1.1	22	1.8	2.8	3.0	34	7.0	**900**
	1,1,2,2-Tetrachloroethane	µg/m³	35 U	0.47 U	0.29 U	0.25 U	0.82 U	0.39 U	0.47 U	0.22 U	1.1 U	0.23 U	1.10 U
	trans-1,2-Dichloroethene	µg/m³	20 U	1.40 U	0.83 U	0.72 U	2.4 U	1.1 U	1.4 U	0.65 U	3.2 U	0.67 U	3.1 U
	Chloromethane	µg/m³	42 U	0.35 U	11	0.19 U	1.0	0.30 U	0.35 U	0.17 U	0.85 U	0.17 U	0.80 U
	Chloroethane	µg/m³	13 U	0.45 U	0.28 U	0.24 U	0.79 U	0.38 U	0.45 U	0.22 U	1.1 U	0.22 U	1.0 U
	Chlorobenzene	µg/m³	23 U	0.31 U	0.19 U	0.17 U	0.55 U	0.26 U	0.31 U	0.15 U	0.76 U	0.15 U	0.71 U
	Carbon Tetrachloride	µg/m³	32 U	1.7	6.3	0.23 U	1.6	3.8	1.3	1.6	1.5	0.49	0.98 U

Legend:

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

Red Bold Highlighted Text - Concentration exceeds Air Guidance Value

U - Not detected at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 13
Building 35 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B35-SS1	B35-SS2	B35-SS3	B35-SS4	B35-SS5
		Sample Date	2/25/08	2/25/08	2/25/08	2/25/08	2/25/08
	COMPOUND	UNIT					
SUB-SLAB	Vinyl chloride	µg/m^3	0.044 U	0.20 U	0.036 U	0.060 U	0.041 U
	1,1-Dichloroethene	µg/m^3	0.068 U	0.32 U	0.21	0.093 U	0.064 U
	1,1-Dichloroethane	µg/m^3	0.14 U	0.65 U	0.11 U	0.19 U	0.13 U
	cis-1,2-Dichloroethene	µg/m^3	0.14 U	23.00	0.11 U	0.18 U	0.13 U
	1,1,1-Trichloroethane	µg/m^3	5.20	0.88 U	18.0	6.20	2.10
	1,2-Dichloroethane	µg/m^3	0.14 U	0.65 U	0.11 U	0.19 U	0.13 U
	Trichloroethene	µg/m^3	4.40	**50.0**	1.60	**110**	**8.80**
	1,1,2-Trichloroethane	µg/m^3	0.19 U	0.88 U	0.15 U	0.29 U	0.18 U
	Tetrachloroethene	µg/m^3	30.0	**900**	4.90	**200**	17.00
	1,1,2,2-Tetrachloroethane	µg/m^3	0.23 U	1.10 U	0.19 U	0.32 U	0.22 U
	trans-1,2-Dichloroethene	µg/m^3	0.68 U	3.20 U	0.55 U	0.93 U	0.64 U
	Chloromethane	µg/m^3	0.18 U	0.83 U	0.79	0.39	0.25
	Chloroethane	µg/m^3	0.22 UJ	1.10 U	0.18 U	0.31 U	0.21 U
	Chlorobenzene	µg/m^3	0.16 U	0.74 U	0.13 U	0.22 U	0.15 U
	Carbon Tetrachloride	µg/m^3	0.41	3.30	0.71	1.20	1.00

Legend:

🟧 - Mitigate and/or Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

🟩 - No further action, Mitigate, and/or Monitor according to Soil Vapor/Indoor Air Matrices

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 14
Building 38 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

	Sample ID Sample Date		B38-A1 2/6/08	B38-A2 2/6/08
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m³	0.041 U	0.044 U
	1,1-Dichloroethene	µg/m³	0.064 U	0.068 U
	1,1-Dichloroethane	µg/m³	0.13 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.13 U	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.91	0.86
	1,2-Dichloroethane	µg/m³	0.13 U	0.14 U
	Trichloroethene	µg/m³	0.17 U	0.18 U
	1,1,2-Trichloroethane	µg/m³	0.18 U	0.19 U
	Tetrachloroethene	µg/m³	0.22 U	0.23 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.23 U
	trans-1,2-Dichloroethene	µg/m³	0.64 U	0.68 U
	Chloromethane	µg/m³	1.30	1.30
	Chloroethane	µg/m³	0.21 U	0.22 U
	Chlorobenzene	µg/m³	0.15 U	0.16 U
	Carbon Tetrachloride	µg/m³	0.48	0.58

	Sample ID Sample Date		B38-SS1 2/12/08	B38-SS2 2/12/08
	COMPOUND	**UNIT**		
SUB-SLAB	Vinyl chloride	µg/m³	0.036 U	0.040 U
	1,1-Dichloroethene	µg/m³	0.055 U	0.061 U
	1,1-Dichloroethane	µg/m³	0.11 U	0.12 U
	cis-1,2-Dichloroethene	µg/m³	0.11 U	0.12 U
	1,1,1-Trichloroethane	µg/m³	0.16	0.25
	1,2-Dichloroethane	µg/m³	0.11 U	0.12 U
	Trichloroethene	µg/m³	0.15 U	0.17 U
	1,1,2-Trichloroethane	µg/m³	0.15 U	0.17 U
	Tetrachloroethene	µg/m³	0.19 U	0.21 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.19 U	0.21 U
	trans-1,2-Dichloroethene	µg/m³	0.55 U	0.31 U
	Chloromethane	µg/m³	0.56	0.16 U
	Chloroethane	µg/m³	0.18 U	0.20 U
	Chlorobenzene	µg/m³	0.13 U	0.14 U
	Carbon Tetrachloride	µg/m³	0.28	0.20 U

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 15
Building 44 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	**B44-A1**	
		Sample Date	**2/12/08**	
	COMPOUND	**UNIT**		
INDOOR AIR	Vinyl chloride	µg/m^3	0.047	U
	1,1-Dichloroethene	µg/m^3	0.072	U
	1,1-Dichloroethane	µg/m^3	0.15	U
	cis-1,2-Dichloroethene	µg/m^3	0.14	U
	1,1,1-Trichloroethane	µg/m^3	0.20	U
	1,2-Dichloroethane	µg/m^3	0.15	U
	Trichloroethene	µg/m^3	0.33	
	1,1,2-Trichloroethane	µg/m^3	0.20	U
	Tetrachloroethene	µg/m^3	0.46	
	1,1,2,2-Tetrachloroethane	µg/m^3	0.25	U
	trans-1,2-Dichloroethene	µg/m^3	0.72	U
	Chloromethane	µg/m^3	1.20	
	Chloroethane	µg/m^3	0.24	U
	Chlorobenzene	µg/m^3	0.17	U
	Carbon Tetrachloride	µg/m^3	0.57	

		Sample ID	**B44-SS1**	
		Sample Date	**2/15/08**	
	COMPOUND	**UNIT**		
SUB-SLAB	Vinyl chloride	µg/m^3	0.039	U
	1,1-Dichloroethene	µg/m^3	0.060	U
	1,1-Dichloroethane	µg/m^3	0.12	U
	cis-1,2-Dichloroethene	µg/m^3	0.12	U
	1,1,1-Trichloroethane	µg/m^3	0.16	U
	1,2-Dichloroethane	µg/m^3	0.12	U
	Trichloroethene	µg/m^3	0.42	
	1,1,2-Trichloroethane	µg/m^3	0.16	U
	Tetrachloroethene	µg/m^3	0.24	
	1,1,2,2-Tetrachloroethane	µg/m^3	0.21	U
	trans-1,2-Dichloroethene	µg/m^3	0.60	U
	Chloromethane	µg/m^3	0.64	
	Chloroethane	µg/m^3	0.20	U
	Chlorobenzene	µg/m^3	0.14	U
	Carbon Tetrachloride	µg/m^3	0.54	

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 16
Building 108 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B108-A1	
		Sample Date	2/12/08	
	COMPOUND	UNIT		
INDOOR AIR	Vinyl chloride	µg/m³	0.043	U
	1,1-Dichloroethene	µg/m³	0.067	U
	1,1-Dichloroethane	µg/m³	0.14	U
	cis-1,2-Dichloroethene	µg/m³	0.13	U
	1,1,1-Trichloroethane	µg/m³	0.18	U
	1,2-Dichloroethane	µg/m³	0.14	U
	Trichloroethene	µg/m³	0.34	
	1,1,2-Trichloroethane	µg/m³	0.18	U
	Tetrachloroethene	µg/m³	0.42	
	1,1,2,2-Tetrachloroethane	µg/m³	0.23	U
	trans-1,2-Dichloroethene	µg/m³	0.67	U
	Chloromethane	µg/m³	1.1	
	Chloroethane	µg/m³	0.22	U
	Chlorobenzene	µg/m³	0.15	U
	Carbon Tetrachloride	µg/m³	0.61	

		Sample ID	B108-SS1	
		Sample Date	2/20/08	
	COMPOUND	UNIT		
SUB-SLAB	Vinyl chloride	µg/m³	0.041	U
	1,1-Dichloroethene	µg/m³	0.064	U
	1,1-Dichloroethane	µg/m³	0.13	U
	cis-1,2-Dichloroethene	µg/m³	0.13	U
	1,1,1-Trichloroethane	µg/m³	0.23	
	1,2-Dichloroethane	µg/m³	0.13	U
	Trichloroethene	µg/m³	1.10	
	1,1,2-Trichloroethane	µg/m³	0.18	U
	Tetrachloroethene	µg/m³	6.40	
	1,1,2,2-Tetrachloroethane	µg/m³	0.25	
	trans-1,2-Dichloroethene	µg/m³	0.64	U
	Chloromethane	µg/m³	0.24	
	Chloroethane	µg/m³	0.21	U
	Chlorobenzene	µg/m³	0.15	U
	Carbon Tetrachloride	µg/m³	0.55	

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 17
Building 110 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B110-SS1 2/14/08	B110-SS2 2/14/08	B110-SS3 2/14/08	B110-SS4 2/14/08	B110-SS5 2/14/08	B110-SS6 2/14/08
	COMPOUND	**UNIT**						
SUB-SLAB	Vinyl chloride	µg/m³	0.070	0.041 U	0.058	0.049	**640**	0.05 U
	1,1-Dichloroethene	µg/m³	0.064 U	0.064 U	0.061 U	0.069 U	13.00	0.07 U
	1,1-Dichloroethane	µg/m³	0.13 U	0.13 U	0.12 U	0.14 U	1.30 U	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.18	0.13 U	0.12 U	0.14 U	**110**	0.94
	1,1,1-Trichloroethane	µg/m³	0.47	0.52	0.78	3.60	1.80 U	0.39
	1,2-Dichloroethane	µg/m³	0.13 U	0.13 U	0.12 U	0.14 U	1.30 U	0.14 U
	Trichloroethene	µg/m³	**32.0**	0.30	**19.0**	**17.0**	**110**	**12.00**
	1,1,2-Trichloroethane	µg/m³	0.18 U	0.18 U	0.17 U	0.19 U	1.80 U	0.20 U
	Tetrachloroethene	µg/m³	83.0	5.60	98.0	13.0	**120**	40.0
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.22 U	0.33	0.29	750	0.24 U
	trans-1,2-Dichloroethene	µg/m³	0.64 U	0.64 U	0.61 U	0.69 U	28.0	0.71 U
	Chloromethane	µg/m³	2.40	0.75	0.61	0.29	1.70 U	0.18 U
	Chloroethane	µg/m³	0.52 J	0.21 U	0.20 U	0.23 U	2.90	0.24 U
	Chlorobenzene	µg/m³	0.15 U	0.15 U	0.14 U	0.16 U	30.0	0.16 U
	Carbon Tetrachloride	µg/m³	1.10	0.21	0.58	0.22 U	2.10 U	0.43

Legend:

🟧 - Mitigate and/or Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

🟩 - No further action, Mitigate, and/or Monitor according to Soil Vapor/Indoor Air Matrices

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

U - Not detected at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 18
Building 112 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B112-A1 2/12/08
	COMPOUND	**UNIT**	
INDOOR AIR	Vinyl chloride	µg/m³	0.048 U
	1,1-Dichloroethene	µg/m³	0.074 U
	1,1-Dichloroethane	µg/m³	0.15 U
	cis-1,2-Dichloroethene	µg/m³	0.15 U
	1,1,1-Trichloroethane	µg/m³	0.31
	1,2-Dichloroethane	µg/m³	0.15 U
	Trichloroethene	µg/m³	0.20 U
	1,1,2-Trichloroethane	µg/m³	0.20 U
	Tetrachloroethene	µg/m³	0.25 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.26 U
	trans-1,2-Dichloroethene	µg/m³	0.74 U
	Chloromethane	µg/m³	1.30
	Chloroethane	µg/m³	0.25 U
	Chlorobenzene	µg/m³	0.17 U
	Carbon Tetrachloride	µg/m³	0.58

		Sample ID Sample Date	B112-SS1 2/20/08
	COMPOUND	**UNIT**	
SUB-SLAB	Vinyl chloride	µg/m³	0.046 U
	1,1-Dichloroethene	µg/m³	0.071 U
	1,1-Dichloroethane	µg/m³	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.23
	1,2-Dichloroethane	µg/m³	0.14 U
	Trichloroethene	µg/m³	1.50
	1,1,2-Trichloroethane	µg/m³	0.20 U
	Tetrachloroethene	µg/m³	3.00
	1,1,2,2-Tetrachloroethane	µg/m³	0.32
	trans-1,2-Dichloroethene	µg/m³	0.71 U
	Chloromethane	µg/m³	0.33
	Chloroethane	µg/m³	0.24 UJ
	Chlorobenzene	µg/m³	0.16 U
	Carbon Tetrachloride	µg/m³	0.51

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 19
Building 114 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B114-A1
		Sample Date	2/12/08
	COMPOUND	UNIT	
INDOOR AIR	Vinyl chloride	µg/m³	0.044 U
	1,1-Dichloroethene	µg/m³	0.068 U
	1,1-Dichloroethane	µg/m³	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.89
	1,1,1-Trichloroethane	µg/m³	0.19 U
	1,2-Dichloroethane	µg/m³	0.14 U
	Trichloroethene	µg/m³	**6.80**
	1,1,2-Trichloroethane	µg/m³	0.19 U
	Tetrachloroethene	µg/m³	27.00
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U
	Chloromethane	µg/m³	1.20
	Chloroethane	µg/m³	0.22 U
	Chlorobenzene	µg/m³	0.16 U
	Carbon Tetrachloride	µg/m³	0.61

		Sample ID	B114-SS1
		Sample Date	2/22/08
	COMPOUND	UNIT	
SUB-SLAB	Vinyl chloride	µg/m³	2.10 U
	1,1-Dichloroethene	µg/m³	3.30 U
	1,1-Dichloroethane	µg/m³	6.80 U
	cis-1,2-Dichloroethene	µg/m³	6.70 U
	1,1,1-Trichloroethane	µg/m³	9.20 U
	1,2-Dichloroethane	µg/m³	6.80 U
	Trichloroethene	µg/m³	**1,400**
	1,1,2-Trichloroethane	µg/m³	9.20 U
	Tetrachloroethene	µg/m³	**8,300**
	1,1,2,2-Tetrachloroethane	µg/m³	12.0 U
	trans-1,2-Dichloroethene	µg/m³	33.0 U
	Chloromethane	µg/m³	8.70 U
	Chloroethane	µg/m³	11.0 U
	Chlorobenzene	µg/m³	7.70 U
	Carbon Tetrachloride	µg/m³	10.0 U

Legend:

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

Red Bold Highlighted Text - Concentration exceeds Air Guidance Value

U - Not detectred at or greater than the Reporting Limit (RL)

Table 20
Building 116 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B116-A1
		Sample Date	2/12/08
	COMPOUND	**UNIT**	
INDOOR AIR	Vinyl chloride	µg/m^3	0.045 U
	1,1-Dichloroethene	µg/m^3	0.069 U
	1,1-Dichloroethane	µg/m^3	0.14 U
	cis-1,2-Dichloroethene	µg/m^3	0.39
	1,1,1-Trichloroethane	µg/m^3	0.19 U
	1,2-Dichloroethane	µg/m^3	0.14 U
	Trichloroethene	µg/m^3	1.60
	1,1,2-Trichloroethane	µg/m^3	0.19 U
	Tetrachloroethene	µg/m^3	2.10
	1,1,2,2-Tetrachloroethane	µg/m^3	0.24 U
	trans-1,2-Dichloroethene	µg/m^3	0.69 U
	Chloromethane	µg/m^3	1.20
	Chloroethane	µg/m^3	0.23 U
	Chlorobenzene	µg/m^3	0.16 U
	Carbon Tetrachloride	µg/m^3	0.58

		Sample ID	B116-SS1
		Sample Date	2/22/08
	COMPOUND	**UNIT**	
SUB-SLAB	Vinyl chloride	µg/m^3	0.14 U
	1,1-Dichloroethene	µg/m^3	0.21 U
	1,1-Dichloroethane	µg/m^3	0.43 U
	cis-1,2-Dichloroethene	µg/m^3	3.80
	1,1,1-Trichloroethane	µg/m^3	0.65
	1,2-Dichloroethane	µg/m^3	0.43 U
	Trichloroethene	µg/m^3	**180**
	1,1,2-Trichloroethane	µg/m^3	0.59 U
	Tetrachloroethene	µg/m^3	**530**
	1,1,2,2-Tetrachloroethane	µg/m^3	0.74 U
	trans-1,2-Dichloroethene	µg/m^3	2.10 U
	Chloromethane	µg/m^3	0.81
	Chloroethane	µg/m^3	0.71 U
	Chlorobenzene	µg/m^3	0.49 U
	Carbon Tetrachloride	µg/m^3	0.68 U

Legend:

🟥 - Mitigate according to Soil Vapor/Indoor Air Matrices 1 or 2

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

U - Not detectred at or greater than the Reporting Limit (RL)

Table 21
Building 120 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

INDOOR AIR

	Sample ID	B120-A1	B120-A2	A-2 (B120-A2 Dup.)	B120-A3	B120-A4	B120-A5	B120-A6	B120-A7
	Sample Date	2/21/08	2/21/08	2/21/08	2/21/08	2/21/08	2/21/08	2/21/08	2/22/08
COMPOUND	**UNIT**								
Vinyl chloride	µg/m³	0.041 U	0.043 U	0.035 U	0.044 U	0.042 U	0.037 U	0.043 U	0.04 U
1,1-Dichloroethene	µg/m³	0.069	0.19	0.18	0.068 U	0.065 U	0.058 U	0.180	0.40
1,1-Dichloroethane	µg/m³	0.13 U	0.14 U	0.11 U	0.14 U	0.13 U	0.12 U	0.14 U	0.13 U
cis-1,2-Dichloroethene	µg/m³	0.13 U	0.13 U	0.11 U	0.14 U	0.13 U	0.12 U	0.13 U	0.12 U
1,1,1-Trichloroethane	µg/m³	0.22	0.93	0.88	0.55	0.44	0.37	1.10	1.30
1,2-Dichloroethane	µg/m³	0.13 U	0.14 U	0.11 U	0.14 U	0.13 U	0.12 U	0.14 U	0.13 U
Trichloroethene	µg/m³	0.18	0.18 U	0.15	0.18 U	0.18	0.18	0.18 U	0.34
1,1,2-Trichloroethane	µg/m³	0.18 U	0.18 U	0.15 U	0.19 U	0.18 U	0.16 U	0.18 U	0.17 U
Tetrachloroethene	µg/m³	0.57	4.40	4.70	1.10	0.73	0.95	1.60	2.60
1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.23 U	0.19 U	0.23 U	0.22 U	0.20 U	0.23 U	0.22 U
trans-1,2-Dichloroethene	µg/m³	0.64 U	0.67 U	0.54 U	0.68 U	0.65 U	0.58 U	0.67 U	0.63 U
Chloromethane	µg/m³	1.20	1.20	1.10	1.10	1.20	1.00	1.10	1.20
Chloroethane	µg/m³	0.21 U	0.22 U	0.18 U	0.22 U	0.22 U	0.19 U	0.22 U	0.21 U
Chlorobenzene	µg/m³	0.15 U	0.15 U	0.12 U	0.16 U	0.15 U	0.13 U	0.15 U	0.14 U
Carbon Tetrachloride	µg/m³	0.43	0.61 J	0.37 J	0.42	0.21 U	0.44	0.37	0.34

SUB-SLAB

	Sample ID	B120-SS1	B120-SS2
	Sample Date	2/28/08	2/28/08
COMPOUND	**UNIT**		
Vinyl chloride	µg/m³	0.041 U	0.042 U
1,1-Dichloroethene	µg/m³	0.064 U	0.10
1,1-Dichloroethane	µg/m³	0.13 U	0.13 U
cis-1,2-Dichloroethene	µg/m³	0.13 U	0.13 U
1,1,1-Trichloroethane	µg/m³	4.10	9.9
1,2-Dichloroethane	µg/m³	0.13 U	0.13 U
Trichloroethene	µg/m³	5.80	5.5
1,1,2-Trichloroethane	µg/m³	0.18 U	0.18 U
Tetrachloroethene	µg/m³	8.80	16
1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.22 U
trans-1,2-Dichloroethene	µg/m³	0.64 U	0.65 U
Chloromethane	µg/m³	0.17 U	0.17 U
Chloroethane	µg/m³	0.21 U	0.22 U
Chlorobenzene	µg/m³	0.15 U	0.15 U
Carbon Tetrachloride	µg/m³	4.40	**12**

Legend:

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

Table 22
Building 121 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B121-A1 2/20/08	A-1 (B121-A1 Dup.) 2/20/08	B121-A2 2/20/08
	COMPOUND	UNIT			
INDOOR AIR	Vinyl chloride	µg/m^3	0.044 U	0.038 U	0.04 U
	1,1-Dichloroethene	µg/m^3	0.068 UJ	0.14 J	0.11
	1,1-Dichloroethane	µg/m^3	0.14 U	0.12 U	0.13 U
	cis-1,2-Dichloroethene	µg/m^3	0.14 U	0.12 U	0.15
	1,1,1-Trichloroethane	µg/m^3	0.70	0.69	0.70
	1,2-Dichloroethane	µg/m^3	0.14 U	0.12 U	0.13 U
	Trichloroethene	µg/m^3	0.18 U	0.16 U	0.17 U
	1,1,2-Trichloroethane	µg/m^3	0.19 U	0.16 U	0.18 U
	Tetrachloroethene	µg/m^3	0.23 U	0.44	0.88
	1,1,2,2-Tetrachloroethane	µg/m^3	0.23 U	0.20 U	0.22 U
	trans-1,2-Dichloroethene	µg/m^3	0.68 U	0.59 U	0.64 U
	Chloromethane	µg/m^3	1.20	1.40	1.20
	Chloroethane	µg/m^3	0.22 UJ	0.20 U	0.21 U
	Chlorobenzene	µg/m^3	0.16 U	0.14 U	0.15 U
	Carbon Tetrachloride	µg/m^3	0.57	0.41	0.20 U

		Sample ID Sample Date	B121-SS1 2/25/08	B121-SS2 2/25/08
	COMPOUND	UNIT		
SUB-SLAB	Vinyl chloride	µg/m^3	0.039 U	0.042 U
	1,1-Dichloroethene	µg/m^3	0.060 U	0.065 U
	1,1-Dichloroethane	µg/m^3	0.12 U	0.13 U
	cis-1,2-Dichloroethene	µg/m^3	0.92	0.27
	1,1,1-Trichloroethane	µg/m^3	0.40	0.18 U
	1,2-Dichloroethane	µg/m^3	0.12 U	0.13 U
	Trichloroethene	µg/m^3	**65.0**	1.90
	1,1,2-Trichloroethane	µg/m^3	0.16 U	0.18 U
	Tetrachloroethene	µg/m^3	17.0	1.30
	1,1,2,2-Tetrachloroethane	µg/m^3	0.21 U	0.22 U
	trans-1,2-Dichloroethene	µg/m^3	0.60 U	0.65 U
	Chloromethane	µg/m^3	0.22	0.22
	Chloroethane	µg/m^3	0.20 U	0.22 U
	Chlorobenzene	µg/m^3	0.14 U	0.15 U
	Carbon Tetrachloride	µg/m^3	0.32	0.45

Legend:

🟨 - Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

Table 24
Building 124 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B124-A1 2/12/08
	COMPOUND	**UNIT**	
INDOOR AIR	Vinyl chloride	µg/m³	0.044 U
	1,1-Dichloroethene	µg/m³	0.068 U
	1,1-Dichloroethane	µg/m³	0.14 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U
	1,1,1-Trichloroethane	µg/m³	0.19 U
	1,2-Dichloroethane	µg/m³	0.14 U
	Trichloroethene	µg/m³	0.18 U
	1,1,2-Trichloroethane	µg/m³	0.19 U
	Tetrachloroethene	µg/m³	0.23 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U
	Chloromethane	µg/m³	1.10
	Chloroethane	µg/m³	0.41
	Chlorobenzene	µg/m³	0.16 U
	Carbon Tetrachloride	µg/m³	0.61

		Sample ID Sample Date	B124-SS1 2/21/08
	COMPOUND	**UNIT**	
SUB-SLAB	Vinyl chloride	µg/m³	0.041 U
	1,1-Dichloroethene	µg/m³	0.091
	1,1-Dichloroethane	µg/m³	0.13 U
	cis-1,2-Dichloroethene	µg/m³	0.13 U
	1,1,1-Trichloroethane	µg/m³	0.32
	1,2-Dichloroethane	µg/m³	0.13 U
	Trichloroethene	µg/m³	1.80
	1,1,2-Trichloroethane	µg/m³	0.18 U
	Tetrachloroethene	µg/m³	6.30
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U
	trans-1,2-Dichloroethene	µg/m³	0.64 U
	Chloromethane	µg/m³	1.30
	Chloroethane	µg/m³	0.21 U
	Chlorobenzene	µg/m³	0.15 U
	Carbon Tetrachloride	µg/m³	1.00

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 23
Building 123 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B123-SS1 2/25/08
	COMPOUND	**UNIT**	
SUB-SLAB	Vinyl chloride	µg/m³	0.27 U
	1,1-Dichloroethene	µg/m³	0.42 U
	1,1-Dichloroethane	µg/m³	0.85 U
	cis-1,2-Dichloroethene	µg/m³	0.83 U
	1,1,1-Trichloroethane	µg/m³	4.70
	1,2-Dichloroethane	µg/m³	0.85 U
	Trichloroethene	µg/m³	**43.0**
	1,1,2-Trichloroethane	µg/m³	1.10 U
	Tetrachloroethene	µg/m³	**840.0**
	1,1,2,2-Tetrachloroethane	µg/m³	1.40 U
	trans-1,2-Dichloroethene	µg/m³	4.20 U
	Chloromethane	µg/m³	1.40
	Chloroethane	µg/m³	1.40 U
	Chlorobenzene	µg/m³	0.97 U
	Carbon Tetrachloride	µg/m³	2.20

Legend:

🟧	- Mitigate and/or Monitor according to Soil Vapor/Indoor Air Matrices 1 or 2
🟩	- No further action, Mitigate, and/or Monitor according to Soil Vapor/Indoor Air Matrices

U - Not detectred at or greater than the Reporting Limit (RL)

Table 25
Building 126 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	B126-A1 2/12/08	
INDOOR AIR	COMPOUND	UNIT		
	Vinyl chloride	µg/m^3	0.044	U
	1,1-Dichloroethene	µg/m^3	0.068	U
	1,1-Dichloroethane	µg/m^3	0.14	U
	cis-1,2-Dichloroethene	µg/m^3	0.14	U
	1,1,1-Trichloroethane	µg/m^3	0.19	U
	1,2-Dichloroethane	µg/m^3	0.14	U
	Trichloroethene	µg/m^3	0.18	U
	1,1,2-Trichloroethane	µg/m^3	0.19	U
	Tetrachloroethene	µg/m^3	0.23	U
	1,1,2,2-Tetrachloroethane	µg/m^3	0.23	U
	trans-1,2-Dichloroethene	µg/m^3	0.68	U
	Chloromethane	µg/m^3	1.30	
	Chloroethane	µg/m^3	0.22	U
	Chlorobenzene	µg/m^3	0.16	U
	Carbon Tetrachloride	µg/m^3	0.49	

		Sample ID Sample Date	B126-SS1 2/22/08	
SUB-SLAB	COMPOUND	UNIT		
	Vinyl chloride	µg/m^3	0.041	U
	1,1-Dichloroethene	µg/m^3	0.064	U
	1,1-Dichloroethane	µg/m^3	0.13	U
	cis-1,2-Dichloroethene	µg/m^3	2.30	
	1,1,1-Trichloroethane	µg/m^3	0.44	
	1,2-Dichloroethane	µg/m^3	0.13	U
	Trichloroethene	µg/m^3	1.00	
	1,1,2-Trichloroethane	µg/m^3	0.18	U
	Tetrachloroethene	µg/m^3	21.00	
	1,1,2,2-Tetrachloroethane	µg/m^3	0.22	U
	trans-1,2-Dichloroethene	µg/m^3	0.64	U
	Chloromethane	µg/m^3	4.50	
	Chloroethane	µg/m^3	2.10	
	Chlorobenzene	µg/m^3	0.15	U
	Carbon Tetrachloride	µg/m^3	0.20	U

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 26
Building 130 Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID	B130-A1
		Sample Date	2/20/08
INDOOR AIR	COMPOUND	UNIT	
	Vinyl chloride	µg/m³	0.041 U
	1,1-Dichloroethene	µg/m³	0.064 U
	1,1-Dichloroethane	µg/m³	0.13 U
	cis-1,2-Dichloroethene	µg/m³	0.13 U
	1,1,1-Trichloroethane	µg/m³	0.18 U
	1,2-Dichloroethane	µg/m³	0.13 U
	Trichloroethene	µg/m³	1.30
	1,1,2-Trichloroethane	µg/m³	0.18 U
	Tetrachloroethene	µg/m³	0.46
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U
	trans-1,2-Dichloroethene	µg/m³	0.64 U
	Chloromethane	µg/m³	0.87
	Chloroethane	µg/m³	0.21 U
	Chlorobenzene	µg/m³	0.15 U
	Carbon Tetrachloride	µg/m³	0.47

		Sample ID	B130-SS1	B130-SS2
		Sample Date	2/26/08	2/26/08
SUB-SLAB	COMPOUND	UNIT		
	Vinyl chloride	µg/m³	0.044 U	0.43 U
	1,1-Dichloroethene	µg/m³	0.21	0.67 U
	1,1-Dichloroethane	µg/m³	0.14 U	1.40 U
	cis-1,2-Dichloroethene	µg/m³	0.14 U	1.30 U
	1,1,1-Trichloroethane	µg/m³	15.00	7.40
	1,2-Dichloroethane	µg/m³	0.14 U	1.40 U
	Trichloroethene	µg/m³	0.27	**960**
	1,1,2-Trichloroethane	µg/m³	0.19 U	1.80 U
	Tetrachloroethene	µg/m³	19.00	**120**
	1,1,2,2-Tetrachloroethane	µg/m³	0.23 U	2.30 U
	trans-1,2-Dichloroethene	µg/m³	0.68 U	6.70 U
	Chloromethane	µg/m³	0.20	1.70 U
	Chloroethane	µg/m³	0.22 U	2.20 U
	Chlorobenzene	µg/m³	0.16 U	1.50 U
	Carbon Tetrachloride	µg/m³	0.27	2.10 U

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 28
Property Boundary Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	SG-1 2/28/08	SG-2 2/28/08	SG-3 2/28/08	SG-4 2/28/08	SG-5 2/28/08	SG-6 2/28/08
	COMPOUND	**UNIT**						
SOIL VAPOR	Vinyl chloride	µg/m³	0.090 U	0.033 U	0.040 U	0.036 U	0.120	120 U
	1,1-Dichloroethene	µg/m³	0.140 U	0.052 U	0.061 U	0.055 U	0.061 U	39 U
	1,1-Dichloroethane	µg/m³	0.28 U	0.10 U	0.12 U	0.11 U	0.12 U	40 U
	cis-1,2-Dichloroethene	µg/m³	0.28 U	0.15	0.12 U	0.11 U	0.12 U	60 U
	1,1,1-Trichloroethane	µg/m³	0.38 U	0.71	0.24	0.15 U	0.17 U	60 U
	1,2-Dichloroethane	µg/m³	0.28 U	0.10 U	0.12 U	0.11 U	0.12 U	62 U
	Trichloroethene	µg/m³	0.38 U	0.52	0.17 U	0.15 U	0.34	60 U
	1,1,2-Trichloroethane	µg/m³	0.38 U	0.14 U	0.17 U	0.15 U	0.17 U	83 U
	Tetrachloroethene	µg/m³	1.60	1.70	1.6	0.2 U	3.9	96 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.48 U	0.18 U	0.21 U	0.19 U	0.21 U	62 U
	trans-1,2-Dichloroethene	µg/m³	1.40	0.52 U	0.61 U	0.55 U	0.61 U	82 U
	Chloromethane	µg/m³	0.36 U	0.63	0.33	1.20	1.70	83 U
	Chloroethane	µg/m³	0.46 U	0.17 U	0.20 U	0.18 U	0.45	100 U
	Chlorobenzene	µg/m³	0.32 U	0.12 U	0.14 U	0.13 U	0.14 U	70 U
	Carbon Tetrachloride	µg/m³	0.44 U	0.43	0.24	0.55	0.55	100 U

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

Table 27
Off-Site Residences Sampling Results
Supplemental Vapor Intrusion Evaluation - 2008
Watervliet Arsenal, Watervliet, New York

		Sample ID Sample Date	307-IA-01 4/7/08	319-IA-01 4/7/08	411-IA-01* 4/7/08
	COMPOUND	**UNIT**			
INDOOR AIR	Vinyl chloride	µg/m³	0.041 U	0.044 U	0.040 U
	1,1-Dichloroethene	µg/m³	0.064 U	0.068 U	0.061 U
	1,1-Dichloroethane	µg/m³	0.13 U	0.14 U	0.12 U
	cis-1,2-Dichloroethene	µg/m³	0.13 U	0.14 U	0.12 U
	1,1,1-Trichloroethane	µg/m³	0.18 U	0.19 U	0.17 U
	1,2-Dichloroethane	µg/m³	0.13 U	2.50	0.12 U
	Trichloroethene	µg/m³	0.17 U	0.18 U	0.17 U
	1,1,2-Trichloroethane	µg/m³	0.18 U	0.19 U	0.17 U
	Tetrachloroethene	µg/m³	0.38	0.23 U	0.21 U
	1,1,2,2-Tetrachloroethane	µg/m³	0.22 U	0.23 U	0.61 U
	trans-1,2-Dichloroethene	µg/m³	0.64 U	0.68 U	0.63 U
	Chloromethane	µg/m³	1.30	1.10	1.00
	Chloroethane	µg/m³	0.21 U	0.22 U	0.20 U
	Chlorobenzene	µg/m³	0.15 U	0.16 U	0.14 U
	Carbon Tetrachloride	µg/m³	0.55	0.52	0.51

		Sample ID Sample Date	307-SS-01 4/8/08	319-SS-01 4/8/08	999-SS-01 (319-SS-01 Dup.) 4/8/08	411-SS-01* 4/8/08
	COMPOUND	**UNIT**				
SUB-SLAB	Vinyl chloride	µg/m³	0.033 UJ	0.041 U	0.037 U	0.032 UJ
	1,1-Dichloroethene	µg/m³	0.051 UJ	0.064 U	0.058 U	0.050 UJ
	1,1-Dichloroethane	µg/m³	0.10 UJ	0.13 U	0.12 U	0.10 UJ
	cis-1,2-Dichloroethene	µg/m³	0.10 UJ	0.13 U	0.12 U	0.10 UJ
	1,1,1-Trichloroethane	µg/m³	0.35 J	0.74	0.66	0.14 UJ
	1,2-Dichloroethane	µg/m³	0.10 UJ	0.13 U	0.12 U	0.10 UJ
	Trichloroethene	µg/m³	0.14 UJ	0.17 U	0.22	0.14 UJ
	1,1,2-Trichloroethane	µg/m³	0.14 UJ	0.18 U	0.16 U	0.14 UJ
	Tetrachloroethene	µg/m³	1.20 J	0.22 J	2.3 J	0.17 UJ
	1,1,2,2-Tetrachloroethane	µg/m³	0.18 UJ	0.22 U	0.20 U	0.17 UJ
	trans-1,2-Dichloroethene	µg/m³	0.51 UJ	0.64 U	0.58 U	0.50 UJ
	Chloromethane	µg/m³	1.20 J	0.22	0.22	0.98 J
	Chloroethane	µg/m³	0.17 UJ	0.21 U	0.19 U	0.17 UJ
	Chlorobenzene	µg/m³	0.12 UJ	0.15 U	0.13 U	0.12 UJ
	Carbon Tetrachloride	µg/m³	0.83 J	0.20 U	0.18 U	0.53 J

Legend:

U - Not detectred at or greater than the Reporting Limit (RL)

J - Concentration or RL estimated due to Quality Control criteria exceedance

* - Sample name changed from "401" to "411" to correspond with the address of the residence in which the samples were collected from.