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March 25, 2010

Mr. Jason Pelton
New York State Department of Environmental Conservation
625 Broadway
Albany New York 12233

Re: Former Scotia Naval Depot, Town of Glenville, New York
Feasibility Study Report

Dear Mr. Pelton:

On behalf of the General Services Administration (GSA), Malcolm Pirnie, Inc. is pleased to provide you with two copies of the enclosed Feasibility Study Report for the above referenced site. Please contact Thomas Burke at (212) 264-0800 or me at (518) 250-7360 if you have any questions.

Very truly yours,

MALCOLM PIRNIE, INC.

Bruce R. Nelson, C.P.G.
Senior Associate

Enclosure
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c. Thomas Burke - General Services Administration (w/ enclosure)

General Services Administration

26 Federal Plaza • New York, New York 10278

Feasibility Study Report

Former Scotia Naval Depot
Town of Glenville, New York

February 2010

Report Prepared By:

Malcolm Pirnie, Inc.

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List of Acronyms

1,1,1-TCA	1,1,1-Trichloroethane
1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-Dichloroethene
AMC	Army Material Command
ARARs	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
BTEX	Benzene, toluene, ethylbenzene, and xylene
C&D	Construction and Demolition
CCl_4	Carbon Tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	centimeters per second
CO_2	Carbon Dioxide
COC	Chemical Compounds of Concern
CONDEC	Consolidated Diesel Electric Company
CVOCs	Chlorinated Volatile Organic Compounds
DER	Division of Environmental Remediation
DHE	Dehalococcoides ethanogenes
DLA	Defense Logistics Agency
DNSC	Defense National Stockpile Center
DO	Dissolved Oxygen
DW	Dry Well
Earth Tech	Earth Tech, Inc.
ESI	Expanded Site Investigation
ESTCP	Environmental Security Technology Certification Program
ETI	Environmental Technology, Inc.
GEP	Glenville Energy Park
GRAs	General Response Actions
GSA	General Services Administration
GSA	General Services Administration
ISCO	In-situ chemical oxidation
$KMnO_4$	Potassium permanganate
MCLs	Maximum Contaminant Levels
MNA	Monitored Natural Attenuation

MnO_2	Manganese dioxide
MTBE	Methyl tertiary-butyl ether
MW	Monitoring Well
$NaMnO_4$	Sodium permanganate
NAPLs	Non-aqueous Phase Liquids
NOM	Natural Organic Matter
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O & M	Operation and Maintenance
PAHs	Polycyclic aromatic hydrocarbons
Parsons	Parsons Engineering Science, Inc.
PCE	Tetrachloroethene
ppm	part-per-million
PRBs	Permeable Reactive Barriers
PSA	Preliminary Site Assessment
RAGS	Risk Assessment Guidance for Superfund
RAOs	Remedial Action Objectives
$S_2O_8^{2-}$	Persulfate anion
SAT	Site Assessment Team
$SO_4^{2-}\bullet$	Sulfate free radical
SSD	Sub-Slab Depressurization
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TDS	Total Dissolved Solids
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VC	Vinyl Chloride
VOCs	Volatile Organic Compounds
World	World Environmental, Inc.

1. Introduction

This Feasibility Study Report has been developed to screen and evaluate remedial measure alternatives for contaminants in soil and groundwater at the Former Scotia Naval Depot (site) in Scotia, New York (Figure 1 of Appendix A) and on adjacent properties south and west. The purpose of this report is to:

- Identify potentially feasible soil and groundwater remedial technologies;
- Evaluate these technologies based on nine United States Environmental Protection Agency (USEPA) criteria; and
- Compare remedial measure alternatives that could be implemented to meet Remedial Action Objectives (RAOs) and provide site-specific information on performance of the remedial technology.

The preferred remedial alternative for soil and groundwater at the site will be selected based on this evaluation. The goals of this remedy are to:

- Reduce the current or potential threat to human health and the environment caused by soil and groundwater contamination at the site;
- Reduce current or potential exposures to volatile organic compounds (VOCs) as a result of soil vapor intrusion; and
- Limit, to the extent practicable, off-site migration of groundwater that does not attain NYSDEC Class GA Ambient Water Quality Criteria.

1.1. Site History

The Former Scotia Naval Depot is adjacent to the north side of New York State (NYS) Route 5 in the Town of Glenville, Schenectady County, New York (Figure 1). The Former Scotia Naval Depot was built in 1942-43 and was commissioned as a United States Navy facility on March 30, 1943. It served as a storage and supply depot for naval forces along the Atlantic coast and Europe, and as a storage and distribution point for National Stockpile materials. The parcel originally consisted of approximately 337 acres. The facility mostly stored large items such as boilers, turbines, and reduction gears and was the home of the Navy's Landing Craft Maintenance and Battle Damage Program and the Navy's Automotive and Handling Equipment Spare Parts Program. Employment peaked in 1945 at 2,342 personnel. On January 1, 1960 the Navy turned the facility over to the General Services Administration (GSA).

During the period between early 1966 and approximately 1973, the U.S. Army Corps of Engineers/Army Material Command (AMC) leased buildings from the Navy for the fabrication and storage of vehicles as well as other military equipment. GSA records indicate that these included the Larc V Amphibious Lighter. These operations were predominantly conducted in buildings 404, 405, and 406 (see Figure 3 for building numbers) by the AMC contractor, Consolidated Diesel Electric Company (CONDEC).

In early 1968 through 1971 inspections at the CONDEC operation indicated the continuing presence of fire and safety hazards. These included the improper storage of flammables and paints, and the "dangerous air contaminants created or released by open surface dip tank operations."

Additionally, between 1967 and 1969, the GSA and the Navy leased to the United States Army/Defense Supply Agency, Buildings 202 and 203. The agreement indicates these buildings were used for the "preservation and rail loading of trucks; storage of trucks, and ten 6x6 AIC vehicles."

Portions of the Former Scotia Naval Depot have been subdivided and sold over the years by the United States Government. The site now consists of several large privately held parcels in addition to a portion of land still administered by the GSA. The private parcels contain a variety of industrial tenants; while the GSA leases its remaining portion to the Defense Logistics Agency/Defense National Stockpile Center (DLA/DNSC) and the Navy. Documents provided to the USEPA Region 2 Site Assessment Team (SAT), by the DLA/DNSC concerning the disposition of land at the Depot, indicate that:

- The first sale, in early 1972, encompassing approximately 77 acres was to Schenectady Industrial Development; now known as Corporations Park (a.k.a. Galesi Corporation);
- Approximately 126 acres were sold to the Schenectady County Development Agency - Scotia Glenville Industrial Park, in June 1985. Additionally, in June 1985, approximately 27 acres were sold to the Galesi Corporation and was added to Corporations Park;
- In mid - 1988, approximately 36 acres were separated to the Navy and the Depot retained the remainder of the GSA administered land as the DLA;
- GSA sold approximately 11.5 acres of the Depot to the Schenectady County Development Agency in July 1997; and
- The Navy currently occupies approximately 14.2 acres and the DLA/DNSC occupies approximately 59.7 acres.

Figures in Appendix A show the approximate boundaries of the Former Scotia Naval Depot when established in 1942 and the approximate current property boundaries. The Former Scotia Naval Depot is owned by the General Services Administration (GSA) and operated by the Defense National Stockpile Center (DNSC). Throughout this report, the assemblage of properties is collectively referred to as the Former Scotia Naval Depot. Where necessary, individual blocks or sub-blocks within the Former Scotia Naval Depot are referenced to orient the reader geographically.

1.2. Site Geology and Hydrogeology

The site overlies a USEPA designated Sole Source Aquifer referred to as the Schenectady or Great Flats Aquifer system, which is adjacent to and extends beneath the Mohawk River over a distance of approximately 12 miles in Schenectady County. Relative to a series of four aquifer protection zones established to protect municipal water supplies relying on the aquifer system, the site lies in Zone III, or the General Aquifer Recharge Area. The Former Scotia Naval Depot is located approximately 1,500 feet southwest of the Village of Scotia well field and approximately 1.25 miles north of the Town of Rotterdam and City of Schenectady well fields, as shown on Figure 1 of Appendix A. On an average day, these three well fields withdraw greater than 20 million gallons of water from the Great Flats Aquifer system.

The Great Flats Aquifer is within the Mohawk Lowlands Physiographic province which includes the Mohawk Valley and the uplands to the north (Glenville hills) and the south (Rotterdam hills). At its widest point near the Village of Scotia and the Town of Rotterdam (just west of the City of Schenectady), the aquifer is approximately three miles wide. The deepest portion of the aquifer is near the Former Scotia Naval Depot where the sand and gravel is more than 200 feet thick. The depth below ground surface to the top of bedrock ranges from approximately 70 to 200 feet in the vicinity of the Former Scotia Naval Depot although no borings have been drilled to bedrock at the site. Five municipalities (City of Schenectady, Village of Scotia, and the Towns of Glenville, Niskayuna, and Rotterdam) rely on the Great Flats Aquifer system as a source of drinking water.

In most locations, the Great Flats Aquifer is predominantly comprised of sand and gravel with an average thickness of approximately 100 feet. The material has commonly been classified as a glacial outwash deposit although the sand and gravel was deposited in a fluvial environment. Specifically, the coarse sand and gravel was transported and deposited nearly 10,000 years ago when there was a catastrophic release of glacial lake water down the Mohawk Valley from Glacial Lake Albany. Within the sand and gravel deposits, there are occasional localized fine sand and silty clay lenses and zones of coarse gravel and cobbles. The sand and gravel is underlain by a dense till deposit.

The Mohawk River is located approximately 1,500 feet west-southwest of the Former Scotia Naval Depot and represents the regional groundwater discharge feature. The water table beneath the Former Scotia Naval Depot is approximately 65 to 70 feet below ground surface (bgs) and flows from northeast to southwest across the majority of the site toward the Mohawk River. The surface water elevation of the Mohawk River is controlled by the operation of the New York State Canal Lock 8, located approximately 2,500 feet south of the Former Scotia Naval Depot. During the navigation season (approximately April to November), the gates at Canal Lock 8 are used to maintain an approximate 12-foot head differential between the upper pool and the lower pool. During the non-navigation season (November to April), the gates at Canal Lock 8 are opened to maintain a less than two-foot head differential between the upper and lower pools. Although the operation of Canal Lock 8 has a direct influence on both surface water flow and groundwater flow in the immediate vicinity of the New York State Canal, the canal does not have a major impact on groundwater flow beneath the Former Scotia Naval Depot site.

1.3. Previous Investigations and Response Activities

A dissolved phase trichloroethene (TCE) plume is known to exist in the groundwater under the Former Scotia Naval Depot and multiple adjacent properties at a depth of approximately 65 to 70 feet bgs. In general, the dissolved phase TCE plume is narrow, approximately 2,500 feet in length, and trends in a northeast-southwest direction from the site to the Mohawk River. Although anecdotal evidence indicates that solvents, including TCE, were used at the Naval Depot, no specific disposal areas have been identified.

1.3.1. Investigations

Since approximately 1995, six separate subsurface investigations have been completed to identify a source area for the TCE contamination and to delineate the margins of the TCE groundwater plume.

In response to the detection of TCE at concentrations less than 1 µg/l and the New York State Standard (5 µg/l) in the Town of Rotterdam and City of Schenectady well fields, the New York State Department of Health (NYSDOH) performed private water supply sampling in 1991. The private water supply sampling included residences located on Amsterdam Road (NYS Route 5) in the Town of Glenville, Schenectady County, New York. These private residences are located southwest of and hydraulically downgradient of the Former Scotia Naval Depot. Volatile organic compounds (VOC's), including TCE, 1,1,1-Trichloroethane (1,1,1-TCA), and tetrachloroethene (PCE), were detected in groundwater collected in some of the residential wells. Consistent with the known groundwater plume at the Former Scotia Naval Depot site, TCE was the primary VOC detected in the residential well water samples (at concentrations as high as 320 ug/l).

Subsequent to the NYSDOH residential groundwater sampling, six subsurface investigations were completed to identify the possible source of TCE in the residential wells and possibly the Town of Rotterdam and City of Schenectady municipal well fields. The six investigations focused on the properties comprising the former 337- acre Scotia Naval Depot. Each of the investigations was summarized in the Expanded Site Investigation Report and is included in the following chronological summary:

NYSDEC Building 15 Preliminary Site Assessment

In 1995 the New York State Department of Environmental Conservation (NYSDEC) performed a Preliminary Site Assessment (PSA) at the Former Scotia Naval Depot (Site I.D. No. 447023). The PSA focused on Building 15 and the 200 Block. Figure 3 shows the overall layout of the Former Scotia Naval Depot with each of the major blocks (e.g. 200, 300, and 400 Blocks, etc.). The 1995 PSA fieldwork included the collection and analysis of surface and subsurface soil samples, sediment samples, and a surface water sample. The PSA additionally included the installation of 12 groundwater monitoring wells (MW-2 through MW-13) and the sampling and analysis of 19 groundwater samples from both existing and newly installed monitoring wells and from three residential wells located on the south-side of Amsterdam Road, downgradient of the Former Scotia Naval Depot.

TCE and TCE degradation compounds (cis-1,2-dichloroethene and vinyl chloride) were detected in groundwater samples collected from the three residential wells on Amsterdam Road and downgradient from the Former Scotia Naval Depot at concentrations ranging from 94 to 180 ug/l. These residential wells were not used for drinking water at the time of the study. TCE was detected at a maximum concentration of 290 ug/L in groundwater collected from on-site monitoring well MW-13 in February 1997.

The distribution of TCE in groundwater indicated the presence of a narrow TCE plume trending northeast to southwest generally along the line of monitoring wells MW-13 and MW-6 and the residential wells on NYS Route 5. The groundwater quality data and the groundwater flow data suggested a TCE source northeast of MW-13 and outside of the PSA study area. A possible source northeast of MW-13 was consistent with statements given by former employees at the Naval Depot that solvents were used and stored in the area of the 400 Block of buildings.

Glenville Energy Park Phase I and Phase II Site Investigations

As part of an investigation for a proposed electrical generation facility referred to as the Glenville Energy Park (GEP), Earth Tech, Inc. (Earth Tech) performed an investigation at the 300 Block in 1999 and 2000 to further delineate the dissolved TCE groundwater plume laterally and vertically. The investigation included a geophysical and soil gas survey, a test pit program, and a subsurface drilling program. The drilling program included the installation of three groundwater monitoring wells (originally identified as MW-99-14, MW-99-15, and MW-99-16, but currently identified as MW-14, MW-15, and MW-16), and the analysis of soil and groundwater samples.

Based on the groundwater sampling program, the highest concentration of TCE (390 ug/l) was detected in groundwater monitoring well MW-15 located along the property line separating the 300 Block (parcel for proposed Glenville Energy Park) from the 400 Block (current Scotia Naval Depot parcel). Earth Tech concluded that the source for the TCE was likely to be hydraulically upgradient from the 300 Block.

Groundwater Investigation at the Scotia Naval Depot

A Groundwater Investigation at the Former Scotia Naval Depot was performed by Parsons Engineering Science, Inc. (Parsons) in 2000 to evaluate a potential off-site source of TCE (a disposal area referred to as the Sacandaga Road Landfill) and to assess the lateral and vertical extent of the TCE plume (Figure 3). The investigation was completed by Parsons and funded jointly by GSA and the DNSC. The GSA represented the owners of the Former Scotia Naval Depot and the DNSC represented the depot operators. The investigation included a test pit program, a drilling program including the installation of five groundwater monitoring wells, and a groundwater sampling program. Three groundwater monitoring wells (PMW-1, PMW-2, PMW-3 on Figure 4) were installed along the northern property line separating the Former Scotia Naval Depot from the Sacandaga Road Landfill. Two additional groundwater monitoring wells, referred to as sentinel wells for the City of Schenectady and Town of Rotterdam well fields, were installed in Maalwyck Park (PMW-6 and PMW-7). PMW-7 is shown on Figure 4. PMW-6 is located approximately 2,300 feet south of PMW-7. No VOCs were detected in groundwater samples collected from PMW-6 or PMW-7 at concentrations greater than respective New York State standards.

Groundwater samples were collected for laboratory analysis from groundwater monitoring wells in August and November 2000. TCE was detected by the laboratory at concentrations less than the laboratory detection limit in two of the groundwater samples from wells located along the upgradient property line (PMW-1 and PMW-2).

The Former Scotia Naval Depot Groundwater Investigation concluded that since high concentrations of TCE were not detected in wells PMW-1, PMW-2, and PMW-3, the Sacandaga Road Landfill did not represent the source of the TCE plume. The Parsons groundwater investigation also included a Monte Carlo simulation to identify probable TCE source areas. Based on the assessment of data and the Monte Carlo simulation, Parsons concluded that a high probability exists that the source of the TCE occurs in a currently vacant area of the 300-series Block. This conclusion was inconsistent with earlier conclusions presented by Earth Tech, Inc. as part of the Glenville Energy Park Project at the 300-series Block. Earth Tech had concluded that the source for the TCE was likely to be hydraulically upgradient from the 300 Block.

Sacandaga Road Landfill Investigation

The Sacandaga Road Landfill is a 16.6-acre parcel located north and east of the Former Scotia Naval Depot and the Scotia-Glenville Industrial Park in the Town of Glenville (Figure 3). The overall purpose of the Sacandaga Road Landfill investigation was to properly assess and classify the site according to one of the hazardous waste site categories pursuant to Section 27-1305 of the Environmental Conservation Law (e.g. Class 1, Class 2, etc.). The investigation was additionally performed to further evaluate if the Sacandaga Road Landfill represents the source area for the TCE groundwater plume. To meet these objectives, the NYSDEC performed a Preliminary Site Assessment in 2002. The investigation included a geophysical survey, a test pit program, and the collection and laboratory analysis of soil samples, and four drum liquid samples. To evaluate groundwater quality hydraulically downgradient from the Sacandaga Road Landfill, the investigation relied on groundwater quality data from the contemporaneous investigation at the Former Scotia Naval Depot (being performed by Parsons as described above). As detailed above, the Former Scotia Naval Depot investigation included the installation of five groundwater monitoring wells, including three monitoring wells (PMW-1, PMW-2, and PMW-3 on Figure 4) adjacent to the property line separating the Depot from the Sacandaga Road Landfill site.

During a site reconnaissance prior to the investigation, it was discovered that the Sacandaga Road Landfill site contained various construction and demolition (C&D) debris including railroad ties, roofing material, blocks of cement, pallets, and several piles containing ruptured drums. Drums were found to be randomly scattered near the Former Scotia Naval Depot fence line within the wooded area and along ravine slopes. As part of the test pit program, 16 soil samples were collected from 26 test pits and submitted for laboratory analysis. Fifteen of the 16 samples contained VOCs. TCE was present in two soil samples (96 ug/kg and 160 ug/kg) from one test pit location on the Sacandaga Road Landfill property. Additional VOCs detected in test pit soil samples included 1,2-dichloroethene (9 ug/kg to 13 ug/kg) and tetrachloroethene (3 ug/kg - 260 ug/kg).

As described under the Former Scotia Naval Depot Investigation, based on the absence of high TCE concentrations in monitoring wells PMW-1, PMW-2, and PMW-3, the investigation concluded that the Sacandaga Road Landfill did not represent the TCE source.

Glenville Energy Park Supplemental Investigation

To expand on the initial Phase II investigation, Earth Tech, Inc. completed a Supplemental Investigation at the 300 Block for the proposed Glenville Energy Park (GEP) in mid-2000. The Supplemental Investigation focused on further delineating the TCE groundwater plume, identifying a source area for the TCE, and confirming or denying the hypothesis by Parsons that the source of the TCE is in the 300-series Block. The Earth Tech Supplemental Investigation included the completion of a geophysical survey, soil gas survey, test pit program, and a groundwater investigation. The groundwater investigation included the installation of four groundwater monitoring wells identified as GEP-1, GEP-2, GEP-3, and GEP-4 (Figure 4) and the collection and analysis of groundwater samples collected from these four newly installed wells and from six existing wells.

The highest concentration of TCE (880 ug/l) was detected in GEP-2 located adjacent to the eastern property boundary (Figure 4). GEP-2 represents the monitoring well located at the most hydraulically upgradient groundwater sampling point of the 300 Block. TCE concentrations decreased with distance hydraulically downgradient of GEP-2. The investigation report concluded that no evidence was acquired suggesting that the source of the TCE is in the GEP parcel (300-series Block). Instead, the additional data further suggested a source area upgradient (northeast) from the 300 Block.

Expanded Site Investigation

The NYSDEC and GeoLogic, Inc. completed an Expanded Site Investigation (ESI) at the Former Scotia Naval Depot site between September 2004 and December 2005. Select figures from the ESI Report are provided in Appendix A. The ESI was specifically completed to attempt to determine:

- If potential soil gas vapors from a known TCE groundwater plume were impacting indoor air quality at private residences located on the south-side of Amsterdam Road (New York State Route 5);
- The source of TCE identified in off-site private residential water supply wells, on-site and off-site groundwater monitoring wells; and
- The source of TCE periodically detected less than the drinking water standard in the Town of Rotterdam well field and historically detected less than the drinking water standard in the City of Schenectady well field.

The ESI data indicated that TCE disposal occurred in the northeast corner of the 401 sub-block and the area near the north corner of the 403 sub-block. The groundwater and soil gas analytical results suggest that disposal may be related to the storm and sanitary sewer lines. Specifically, both of these 400 Block areas contained the highest concentrations of TCE during the passive and active soil gas surveys completed during the ESI. The soil gas data is further supported by the groundwater analytical data. For the first time, TCE was detected in groundwater (260 ppb in MW-18 and 200 ppb in MW-20) upgradient from the series of monitoring wells located along the border between the 300 and 400 Blocks (GEP-1, GEP-2, and GEP-3). Additionally, low levels of TCE were detected in soil samples collected from the vadose zone in these areas during the installation of monitoring well MW-18 and in soil samples collected during the test pitting program. Although high levels of TCE were not detected in the vadose zone soil samples, the presence of low levels of TCE in the vadose zone soil samples suggest that a TCE release had occurred. The ESI data suggested that the historic release of TCE in these areas is responsible for the TCE groundwater plume that trends northeast-southwest across the Former Scotia Naval Depot and off-site beneath the residential area along New York State Route 5.

In addition to the dissolved phase TCE plume, data collected as part of the ESI, and from past investigations, suggest that an east-west trending carbon tetrachloride (CCl_4) groundwater plume is also present beneath the Former Scotia Naval Depot site. The CCl_4 plume is located offset and to the north of the TCE plume. CCl_4 was detected in monitoring wells MW-5, MW-8, MW-11, MW-12, and PMW-3 at concentrations ranging from 1 to 10 µg/l. The groundwater sampling results, along with the results of previous investigations, suggest that the source of the CCl_4 was likely related to a former drywell near the northeast corner of the 300 Block. Shallow soil and sediment samples collected in this area contained CCl_4, indicating that historic disposal of CCl_4 in the drywell and associated drainage lines may have occurred in this area. Although only marginally greater than the groundwater quality standard of 5 µg/l, it was concluded that the CCl_4 groundwater plume could be impacting the quality of sub-slab and indoor air at residential properties located above the plume.

Groundwater sampled from monitoring wells MW-14, MW-17, and MW-21, located along the western margin of the TCE plume, contained the highest concentrations of PCE, 1,1,1-TCA, and 1,1-DCA. The ESI Report concluded that historic operations in the general area of the burn pit, located in the 301 sub-block, may represent a source for these low levels of additional chlorinated volatile organic compounds (CVOCs).

Summary of Previous Investigations

Subsurface investigations at the Former Scotia Naval Depot have been completed in response to the detection of TCE in both nearby municipal well fields and individual domestic water supply wells. In total, six separate investigations were completed to identify a source for the TCE in groundwater and delineate the extent of the TCE groundwater plume. Analytical data indicates that TCE disposal occurred in the northeast corner of the 401 sub-block and the area near the north corner of the 403 sub-block. It was determined that the TCE plume trends northeast to southwest across the

300 Block toward the Mohawk River. The highest TCE concentrations were consistently detected in monitoring wells GEP-2, located along the boundary between the 300 Block and the 400 Block, and MW-13, located along the boundary between the 303 and 304 sub-blocks. The investigations documented a persistent TCE groundwater plume with a length of at least 2,500 feet and a width of approximately 500 feet. Data also indicates that a separate northeast-southwest trending CCl_4 groundwater plume from a separate source is also present beneath the Former Scotia Naval Depot site, with a potential source near the northeast corner of the 300 Block.

1.3.2. Soil Removals

The DNSC has completed two removal projects aimed at returning the site to its original soil quality condition. Soils were removed from around the former ferrochrome and lead/zinc open storage areas, located in the 402 and 301 sub-blocks, respectively. The excavated soils were disposed as nonhazardous solid waste, and the excavations were backfilled with native soil that was shown to be consistent with background soil quality. Two dry wells and a storm water catch basin were removed from the vicinity of the former lead/zinc open storage area. The excavated materials were disposed as nonhazardous solid waste, and the excavations were backfilled with native soil that was shown to be consistent with background soil quality. Six other catch basins were decommissioned and backfilled with native soil. All work was conducted in consultation with NYSDEC and USEPA. Control of the parcel in which these former open storage areas are located has been returned to the property owner, the GSA.

The June 2006 Soil and Dry Well Removal Documentation Report describes the procedures and results of a soil removal action at the former lead/zinc and ferrochrome open storage areas at Former Scotia Naval Depot. DNSC voluntarily removed the soils immediately adjacent to the two storage pads as a good-faith effort to improve soil quality and to return the property to approximately its original soil quality condition.

In the former lead/zinc storage area, the metals concentrations in soils around and beneath the asphalt pad were slightly above background concentrations prior to soil removal activities. The soil quality did not pose a threat to human health or the environment. In addition, the asphalt pad acts as a cover over the soil, restricting the possibility of direct contact with, or migration of the soil. The removal action at the former lead/zinc storage area consisted of scraping a layer of soil/sediment off the top of the asphalt surface from around the outside perimeter of the fenced storage area. At the east end of the storage area, the edge of the asphalt pad is closer to the fence line. In that area the top two feet of soil was removed, extending out about five feet from the edge of the pad.

In the former ferrochrome storage area, the soils adjacent to the concrete pad contained metal concentrations slightly greater than background concentrations prior to the soil being excavated and disposed of. The soil quality did not pose a threat to human health or the environment. However, DNSC chose to voluntarily remove the soil in a good-faith effort to improve soil quality and to return the property to approximately its original soil-quality condition. The top two feet of soil, extending five feet out from the perimeter of the concrete pad, were removed.

The removal action at the former lead/zinc and ferrochrome open storage areas at the Former Scotia Naval Depot involved excavation of approximately 560 tons of soil. Excavated soil was deposited directly into trucks for transportation and disposal as nonhazardous solid waste in the Colonie Landfill, a local municipal sanitary landfill. The soil was excavated with a backhoe by depot employees. Around much of the lead/zinc storage area, there was a layer of soil on top of the asphalt pad. That soil was scraped up and disposed with the other excavated soils. To the extent possible, operators were careful to not excavate asphalt with the soil. Given the shallow excavation depths, groundwater was not encountered during the removal action. The removal areas were re-graded using native backfill soils, as needed. The source of the native backfill soils was an undisturbed area of the Depot, which is located east of the former lead/zinc open storage area.

A series of storm water catch basins, seven of which drain to two dry wells, were in place in the vicinity of the former lead/zinc open storage area. Most of this drainage system was in place since the depot was built in the early 1940s. Dry wells are subsurface structures, often constructed with wood, metal or concrete conduit, that act as a basin where surface water can collect and infiltrate into the ground.

Dry wells in New York State that are in areas where groundwater is a drinking water source are regulated by the USEPA, and are considered underground injection points. The Former Scotia Naval Depot is located over a sole-source drinking water aquifer. After consultation with NYSDEC and USEPA, DNSC chose to decommission and remove the two dry wells located around the perimeter of the former lead/zinc storage area. DNSC also chose to remove or backfill the seven catch basins that drain to the two dry wells.

On November 28, 2005, World Environmental, Inc. (World), a contractor for DNSC, excavated the two dry wells (DW-1 and DW-2) and one catch basin. The excavated soil and dry well/catch basin materials were disposed as solid waste at the City of Albany Landfill. The dry well/catch basin excavations were then backfilled with soil from the nearby source on the depot. Four catch basins were also backfilled by World, and two catch basins were subsequently backfilled by depot employees.

1.4. Nature and Extent of Contamination

1.4.1. Contaminants of Concern

Based on the information collected during previous investigations, chemical compounds of concern (COC) by environmental medium have been identified. COCs were selected based on frequency of detection, range of concentration, and potential for migration. There are no identified remaining sources of soil contamination, therefore no soil COCs have been identified. TCE is the primary COC in groundwater. Other chlorinated compounds that have also been detected in groundwater samples collected from the Former Scotia Naval Depot include tetrachloroethene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), CCl_4, 1,1-dichloroethene (1,1-DCE) and 1,1-dichloroethane (1,1-DCA).

1.4.2. Soil Contamination

Low levels of TCE were detected in soil samples collected from the vadose zone along the border between the 300 and 400 Blocks during the installation of monitoring well MW-18 and in soil samples collected during the test pit program. Although high levels of TCE were not detected in the vadose zone soil samples, the presence of low levels of TCE in the vadose zone soil samples suggest that a TCE release had occurred.

As discussed in Section 1.3.2, soil contamination source removal actions were conducted at the former lead/zinc and ferrochrome open storage areas and at the two dry wells and catch basins. No additional contamination sources in the soil have been identified. As such, soil remedial measures at the Former Scotia Naval Depot are not considered further in this Feasibility Study.

1.4.3. Groundwater Contamination

Groundwater at the site flows to the south and west toward the Mohawk River. The TCE groundwater plume extends east to west across the 300 Block toward the Mohawk River over a distance of approximately 2,700 feet. At its widest point, the TCE groundwater plume is approximately 700 feet in width. On the Former Scotia Naval Depot property, the highest TCE concentrations (approximately 800 µg/l) have consistently been detected in groundwater sampled from monitoring wells located at the boundary between the 300 and 400 Blocks. Off-site, TCE has been consistently detected in out-of-service residential water supply wells at concentrations ranging from 50 to 100 µg/l. The ESI concluded that the source of TCE in the site groundwater was related to historic TCE disposal in the northeast corner of the 401 sub-block and the area near the north corner of the 403 sub-block.

In addition to the TCE groundwater plume, data collected as part of the ESI, and from past investigations, suggest that a northeast-southwest trending CCl_4 groundwater plume is also present beneath the Former Scotia Naval Depot. The CCl_4 plume is located offset and to the north of the TCE plume and likely extends off-site. Data suggest that a source for the CCl_4 exists near the northeast corner of the 300 Block. CCl_4 was detected in monitoring wells MW-5, MW-8, MW-11, MW-12, and PMW-3 at concentrations ranging from 1 ppb to 10 ppb. Shallow soil and sediment samples collected by NYSDEC in this area contained CCl_4, indicating that historic disposal of CCl_4 in the drywell and associated drainage lines may have occurred in this area. Although only marginally greater than the groundwater quality standard of 5 µg/l, air sampling results indicate that the CCl_4 groundwater plume is impacting the quality of sub-slab and indoor air at residential properties located above the plume.

The highest concentrations of PCE, 1,1,1-TCA, and 1,1-DCA have been present in monitoring wells MW-14, MW-17, and MW-21. These wells are located along the western margin of the TCE plume and suggest a separate source. The ESI Report concluded that historic operations in the general area of the burn pit, located in the 301 sub-block, may represent a source for these low levels of additional CVOCs identified in monitoring wells along the western margin of the TCE plume.

1.4.4. Potential Exposure Pathways

The four elements that must be present in order for an exposure pathway to be complete are:

- A source and mechanism of chemical release to the environment;
- An environmental transport mechanism (e.g., leaching from soil to groundwater);
- A point of receptor contact; and
- An exposure route (i.e., ingestion, dermal contact, or inhalation).

Since groundwater under the Former Scotia Naval Depot is approximately 65 feet bgs and is not used for drinking water, dermal contact with or ingestion of groundwater is unlikely to be an exposure pathway. However if there are no institutional controls in place limiting groundwater use at the site, the potential does exist for exposure. Currently dermal contact with or ingestion of surface and subsurface soils are not considered potential exposure pathways because they are inaccessible or soil VOC sources have been removed.

Soil vapor/indoor air intrusion is a potential exposure pathway above the TCE and CCl_4 plumes. The basic model for soil vapor intrusion into a building is vertical migration from a subsurface source through cracks, foundation joints, or other openings in the floor. As discussed in Section 1.4, groundwater at the Former Scotia Naval Depot contains

TCE, CCl_4 and several other VOCs. The results of the soil vapor intrusion evaluation (as part of the ESI) indicate off-site groundwater is not influencing the quality of indoor air at homes that directly overlie or that are near the TCE plume. Low levels of CCl_4 in a dissolved phase plume offset to the west of the TCE plume, however, are potentially influencing both sub-slab and indoor air quality. The vapor intrusion pathway has not been evaluated on-site.

2. Remedial Action Objectives and Evaluation Criteria

This section outlines the Remedial Action Objectives (RAOs) proposed for the final site-wide remedy, and the Applicable or Relevant and Appropriate Requirements (ARARs) to be considered in addressing the RAOs.

2.1. Remedial Action Objectives

For the purposes of this feasibility study and based on the results of previous site investigations, the RAOs for the site are:

- Eliminate, to the extent practicable, off-site migration of groundwater that does not attain NYSDEC Class GA Ambient Water Quality Criteria;
- Attain, to the extent practicable, New York State Class GA Groundwater Standards for both on-site and off-site groundwater; and
- Eliminate, to the extent practicable, exposures to volatile organic compounds as a result of soil vapor intrusion.

2.2. Applicable or Relevant and Appropriate Requirements

ARARs consistent with appropriate Federal and NYSDEC guidance are listed in this section. "Applicable" requirements are those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. "Relevant and appropriate" requirements are those clean-up standards which, while not "applicable" at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. ARARs can be action specific, location-specific, or chemical-specific.

The principal ARARs for the site include:

General:

6 NYCRR Part 375 – Environmental Remediation Programs, including the Inactive Hazardous Waste Disposal Site Remedial Program

6 NYCRR Part 371 – Identification and Listing of Hazardous Wastes

NYSDEC Division of Environmental Remediation (DER) policy, DER-15: Presumptive/ Proven Remedial Technologies.

Risk Assessment Guidance for Superfund, Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk- Based Preliminary Remediation Goals), (RAGS, EPA-540/R-92/003, OSWER Directive 9285.7-01B, December 1991)

Soil:

- 6 NYCRR Part 375 – Soil Clean-up Objectives
- 6 NYCRR Part 376 – Land Disposal Restrictions
- NYSDEC Division of Solid and Hazardous Materials TAGM 3028 “Contained-in” Criteria for Environmental Media (8/97)

Water:

- 6 NYCRR Part 700-705, Water Quality Regulations for Surface Water and Groundwater
- NYSDEC Division of Water TOGS 1.1.1 – Ambient Water Quality Standards and Groundwater Effluent Limitations

Air:

- NYSDEC Division of Air Resources Policy DAR-1 – Guidelines for Control of Toxic Ambient Air Contaminants
- 6 NYCRR Part 212 – General Process Emissions Sources
- NYSDOH October 2006 Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York

2.3. Evaluation Criteria

The remedial measure alternatives developed in this Feasibility Study will be screened based on an evaluation of the following criteria:

- Overall Protection of Human Health and the Environment;
- Compliance with ARARs;
- Long-term Effectiveness and Permanence;
- Reduction of Toxicity, Mobility, and Volume;
- Short-term Effectiveness;
- Implementability;
- Cost;
- State (or Support Agency) Acceptance; and
- Community Acceptance.

Overall Protection of the Human Health and the Environment

This criterion serves as a final check to assess whether each alternative meets the requirements that are protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under other evaluation criteria; especially long-term effectiveness and performance, short-term effectiveness, and compliance with ARARs. This evaluation focuses on how a specific alternative achieves protection over time and how site risks are reduced. The analysis includes how each source of contamination is to be eliminated, reduced or controlled for each alternative.

Compliance with ARARs

This evaluation criterion determines how each alternative complies with applicable or relevant and appropriate requirements, as discussed and identified in Sections 3 and 4 of this Report. The actual determination of which requirements are applicable or relevant and appropriate is made by the General Services Administration in consultation with the NYSDEC and NYSDOH. If an ARAR is not met, the basis for one of the four waivers allowed under 6 NYCRR Part 375-1.10(c)(i) is discussed. If an alternative does not meet the ARARs and a waiver is not appropriate or justifiable, such an alternative should not be considered further.

Short-term Effectiveness

This evaluation criterion assesses the effects of the alternative during the construction and implementation phase. Alternatives are evaluated with respect to the effects on human health and the environment during implementation of the remedial action. The aspects evaluated include: protection of the community during remedial actions, environmental impacts as a result of remedial actions, time until the remedial response objectives are achieved, and protection of workers during the remedial action.

Long-term Effectiveness and Permanence

This evaluation criterion addresses the results of a remedial action in terms of its permanence and quantity/nature of waste or residual remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the waste or residual remaining at the site and operating system necessary for the remedy to remain effective. The factors being evaluated include the permanence of the remedial alternative, magnitude of the remaining risk, adequacy of controls used to manage residual waste, and reliability of controls used to manage residual waste.

Reduction of Toxicity, Mobility, and Volume

This evaluation criterion assesses the remedial alternative's use of the technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous wastes as their principal element. The NYSDEC's policy is to give preference to alternatives that eliminate any significant threats at the site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in the contaminants mobility, or reduction of the total volume of contaminated media. This evaluation includes: the amount of the hazardous materials that would be destroyed or treated, the degree of expected reduction in toxicity, mobility, or volume measured as a percentage, the degree in which the treatment would be irreversible, and the type and quantity of treatment residuals that would remain following treatment.

Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. The evaluation includes: feasibility of construction and operation; the reliability of the technology; the ease of undertaking additional remedial action; monitoring considerations; activities needed to coordinate with other offices or agencies; availability of adequate off-site treatment, storage, and disposal services; availability of equipment; and the availability of services and materials.

Cost

Cost estimates are prepared and evaluated for each alternative. The cost estimates include capital costs, operation and maintenance (O&M) costs, and future capital costs. A cost sensitivity analysis is performed which includes the following factors: the effective life of the remedial action, the O&M costs, the duration of the clean-up, the volume of contaminated material, other design parameters, and the discount rate. Cost estimates developed at the detailed analysis of alternatives phase of a feasibility study generally have an expected accuracy range of –30 to +50 percent (USEPA, 2000).

State (or support agency) Acceptance

A draft Feasibility Study will be submitted to the GSA and the NYSDEC for review and comment. Malcolm Pirnie will include the requested edits in the final document. The GSA and NYSDEC will review, comment on, and approve the final Feasibility Study.

Community Acceptance

GSA and NYSDEC will discuss the results of the feasibility study and if applicable, prospective developers or municipal entities may also be involved in these discussions. This evaluation will lead to the selection of a proposed site remedy, which will be presented in a report for public review. Community concerns regarding the proposed site remedy will be evaluated by the NYSDEC and GSA. After this review, a final remedy will be selected and publicized. If the final remedy selected differs significantly from the proposed remedy, public notices will include descriptions of the differences and the reason for the changes.

3. Identification and Screening of Technologies

General response actions (GRAs) are remedial technologies that have the potential to satisfy the RAOs as discussed in Section 2. In this section the GRAs are described in general and are screened for their implementability and applicability to the site. Based on this screening, GRAs are retained or not retained for further consideration.

Technology types include such general categories as treatment or containment, whereas process options are specific processes within the general technology types (e.g., treatment via chemical oxidation, or containment using a treatment barrier). This section develops a list of potential technology types and process options for treatment and/or containment of groundwater impacted by VOCs in groundwater at the site. The retained technologies and process options are subsequently evaluated based on the evaluation criteria discussed in Section 2.

The GRA evaluated for soil vapor intrusion is the installation of sub-slab depressurization (SSD) systems for affected off-site and on-site structures. SSD systems could also be included in the design for future structures to be constructed on-site, specifically in the 300 block.

GRAs for groundwater treatment identified for evaluation include:

- No Further Action;
- Monitored Natural Attenuation (MNA);
- Biodegradation/Enhanced Biodegradation;
- In-Situ Chemical Oxidation;
- Groundwater Extraction;
- Containment/Barrier Technologies;
- Air Sparge/Soil Vapor Extraction; and
- In-well Air Stripping.

3.1. No Further Action

The “no further action” option, by definition, involves no further institutional controls, environmental monitoring, or remedial action, and, therefore, includes no technological barriers. The no further action option does not include groundwater monitoring to evaluate the effects of any natural attenuation processes at the site.

Although the no further action option would be unable to meet the RAOs, it will be retained to provide a basis for comparison to other remedial technologies.

3.2. Monitored Natural Attenuation (MNA)

MNA, also known as intrinsic remediation, bioattenuation, or intrinsic bioremediation, refers specifically to the use of natural processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, as part of overall site remediation. MNA is a non-engineered remedial technique, which involves the degradation of the VOCs in the groundwater by naturally occurring processes (i.e., biodegradation). Such degradation is monitored over time under a long-term monitoring program.

Consideration of this option usually requires evaluating contaminant degradation rates and pathways and predicting contaminant concentrations at downgradient receptor points. The primary objective of this evaluation would be to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. Long-term monitoring should be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting clean-up objectives.

MNA is not the same as “No Further Action”, although it often is perceived as such. CERCLA requires evaluation of a no further action alternative but does not require evaluation of MNA. MNA is considered on a case-by-case basis. In all cases where MNA is being considered, extensive site characterization and monitoring would be required, both before and after any potential implementation of this remedial alternative.

Compared with other remedial technologies, MNA has the following advantages:

- Less generation or transfer of remediation wastes;
- Less intrusive;
- May be applied to all or part of a given site, depending on site conditions and clean-up objectives;
- May be used in conjunction with, or as a follow-up to, other (active) remedial measures; and
- Overall cost will likely be lower than active remediation.

Potential disadvantages of MNA include:

- Data used as input parameters for modeling need to be collected;
- Intermediate degradation products may be more mobile and more toxic than the original contaminant;
- Natural attenuation is not appropriate where imminent site risks are present;
- Contaminants may migrate before they are degraded;
- Institutional controls may be required, and the site may not be available for its highest reuse potential until contaminant levels are reduced;
- It is not meant to address source areas of relatively high contamination;
- There are long-term monitoring costs associated with this alternative; and
- Longer time frames would be required to achieve remedial objectives, compared to active remediation.

Analytical data indicates that natural biological degradation of the groundwater contamination is not occurring at the site. However, MNA will be considered further and its effectiveness as a polishing or supplemental technology may also be considered further as a secondary component of other alternatives.

3.3. Biodegradation/Enhanced Biodegradation

Biodegradation, or bioremediation, is the controlled management of microbial processes in the subsurface. Enhanced bioremediation is accomplished by injecting an organic carbon source, nutrients (including phosphate, nitrate, and potassium), electron donors, and/or microbial cultures into the impacted groundwater or soil to stimulate degradation. This differs from monitoring of bioremediation processes under MNA by being an active, designed, and managed process. Some microorganisms, such as Dehalococcoides ethanogenes (DHE), break down VOCs to the end products ethane and ethene. Therefore, bioremediation can often be enhanced through biostimulation (substrates injected in-situ to promote microbial activity) or bioaugmentation (increasing of bioremediation by adding microbial cultures). Biostimulation is used to set the proper conditions for increased microbial activity and may be all that is needed for satisfactory remediation. Biostimulation is often focused in areas where microbial populations are marginal and/or under conditions that are insufficient to support practical biodegradation rates. Common carbon sources for anaerobic sites include lactic acid, sodium benzoate, methanol, and yeast extract.

The presence of DHE can be quantified to evaluate if bioaugmentation with DHE would be necessary to further facilitate chlorinated VOC degradation. If bacteria counts are low, additional cultures can be added to the subsurface to increase populations.

However, where dechlorination end products (such as ethene) are already present at the site and DHE are present in large numbers, it is likely that sufficient reductive dechlorinators are already present and bioaugmentation may not be necessary.

Favorable in-situ conditions must be present to ensure successful bioremediation. Subsurface heterogeneity can complicate the distribution of biostimulants. Bioremediation of chlorinated compounds works best under reducing conditions, with methanogenic conditions being the most favorable. Under sulfate-reducing conditions and in the absence of certain DHE strains biodegradation commonly stalls at cis-DCE. Dechlorinators are also limited if the pH is outside the normal range (greater than 8 or less than 5).

With the right conditions, chlorinated ethenes can be degraded under anaerobic conditions through reductive dechlorination. Reductive dechlorination is a reaction catalyzed by microorganisms in which a hydrogen atom replaces the chlorine atom on CVOCs such as TCE. Though this can occur naturally, it may not happen within an adequate timeframe to meet remedial goals. The injection of hydrogen-releasing compounds can be used to enhance dechlorination processes. Anaerobic conditions can be created through the introduction of large amounts of carbon sources, and monitored by measuring redox to determine if anaerobic conditions have been achieved.

Enhanced bioremediation vendors agree that this technology can effectively treat CVOCs, including TCE, CCl_4, 1,1,1-TCA, 1,1-DCE, and VC under the right conditions. Since conditions vary significantly, in-situ bioremediation pilot studies are often conducted to evaluate the applicability, effectiveness, and cost of this remedial technology. Pilot studies provide data to better evaluate remedial alternatives, support the remedial design of a selected alternative, and reduce full-scale implementation cost and performance uncertainties.

A key factor in the design of an enhanced bioremediation program is the mechanism for delivering amendments and nutrients to the target portion of the dissolved phase groundwater contaminant plume. For sites in which treatment of highly concentrated portions of a dissolved phase plume is the goal, systems with multiple injection and extraction wells may provide semi-closed recirculation loops in the groundwater which reduce downgradient flow and allow for greater biodegradation of the contaminants.

A form of in-situ bioremediation is a biological barrier which acts as a passive control to dissolved phase plume flow when microorganisms break down VOCs that pass by them in groundwater. Biological barriers have recently been installed using emulsified edible oil inserted into the soil with the help of chase water and an emulsifying agent (to reduce viscosity). This type of biological barrier does not require excavation; it can be installed by injecting the oil, chase water, and emulsifying agent in to the subsurface through temporary injection points or permanent injection wells.

A disadvantage of a biological barrier is the possible increase of DCE and vinyl chloride (VC) downgradient of the treatment area. This is due to the TCE byproduct's (DCE and vinyl chloride) slower reduction rates. Heterogeneity in the soil can disrupt continuity of the wall resulting in gaps that can transmit contaminated water. Increased bio fouling can also reduce the permeability of the barrier, potentially causing water to flow around the treatment zone. Additional byproducts of bioremediation by biostimulation may include increased methane and increased concentration of dissolved iron and manganese and occasionally other metals if the local pH is significantly lowered through biological activity.

Enhanced bioremediation is appropriate for sites in which natural biological activity has been confirmed. Anaerobic conditions are generally required for chlorinated compounds such as PCE, TCE, 1,1,1-TCA, and DCE. Because naturally occurring bacteria are the primary degradation mechanism, enhanced bioremediation can be much less expensive than chemical or physical treatment technologies.

Advantages of anaerobic biodegradation where the conditions are right can include:

- It can effectively reduce CVOC concentrations under the right conditions;
- CVOCs are degraded in-situ; and
- It is generally less expensive than other remedial technologies.

Disadvantages of anaerobic biodegradation can include:

- The presence of dissolved oxygen (DO) at levels greater than 1 part-per-million (ppm) limit anaerobic degradation and would require the introduction of a carbon source to reduce DO levels;
- Depending on soil type, degree of heterogeneity, and groundwater depth, this technology may require closely spaced injection sites and can be cost prohibitive;
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient;
- When adding nutrients or stimulants, biofouling of the injection wells may need to be addressed;
- Not all compounds are readily amenable to biological degradation;
- Some intermediate compounds in the biodegradation pathway are more mobile and/or toxic than their parent compounds (i.e., vinyl chloride is such a degradation product of PCE); and

- Enhanced bioremediation is limited at how quickly target compounds are degraded. This alternative can take a significantly longer time to remediate an area compared to physical or chemical treatment technologies.

The lack of TCE byproducts at the site suggests that biological degradation is not occurring, and that conditions may not be amenable for anaerobic degradation. Because conditions could be altered through injection of amendments, bio-degradation/enhanced bio-degradation will be retained for further consideration.

3.4. In-Situ Chemical Oxidation

In-situ chemical oxidation (ISCO) has been used since the early 1990s to treat environmental contaminants in groundwater, soil, and sediment. Many of these projects have focused on the treatment of chlorinated solvents (e.g., TCE and PCE), although several projects have also used the process to treat petroleum compounds [(i.e., benzene, toluene, ethylbenzene, and xylene (BTEX) and methyl tertiary-butyl ether (MTBE)] and semi-volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and pesticides (USEPA, 1998 and Siegrist, 2001).

ISCO is defined as the delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants of concern typically into innocuous end products such as carbon dioxide (CO_2), water, and inorganic compounds. A chemical oxidant is injected in areas where a reduction in groundwater contaminant concentration is desired. Injection locations can be either permanently installed wells or temporary injection points installed using direct-push methods. When oxidants come in contact with chlorinated VOCs they are broken down into non-toxic components. However, contact between the oxidant and contaminant required to facilitate the reaction (before the oxidant is destroyed) is the most important technical limitation of this technology, as it can be difficult to accomplish.

Accordingly, this remedial approach generally includes several injections over time accompanied by groundwater sampling and analysis. Numerous injections are typically required to remediate the treatment area. Given this and depending on the final contaminant concentration desired, the overall costs are typically medium to high relative to other technologies. Since the reaction with the contaminant and the chemical oxidant generally occurs over a relatively short period, treatment can be more rapid than other in-situ technologies. This technology does not generate large volumes of residual waste material that must be treated and/or disposed.

ISCO can be used to treat localized source areas and dissolved phase plumes since it is capable of treating high concentrations of contaminants by adding more oxidants. ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration endpoints.

Advantages of ISCO can include:

- Relatively short remediation times (typically one to two years) in areas where groundwater flow does not introduce additional contaminants with time;
- Limited long-term O&M costs in such settings;
- Treats both dissolved and sorbed contaminants concurrently;
- Treats compounds that are not easily biodegradable; and
- Breakdown of chlorinated VOCs typically without the generation of potentially more toxic degradation products (although not all chlorinated VOC mass may break down).

Disadvantages of ISCO can include:

- Its application to areas with only the highest contaminant concentrations is typically most cost effective;
- The need to inject large volumes of oxidant (especially in areas where groundwater flow introduces additional contaminants over a long period of time from upgradient directions);
- The need for multiple injections;
- Because of the difficulty of contacting oxidants with groundwater contaminants intended for destruction particularly when injecting into low permeability or heterogeneous formations;
- Health and safety issues pertaining to field personnel associated with the handling and injection of oxidants and reagents; and
- Relatively high costs per volume treated.
- Naturally occurring carbon sources increase the oxidant demand in the treatment zone. The presence of carbonates can also add to the oxidant demand for certain ISCO chemicals.

The most common oxidants utilized for ISCO are hydrogen peroxide (Fenton's reagent), potassium and sodium permanganate, and sodium persulfate. A general summary of each of these oxidants is presented below.

Fenton's Reagent (Hydrogen Peroxide)

Hydrogen peroxide-based in-situ chemical oxidation is driven by the formation of a hydroxyl free radical in the presence of a metal catalyst. This reaction, known as the Haber-Weiss mechanism, was first utilized for the treatment of organic compounds in wastewater in the 1890s by H.J.H. Fenton using an iron catalyst (Fenton's reagent). The hydroxyl free radical is a powerful oxidizer of organic compounds, thus many organic compounds in the subsurface that contact the chemical oxidant are readily degraded to innocuous compounds (e.g., water and carbon dioxide). Any residual hydrogen peroxide remaining after the reaction, decomposes to water and oxygen. The highly soluble ferrous iron salt transition metal catalyst added to the subsurface during injection of the oxidant mixture, is precipitated out of solution after conversion to the slightly soluble ferric iron salt.

Typical hydrogen peroxide concentrations utilized for treatment with Fenton's reagent range from five to 50 percent by weight, however, concentrations less than 15 percent are utilized at a majority of sites. The hydrogen peroxide concentration used in the injection fluid is based on contaminant concentrations, subsurface characteristics, and treatment volume. Acids are also typically added to the injection solution to lower the pH of the contaminated zone if the natural pH is not low enough to promote the Fenton's reaction.

Compared to other oxidants, Fenton's reagent has a relatively short life once injected into the subsurface. Therefore, a larger number of Fenton's reagent injections would be required to sustain the oxidant in the subsurface compared to injections of other oxidants.

Sodium and Potassium Permanganate

Permanganate is an oxidizing agent with a unique affinity for oxidizing organic compounds with carbon-carbon double bonds (e.g., TCE and PCE), aldehyde groups or hydroxyl groups (alcohols). There are two forms of permanganate that are used for ISCO, potassium permanganate ($KMnO_4$) and sodium permanganate ($NaMnO_4$). Potassium permanganate has been used in drinking water and wastewater treatment for several decades to oxidize raw water contaminants, typically for odor control. Potassium permanganate is available as a dry crystalline material, while sodium permanganate is a liquid. Permanganate turns bright purple when dissolved in water; this purple color is an indicator of unreacted chemical. Reacted permanganate is black or brown, indicating the presence of a manganese dioxide (MnO_2) byproduct.

Sodium permanganate has a much higher solubility in water than potassium permanganate, allowing it to be used for ISCO at higher concentrations, compared to two to five percent for potassium permanganate. Since it is supplied in liquid form, the use of sodium permanganate commonly requires no on-site mixing.

Permanganate will be considered further for the TCE plume but not for the CCl_4 plume as it is ineffective at treating groundwater impacted with CCl_4.

Sodium Persulfate

Sodium persulfate is a strong oxidant that derives its oxidizing potential through the persulfate anion ($S_2O_8^{2-}$). The persulfate anion is capable of oxidizing a wide range of contaminants, including chlorinated ethenes, BTEX, phenols, MTBE, and low molecular weight PAHs. However, when catalyzed in the presence of heat (thermal catalyzation) or transition metals ions (i.e., ferrous iron), the persulfate ion is converted to the sulfate free radical ($SO_4^{2-}\bullet$), which is second only to Fenton's reagent in oxidizing potential. Sodium persulfate is supplied in an aqueous solution at concentrations up to 50 percent by weight. The use of sodium persulfate for the treatment of CVOCs is a relatively new process in the marketplace.

In-situ chemical oxidation using permanganate, sodium persulfate or Fenton's reagent will be retained for further evaluation as a potential remedial alternative for the site.

3.5. Groundwater Extraction

Groundwater extraction, also referred to as pump and treat, would involve the removal of contaminant-containing groundwater through the use of pumping wells. The extracted water would be treated and returned to the subsurface, a surface water body, or sewer system. Groundwater pumping systems can also be used to prevent dissolved phase plume migration.

Site characteristics, such as hydraulic conductivity, will determine the range of groundwater extraction remedial options possible. Chemical properties of the site and dissolved phase plume need to be determined to characterize transport of the contaminant and evaluate the feasibility of groundwater pumping. To determine if groundwater extraction is appropriate for the site, the following information is needed to design an effective groundwater pumping strategy:

- Characteristics of the contaminant source;
- Properties of the subsurface; and
- The biological and chemical contaminant characteristics.

The following factors may limit the applicability and effectiveness of groundwater pumping as part of the remedial process:

- It is possible that a long time may be necessary to achieve the remediation goal;
- Residual saturation of the contaminant in the soil pores cannot be removed by groundwater pumping. Contaminants tend to be sorbed in the soil (clay and silts). Groundwater pumping typically is not applicable to contaminants with high residual saturation, contaminants with high sorption capabilities, and soils with hydraulic conductivity less than 10-5 centimeters per second (cm/sec);

- The cost of procuring and operating treatment systems can be high, in the long-term. Additional cost may also be attributed to the disposal of treatment media and/or residuals; and
- Bio-fouling of the extraction wells, and associated treatment stream, is a common problem which can severely affect system performance. The potential for this problem should be evaluated prior to the installation.

Extracted groundwater with CVOCs is generally treated by granular activated carbon, air stripping, or ultraviolet (UV) oxidation and/or some contamination thereof. Extracted vapors may also need to be treated. Carbon adsorption is most appropriate for low concentrations and/or low flow rates of contaminated water. In addition, several compounds, including vinyl chloride, TCA, DCA, chloroform, methylene chloride, and alcohols, have a poor affinity for carbon absorption. Air stripping is most appropriate for VOCs that are easily evaporated from water. Compounds which are highly soluble, such as alcohols and ketones, are difficult to remove with air stripping. During UV oxidation organic compounds are broken down by UV light and an oxidizing compound (usually hydrogen peroxide). Although it is effective at treating a wide variety of compounds, UV oxidation will not be considered further because of its high costs relative to granular activated carbon and air stripping. Despite the potential drawbacks, groundwater treatment using granular activated carbon or air stripping will be retained for further consideration. Following treatment, the water would be discharged to a sanitary sewer or surface water in accordance with SPDES permit requirements or re-injected into the subsurface.

Groundwater extraction will be retained for further evaluation as a potential remedial alternative for the site.

3.6. Containment/Barrier Technologies

Hydraulic containment features are installed to contain and control the lateral flow of contaminated groundwater, divert uncontaminated groundwater flow, and/or provide a barrier for a groundwater treatment system. Hydraulic containment features include physical walls, such as grout curtains, slurry walls, or sheet pile retaining walls, and permeable reactive barriers (PRBs), which are vertical zones of material that are installed in the subsurface to passively intercept groundwater flow. As discussed in Section 3.8, groundwater pumping systems can also be used to prevent dissolved phase plume migration.

A physical wall will contain contaminants within a specific area. However, further remediation is often necessary because, unlike a PRB, a physical wall does not treat or destroy the contaminants. In order for a physical wall to be effective it must be set into a confining layer which would limit the downward migration of the contaminants. There is no confining layer within 65 feet bgs and it is considered too costly to install a physical wall to greater depths. Physical walls will not be considered for further evaluation.

A form of in-situ bioremediation is a biological barrier which acts as a passive control to dissolved phase plume flow when microorganisms break down VOCs that pass by them in groundwater. Biological barriers can be constructed with a variety of materials including mulch and chitin (though inexpensive, mulch and chitin are limited in the depth to which they can be emplaced) and food waste products such as cheese whey. These types of biological barrier will not be considered further because of the difficulties associated with trenching and/or delivering the barrier material to the required depths.

PRBs are installed in or down gradient of a dissolved phase plume by excavating a trench across the path of a migrating dissolved phase plume and filling it with the appropriate reactive material (such as a mixture of sand and iron particles), or by injecting the reactive material into the ground as a mobile slurry using direct push technology or injection wells. Groundwater flowing passively under a hydraulic gradient through the PRB is treated as the contaminants in the dissolved phase plume are broken down into byproducts or immobilized by precipitation or sorption after reacting with the substrate inside the PRB. Although PRBs are a remedial technology that requires no pumping, the rate of groundwater treatment can be accelerated by groundwater withdrawal or injection in the vicinity of the PRB.

PRB systems have been used successfully to treat chlorinated organic compounds, including TCE, 1,1,1-TCA, and 1,1-DCE at numerous full-scale applications. PRBs intended for groundwater containing VOCs are commonly constructed with zero-valent iron. Such PRBs can be constructed as a wall beneath the ground surface either by open trenching or with minimal disturbance to above-ground structures and property using trenchless injection technology. Another emerging PRB method utilizes an electrolysis process to break apart the VOC constituents. Probes are installed into the ground, which generate a current in the subsurface that degrades the VOC constituents.

Zero-valent Iron PRB

The most common PRB technology utilizes zero-valent iron particles, typically in granular (macro-scale) form, to completely degrade chlorinated VOCs via abiotic reductive dehalogenation. As the iron is oxidized, a chlorine atom is removed from the compound using electrons supplied by the oxidation of iron. As the groundwater containing CVOCs flows through the reactive material, a number of reactions occur that indirectly or directly lead to the reduction of the chlorinated solvents. One mechanism is the reaction of iron filings with oxygen and water, which produces hydroxyl radicals. The hydroxyl radicals in turn oxidize the contaminants. During this process, the chloride in the compound is replaced by hydrogen, resulting in the complete transformation of chlorinated VOCs to byproducts (ethene, ethane, and chloride ions). Since degradation rates using the process are several orders of magnitude greater than under natural conditions, any intermediate degradation byproducts formed during treatment (e.g., VC) are also reduced to byproducts in a properly designed treatment zone. The use of zero-valent iron to treat chlorinated VOCs has been well documented, and is covered under several patents, depending on the installation method.

PRB longevity using zero-valent iron is dependent on contaminant concentration, groundwater flow velocity, and the geochemical makeup of the groundwater. The oldest full-scale PRB was installed in February 1995 at a site in Sunnyvale, California. This PRB has successfully reduced the concentrations of TCE, DCE, VC, and Freon throughout its 11 years of operation (ETI, 2006). Since the age of the oldest PRB is only approximately 13 years, bench scale studies using reactive iron columns (from both cores obtained from emplaced reactive walls and from virgin reactive iron) have been conducted to evaluate long-term PRB longevity. These tests have shown that, although the reactivity of the iron declines with long-term exposure to groundwater, conditions promoting the dehalogenation of chlorinated solvents are maintained over the long-term. Based on these studies, the expected life of a typical reactive wall (where life is defined as the period over which the reactivity of the iron declines by a factor of two) is approximately 30 years (ESTCP, 2003). However, these studies also indicated that groundwater geochemistry, specifically the concentration and resulting flux of natural organic matter (NOM), total dissolved solids (TDS), and carbonate, along with the distribution of VOC concentrations, greatly influences the lifetime of the reactive iron and should be considered in the reactive wall design process (Klausen et al., 2003).

Zero-valent iron PRBs can be installed by direct-injection of iron or iron substrate into a series of injection wells or boreholes along the barrier alignment. The iron particles are injected into the subsurface to form a continuous barrier between the wells/boreholes. During injection, the barrier geometry can be monitored in real-time to ensure fracture coalescence or overlap using resistivity sensors in the subsurface. Once installed, the hydraulic continuity of the PRB can also be verified using hydraulic pulse interference testing. This test involves a cyclic injection of fluid into a source well on one side of the PRB and high precision measurement of the pressure pulse using a receiver transducer in an observation well on the other side of the PRB. The time delay and attenuation of the hydraulic pulse is used to evaluate the hydraulic effectiveness and continuity of the wall. PRBs have been installed to depths exceeding 100 feet below grade and barrier lengths exceeding 1,000 feet. This trenchless method generates little waste that would require disposal or treatment.

In contrast, PRB installation using trenching technologies is typically physically limited to approximately 60 feet below grade, although a trenched PRB is rarely installed to a depth of more than 30 feet below grade. Also, trenching results in larger volumes of waste in the form of soil that must be disposed of or otherwise treated. Also, trenching technology can create significant disruption to surrounding communities and infrastructure, and is generally limited to areas where underground utilities are not present or, if present, can be disturbed. Because the water table is approximately 65 feet bgs, a PRB installed using trenching technologies will not be considered further.

Advantages of zero-valent iron PRBs typically include:

- The zero-valent iron PRB is a passive method of treatment and long-term operations and maintenance costs will remain low as long as no adjustments need to be made to the barrier;
- Because it is a barrier technology, PRBs can be an effective method of dissolved phase plume control; and
- PRB installation using direct injection technology is not constrained by utilities and is typically a relatively low-impact method for PRB installation.

Disadvantages of zero-valent iron PRBs typically include:

- Emplacement of a PRB using conventional trenching methods can be complicated if underground utilities are present;
- Once emplaced the PRB is expensive to adjust, re-locate or remove;
- Changes in groundwater direction or velocity, though unlikely, can reduce the PRB effectiveness;
- Relatively high capital costs; and
- Infeasible in bedrock.

Because of its relatively easy implementation using trenchless technology, a PRB using zero-valent iron is retained for evaluation as a potential IRM alternative for the site.

Electrically-induced Redox Barrier

Application of this technology involves the insertion of closely spaced permeable electrodes through the dissolved phase plume. A low voltage direct current drives the oxidation of CVOCs. An electrically-induced redox barrier is an effective method for reduction of CVOCs in groundwater.

Advantages of an electrically-induced redox barrier typically include:

- Like other passive technologies electrically induced barrier has reasonable long-term O&M costs, mostly relating to power usage; and

- The electronic barrier has the potential to control mineral accumulation common on other barriers by periodic reversal of electrode potentials, thereby minimizing potential problems related to decreasing permeability.

Disadvantages of an electrically-induced redox barrier typically include:

- This is a relatively new concept having only limited field testing (conducted by Environmental Security Technology Certification Program and Colorado State University at F.E. Warren Air Force Base);
- A trench and fill system is the only way to initially emplace the barrier making it impractical in deep aquifers or urban/suburban areas; and
- The barrier needs to equilibrate with the dissolved phase plume for a few months before implementing the charge.

Although an electrically-induced redox barrier may be feasible for site treatment, it will not be retained for future consideration. This technology is an unproven technology that has had limited field testing.

3.7. Air Sparging/Soil Vapor Extraction

Air sparging with soil vapor extraction involves injecting air into groundwater to volatilize contaminants and enhance aerobic biodegradation. A series of injection wells are installed into the saturated zone and soil vapor extraction wells are installed into the vadose zone. After air is injected, air rises in channels through pores in sand and silt with the lowest air-entry pressure (usually the coarser materials) and the contaminants are removed (stripped) from the groundwater and are carried up into the unsaturated zone. A soil vapor extraction system is usually installed to remove vapors from the unsaturated zone. The volume of extracted soil vapor is typically two to three times more than the air injected into the aquifer.

The system would be designed so that the area of influence of the systems overlap, although this may not be feasible if sufficient thickness of uncontaminated aquifer material is not available beneath the contaminated zone. Pilot tests are often performed to evaluate the most effective distance between injection wells. An injection pump and vacuum extractor would be located above ground. The extracted soil vapor may be treated on-site prior to release to the atmosphere.

Advantages of air sparging with soil vapor extraction typically include:

- Relatively easy installation with readily available equipment;
- Minimal disturbance to site activities during installation; and
- Air can be injected at the exact location desired.

Disadvantages of air sparging with soil vapor extraction typically include:

- Heterogeneities or stratified soils would cause air to not flow uniformly through the subsurface causing some zones to be less treated;
- Ex-situ vapor treatment is commonly required, resulting in the need to properly manage vapor-phase granular activated carbon;
- Surface treatment, vapor extraction, and injection structures are needed; and
- Cannot be used for treating confined aquifers.

Air sparging with soil vapor extraction is retained for evaluation as a potential remedial alternative for the site.

3.8. In-well Air Stripping (a.k.a. Groundwater Recirculation)

An in-well air stripping system uses a series of groundwater circulation wells to recapture and re-circulate groundwater within an aquifer. The groundwater circulation well system creates in-situ vertical groundwater circulation cells by drawing groundwater from the aquifer through the lower screen of a double-screened well and discharging it through the upper screen section. No groundwater is removed from the ground. Air is injected into the well, releasing bubbles into the contaminated groundwater, which aerate the water and form an air-lift pumping system (due to an imparted density gradient) that causes groundwater to flow upward in the well.

As the bubbles rise, VOC contamination in the groundwater is transferred from the dissolved state to the vapor state through an air stripping process. The air/water mixture rises in the well until it encounters the dividing device within the inner casing, which is designed to maximize volatilization. The air/water mixture flows from the inner casing to the outer casing through the upper screen. A vacuum is applied to the outer casing, and contaminated vapors are drawn upward through the annular space between the two casings. The partially treated groundwater re-enters the subsurface through the upper screen and infiltrates back to the aquifer and the zone of contamination where it is eventually cycled back through the well, thus allowing groundwater to undergo sequential treatment cycles until the remedial objectives are met. Off gas from the stripping system is collected and treated, typically using granular activated carbon. Pilot testing and field measurements is generally required to determine the exact well and piping configuration.

In-well air stripping has been demonstrated to be effective and has been used or selected as a remedy at numerous sites, particularly in coarse media with little silt or clay lenses.

As of January 2006, over 1,300 wells have been installed in more than 75 sites, including federal sites, in 24 states (NYSDEC DER-15). Only a limited number of vendors are available to design and construct an in-well air stripping system.

In general, in-well air strippers are most effective at sites containing high concentrations of dissolved contaminants. The effectiveness of in-well air stripping systems may be limited in shallow aquifers. These systems are typically more cost-effective for remediating groundwater at sites with deep water tables because the groundwater does not need to be brought to the surface. To prevent smearing the contaminants in the area immediately above the water table, this technology should not be used at sites containing non-aqueous phase liquids (NAPLs).

In-well air stripping will be retained for further evaluation as a potential remedial alternative for the site.

4. Development and Screening of Alternatives

Because the VOC concentrations in the CCl_4 plume are only marginally greater than the groundwater quality standard of 5 µg/l, MNA is proposed as the remedy for the CCl_4 plume. The need for soil vapor intrusion mitigation to reduce exposures related to the CCl_4 plume would be evaluated as part of the remedy. The remedial alternatives discussed below have been developed to address the TCE plume.

The selection and development of the remedial alternatives was conducted in accordance with New York state NYSDEC Division of Environmental Remediation (DER) policy, DER-15: Presumptive/Proven Remedial Technologies. The presumptive remedy approach is to select remedies that have already been proven to be both feasible and cost effective so as to make the remedy selection quicker. In accordance with Section 1 of DER-15 and with the concurrence of GSA and NYSDEC, PRBs and bioremediation alternatives are evaluated in this section along with the presumptive remedies for groundwater contaminated with CVOCs.

The remedial alternatives selected for evaluation are consistent with the goals of the remediation, which is not to remediate the entire plume, but to focus on reducing or eliminating off-site migration of contaminated groundwater and exposure pathways.

The no further action alternative was retained for evaluation to facilitate the comparison of the other remedial alternatives but will not be discussed further. As part of each remedial scenario, groundwater would be sampled from locations both upgradient and downgradient of the treatment area, to monitor the effectiveness of the remedial alternative at reducing contaminant concentrations and protecting downgradient areas from further plume migration. Soil vapor intrusion monitoring in on-site buildings located above the TCE and CCl_4 plumes (Buildings 201, 202, 203, 204, and 403) is included as part of each remedial alternative. It is also assumed that for each alternative, soil vapor intrusion mitigation systems would be installed and operated to address any potential vapor intrusion pathways.

Based on the screening of remedial technologies in Section 3, the remedial alternatives for the TCE plume to be evaluated are:

- Biodegradation/Enhanced Biodegradation;
- In-Situ Chemical Oxidation (ISCO);

- Groundwater Extraction;
- Permeable Reactive Barrier (PRB);
- Air Sparging/Soil Vapor Extraction (SVE);
- In-well Air Stripping (a.k.a. Groundwater Recirculation); and
- Soil Vapor Intrusion Mitigation and MNA.

These alternatives are described and evaluated below.

4.1. Biodegradation/Enhanced Biodegradation

Implementation of an in-situ biodegradation (or in-situ bioremediation) treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of in-situ bioremediation treatment and the amount of biostimulant or bacteria required for treatment.
- Implementation and evaluation of a field pilot test to evaluate injection efficacy, distribution, and persistence in the subsurface.
- Injection of biostimulant and/or bacteria into either temporary direct-push injection points or permanent injection wells.
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

Since in-situ bioremediation relies on direct contact between bacteria and the contaminant, the success of the in-situ bioremediation treatment would be highly dependent on the ability to effectively distribute the biostimulant or bacteria through the treatment area. If such distribution can be achieved, it is anticipated that in-situ bioremediation is capable of meeting the RAOs for the site. Biostimulants are typically emulsified oils, lactate, or molasses.

The injection of biostimulant or bacteria would be in a linear treatment zone generally perpendicular to groundwater flow to the northeast of Route 5. Groundwater monitoring both upgradient, and downgradient of the treatment area would be required to evaluate the effectiveness of the in-situ bioremediation injections at reducing contaminant concentrations and protecting downgradient areas from further dissolved phase plume migration. Multiple injections, commonly one to two years apart for emulsified oils or lactate and up to monthly for molasses, are required to sustain anaerobic conditions and microbial populations in the subsurface.

In-situ bioremediation would treat the plume as the affected groundwater flows through the treatment area, which would limit migration of the constituents of the plume. There would also be limited downgradient treatment because the bioremediation amendments would flow with the groundwater. However, areas of the plume downgradient of the treatment area would continue to migrate toward the Mohawk River. An in-situ bioremediation pilot study would be conducted to evaluate the injection well spacing, implementability, effectiveness, and feasibility of this technology at the site.

Overall Protection of the Human Health and the Environment

This alternative, in the long-term, would help reduce contaminant concentrations in groundwater migrating off-site and therefore would be protective of human health and the environment.

Compliance with ARARs

If distribution of the biostimulant or bacteria can be achieved, in-situ bioremediation can be used to effectively reduce contaminant concentrations within the treatment area, thus achieving ARARs.

Long-term Effectiveness and Permanence

If distribution of the biostimulant or bacteria can be achieved, in-situ bioremediation is considered to be effective in the long-term because groundwater VOC concentrations would be reduced within the treatment area as long as subsurface conditions amenable to bioremediation are maintained. In-situ bioremediation is expected to be effective for at least six months and potentially up to two years before additional injections are required if emulsified oils or lactate are the biostimulant injected.

There is a potential for incomplete degradation of contaminants if the aquifer is not conducive to anaerobic adjustment or the injection frequency and concentration is not sufficient. The potential for incomplete contaminant degradation will be evaluated using available data, including those from pilot studies.

Reduction of Toxicity, Mobility, and Volume

In-situ bioremediation is considered to be effective at reducing the toxicity, mobility, or volume of the plume because bacteria that are stimulated or added can convert the contaminants to non-toxic byproducts if sufficient distribution can be achieved.

Short-term Effectiveness

This alternative is not as effective in the short-term as some other alternatives because it can take years for bioremediation to reduce contaminant concentrations.

Implementability

In-situ bioremediation could be implemented using readily available technologies. There does not appear to be any significant obstacles to implementing this technology at the site. In-situ bioremediation is expected to be effective for at least six months and potentially more than one year before additional injections are required if emulsified oils or lactate are the biostimulant injected. In-situ bioremediation injections do not generate significant waste, so treatment and disposal considerations are negligible.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 1. The cost opinion is based on two injections of a biostimulant for each of 5 or 30 years. The capital costs include the installation of 12 injection wells to 100 feet bgs and four monitoring wells to 100 feet bgs and soil vapor intrusion investigation and mitigation. Capital costs including the first year of operation and maintenance (O&M) would be approximately $1.4 million. Annual O&M costs are estimated to be $370,000 including two injections of biostimulant and post injection groundwater monitoring and laboratory analysis. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $7.1 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept bioremediation as a remedial alternative.

Community Acceptance

Implementation of in-situ bioremediation would cause no significant disruption to the community. It is anticipated that in-situ bioremediation would be acceptable to the community because it would be an effective approach for attaining the RAOs for the site by reducing the contaminant concentrations within the treatment area.

4.2. In-Situ Chemical Oxidation

Although there are several chemical oxidants capable of treating VOCs, the most commonly used chemical oxidant for VOC remediation is permanganate because it is stable in the subsurface and relatively easier and safer to handle than other oxidants. Permanganate, activated sodium persulfate and Fenton's reagent will be considered in the following alternative. Implementation of an ISCO treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of ISCO treatment and the amount of oxidant required for treatment.
- Implementation and evaluation of a field pilot test to evaluate oxidant distribution and persistence in the subsurface.
- Injection of oxidant into either temporary direct-push injection points or permanent injection wells into the subsurface.
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

The injection of oxidant would be in a linear treatment zone generally perpendicular to groundwater flow to the northeast of Route 5. ISCO injections would treat the plume as the affected groundwater flows through the treatment area. However, areas of the plume downgradient of the treatment area would continue to migrate toward the Mohawk River. Groundwater monitoring both upgradient, downgradient, and within the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations.

Since ISCO relies on direct contact between the oxidant solution and the contaminant, the success of the ISCO treatment would be highly dependent on the ability to effectively distribute the oxidant through the treatment area. If such distribution can be achieved, it is anticipated that the ISCO treatment is capable of meeting the RAOs for the site. Multiple injections are required to sustain the oxidants in the subsurface, commonly 3 to 6 months apart. An ISCO pilot study would be conducted to evaluate the implementability, effectiveness, and feasibility of this technology at the site.

Overall Protection of the Human Health and the Environment

Assuming the oxidant solution is able to come into contact with the contaminants and the oxidants can be sustained in the subsurface, the implementation of ISCO would be protective of human health by reducing concentrations of COCs in groundwater.

Compliance with ARARs

Assuming that the oxidant is effectively distributed and can be sustained in the subsurface, the implementation of ISCO as a remedy would be in compliance with ARARs because there would be a reduction of COC concentrations within the treatment area.

Long-term Effectiveness and Permanence

If distribution of the oxidant can be achieved and sustained in the subsurface, ISCO is considered to be effective in the long-term because further migration of the dissolved phase plume could be minimized. The limiting factor to the long-term effectiveness of ISCO is the number of injections necessary to maintain the oxidant in the subsurface.

Reduction of Toxicity, Mobility, and Volume

ISCO is considered to be effective at reducing the toxicity, mobility, or volume of the plume because ISCO can convert the VOCs to non-toxic byproducts if sufficient distribution can be achieved.

Short-term Effectiveness

ISCO would be effective in the short-term since ISCO treatment oxidizes VOCs almost immediately upon contact. However, ISCO is ineffective at treating groundwater upgradient and downgradient of the ISCO injection locations.

Implementability

ISCO treatment could be implemented using readily available technologies and is considered easy to implement. However, the success of the treatment would be dependent on the degree to which the oxidant solution is able to come into contact with the contaminants and the number of injections required. There would be minimal disruption to site activities during ISCO injection events because no surface structures are needed, other than injection wells. ISCO injections do not generate significant waste, so treatment and disposal considerations are negligible.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 2. The cost opinion assumes that 4 injections of an oxidizing compound will be required annually for each of 5 or 30 years. The capital costs include the installation of 12 injection wells to 100 feet bgs and four monitoring wells to 100 feet bgs and soil vapor intrusion investigation and mitigation. The estimated capital cost including the first year of O&M is approximately $1.6 million. Annual O&M cost are estimated to be approximately $530,000 million including 4oxidizing compound injection events per year and post injection groundwater monitoring and laboratory analysis. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $9.6 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept ISCO as a remedial alternative.

Community Acceptance

Implementation of ISCO would cause no significant disruption to the community. It is anticipated that ISCO would be acceptable to the community because it would be an effective approach for attaining the RAOs for the site by reducing the contaminant concentrations within the treatment area.

4.3. Groundwater Extraction

A groundwater extraction system would consist of a series of recovery wells piped to an ex-situ treatment system, in which groundwater would be treated before discharging to a sewer system or a surface water body or re-injecting back to the aquifer through a series of injection wells. The extraction wells would be installed in a pattern perpendicular to groundwater flow to provide hydraulic control of the plume and limit further downgradient plume migration. The extracted water would be treated using granular activated carbon or air stripping to remove VOCs from the water. The treated water could be re-injected downgradient from the extraction wells to improve the hydraulic capture of the plume or discharged to a sanitary sewer or surface water in accordance with SPDES permit requirements.

An aquifer pumping test would be performed to provide additional information for design of the groundwater extraction system. Analytical sampling performed during the aquifer test would provide additional information for design of an air stripping or carbon treatment system. After system installation, a comprehensive O&M plan, including annual review procedures, would be developed for the system to ensure proper system performance.

Overall Protection of Human Health and the Environment

A groundwater extraction and ex-situ treatment system would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass and controlling the plume hydraulically. The system would achieve the RAO for the site by minimizing contaminant mass flux from the site. Groundwater quality in areas downgradient of the groundwater extraction wells would be monitored to evaluate the reduction of contaminant levels over time.

Compliance with ARARs

Groundwater extraction and ex-situ treatment systems typically have difficulty in achieving maximum contaminant levels (MCLs) for contaminants in source areas. However, groundwater extraction and ex-situ treatment would be effective at decreasing the mass flux of VOCs downgradient of the site.

Long-term Effectiveness and Permanence

Long-term operation of groundwater extraction systems typically result in reduced efficiency, caused by factors such as aquifer heterogeneity and adsorptive partitioning of contaminants between the groundwater and aquifer materials. The result is a decrease in contaminant mass removal, also referred to as tailing or asymptotic reduction. Tailing typically limits the ability of the groundwater extraction system to achieve remediation goals for remediation in a reasonable timeframe. Additionally, as less contaminant is removed from the aquifer, the cost-effectiveness of the treatment system per amount of contaminant treated decreases with time. Therefore, a groundwater extraction system is more effective as an interim corrective measure than a final remedy unless used in conjunction with other remedial technologies. Although potentially less effective than some other remedial technologies, a groundwater extraction system would control the plume migration and volume, thus meeting the RAO for the site.

Reduction of Toxicity, Mobility, and Volume

Initially, groundwater extraction systems are typically effective at controlling plume migration, reducing the plume area, and removing contaminant mass from the aquifer. During initial operation of groundwater extraction systems contaminant mass is most quickly reduced. As operation continues, however, the slow release of contaminants from a residual source such as adsorbed mass can cause tailing of contaminant mass removal. Tailing typically limits the ability of the groundwater extraction system to achieve remediation goals for remediation in a reasonable timeframe without system enhancements via additional remedial technologies. However, the tailing effect would not impact the ability of the groundwater extraction system to limit plume migration. The groundwater extraction system would not affect distal portions of the plume, and portions of the plume downgradient from the wells would continue to migrate toward the Mohawk River.

Short-term Effectiveness

Groundwater extraction systems are typically effective at controlling migration of the contaminant plume and removing contaminant mass from the aquifer over the short-term. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting plume migration within days or weeks of system startup. Implementation and initial operation of the groundwater extraction and ex-situ treatment system are not expected to pose significant risk to the community. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using work practices and engineering controls.

Implementability

A groundwater extraction system with ex-situ treatment consists of readily available technologies. Therefore, it is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation.

The implementation of a groundwater extraction and ex-situ treatment system would require significant pre-design studies to finalize design of the system. Installation of a groundwater extraction system may generate secondary waste, including contaminated soils from drill cuttings and contaminated purge water during well development. Waste generated during implementation and initial operation could be managed using generally accepted methods for off-site disposal and/or treatment.

Operation of a groundwater extraction system over a long time period requires significant O&M activities. The groundwater extraction system and treatment system must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of the treatment system must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment and/or granular activated carbon drums.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 3. The cost opinion is based on the installation of a groundwater extraction system including five 6-inch diameter PVC extraction wells installed to 100 feet bgs, and groundwater treatment through three carbon canisters set in series. The capital costs include the costs for the groundwater treatment system components, a shed to house the treatment system, the extraction wells, the installation of four 100-foot deep monitoring wells and soil vapor intrusion investigation and mitigation. The total assumed capital costs including the first year of O&M is approximately $1.7 million. Annual O&M cost including maintenance of the groundwater treatment system and groundwater sampling and laboratory analysis is estimated at $120,000. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $3.5 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept groundwater extraction as a remedial alternative.

Community Acceptance

It is anticipated that this alternative will be acceptable to the community although noise and waste concerns would need to be addressed prior to implementation of this alternative.

4.4. Permeable Reactive Barrier

Zero-valent iron PRBs would be installed by direct-injection as discussed in Section 3.6. The PRB would be constructed using a series of injection wells or boreholes oriented generally perpendicular to groundwater flow to the northeast of Route 5. The PRB would extend vertically from approximately 65 feet bgs (average depth of the water table) to an approximate average depth of 105 feet bgs. Assuming a 250-foot long PRB, the treatment area would contain approximately 250 to 300 tons of iron, depending on the barrier thickness.

The PRB would be installed in a linear treatment zone generally perpendicular to groundwater flow to the northeast of Route 5. A PRB would treat the plume as the affected groundwater flows through the treatment area, which would limit migration of the plume from its source. However, areas of the plume downgradient of the PRB would continue to migrate toward the Mohawk River. Groundwater monitoring both upgradient, downgradient, and within the treatment area would be required to evaluate the effectiveness of the PRB at reducing contaminant concentrations and protecting downgradient areas from further dissolved phase plume migration.

Overall Protection of the Human Health and the Environment

Zero-valent iron is effective at reducing contaminant concentrations if contact between the iron and contaminated groundwater is attained. The treatment process is in-situ, eliminating treatment process disposal issues and preventing potential contact with contaminated groundwater during the treatment process. PRBs have been shown to be effective at meeting MCLs for organic contaminants, and are likely to reduce contaminant concentrations within the treatment area to comply with the applicable MCLs.

Compliance with ARARs

Assuming that the PRB is properly installed, the RAO would be met because the mass discharge of the contaminants to downgradient areas would be reduced. It is anticipated that the PRB would effectively treat contaminated groundwater as it flows through the PRB. After treatment of chlorinated VOCs, the remaining byproducts (e.g., ethane, ethane, and chloride ions) are non-toxic, and do not pose significant risk to human health or the environment.

Long-term Effectiveness and Permanence

Zero-valent iron longevity is dependent on the contaminant concentration, groundwater flow velocity, and the geochemical makeup of the groundwater. Bench scale studies using reactive iron columns (from both cores obtained from emplaced reactive permeable reactive zero-valent iron walls and from virgin reactive iron) have been conducted to evaluate long-term zero-valent iron longevity. These tests have shown that conditions promoting the dehalogenation of chlorinated solvents are maintained in a permeable reactive zero-valent iron wall over the long-term. Based on these studies, the expected life of a typical reactive wall is approximately 30 years (ESTCP, 2003).

Reduction of Toxicity, Mobility, and Volume

It is anticipated that a PRB would significantly and permanently reduce the toxicity, mobility, and volume of contaminants in groundwater which flows through the PRB. The reduction of chlorinated VOCs using zero-valent iron is a proven technology that has been employed at numerous sites throughout the United States. After treatment of chlorinated VOCs, the remaining byproducts (e.g., ethane, ethane, and chloride ions) are non-toxic, and do not pose significant risk to human health or the environment. As this alternative involves an in-situ process, there are no other treatment residuals that would require additional handling or disposal.

A PRB would be effective at meeting the RAO for the site by reducing contaminant concentrations and minimizing off-site migration of contaminated groundwater. A PRB would reduce the mobility of the plume by treating the groundwater as it flows through the PRB. Contaminated groundwater downgradient of the proposed PRB location would be evaluated with groundwater monitoring.

Short-term Effectiveness

A PRB would be effective in the short-term because chlorinated VOCs would be completely degraded to ethene and ethane as groundwater passes through the PRB. However, a PRB is ineffective at treating groundwater upgradient and downgradient of the PRB. VOC concentrations downgradient of the PRB would decrease over months to years, which limits the short-term effectiveness.

Implementability

Trenchless technologies for the installation of PRBs are relatively simple and technically feasible processes for the site. The uncertainties associated with PRB construction consist of minimizing gaps in the barrier and sufficient barrier thickness. These uncertainties could be mitigated using the testing and monitoring procedures discussed in Section 3.6. The effectiveness of the PRB could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the

PRB. As discussed in Section 3.6, PRB installation using direct injection does not generate significant waste, so treatment and disposal considerations are negligible.

It is anticipated that the necessary specialists and equipment are available to complete the PRB installation. There are a limited number of specialized PRB direct-injection vendors which could potentially limit the ability for competitive bidding. However, when comparing costs and technical feasibility of various PRB technologies, direct-injection is the most applicable and cost-effective method of PRB installation given the site characteristics and proposed PRB location and depth.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 4. This cost opinion is based on the installation of a 250-linear foot PRB along the width of the plume. Capital costs include the installation of the PRB, the installation of four monitoring wells to 100-feet bgs, the first year of O&M, and soil vapor intrusion investigation and mitigation. The capital cost for the PRB alternative is approximately $2.7 million. Annual O&M costs for groundwater sampling and laboratory analysis is estimated at $42,000. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $3.3 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept a PRB as a remedial alternative.

Community Acceptance

Installation of a PRB would cause no significant disruption to the community. It is anticipated that this alternative would be acceptable to the community because it would be an effective approach for attaining the RAOs for the site by reducing the contaminant concentrations within the treatment area.

4.5. Air Sparging/Soil Vapor Extraction

Air sparging wells would be installed using a series of injection wells oriented generally perpendicular to groundwater flow to the northeast of Route 5. Soil vapor extraction wells would be installed in the vadose zone in the vicinity of the air sparging wells. Air would be injected from approximately 65 feet bgs (average depth of the water table) to an approximate average depth of 105 feet bgs, although the majority of air would be injected in the lower 20 feet of this interval. Soil vapor extraction (SVE) wells would be installed to within 10 feet above the water table.

Electrical lines would be run to a treatment shed, which would contain a series of blowers and a control system. The air sparging and soil vapor extraction PVC piping would be buried to prevent freezing during the winter. Periodic on-site monitoring of the system would be conducted to evaluate the system effectiveness and perform system maintenance. Groundwater monitoring both upgradient and downgradient of the air sparging injection area would be required to evaluate the effectiveness of the air sparging system at reducing VOC concentrations and protecting downgradient areas from further dissolved phase plume migration.

Air sparging would treat the plume as the affected groundwater flows through the treatment area. However, areas of the dissolved phase plume downgradient of the treatment area would continue to migrate toward the Mohawk River. Groundwater sampling in areas downgradient of the air sparging treatment area would be conducted to monitor the reduction of concentrations over time.

Overall Protection of the Human Health and the Environment

Assuming all zones within the treatment area are treated and the area of influence of the air sparging wells overlap, the implementation of air sparging and SVE would be protective of human health by reducing concentrations of VOCs in groundwater. An air sparging and soil vapor extraction treatment system would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass. The system would achieve the RAO for the site by minimizing contaminant mass flux from the site.

Compliance with ARARs

Air sparging and SVE can be used to effectively reduce contaminant concentrations within the treatment area, thus achieving ARARs.

Long-term Effectiveness and Permanence

If uniform treatment of the dissolved phase plume can be achieved, air sparging and SVE is considered to be effective in the long-term because groundwater VOC concentrations would be reduced within the treatment area as long as the remedial system is continuously operated. There is a potential for incomplete treatment of contaminants if heterogeneities or stratified soils are present or if the area of influence of the air sparging wells do not overlap. Subsurface heterogeneities may cause non-uniform treatment and this would decrease the long-term effectiveness of his technology, decreasing the effectiveness of this technology. The rate at which the contaminant mass would be removed decreases as air sparging operations proceed and concentrations of dissolved constituents are reduced. This effect would be minimized if contaminated groundwater continues to flow into the treatment area.

Reduction of Toxicity, Mobility, and Volume

Air sparging and SVE is considered to be effective at reducing the toxicity, mobility, or volume of the plume because air sparging can remove contaminants from the groundwater if uniform treatment is achieved. This alternative would be effective at meeting the RAO for the site by reducing contaminant concentrations and minimizing off-site migration of contaminated groundwater. Air sparging and SVE would reduce the mobility of the plume by treating the groundwater as it flows through the treatment area. Contaminated groundwater downgradient of the proposed treatment area would not be addressed.

Short-term Effectiveness

Air sparging and SVE is effective in the short term assuming uniform treatment of the dissolved phase plume can be achieved and the system is operated continuously. In general, air sparging is more effective for constituents with greater volatility and lower solubility and for soils with higher permeability.

Implementability

An air sparging and SVE system could be installed relatively easily with readily available equipment. It is anticipated that the necessary specialists and equipment are available to complete the project. There does not appear to be any significant obstacles to implementing this technology at the site, although the potential effects of silt and silty-sand zones may need to be further investigated. An air sparging and SVE system could be installed with minimal disturbance to the site. However, at a minimum, an injection pump, vacuum extractor and surface treatment structures would need to be located above ground.

Although air could be injected at the exact location desired, difficulties associated with air sparging include effective treatment within the air sparging area and minimizing fugitive vapors, which are prevented by implementing effective vapor extraction. Heterogeneities or stratified soils may cause air to not flow uniformly through the subsurface causing some zones to remain untreated. The area of influence of the air sparging wells would need to overlap to maximize the treatment area and effectiveness. The effectiveness of the air sparging system could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area. A pilot test would be performed to evaluate an appropriate distance between injection wells.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 5. The cost opinion assumes that the remedial system will be composed of 12 air sparge wells installed to 100 feet, 12 SVE wells will be installed to 50 feet, and a treatment shed containing the controls and blowers would be designed and constructed. The capital costs include the installation of the remedial system, the installation of four monitoring wells, the first year of O&M, and soil vapor intrusion investigation and mitigation. The approximate capital cost is $1.9 million. Approximate annual O&M costs including the maintenance of the air sparge/SVE system and sampling and laboratory analysis is $140,000. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $4.0 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept air sparging and soil vapor extraction as a remedial alternative.

Community Acceptance

It is anticipated that this alternative will be acceptable to the community although noise, waste, and fugitive vapor concerns would need to be addressed prior to implementation of this alternative.

4.6. In-well Air Stripping (a.k.a. Groundwater Recirculation)

An in-well air stripping system would be installed using a series of in-well air stripping wells oriented generally perpendicular to groundwater flow to the northeast of Route 5. The in-well air stripping wells would recapture and re-circulate groundwater to create in-situ vertical groundwater circulation cells by drawing groundwater from the aquifer through the lower screen of a double-screened well and discharging it through the upper screen section. Off gas from the stripping system would be collected and treated using granular activated carbon.

The radius of influence is limited by the pumping capacity of each well and the hydrogeologic characteristics of the site. Effective installations require a well-defined contaminant plume and well-placed screens to prevent the spreading of the contamination. Pilot testing and field measurements would be required to determine the exact well and piping configuration.

Electrical lines would need to be run to the treatment system to power the pumps. Periodic on-site monitoring of the system would be conducted to evaluate the system effectiveness and perform system maintenance. Groundwater monitoring both upgradient and downgradient of the treatment area would be required to evaluate the effectiveness of the in-well air stripping system at reducing VOC concentrations and protecting downgradient areas from further dissolved phase plume migration.

In-well air stripping would treat the plume as the affected groundwater flows through the treatment area. However, areas of the dissolved phase plume downgradient of the treatment area would continue to migrate toward the Mohawk River. Groundwater sampling in areas downgradient of the air sparging treatment area would be conducted to monitor the reduction of contaminant levels over time.

Overall Protection of the Human Health and the Environment

Assuming all zones within the treatment area are treated and the area of influence of the in-well air stripping wells overlap, the implementation of in-well air stripping would be protective of human health by reducing concentrations of VOCs in groundwater. An in-well air stripping system would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass. The system would achieve the RAO for the site by minimizing contaminant mass flux from the site.

Compliance with ARARs

In-well air stripping can be used to effectively reduce contaminant concentrations within the treatment area, thus achieving ARARs.

Long-term Effectiveness and Permanence

If uniform treatment of the dissolved phase plume can be achieved, in-well air stripping is considered to be effective in the long-term because groundwater VOC concentrations would be reduced within the treatment area as long as the remedial system is continuously operated. There is a potential for incomplete treatment of contaminants if the area of influence of the in-well air stripping do not overlap or if groundwater is not completely treated after it passes through the in-well air stripping system.

Reduction of Toxicity, Mobility, and Volume

In-well air stripping is considered to be effective at reducing the toxicity, mobility, or volume of the plume because it can remove contaminants from the groundwater. The amount of reduction of the toxicity, mobility, or volume of the plume is dependent on degree to which uniform treatment is achieved. This alternative would be effective at meeting the RAO for the site by reducing contaminant concentrations and minimizing off-site migration of contaminated groundwater. In-well air stripping would reduce the mobility of the plume by treating the groundwater as it flows through the treatment area. Contaminated groundwater downgradient of the proposed treatment area would not be addressed.

Short-term Effectiveness

An in-well air stripping system is effective in the short term assuming uniform treatment of the dissolved phase plume can be achieved and the system is operated continuously. In general, in-well air stripping is more effective for constituents with greater volatility and lower solubility.

Implementability

A limited number of vendors are available to design and construct an in-well air stripping system. The success of these systems depends on the geology of the aquifer and the ability to maintain a treatment cell, which requires a hydraulic connection between upper and lower well screens. Despite this, in-well air stripping systems have successfully been installed at numerous sites. It is anticipated that the necessary specialists and equipment are available to complete the project. There does not appear to be any significant obstacles to implementing this technology at the site. An in-well air stripping system could be installed with minimal disturbance to the site. However, at a minimum, a vacuum extractor and surface treatment structures would be located above ground.

Difficulties associated with in-well air stripping include effective plume capture within the treatment area and minimizing fugitive vapors, which are controlled by implementing effective vapor extraction. The area of influence of the air stripping wells would need to overlap to maximize the treatment area and effectiveness. The effectiveness of the air stripping system could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area. A pilot test would be performed to evaluate an appropriate distance between air stripping wells.

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 6. The cost opinion assumes that the remedial system will be composed of 2 groundwater circulation wells installed to 100 feet, and a treatment shed containing the controls, blowers, and vapor phase carbon units. The capital costs include the installation of the remedial system, the installation of eight monitoring wells, the first year of O&M, and soil vapor intrusion investigation and mitigation. The approximate capital cost is $1.6 million. Approximate annual O&M costs including the maintenance of the system, electricity, and groundwater sampling and laboratory analysis is $190,000. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $4.5 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept in-well air stripping as a remedial alternative.

Community Acceptance

It is anticipated that this alternative will be acceptable to the community although noise, waste, and fugitive vapor concerns would need to be addressed prior to implementation of this alternative.

4.7. Soil Vapor Intrusion Mitigation and MNA

This alternative would consist of quarterly groundwater monitoring for VOCs and natural attenuation parameters, a soil vapor intrusion investigation, and soil vapor intrusion mitigation as needed. No active groundwater remediation is included in this alterative. The installation of soil vapor intrusion mitigation systems would be offered to residents in homes located on Amsterdam Road to the southwest of the Former Scotia Naval Depot where previous sampling results indicated mitigation was warranted but previously declined. No investigations have been conducted to evaluate the potential for vapor intrusion into current and future on-site buildings. A soil vapor sampling program would be conducted in accordance with the October 2006 Final NYSDOH Guidance for Evaluating Soil Vapor Intrusion in the State of New York to assess the nature and extent of concentrations of VOCs in the indoor air and sub-slab soil vapors of existing site buildings located above the TCE and CCl_4 plumes (Buildings 201, 202, 203, 204, and 403) and the potential for vapor intrusion into future site buildings. A deed restriction would be placed on the site so that vapor intrusion mitigation systems would be designed and installed as future buildings are constructed.

Indoor air and sub-slab soil vapor samples would be collected from on-site buildings and off-site homes. Soil vapor sampling points would be installed in undeveloped portions of the site, primarily in the 300 block. Outdoor (ambient) air samples would be collected to evaluate background VOC concentrations.

Overall Protection of the Human Health and the Environment

Although it would not reduce contaminant concentrations in groundwater, this alternative would be protective of human health because there are no groundwater exposure pathways at the site and potential soil vapor intrusion pathways would be mitigated. This alternative would not be protective of the environment because groundwater contaminant concentrations would not be actively treated.

Compliance with ARARs

Groundwater contaminant concentrations would not be reduced so this alternative would not be in compliance with groundwater ARARs. Soil vapor intrusion mitigation would be implemented in accordance with NYSDOH Guidance.

Long-term Effectiveness and Permanence

Assuming the soil vapor intrusion mitigation systems are operated continuously, the soil vapor intrusion mitigation and MNA alternative would be effective in the long-term and be permanent because there would be no exposure to site contaminants. However, site groundwater would not be treated if this alternative is implemented.

Reduction of Toxicity, Mobility, and Volume

The toxicity, mobility, and volume of the dissolved phase VOC plume would not be reduced if this alterative is selected.

Short-term Effectiveness

Assuming the soil vapor intrusion mitigation systems are operated continuously, this alternative would be effective in the short-term because there would be no exposure pathways to site groundwater. However, site groundwater would not be treated if this alternative is implemented.

Implementability

The soil vapor intrusion mitigation and MNA alternative would be easy to implement. There does not appear to be any significant obstacles to implementing this alternative at the site.

Operation of a soil vapor intrusion mitigation system requires long-term O&M activities. The mitigation systems would be inspected periodically, with annual reviews to evaluate overall system performance. The maintenance of the mitigation systems must be performed to ensure adequate system performance, including sub-slab pressure monitoring and testing and replacement of treatment system equipment (i.e. fans).

Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Appendix B, Table 7. This cost opinion is based on quarterly groundwater monitoring, a soil vapor intrusion investigation, and the installation of soil vapor intrusion mitigation systems in two off-site residences and five on-site buildings located above the TCE and CCl_4 plumes. Capital costs include an on-site soil vapor intrusion investigation, the installation of the soil vapor intrusion mitigation systems, and quarterly groundwater monitoring. The capital cost for this alternative is approximately $410,000. Annual O&M cost for groundwater sampling, laboratory analysis, and mitigation system O&M is estimated at $51,000. The total present value of this alternative based on a 5 percent discount rate over a 30-year period is approximately $1.2 million.

State (or Support Agency) Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would accept the soil vapor intrusion mitigation and MNA alternative as a remedial alternative because there are no groundwater exposure pathways and this alternative would eliminate the soil vapor intrusion exposure pathway.

Community Acceptance

The implementation of the soil vapor intrusion mitigation and MNA alternative would cause no significant disruption to the community. It is anticipated that this alternative would be acceptable to the community because the site groundwater is not used for drinking water and soil vapor intrusion would be mitigated.

5. Detailed Analysis of Alternatives

The seven remedial alternatives that were screened in Section 4 are evaluated below relative to the criteria summarized in Section 2.3. The primary RAO is to limit off-site migration of contaminated groundwater. The secondary RAO of reducing the potential for soil vapor intrusion would be addressed through additional investigations (as discussed in Section 6.0) and engineering (sub-slab depressurization systems) and institutional controls .

As part of each remedial scenario, groundwater will be sampled from locations both upgradient and downgradient of the treatment area to monitor the effectiveness of the remedial alternative at reducing contaminant concentrations and protecting downgradient areas from further plume migration.

5.1. Overall Protection of Human Health and the Environment

With the exception of the soil vapor intrusion mitigation and MNA alternative, each alternative would be effective at minimizing further off-site migration of contaminated groundwater by removing contaminant mass and controlling migration of the plume. The six groundwater treatment alternatives would achieve the primary RAO for the site by minimizing contaminant mass flux from the site. All of the alternatives, including the soil vapor intrusion mitigation and MNA alternative, would effectively meet the secondary RAO by addressing any documented or potential soil vapor intrusion pathways through mitigation.

The groundwater extraction, air sparging/SVE and in-well air stripping alternatives physically remove contaminant mass from the groundwater and include components for ex-situ treatment and disposal. In contrast, biodegradation/enhanced biodegradation, ISCO, and PRBs are in-situ alternatives that biologically or chemically degrade VOCs to non-toxic byproducts (e.g., ethane, ethane, and/or chloride ions). These in-situ alternatives are therefore slightly more protective of human health and the environment than those with ex-situ components.

5.2. Compliance with ARARs

The six groundwater treatment alternatives would reduce the mass discharge of site contaminants to downgradient areas. It is anticipated that each of these alternatives would effectively treat contaminated groundwater as it flows through the treatment area. The soil vapor intrusion mitigation and MNA alternative would not limit off-site discharge of site contaminants in groundwater, but would address vapor intrusion pathways in accordance with the October 2006 Final NYSDOH Guidance for Evaluating Soil Vapor Intrusion in the State of New York.

5.3. Long-Term Effectiveness and Permanence

Each of the groundwater treatment remedial alternatives are considered to be effective in the long-term because VOC concentrations in groundwater would be reduced within the treatment area. The soil vapor intrusion mitigation and groundwater MNA includes long-term O&M of vapor intrusion mitigation systems and long-term monitoring of groundwater.

An air sparging/SVE, in-well air stripping, or groundwater extraction system would need to be operated continuously to be effective. There is a potential for incomplete capture and/or treatment of contaminants if heterogeneities or stratified soils are present or if the area of influence of the air sparging, air stripping, or extraction wells do not overlap. The potential for incomplete contaminant degradation would be evaluated using available data, including those from pilot studies.

Biostimulant/bacteria or oxidants would need to be sustained in the subsurface by developing a periodic injection schedule for the biodegradation/enhanced biodegradation or ISCO alternatives, respectively, to be effective. The biodegradation/enhanced biodegradation and ISCO alternatives are only effective as a barrier to plume migration if the biostimulant/bacteria or the oxidants, respectively, are distributed throughout the treatment area. The spacing of the injection wells would need to be designed so as to achieve uniform treatment across the width of the dissolved phase plume.

The PRB alternative is the most effective and permanent because the integrity of the PRB can be confirmed and a PRB will remain effective longer than other alternatives with no need for additional injections or maintenance of remedial equipment. Bench scale studies indicate that a PRB can remain effective for approximately 30 years. The continuity of the PRB can also be verified using pulse interference testing, as discussed in Section 3.6.

5.4. Reduction of Toxicity, Mobility, or Volume

The groundwater treatment remedial alternatives would reduce the mobility of the plume by treating the groundwater as it flows through the treatment area, thereby minimizing off-site migration of contaminated groundwater. These alternatives will not affect distal portions of the plume and portions of the plume downgradient from the wells would continue to migrate toward the Mohawk River. These alternatives would limit plume migration and reduce contaminant concentrations in the treatment area, thereby reducing the toxicity, mobility, and volume of the plume. Because there is no evidence of natural biological degradation of site contaminants, the soil vapor intrusion mitigation and MNA alternative would not reduce the toxicity, mobility or volume of site contaminants, with the exception of volatilizing vapor-phase contaminants within the influence of sub-slab depressurization systems.

The in-situ bioremediation and ISCO alternatives are considered to be effective at reducing the toxicity, mobility, or volume of the plume because bacteria or ISCO, respectively, can convert the contaminants (albeit in different timeframes) to non-toxic byproducts if sufficient distribution can be achieved.

The groundwater extraction, air sparging/SVE and in-well air stripping alternatives physically remove contaminant mass from the groundwater. In contrast, the biodegradation/enhanced biodegradation, ISCO, and PRB alternatives can biologically or chemically degrade VOCs to non-toxic byproducts (e.g., ethane, ethane, and/or chloride ions).

The amount of reduction of the toxicity, mobility, or volume of the plume is dependent on degree to which uniform treatment is achieved within the treatment area. The degree to which uniform treatment is achieved for each alternative, other than the PRB alternative for which the continuity of the barrier can be verified using pulse interference testing, is primarily related to the area of influence and spacing of the injection/extraction wells. Each of the remedial alternatives has uncertainties related to the ability to achieve uniform treatment although the PRB alternative has the least uncertainty because the continuity of the PRB can be verified.

It is anticipated that the PRB alternative is the most likely to significantly and permanently reduce the toxicity, mobility, and volume of contaminants in groundwater which flows through the PRB. After treatment of chlorinated VOCs, the remaining byproducts (e.g., ethane, ethane, and chloride ions) are non-toxic, and do not pose significant risk to human health or the environment.

5.5. Short-Term Effectiveness

Once any of the groundwater treatment remedial alternatives is installed, contaminant concentrations will begin to be reduced as groundwater flows through the treatment area. However, the biodegradation/enhanced biodegradation alternative is not as effective in the short-term as some other alternatives because it can take years for bioremediation to reduce contaminant concentrations. With the exception of biodegradation/enhanced biodegradation, each of the groundwater treatment alternatives will be effective in the short term assuming sufficient distribution of injected material and uniform treatment is achieved. The short-term effectiveness of each remedial alternative could be monitored using standard groundwater monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area.

ISCO would be effective in the short-term since ISCO treatment oxidizes VOCs almost immediately upon contact. Groundwater extraction systems are typically effective at controlling migration of a contaminant plume and removing contaminant mass from the aquifer over the short-term. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting plume migration within days or weeks of system startup. A PRB will be effective in the short-term because it would be designed so that VOCs are completely treated by the time groundwater passes through the PRB. Air sparging/SVE and in-well air stripping are effective in the short term assuming uniform treatment of the dissolved phase plume can be achieved and the system is operated continuously.

The soil vapor intrusion mitigation and MNA alternative would be effective in the short-term for evaluating and addressing any potential soil vapor intrusion pathways. This alternative would not have any active short-term effect on groundwater concentrations.

5.6. Implementability

There does not appear to be any significant obstacles to implementing any of the remedial alternatives with minimal disturbance to the site. It is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation of each of the remedial alternatives using readily available technologies. A limited number of vendors are available to design and construct an in-well air stripping system or PRB. Despite this, in-well air stripping systems and PRBs have successfully been installed at numerous sites. The implementation of each of the groundwater treatment remedial alternatives would require significant pre-design studies to finalize design of the system. A pilot test may be necessary to evaluate the feasibility of the selected remedial alternative at the site.

The biodegradation/enhanced biodegradation, ISCO, PRB, and in-well air stripping alternatives do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruptions to site activities during implementation of the biodegradation/enhanced biodegradation, ISCO, and PRB alternatives because no surface structures, other than possibly injection wells, are needed.

Above ground structures, such as an injection pump, vacuum extractor, and surface treatment structures would be needed for the operation of groundwater extraction, air sparging/SVE, or in-well air stripping systems. Operation of these systems over a long time period requires significant O&M activities. These systems must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of these treatment systems must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment and/or granular activated carbon drums.

5.7. Cost

A summary of opinion of probable costs for each remedial alternative is provided in Appendix B.

The PRB alternative has a higher capital cost (excluding the first year O&M) but lower O&M cost than all other groundwater treatment alternatives. Over a five year time period, the PRB alternative would be more expensive than all other alternatives with the exception of the ISCO alternatives because of the large number of ISCO injections required to maintain an effective treatment zone. Over a thirty year time period, the PRB alternative is only slightly more expensive than the groundwater extraction, air sparging/SVE, and in-well air stripping alternatives but is significantly less expensive than the ISCO and biodegradation/enhanced biodegradation alternatives.

The material costs per injection event for ISCO are greater than the costs for in-situ bioremediation and less than the costs for installation of PRBs. However, to maintain the oxidant in the treatment zone, ISCO would need to be injected multiple times per year, resulting in greater costs for ISCO than all other remedial alternatives considered.

The groundwater extraction, air sparging/SVE, and in-well air stripping alternatives require extensive O&M efforts. Capital costs (excluding the first year of O&M) for these alternatives are typically more than for injection technologies but less than PRB installations. However, O&M costs could be substantial if the system is operated for many years. O&M costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks. Capital costs would include construction of the treatment shed, running electrical and air/water lines to the treatment shed, and installation of the piping, monitoring wells, and injection wells.

The soil vapor intrusion mitigation and MNA alternative would be the least expensive alternative to implement because the other remedial alternatives include vapor intrusion mitigation and groundwater monitoring in addition to active groundwater treatment.

5.8. State Acceptance

The GSA and NYSDEC will review, comment on, and approve the recommended remedial alternative prior to selection and implementation of a site remedy. It is expected that the GSA and NYSDEC would find each of the remedial alternatives acceptable.

5.9. Community Acceptance

It is anticipated that each of the alternatives will be acceptable to the community although noise, waste, and fugitive vapor concerns would need to be addressed prior to implementation of several of the alternatives. Installation of any of the remedial alternatives would cause no significant disruption to the community. Each of the alternatives would be an effective approach for attaining the RAOs for the site by reducing the contaminant concentrations within the treatment area.

5.10. Remedial Alternatives Evaluation

The soil vapor intrusion mitigation and MNA alternative is the least expensive and easiest to implement but does not include active groundwater treatment. This alternative would effectively meet the secondary RAO by addressing any documented or potential soil vapor intrusion pathways through mitigation.

Assuming each of the groundwater treatment remedial alternatives is designed and installed appropriately, each of these alternatives would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass and controlling the plume. These alternatives would each be protective of human health and the environment, would be in compliance with ARARs, would reduce the toxicity, mobility, and volume of the plume, and are anticipated to be acceptable to the GSA, NYSDEC, and the community. As such, the criteria that are considered to be the most important for selecting a remedial alternative are short- and long-term effectiveness, implementability, and cost.

Assuming uniform treatment of the dissolved phase plume can be achieved, each of the remedial alternatives would be effective in the long- and short-term. The implementation of each of the remedial alternatives would require significant pre-design studies to finalize design of the system. A pilot test would be performed to evaluate the feasibility of the selected remedial alternative at the site and to design the remedy.

The biodegradation/enhanced biodegradation alternative can be relatively easily implemented but can be costly as injections may be required as often as twice a year to distribute and sustain biostimulant or bacteria in the subsurface. ISCO is typically only used to treat a source area as the costs associated with maintaining an ISCO barrier to limit migration of the plume make this alternative infeasible because of the frequent injections and the costs associated with sustaining the oxidant in the subsurface. The groundwater extraction, air sparging/SVE, and in-well air stripping alternatives each require above ground structures and extensive O&M efforts, especially if the system is operated for many years.

The PRB alternative would be the most effective and most likely to produce uniform plume treatment but has a higher capital cost (excluding the first year O&M) than all other alternatives. However, the O&M costs for the PRB alternative are lower than all other alternatives because installation of a PRB is a one-time cost requiring no additional injections and there are no treatment systems to power or maintain.

6. Data Gaps

Data gaps that would need to be addressed to implement a remedial alternative at the site are summarized below. The details of the scope of the data gap investigations are not included in this report, however brief descriptions of these investigations are provided below. Opinions of probable ranges of costs are provided below and in Appendix B for planning and discussion purposes.

6.1. Source Identification

There are no identified sources of contamination at the site. The Former Scotia Naval Depot Groundwater Investigation and the Sacandaga Road Landfill Investigation concluded that the Sacandaga Road Landfill was not the source of the TCE in site groundwater. Analytical data collected as part of the ESI indicates that TCE disposal occurred in the northeast corner of the 401 sub-block and the area near the north corner of the 403 sub-block. The groundwater sampling results, along with the results of previous investigations, suggest that a source of CCl_4 was present near the northeast corner of the 300 Block. No vadose zone source contamination, which could have been an on-going contribution to groundwater contamination, is known to exist at the site. No additional subsurface source investigations are needed to implement a dissolved phase plume barrier remedy.

It is anticipated that there would be no additional costs associated with source identification for the selected remedy.

6.2. Pre-Design and Pilot Studies

The vertical extent of groundwater contamination and depth to bedrock at the site are unknown, with the exception of the area near well cluster MW-6/MW-9, where TCE has not been detected in groundwater sampled from MW-9, which is screened from 110 to 120 feet bgs. The depth below ground surface to the top of bedrock ranges from approximately 70 to 200 feet in the vicinity of the Former Scotia Naval Depot although no borings have been drilled to bedrock at the site. Installation of additional monitoring wells would provide stratigraphic information to further delineate the vertical extent of the plume. This information is needed to evaluate the appropriate depth of a treatment barrier, which could significantly influence the cost to implement the remedy.

Probable costs associated with additional vertical delineation of the plume would be approximately $100,000 to $150,000.

A pilot test would be performed to evaluate the implementability, effectiveness, and feasibility of the selected remedial alternative at the site and to design the remedy. Pilot testing and field measurements are generally required to assess the best well and equipment configuration and to evaluate injection efficacy, distribution, and persistence in the subsurface.

If the biodegradation/enhanced biodegradation or ISCO alternatives are selected, a bench-scale laboratory treatability study could be conducted to evaluate the effectiveness of the selected remedial alternative on representative site-specific soil and groundwater samples and to estimate the amount of injected material required to treat the measured site contaminants. An effective spacing between biodegradation/enhanced biodegradation or ISCO injection wells would be assessed during a pilot test. If the groundwater extraction, air sparging/SVE, or in-well air stripping alternatives are selected, a pumping/injection test would be conducted to evaluate the radius of influence and the pumping/injection well configuration needed for full-scale implementation.

Depending on the remedy selected, probable costs for designing and implementing pilot tests could range from $75,000 to $150,000.

6.3. Soil Vapor Intrusion

Soil vapor intrusion has been evaluated in residences located on Amsterdam Road to the southwest of the Former Scotia Naval Depot. As discussed in the ESI Report, homeowners declined NYSDEC's offered to install soil vapor intrusion mitigation systems in two residences. No investigations have been conducted to evaluate the potential for vapor intrusion into current and future on-site buildings. As such, soil vapor intrusion will be evaluated as part of each remedial alternative. A soil vapor intrusion investigation is needed to assess the nature and extent of concentrations of VOCs in the indoor air and sub-slab soil vapors of existing site buildings located above the TCE and CCl_4 plumes (Buildings 201, 202, 203, 204, and 403) and the potential for vapor intrusion into future site buildings. The information developed from the sampling and analysis is expected to be used for future planning and development efforts, and potential design and installation of mitigation systems.

The sampling program would be conducted in accordance with the October 2006 Final NYSDOH Guidance for Evaluating Soil Vapor Intrusion in the State of New York. Indoor air and sub-slab soil vapor samples would be collected from site buildings. Soil vapor sampling points would be installed in undeveloped portions of the site. Outdoor (ambient) air samples would be collected to evaluate background VOC concentrations.

An estimate of probable costs to implement a vapor intrusion investigation would be approximately $75,000 to $100,000 and are included in the tables in Appendix B. Also included in these tables are estimated costs for mitigation of up to five on-site buildings and two homes on Amsterdam Road where the homeowners declined NYSDEC's offer to install mitigation systems.

7. References

Alpha Geoscience. Hydrogeology of the Great Flats Aquifer in the vicinity of the Glenville Energy Park Site. December 2001.

Beyke, Gregory, and Fleming, David. 2005, In Situ Thermal Remediation of DNAPL and LNAPL Using Electrical Resistance Heating. In: *Remediation*, Summer 2005. Pages 5-22.

Earth Tech, Inc. Supplemental Investigation, Proposed Glenville Energy Park. January 2002.

Earth Tech, Inc. Phase I Environmental Site Assessment, Proposed Glenville Energy Park. January 2002.

Earth Tech, Inc. Final Phase II Site Investigation, Proposed Glenville Energy Park. Revised January 2002.

Ecology & Environment Engineering, P.C. Preliminary Site Assessment (PSA) Investigation at the Scotia Naval Depot, I. D. No. 47023. 2004

Environmental Technology, Inc. (ETI), 2006, personal communication concerning iron reactive wall longevity.

Environmental Security Technology Certification Program (ESTCP), 2003, Evaluating the Longevity and Hydraulic Performance of Permeable Reactive Barriers at Department of Defense Sites, ESTCP Cost and Performance Report (CU-9907).

NYSDEC and GeoLogic NY, Inc. Expanded Site Investigation Report, Scotia Naval Depot. August 3, 2007.

NYSDEC Division of Environmental Remediation (DER) policy, February 27, 2007, DER-15: Presumptive/ Proven Remedial Technologies.

NYSDEC Preliminary Site Assessment Investigation Report, Scotia Naval Depot Building 15. December, 1999.

NYSDEC Preliminary Site Assessment Investigation Report, Sacandaga Road Landfill. April 17, 2002.

Parsons Engineering Science, Inc. Focused Site Investigation Report, Scotia Depot for the U.S. Army Corps of Engineers. March 2001.

Parsons Engineering Science, Inc. Groundwater Investigation Report, Scotia Depot for the U.S. Army Corps of Engineers. August 2001.

Parsons Engineering Science, Inc. Preliminary Assessment Report, Scotia Depot for the U.S. Army Corps of Engineers. February 2001.

Parsons Engineering Science, Inc. Soil Removal Work Plan, Scotia Depot for the U.S. Army Corps of Engineers. August 2002.

Parsons Engineering Science, Inc. Soil and Dry Well Removal Documentation report, Scotia Depot for the U.S. Army Corps of Engineers. June 2006.

PMK Group. Phase II Assessment Report, GSA Naval Depot for United States General Services Administration Region 2. July 19, 1999.

Klausen, J., P.J. Vikesland, T. Kohn, D.R. Burris, W. Ball, and A.L. Roberts, 2003, Longevity of Granular Iron in Groundwater Treatment Processes: Solution Composition Effects on Reduction of Organochlorides and Nitroaromatic Compounds, Environmental Science and Technology, v.37, no. 6, pp. 1208-1218.

Siegrist, R.L., et al., 2001, Principles and Practices of In Situ Chemical Oxidation Using Permanganate, Battelle Press, Columbus, OH. 347 p.

USEPA, 1998, Field Applications of In Situ Remediation Technologies: Chemical Oxidation: United States Environmental Protection Agency Innovative Technology Office Report. Office of Solid Waste and Emergency Response Publication EPA 542-R-98-008 (September 1998).

USEPA, 2000, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002, Office of Solid Waste and Emergency Response Publication 9355.0-75 (July 2000).

General Services Administration
Scotia Naval Depot
Feasibility Study Report

Appendix A: Select Figures from Expanded Site Investigation Report and Soil And Dry Well Removal Documentation Report

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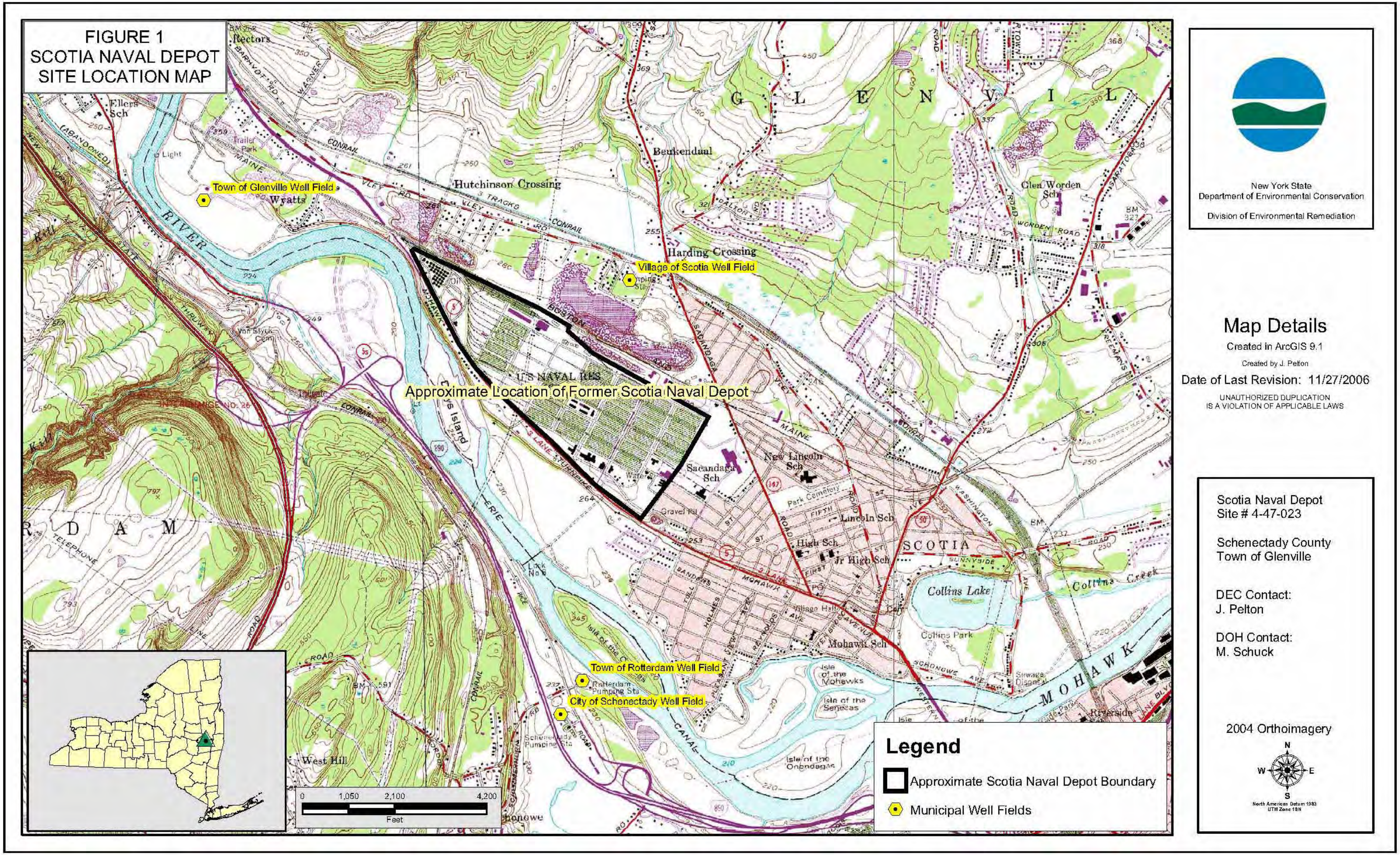

FIGURE 1
SCOTIA NAVAL DEPOT
SITE LOCATION MAP
Town of Glenville Well Field
Village of Scotia Well Field
Approximate Location of Former Scotia Naval Depot
Town of Rotterdam Well Field
City of Schenectady Well Field
Legend
Approximate Scotia Naval Depot Boundary
Municipal Well Fields
0 1,050 2,100 4,200
Feet
New York State
Department of Environmental Conservation
Division of Environmental Remediation
Map Details
Created in ArcGIS 9.1
Created by J. Pelton
Date of Last Revision: 11/27/2006
UNAUTHORIZED DUPLICATION
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Scotia Naval Depot
Site # 4-47-023
Schenectady County
Town of Glenville
DEC Contact:
J. Pelton
DOH Contact:
M. Schuck
2004 Orthoimagery
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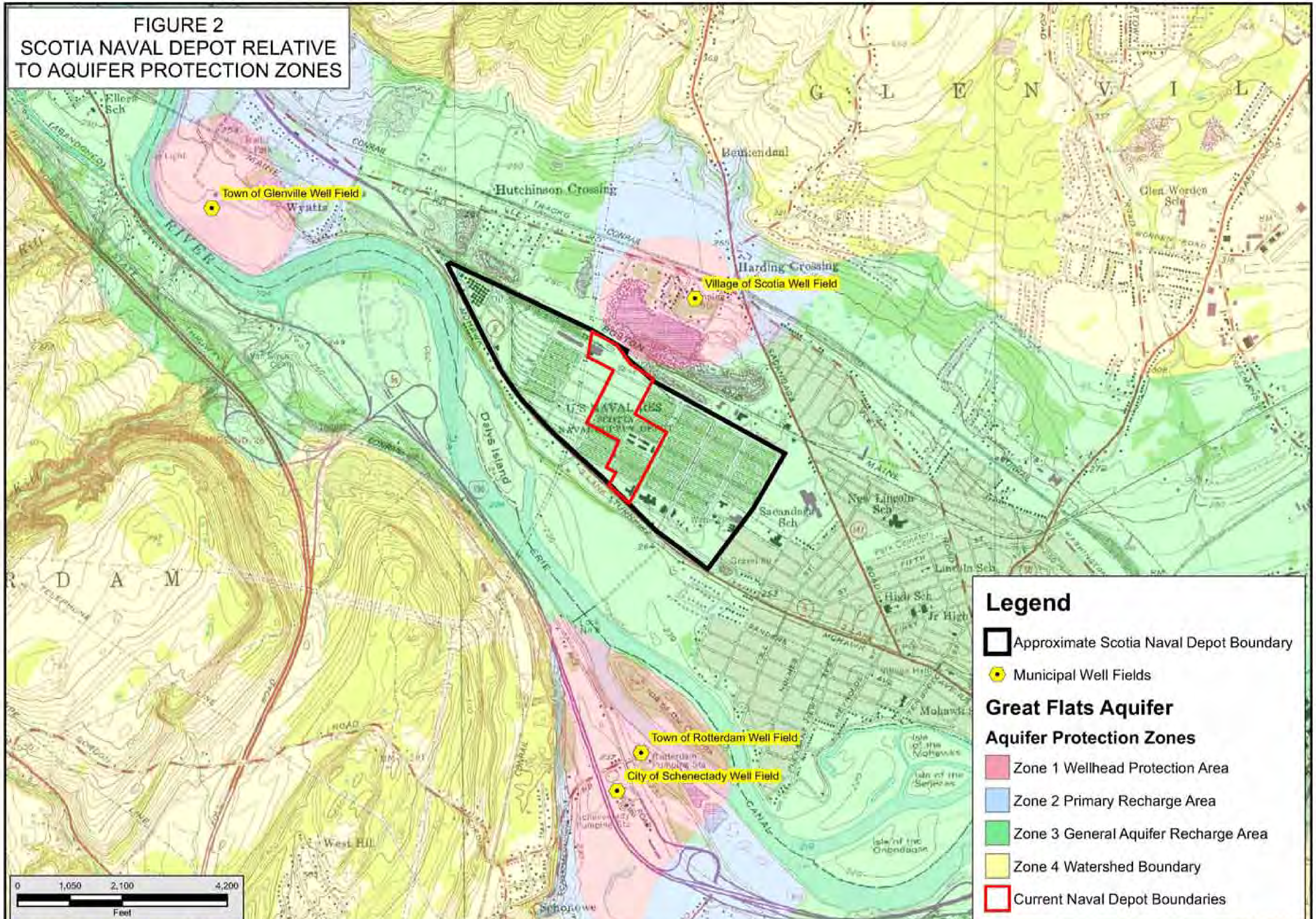
North American Datum 1983
UTM Zone 18N

FIGURE 2
SCOTIA NAVAL DEPOT RELATIVE TO AQUIFER PROTECTION ZONES



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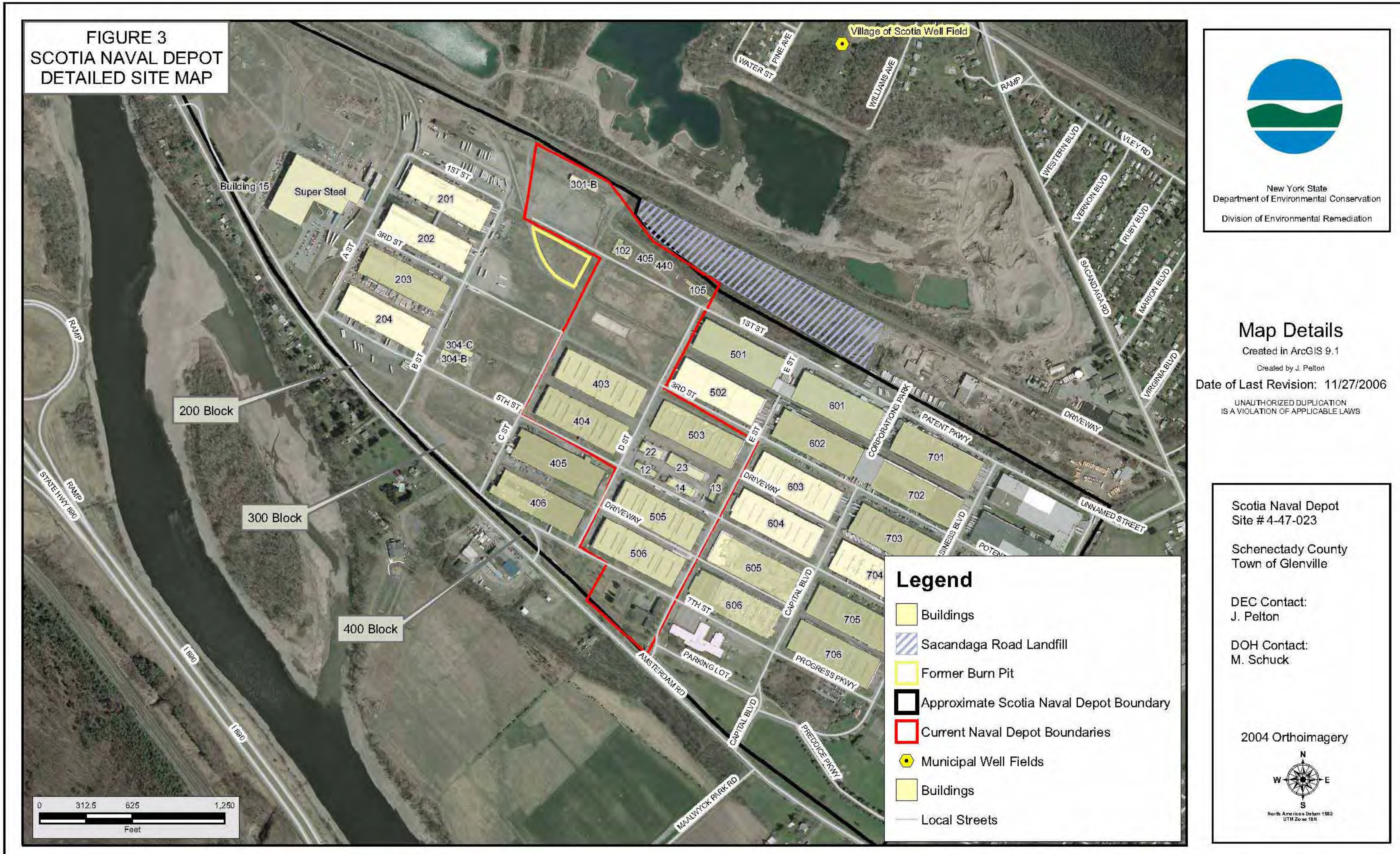

FIGURE 3
SCOTIA NAVAL DEPOT
DETAILED SITE MAP
Village of Scotia Well Field
Building 15
Super Steel
201
202
203
204
301-B
102
405
440
105
304-C
304-B
501
502
503
403
404
405
406
505
506
22
12
23
14
13
601
602
603
604
605
606
701
702
703
704
705
706
1ST ST
3RD ST
5TH ST
7TH ST
A ST
B ST
C ST
D ST
E ST
DRIVEWAY
CORPORATIONS PARK
PATENT PKWY
UNNAMED STREET
CAPITAL BLVD
PROGRESS PKWY
PARKING LOT
AMSTERDAM RD
PREDDICE PKWY
MAALWYCK PARK RD
STATE HWY 890
I 890
RAMP
WATER ST
PINE AVE
WILLIAMS AVE
WESTERN BLVD
VERNON BLVD
RUBY BLVD
SACANDAGA RD
MARION BLVD
VIRGINIA BLVD
VLEY RD
200 Block
300 Block
400 Block
0
312.5
625
1,250
Feet
Legend
Buildings
Sacandaga Road Landfill
Former Burn Pit
Approximate Scotia Naval Depot Boundary
Current Naval Depot Boundaries
Municipal Well Fields
Buildings
Local Streets
New York State
Department of Environmental Conservation
Division of Environmental Remediation
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FIGURE 4
SCOTIA NAVAL DEPOT
SITE MONITORING WELLS

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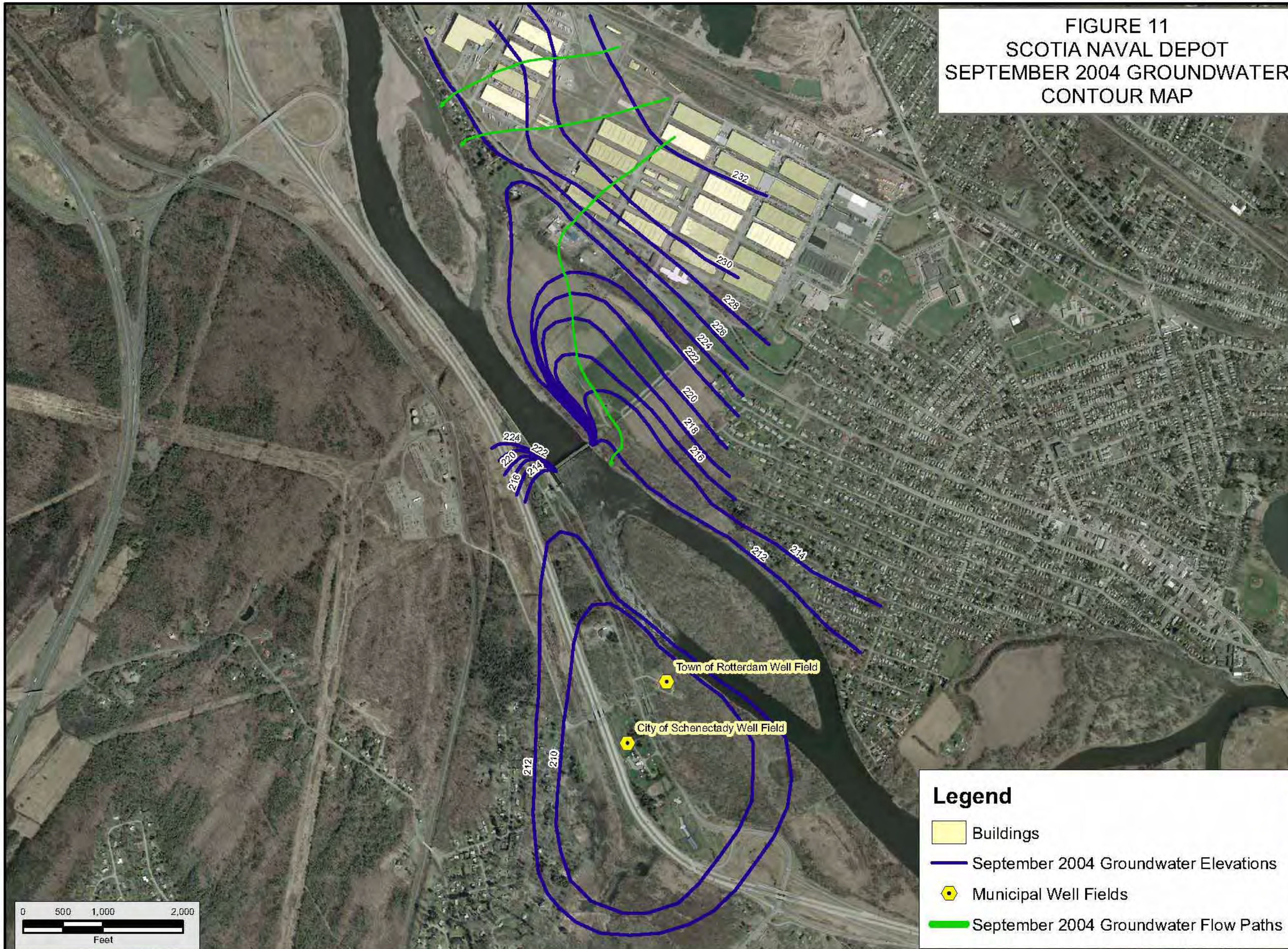

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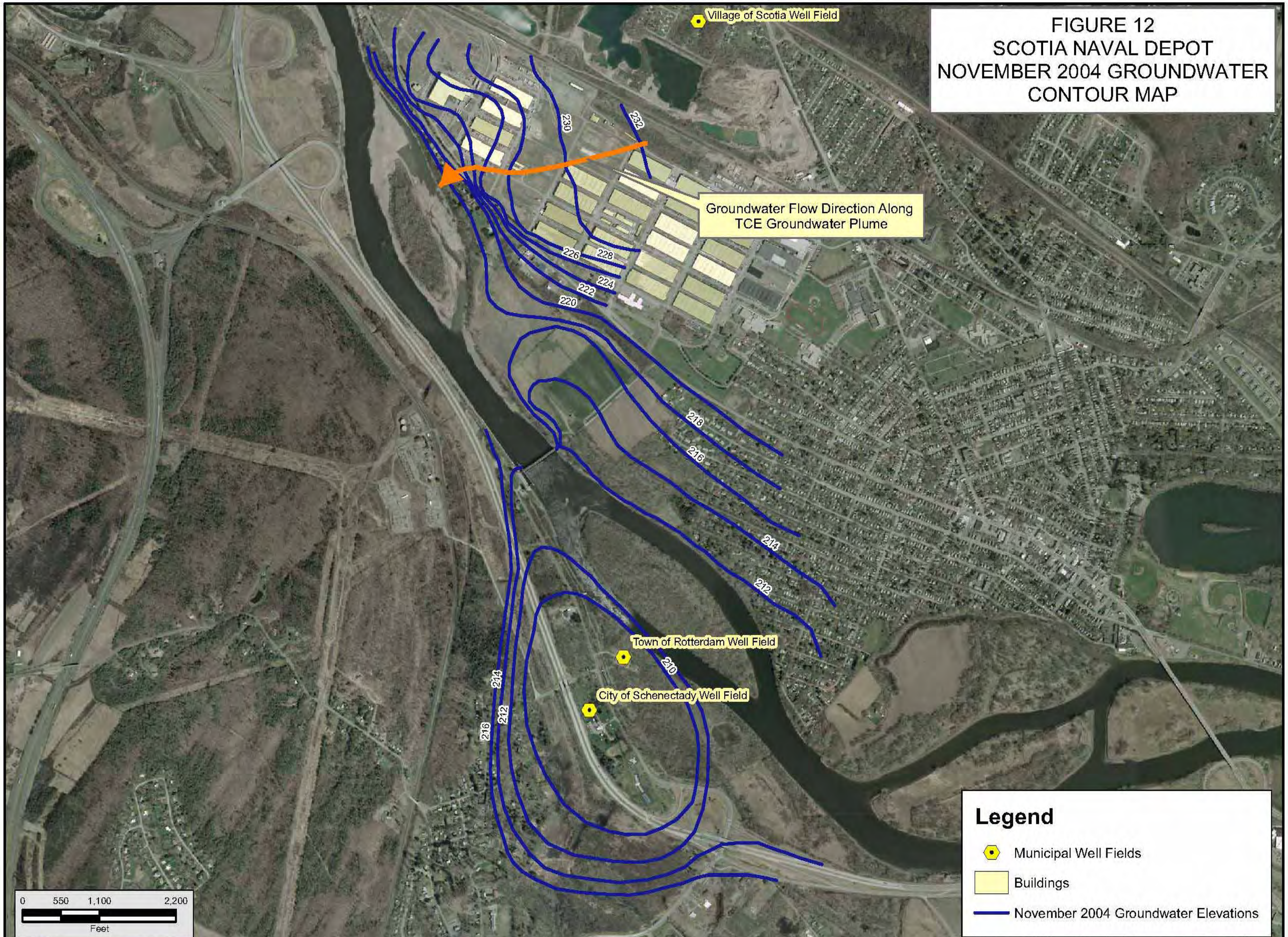

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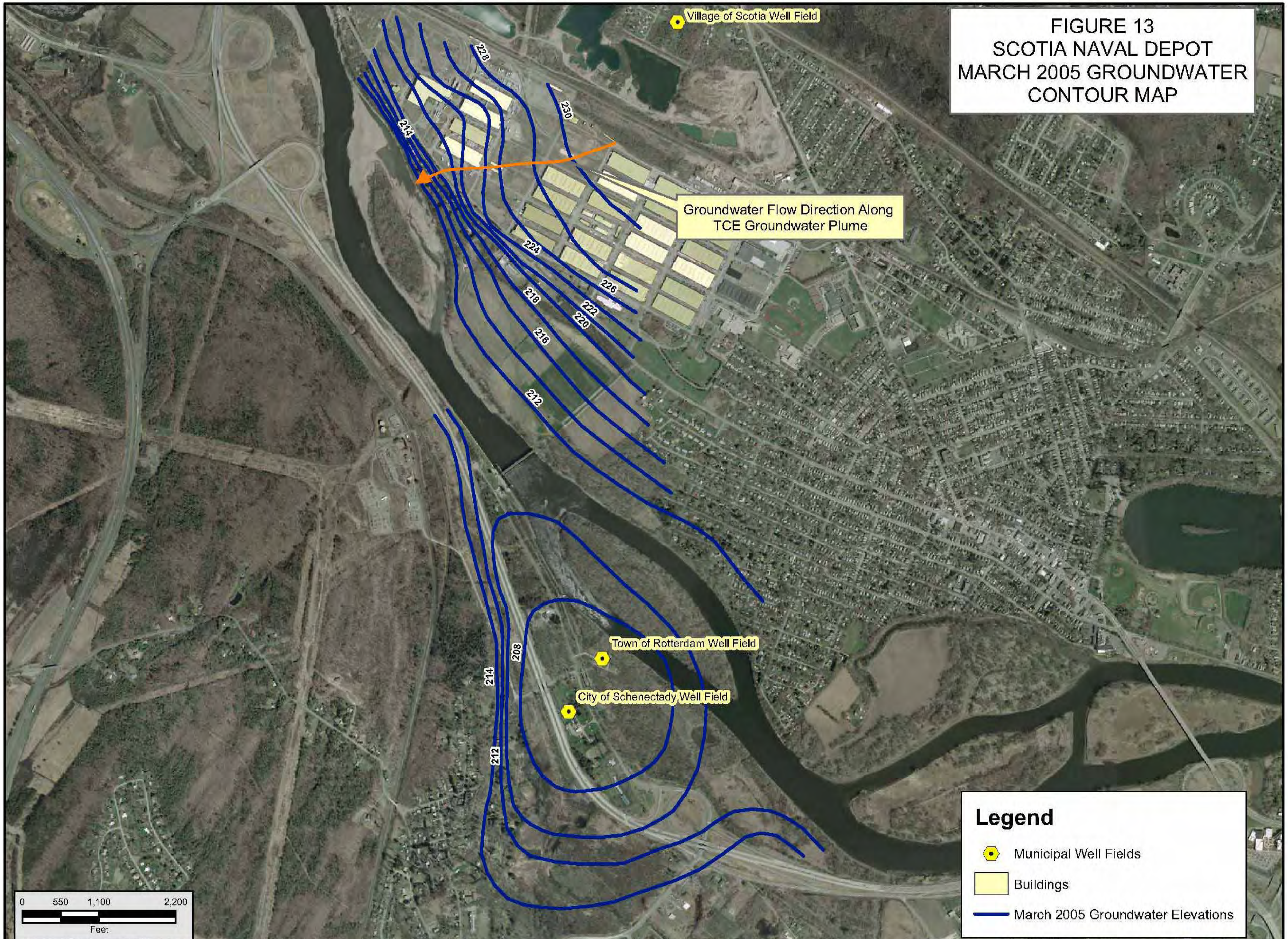

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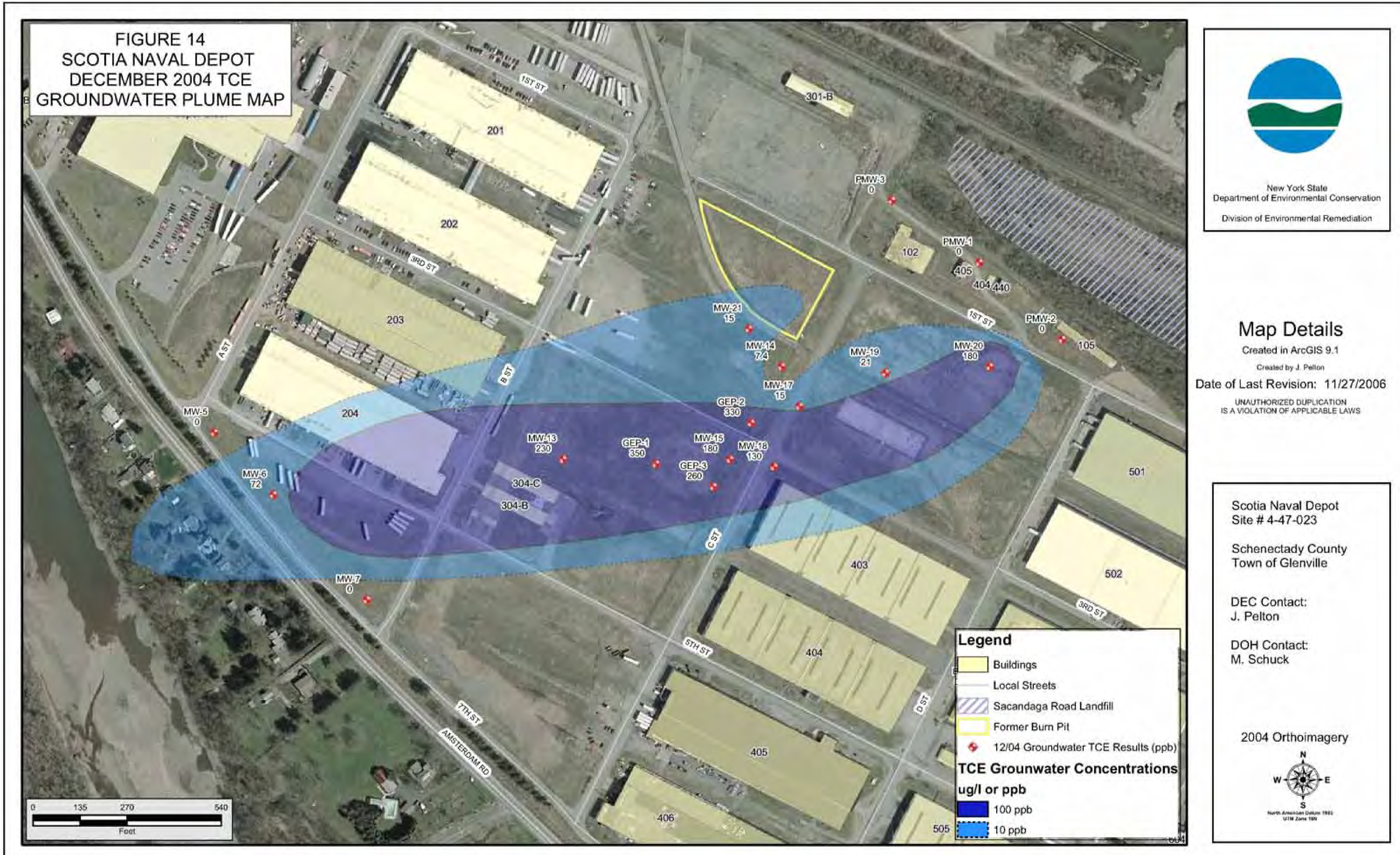
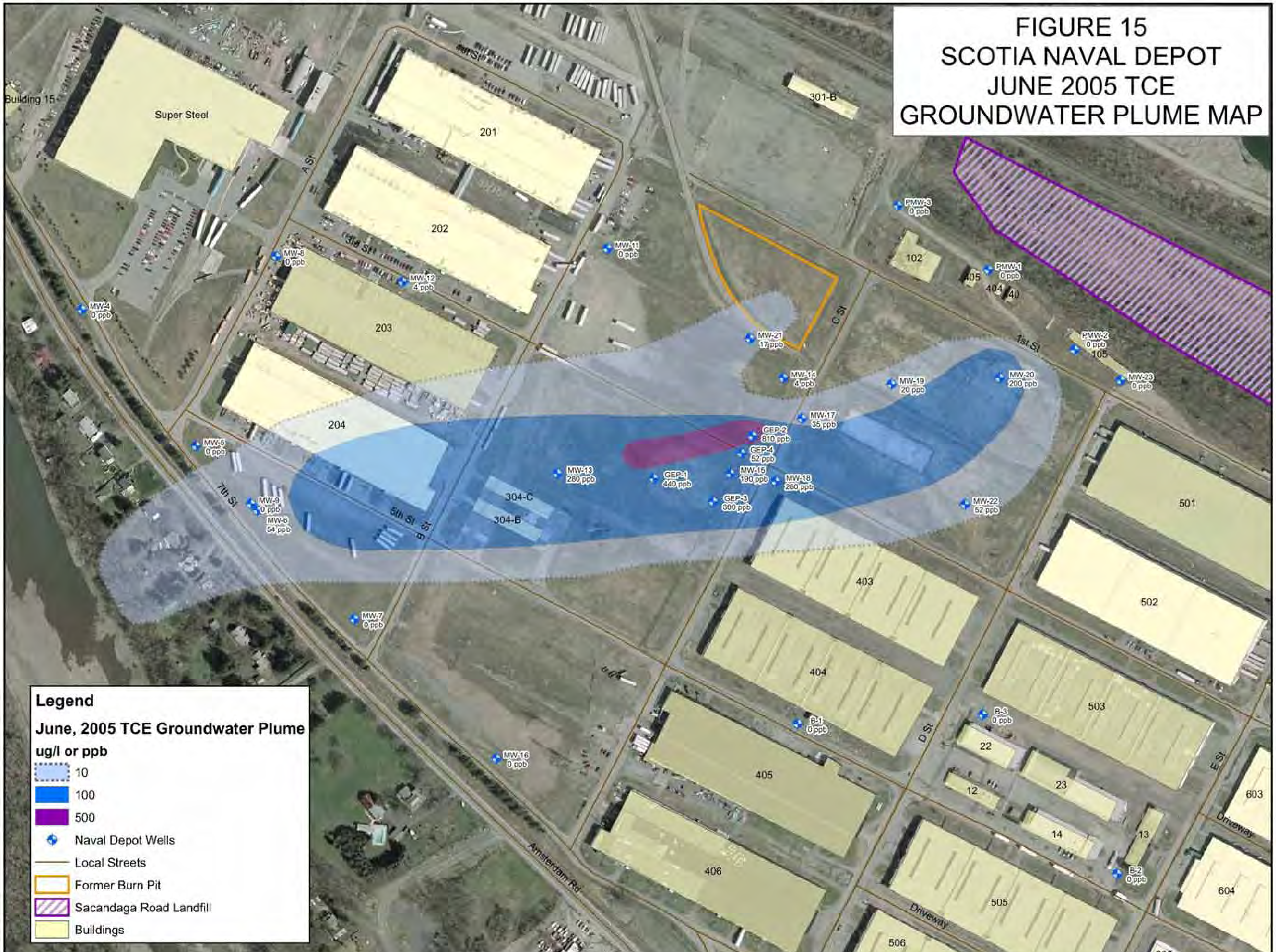


FIGURE 14
SCOTIA NAVAL DEPOT
DECEMBER 2004 TCE
GROUNDWATER PLUME MAP

FIGURE 15
SCOTIA NAVAL DEPOT
JUNE 2005 TCE
GROUNDWATER PLUME MAP



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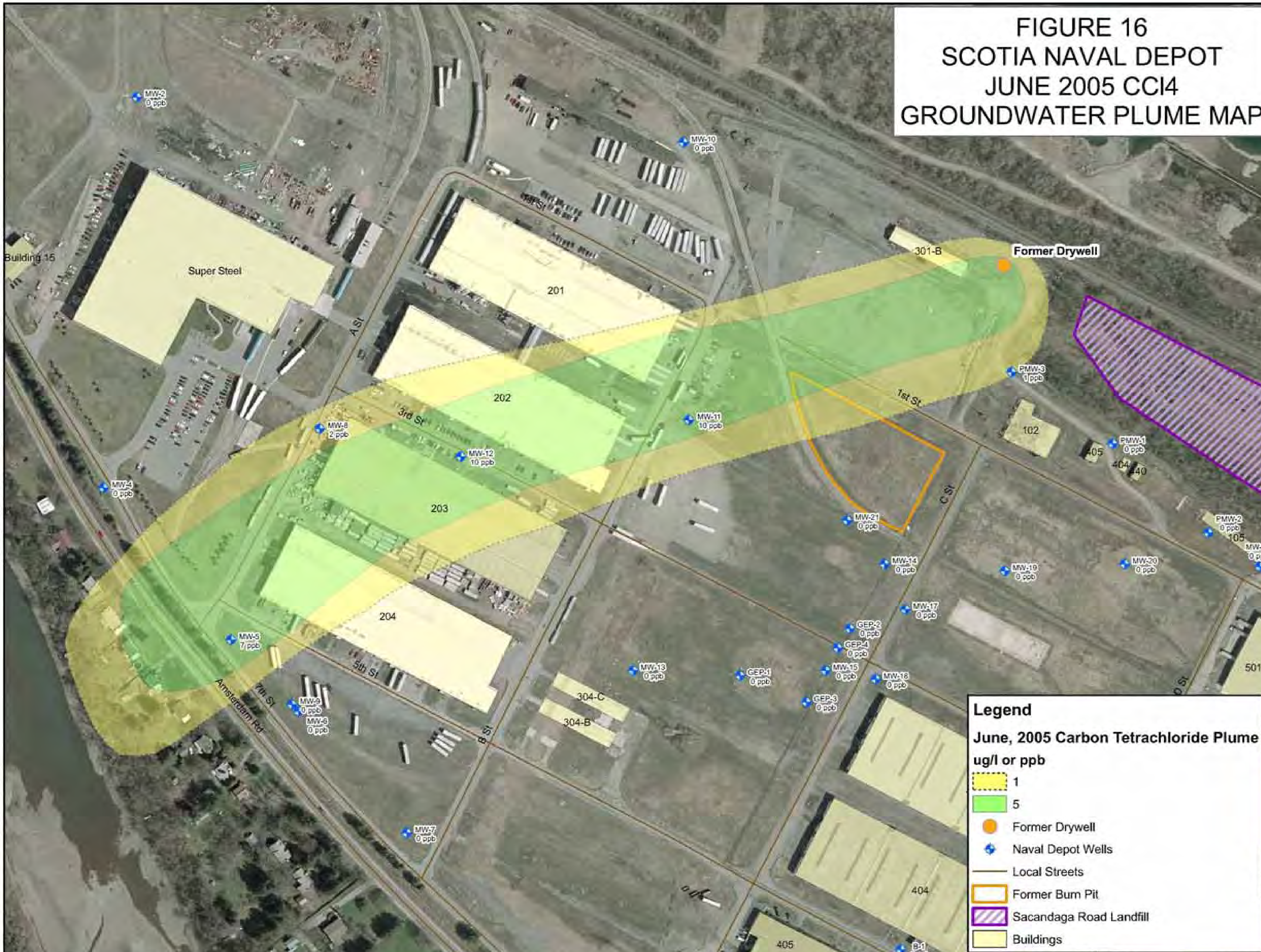
North American Datum 1983
UTM Zone 18N

FIGURE 16
SCOTIA NAVAL DEPOT
JUNE 2005 CCl4
GROUNDWATER PLUME MAP



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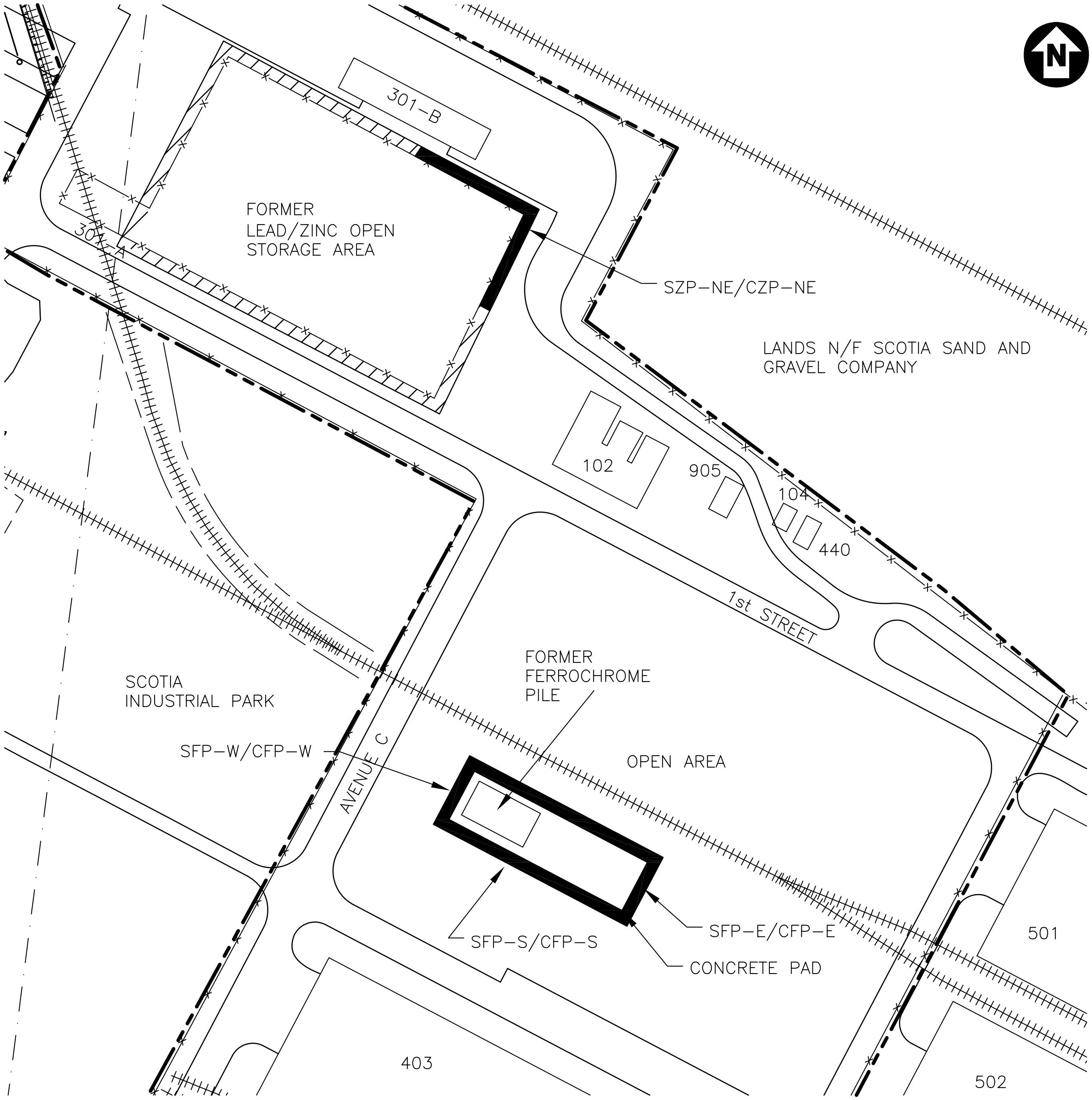

BASE MAP SOURCE: EARTH TECH

LEGEND:

SOIL REMOVED FROM ASPHALT SURFACE

SCOTIA DEPOT PROPERTY LINE

SOIL REMOVED TO DEPTH OF 2 FT

SFP-W/CFP-W CONFIRMATORY SOIL SAMPLE LOCATION

200 100 0 200 400

APPROXIMATE SCALE IN FEET

No XREFs
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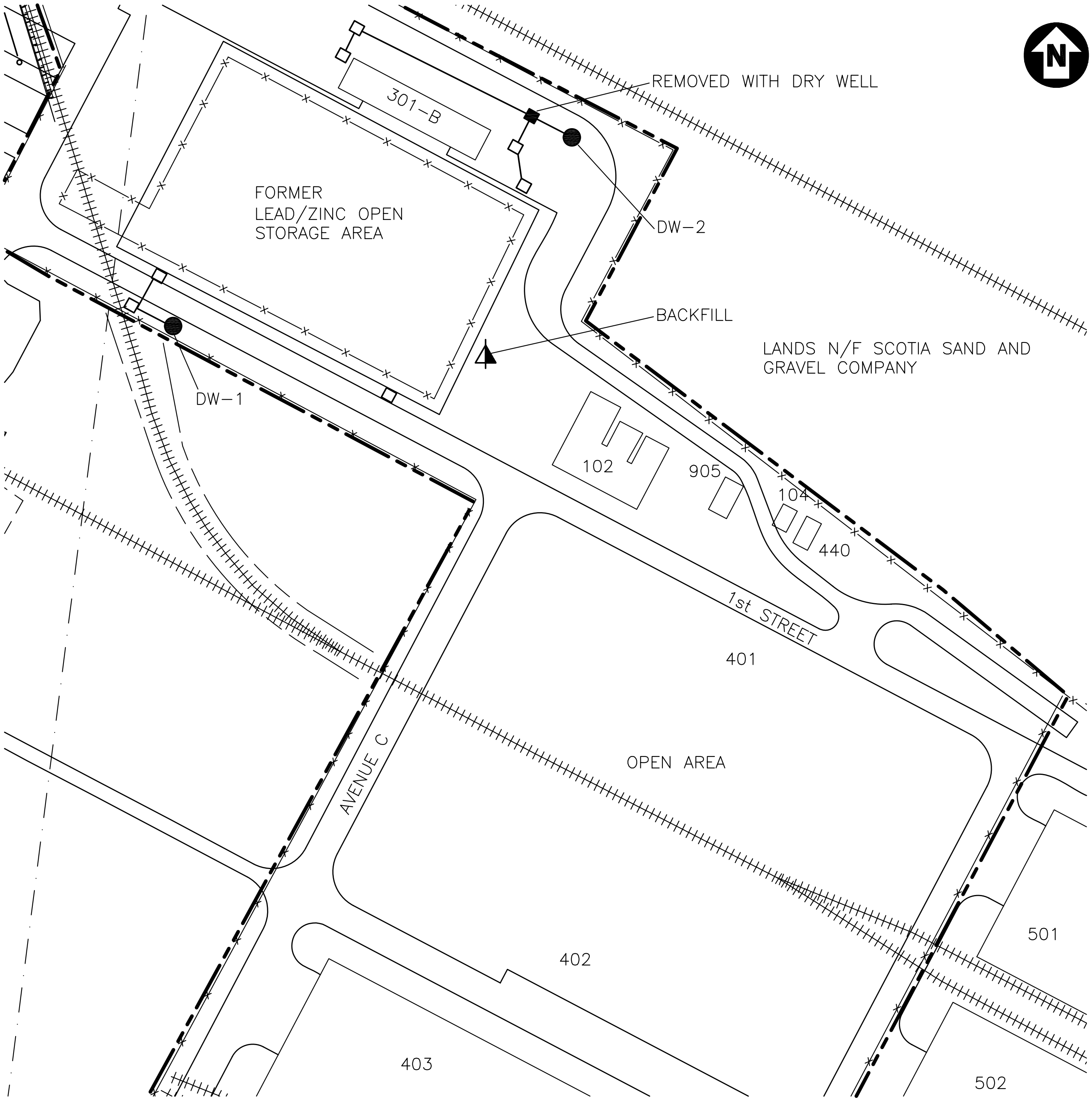
FIGURE 6

DLA/DNSC
SCOTIA DEPOT

SOIL REMOVAL AREAS

PARSONS

290 ELWOOD DAVIS ROAD, SUITE 312, LIVERPOOL, N.Y. 13088, PHONE: 315-451-9560



LEGEND:

- SCOTIA DEPOT PROPERTY LINE
- CATCH BASIN (BACKFILLED)
- CATCH BASIN (REMOVED)
- DW-1 DRY WELL (REMOVED) AND CONFIRMATORY SOIL SAMPLE LOCATION
- BACKFILL SAMPLE OF SOIL BACKFILL SOURCE

200 100 0 200 400

APPROXIMATE SCALE IN FEET

No XREFs
P:\742466\CAD\FIGURE 8.dwg, 5/31/06 , CLW

FIGURE 8

DLA/DNSC
SCOTIA DEPOT

DRY WELL WASTE AND BACKFILL SOIL CHARACTERIZATION AND POST-REMOVAL SAMPLE LOCATIONS

PARSONS

290 ELWOOD DAVIS ROAD, SUITE 312, LIVERPOOL, N.Y. 13088, PHONE: 315-451-9560

General Services Administration
Scotia Naval Depot
Feasibility Study Report

Appendix B: Remedial Alternative Opinion of Probable Costs

4672006 / ALB

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Table 1
Remedial Alternative Opinion of Probable Cost

Alternative 1
IN-SITU BIOREMEDIATION

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 1 consists of in-situ bioremediation to treat groundwater in a 250 foot width of the plume and soil vapor intrusion investigation and mitigation. Assumes 2 bioremediation injections per year. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Pilot Test Design and Implementation	1	lump sum	$100,000.00	$100,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
In-situ Bioremediation					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Injection Well Drilling	1,200	linear feet	$40.00	$48,000	Sonic Drilling, 12 wells to 100 feet
Injection Well Installation	1,200	linear feet	$23.00	$27,600	2" PVC, Schedule 40
Stick-up Injection Well Casing	12	wells	$235.00	$2,820	
Well Install. & Development Oversight	200	hours	$80.00	$16,000	
Drums	20	Drums	$55.00	$1,100	
Purge Water and Cuttings Disposal	20	Drums	$250.00	$5,000	
First year operation and maintenance	1	lump sum	$372,000.00	$372,000	Cost breakdown provided below
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$908,796	
Contingency	25%			$227,199	10% scope + 15% Bid
SUBTOTAL				$1,135,994	
Project Management	6%			$68,160	
Remedial Design	12%			$136,319	
Construction Management	8%			$90,880	
TOTAL CAPITAL COST				$1,431,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	8	samples	$250.00	$2,000	Biological indicators
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$28,600	
Bioremediation Injections					
Injection Materials	2	lump sum	$70,000.00	$140,000	2 Injections per year across 250 ft barrier
Vendor/Subcontractor Field Support	2	lump sum	$40,000.00	$80,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$230,000	
SUBTOTAL				$258,600	
Contingency	25%			$64,650	
SUBTOTAL				$323,250	
Project Management	5%			$16,163	
Technical Support	10%			$32,325	
TOTAL ANNUAL O&M COST				$372,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$1,431,000	$1,431,000	1.00	$1,431,000	
Annual O&M	2-5	$1,488,000	$372,000	3.55	$1,319,094	
		$2,919,000			$2,750,094	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$2,750,000	
Capital	1	$1,431,000	$1,431,000	1.00	$1,431,000	
Annual O&M	2-30	$10,788,000	$372,000	15.14	$5,632,479	
		$12,219,000			$7,063,479	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$7,063,000	

Table 2
Remedial Alternative Opinion of Probable Cost

Alternative 2
IN-SITU CHEMICAL OXIDATION

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 2 consists of in-situ chemical oxidation to treat groundwater in a 250 foot width of the plume and soil vapor intrusion investigation and mitigation. Assumes 12 ISCO injections per year. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Pilot Test Design and Implementation	1	lump sum	$100,000.00	$100,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
In-Situ Chemical Oxidation					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Injection Well Drilling	1,200	linear feet	$40.00	$48,000	Sonic Drilling, 12 wells to 100 feet
Injection Well Installation	1,200	linear feet	$23.00	$27,600	2" PVC, Schedule 40
Stick-up Injection Well Casing	12	wells	$235.00	$2,820	12 Injection Wells
Well Install. & Development Oversight	200	hours	$80.00	$16,000	
Drums	20	Drums	$55.00	$1,100	
Purge Water and Cuttings Disposal	20	Drums	$250.00	$5,000	
First year operation and maintenance	1	lump sum	$527,000.00	$527,000	Cost breakdown provided below
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$1,063,796	
Contingency	25%			$265,949	10% scope + 15% Bid
SUBTOTAL				$1,329,744	
Project Management	5%			$66,487	
Remedial Design	8%			$106,380	
Construction Management	6%			$79,785	
TOTAL CAPITAL COST				$1,582,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$26,600	
ISCO Injections					
Injection Materials	4	lump sum	$85,000.00	$340,000	4 Injections per year across 250 ft barrier
Vendor/Subcontractor Field Support	1	lump sum	$40,000.00	$40,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$340,000	
SUBTOTAL				$366,600	
Contingency	25%			$91,650	
SUBTOTAL				$458,250	
Project Management	5%			$22,913	
Technical Support	10%			$45,825	
TOTAL ANNUAL O&M COST				$527,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$1,582,000	$1,582,000	1.00	$1,582,000	
Annual O&M	2-5	$2,108,000	$527,000	3.55	$1,868,716	
		$3,690,000			$3,450,716	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$3,451,000	
Capital	1	$1,582,000	$1,582,000	1.00	$1,582,000	
Annual O&M	2-30	$15,283,000	$527,000	15.14	$7,979,346	
		$16,865,000			$9,561,346	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$9,561,000	

Table 3
Remedial Alternative Opinion of Probable Cost

Alternative 3
GROUNDWATER EXTRACTION

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 3 consists of a groundwater extraction system to treat groundwater in a 250 foot width of the plume and soil vapor intrusion investigation and mitigation. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Pilot Test Design and Implementation	1	lump sum	$100,000.00	$100,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
Extraction System Installation					
Mobilization, Bond, and Insurance	1	lump sum	$60,000.00	$60,000	
6-inch Vertical Extraction Wells x 5 (installed)	500	LF	$150	$75,000	See Note 1
4" submersible pump, 20-50 gpm, 3 hp	5	EA	$5,250	$26,250	See Note 2
Power and data line conduit	3000	LF	$20	$60,000	See Note 3
Treatment Shed	1	lump sum	$50,000.00	$50,000	
SCADA SYSTEM	1	LS	$20,000	$20,000	
Pipe System					
12" HDPE, SDR 17 (100 psi) pipe w/ testing	1000	LF	$21.0	$21,000	
Fittings, tees, elbows, reducers, and ball valves	1	LS	$20,000	$20,000	
5 hp booster pump, 100 gpm, w/ fittings and labor	5	EA	$7,000	$35,000	See Note 2
Disposal of Excess Soils					
Drums	20	Drums	$55.00	$1,100	
Purge Water and Cuttings Disposal	20	Drums	$250.00	$5,000	
O&M					
Carbon Cannisters	6	EA	$15,000	$90,000	See Note 4
Heat Exchanger	3	EA	$3,500	$10,500	See Note 5
Carbon Material	30,000	LB	$1.00	$30,000	See Note 6
First year operation and maintenance	1	lump sum	$123,000.00	$123,000	Cost breakdown provided below
Well Installation					
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Well Install. & Development Oversight	200	hours	$80.00	$16,000	
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$1,067,626	
Contingency	25%			$266,906	10% scope + 15% Bid
SUBTOTAL				$1,334,532	
Project Management	6%			$80,072	
Remedial Design	12%			$160,144	
Construction Management	8%			$106,763	
TOTAL CAPITAL COST				$1,682,000	

Notes: Cost data obtained from 2005 RSMeans Environmental Remediation (ER), Building Construction (BC), or Heavy Construction (HC) Cost Data, vendor quotes, and previous Malcolm Pirnie project experience.
1) Assumes 6" diameter PVC wells, 30' screens and 100' average depth. Includes labor & materials.
2) RSM ER 33 23 0528. Includes 1 backup pump for each pump location.
3) Includes 2" diam. rigid galvanized conduit (RSM BC 16120 120 0350) and 600 V armoured #8 cable, 3 conductor solid (RSM BC 16132 240 200).
4) Includes cannisters in series (3 on-line at once)
5) Includes 1 heat exchanger for each on-line canister for humidity removal
6) Includes initial carbon material for new cannisters

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
O&M					
O&M Labor	250	hours	$100	$25,000	
Pipe Maintenance	1	ls	$10,000	$10,000	
Pump Repair and Maintenance	5	ea	$425	$2,125	
Carbon replacement	10,000	lb	$0.70	$7,000	
Removal/Reinstall Adsorber Unit	21	ea	$200	$4,200	
Carbon O&M	1	ea	$400	$400	
Electrical Consumption	100000	KWh	0.1	$10,000	
SUBTOTAL				$85,325	
Contingency	25%			$21,331	
SUBTOTAL				$106,656	
Project Management	5%			$5,333	
Technical Support	10%			$10,666	
TOTAL ANNUAL O&M COST				$123,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$1,682,000	$1,682,000	1.00	$1,682,000	
Annual O&M	2-5	$492,000	$123,000	3.55	$436,152	
		$2,174,000			$2,118,152	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$2,118,000	
Capital	1	$1,682,000	$1,682,000	1.00	$1,682,000	
Annual O&M	2-30	$3,567,000	$123,000	15.14	$1,862,352	
		$5,249,000			$3,544,352	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$3,544,000	

Table 4
Remedial Alternative Opinion of Probable Cost

Alternative 4
PERMEABLE REACTIVE BARRIER

Site:	Scotia Naval Depot
Location:	Scotia, New York
Phase:	Feasibility Study
Base Year:	2009
Date:	July 1, 2009

Description: Alternative 4 consists of installation of a permeable reactive barrier to treat groundwater in a 250 foot width of the plume and soil vapor intrusion investigation and mitigation. Assumes one time installation based on a vendorquotation. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Bench-Scale Treatabiligy Test	1	lump sum	$20,000.00	$20,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
SUBTOTAL				$109,700	
Well Installation and Sampling					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Well Install. & Development Oversight	200	hours	$80.00	$16,000	
Drums	20	Drums	$55.00	$1,100	
Purge Water and Cuttings Disposal	20	Drums	$250.00	$5,000	
First year operation and maintenance	1	lump sum	$42,000.00	$42,000	Cost breakdown provided below
SUBTOTAL				$100,800	
PRB Installation					
Subcontractor and Material Costs	250	feet	$5,000.00	$1,250,000	PRB installed
ETI Patent License Fee	1	lump sum	$120,000.00	$120,000	
SUBTOTAL				$1,370,000	
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$1,790,376	
Contingency	25%			$447,594	10% scope + 15% Bid
SUBTOTAL				$2,237,969	
Project Management	5%			$111,898	
Remedial Design	8%			$179,038	
Construction Management	6%			$134,278	
TOTAL CAPITAL COST				$2,663,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$26,600	
SUBTOTAL				$26,600	
Contingency	25%			$6,650	
SUBTOTAL				$33,250	
Project Management	5%			$1,663	
Technical Support	20%			$6,650	
TOTAL ANNUAL O&M COST				$42,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$2,663,000	$2,663,000	1.00	$2,663,000	
Annual O&M	2-5	$168,000	$42,000	3.55	$148,930	
		$2,831,000			$2,811,930	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$2,812,000	
Capital	1	$2,663,000	$2,663,000	1.00	$2,663,000	
Annual O&M	2-30	$1,218,000	$42,000	15.14	$635,925	
		$3,881,000			$3,298,925	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$3,299,000	

Table 5
Remedial Alternative Opinion of Probable Cost

Alternative 5
AIR SPARGING AND SOIL VAPOR EXTRACTION

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 5 consists of an Air Sparge and Soil Vapor Extraction Unit and soil vapor intrusion investigation and mitigation. Assuming a 10 ft radius of influence for Air Sparge and Soil Vapor Exctraction Wells. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Pilot Test Design and Implementation	1	lump sum	$100,000.00	$100,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
Air Sparging and SVE					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Air Sparge Well Drilling	1,200	linear feet	$40.00	$48,000	Sonic Drilling, 12 wells to 100 feet
Air Sparge Well Installation	1,200	linear feet	$23.00	$27,600	2" PVC, Schedule 40
SVE Well Drilling	600	linear feet	$40.00	$24,000	Sonic Drilling, 12 wells to 50 feet
SVE Well Installation	600	linear feet	$23.00	$13,800	2" PVC, Schedule 40
Well Install. & Development Oversight	200	hours	$80.00	$16,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
SVE/AS Mobilization, Bond, and Insurance	1	lump sum	$60,000.00	$60,000	
Trench for piping	1	lump sum	$6,000.00	$6,000	
Above ground PVC piping	1	lump sum	$14,000.00	$14,000	
Tees, elbows, reducers, and ball valves	1	lump sum	$20,000.00	$20,000	
Valve Vaults	1	lump sum	$105,000.00	$105,000	40 Vaults
Electrical Service	1	lump sum	$60,000.00	$60,000	
Treatment Shed, Blowers, and Controls	1	lump sum	$220,000.00	$220,000	
First year operation and maintenance	1	lump sum	$137,000.00	$137,000	Cost breakdown provided below
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$1,199,876	
Contingency	25%			$299,969	10% scope + 15% Bid
SUBTOTAL				$1,499,844	
Project Management	6%			$89,991	
Remedial Design	12%			$179,981	
Construction Management	8%			$119,988	
TOTAL CAPITAL COST				$1,890,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
OM&M Inspection	250	hours	$80.00	$20,000	
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$46,600	
Misc.					
Electrical	1	Lump Sum	$15,000.00	$15,000	
System effluent sampling	12	samples	$300.00	$3,600	
Carbon replacement	1	Lump Sum	$20,000.00	$20,000	
OM&M Equipment and Materials	1	Lump Sum	$10,000.00	$10,000	
SUBTOTAL				$48,600	
SUBTOTAL				$95,200	
Contingency	25%			$23,800	
SUBTOTAL				$119,000	
Project Management	5%			$5,950	
Technical Support	10%			$11,900	
TOTAL ANNUAL O&M COST				$137,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$1,890,000	$1,890,000	1.00	$1,890,000	
Annual O&M	2-5	$137,000	$137,000	3.55	$485,795	
		$2,027,000			$2,375,795	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$2,376,000	
Capital	1	$1,890,000	$1,890,000	1.00	$1,890,000	
Annual O&M	2-30	$3,973,000	$137,000	15.14	$2,074,327	
		$5,863,000			$3,964,327	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$3,964,000	

Table 6
Remedial Alternative Opinion of Probable Cost

Alternative 6
IN-WELL AIR STRIPPING

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 6 consists of 2 groundwater circulation wells (GCWs) and soil vapor intrusion investigation and mitigation. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design and Pilot Studies					
Pilot Test Design and Implementation	1	lump sum	$100,000.00	$100,000	
Monitoring Well Drilling	900	linear feet	$40.00	$36,000	Sonic Drilling, 6 borings to 150 feet
Monitoring Well Installation	900	linear feet	$23.00	$20,700	2" PVC, Schedule 40
Field oversight	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	20	samples	$100.00	$2,000	VOC analysis
Reporting	150	hours	$100.00	$15,000	
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	400	linear feet	$40.00	$16,000	Sonic Drilling, 4 wells to 100 feet
Monitoring Well Installation	400	linear feet	$23.00	$9,200	2" PVC, Schedule 40
Groundwater Circulation Wells	2	lump sum	$50,000.00	$100,000	
GCW Support Structures	2	lump sum	$83,000.00	$166,000	includes piping, packer, blower
Well Install. & Development Oversight	100	hours	$80.00	$8,000	
Drums	10	Drums	$55.00	$550	
Purge Water and Cuttings Disposal	10	Drums	$250.00	$2,500	
Mobilization, Bond, and Insurance	1	lump sum	$60,000.00	$60,000	
Valve Vaults	2	lump sum	$6,400.00	$12,800	
Electrical Service	1	lump sum	$10,000.00	$10,000	
Treatment Shed, Plumbing, Heating	2	lump sum	$30,000.00	$60,000	
First year operation and maintenance	1	lump sum	$187,000.00	$187,000	Cost breakdown provided below
Vapor Intrusion Investigation and Mitigation	1	lump sum	$209,875.50	$209,876	Cost breakdown provided in Table 7
SUBTOTAL				$1,043,126	
Contingency	25%			$260,781	10% scope + 15% Bid
SUBTOTAL				$1,303,907	
Project Management	6%			$78,234	
Remedial Design	12%			$156,469	
Construction Management	8%			$104,313	
TOTAL CAPITAL COST				$1,643,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
OM&M Inspection	250	hours	$80.00	$20,000	
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 3 days
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$46,600	
Misc.					
Electrical	1	Lump Sum	$50,000.00	$50,000	
System effluent sampling	12	samples	$300.00	$3,600	
Carbon replacement	1	Lump Sum	$20,000.00	$20,000	
OM&M Equipment and Materials	1	Lump Sum	$10,000.00	$10,000	
SUBTOTAL				$83,600	
SUBTOTAL				$130,200	
Contingency	25%			$32,550	
SUBTOTAL				$162,750	
Project Management	5%			$8,138	
Technical Support	10%			$16,275	
TOTAL ANNUAL O&M COST				$187,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$1,643,000	$1,643,000	1.00	$1,643,000	
Annual O&M	2-5	$748,000	$187,000	3.55	$663,093	
		$2,391,000			$2,306,093	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$2,306,000	
Capital	1	$1,643,000	$1,643,000	1.00	$1,643,000	
Annual O&M	2-30	$5,423,000	$187,000	15.14	$2,831,381	
		$7,066,000			$4,474,381	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$4,474,000	

Table 7
Remedial Alternative Opinion of Probable Cost

Alternative 7
VI MITIGATION AND MNA

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Description: Alternative 7 consists of soil vapor intrusion investigation and mitigation with quarterly groundwater monitoring for VOCs and natural attenuation parameters. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5 or Years 1-30.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Soil Vapor Intrusion Monitoring and Mitigation					
Work Plan Development	80	hours	$100.00	$8,000	
Drilling Mobilization	1	lump sum	$200.00	$200	
Soil Vapor Point Drilling Subcontractor	5	days	$2,000.00	$10,000	Geoprobe rig
Soil Vapor Point Drilling Oversight	50	hours	$80.00	$4,000	1 person, 1 week
Soil Vapor Point Supplies	1	lump sum	$500.00	$500	
Field Equipment	1	lump sum	$2,000.00	$2,000	
Air and Soil Vapor Sampling	200	hours	$80.00	$16,000	2 people, 2 weeks
Air and Soil Vapor Laboratory Analysis	60	samples	$300.00	$18,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
Mileage	300	miles	$0.585	$176	
Residential Home VI Mitigation Contractor	2	homes	$3,000.00	$6,000	
Residential Home VI Mitigation Oversight	40	hours	$80.00	$3,200	
On-site VI Mitigation Contractor	5	building	$24,000.00	$120,000	$5/ft^2, 120,000 ft^2 per building
On-site VI Mitigation Oversight	150	hours	$80.00	$12,000	
Reporting	80	hours	$100.00	$8,000	
SUBTOTAL				$209,876	
Groundwater Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	60	samples	$100.00	$6,000	VOC analysis
Groundwater Laboratory Analysis	60	samples	$300.00	$18,000	Natural Attenuation Parameters
Groundwater Laboratory Analysis	12	samples	$300.00	$3,600	Dehalococcoides
Groundwater Laboratory Analysis	12	samples	$150.00	$1,800	Disolved Hydrogen
SUBTOTAL				$45,400	
SUBTOTAL				$255,276	
Contingency	25%			$63,819	10% scope + 15% Bid
SUBTOTAL				$319,094	
Project Management	8%			$25,528	
Remedial Design	10%			$31,909	
Construction Management	10%			$31,909	
TOTAL CAPITAL COST				$408,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week
Groundwater Laboratory Analysis	30	samples	$100.00	$3,000	VOC analysis
Groundwater Laboratory Analysis	30	samples	$300.00	$9,000	Natural Attenuation Parameters
Air and Soil Vapor Sampling and O&M	60	hours	$80.00	$4,800	2 people, 2 weeks
Air and Soil Vapor Laboratory Analysis	30	samples	$300.00	$9,000	TO-15 VOC analysis
Data Validation	60	samples	$30.00	$1,800	
SUBTOTAL				$35,600	
Contingency	25%			$8,900	
SUBTOTAL				$44,500	
Project Management	5%			$2,225	
Technical Support	10%			$4,450	
TOTAL ANNUAL O&M COST				$51,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$408,000	$408,000	1.00	$408,000	
Annual O&M	2-5	$204,000	$51,000	3.55	$180,843	
		$612,000			$588,843	5 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$589,000	
Capital	1	$408,000	$408,000	1.00	$408,000	
Annual O&M	2-30	$1,479,000	$51,000	15.14	$772,195	
		$1,887,000			$1,180,195	30 years, 5 %
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$1,180,000	

Table 9
Remedial Alternative Opinion of Probable Cost

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

Alternative	Description	Capital Costs	Annual OM&M Costs	Total Present Value
Alternative 1	IN-SITU BIOREMEDIATION	$1,431,000	$372,000	
	2 injections per year for 5 years			$2,750,000
	2 injections per year for 30 years			$7,063,000
Alternative 2	IN-SITU CHEMICAL OXIDATION	$1,582,000	$527,000	
	4 injections per year for 5 years			$3,451,000
	4 injections per year for 30 years			$9,561,000
Alternative 3	GROUNDWATER EXTRACTION	$1,682,000	$123,000	
	1 time installation OM&M for 5 years			$2,118,000
	1 time installation OM&M for 30 years			$3,544,000
Alternative 4	PERMEABLE REACTIVE BARRIER	$2,663,000	$42,000	
	1 time installation OM&M for 5 years			$2,812,000
	1 time installation OM&M for 30 years			$3,299,000
Alternative 5	AIR SPARGING AND SOIL VAPOR EXTRACTION	$1,890,000	$137,000	
	1 time installation OM&M for 5 years			$2,376,000
	1 time installation OM&M for 30 years			$3,964,000
Alternative 6	IN-WELL AIR STRIPPING	$1,643,000	$187,000	
	1 time installation OM&M for 5 years			$2,306,000
	1 time installation OM&M for 30 years			$4,474,000
Alternative 7	VI MITIGATION AND MNA	$408,000	$51,000	
	5 years of monitoring			$589,000
	30 years of monitoring			$1,180,000
Alternative 8	NO FURTHER ACTION	$0	$0	$0

Notes:
Total Present Value (or Present Net Worth) is based on a 5% discount rate.
Capital costs, which include the first year of O&M, occur in year 1.
Assumes O&M costs incurred at the end of each year.
Cost estimate expected accuracy range of –30 to +50 percent.
Alternative 7 is stand-alone, but vapor intrusion investigation and mitigation is included in Alternatives 1 through 6.

Table 10
Remedial Alternative 30-Year Cost Summary

OPINION OF PROBABLE COST SUMMARY

Site: Scotia Naval Depot
Location: Scotia, New York
Phase: Feasibility Study
Base Year: 2009
Date: July 1, 2009

	1	2	3	4	5	6	7
Alternative	Bio	ISCO	Groundwater Extraction	PRB	Air Sparging	In-Well Air Stripping	VI Mitigation & MNA
Capital Cost	$1,431,000	$1,582,000	$1,682,000	$2,663,000	$1,890,000	$1,643,000	$408,000
Annual O&M	$372,000	$527,000	$123,000	$42,000	$137,000	$187,000	$51,000
Year	Present Net Worth						
1	$1,431,000	$1,582,000	$1,682,000	$2,663,000	$1,890,000	$1,643,000	$408,000
2	$1,785,286	$2,083,905	$1,799,143	$2,703,000	$2,020,476	$1,821,095	$456,571
3	$2,122,701	$2,561,909	$1,910,707	$2,741,095	$2,144,739	$1,990,710	$502,830
4	$2,444,048	$3,017,152	$2,016,960	$2,777,376	$2,263,085	$2,152,247	$546,886
5	$2,750,094	$3,450,716	$2,118,152	$2,811,930	$2,375,795	$2,306,093	$588,843
6	$3,041,565	$3,863,634	$2,214,526	$2,844,838	$2,483,138	$2,452,612	$628,803
7	$3,319,157	$4,256,890	$2,306,310	$2,876,179	$2,585,370	$2,592,154	$666,860
8	$3,583,531	$4,631,419	$2,393,724	$2,906,028	$2,682,733	$2,725,052	$703,105
9	$3,835,315	$4,988,113	$2,476,975	$2,934,455	$2,775,460	$2,851,621	$737,624
10	$4,075,110	$5,327,822	$2,556,262	$2,961,529	$2,863,772	$2,972,163	$770,499
11	$4,303,485	$5,651,354	$2,631,773	$2,987,313	$2,947,878	$3,086,964	$801,808
12	$4,520,986	$5,959,480	$2,703,689	$3,011,869	$3,027,979	$3,196,299	$831,627
13	$4,728,130	$6,252,934	$2,772,180	$3,035,257	$3,104,265	$3,300,428	$860,026
14	$4,925,409	$6,532,413	$2,837,409	$3,057,530	$3,176,919	$3,399,598	$887,072
15	$5,113,294	$6,798,584	$2,899,533	$3,078,743	$3,246,114	$3,494,046	$912,831
16	$5,292,233	$7,052,080	$2,958,698	$3,098,946	$3,312,013	$3,583,996	$937,363
17	$5,462,650	$7,293,505	$3,015,046	$3,118,186	$3,374,774	$3,669,663	$960,726
18	$5,624,953	$7,523,433	$3,068,710	$3,136,511	$3,434,547	$3,751,250	$982,977
19	$5,779,526	$7,742,412	$3,119,819	$3,153,963	$3,491,473	$3,828,953	$1,004,169
20	$5,926,739	$7,950,964	$3,168,494	$3,170,583	$3,545,689	$3,902,955	$1,024,351
21	$6,066,942	$8,149,585	$3,214,852	$3,186,413	$3,597,323	$3,973,433	$1,043,573
22	$6,200,469	$8,338,747	$3,259,002	$3,201,488	$3,646,498	$4,040,556	$1,061,879
23	$6,327,637	$8,518,902	$3,301,049	$3,215,846	$3,693,331	$4,104,481	$1,079,313
24	$6,448,749	$8,690,478	$3,341,095	$3,229,520	$3,737,935	$4,165,363	$1,095,917
25	$6,564,095	$8,853,884	$3,379,233	$3,242,543	$3,780,414	$4,223,346	$1,111,731
26	$6,673,947	$9,009,509	$3,415,555	$3,254,946	$3,820,870	$4,278,568	$1,126,791
27	$6,778,569	$9,157,723	$3,450,148	$3,266,758	$3,859,400	$4,331,160	$1,141,134
28	$6,878,209	$9,298,879	$3,483,093	$3,278,007	$3,896,096	$4,381,247	$1,154,795
29	$6,973,103	$9,433,313	$3,514,470	$3,288,721	$3,931,043	$4,428,950	$1,167,804
30	$7,063,479	$9,561,346	$3,544,352	$3,298,925	$3,964,327	$4,474,381	$1,180,195

Notes:

Present Net Worth is based on a 5% discount rate.

Capital costs, which include the first year of O&M, occur in year 1.

Assumes O&M costs incurred at the end of each year.

Cost estimate expected accuracy range of –30 to +50 percent.