New York State Department of Environmental Conservation
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Feasibility Study Report

Crown Dykman
Town of Glen Cove, New York
Site # 130054

Work Assignment # D-004439-4.1

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Executive Summary

The results of the remedial investigation conducted at the Crown Dykman site (NYSDEC site number 130054) located in the Town of Glen Cove, New York indicate that remediation of soil, beyond the current soil vapor extraction (SVE) system, is not warranted. The data, however, does indicate that light non-aqueous phase liquid (LNAPL) and chlorinated volatile organic compounds (CVOCs) are present in the groundwater at concentrations exceeding the standards, criteria, and guidance (SCGs). Therefore, the groundwater will require remediation. This Feasibility Study outlines the Remedial Action Objectives (RAOs) proposed for the final site-wide remedy, and the SCGs to be considered in addressing the RAOs. Based on the RAOs and the SCGs, the following groundwater treatment technologies were identified for evaluation:

- No Further Action (NFA)
- Monitored Natural Attenuation (MNA)
- Biodegradation/ Bioenhancement
- In-situ Chemical Oxidation (ISCO)
- In-situ Thermal Treatment
- Groundwater Extraction and Treatment
- Zero-valent Iron Injections
- Barrier Technologies
- Air Sparging/Soil Vapor Extraction

Of the above technologies, the following were selected for further evaluation as remedial alternatives.

- NFA
- ISCO with sodium permanganate
- Zero-valent Iron Permeable Reactive Barrier
- Zero-valent Iron Injections

In addition, an alternative capable of restoring the site to pre-disposal conditions was evaluated for comparison purposes. Soil vapor extraction and LNAPL recovery were included as components of each of the remedial alternatives except NFA.

1. Introduction

This Feasibility Study (FS) Report has been developed to evaluate remedial measure alternatives for the Crown Dykman Site (NYSDEC site number 130054) located at 66 Herb Hill Road in the City of Glen Cove, Nassau County, New York (**Figure 1**). This FS Report expands on earlier site investigations and describes the screening of potential remedial measures to address contamination at the site. The purpose of this report is to:

- Identify containment/control remedial technologies for the dissolved-phase CVOC plume;
- Identify containment/control remedial technologies for both the dissolved-phase petroleum plume and free-phase light non-aqueous phase liquid (LNAPL);
- Screen these technologies based on eight criteria; and
- Present and evaluate remedial alternatives based on technologies that could be implemented to meet Remedial Action Objectives (RAOs) and provide site-specific information on performance of the remedial technology.

The overall goal of these remedies is to reduce the current or potential threat to public health and the environment caused by contamination at the site. This FS was completed in accordance with New York State Department of Environmental Conservation (NYSDEC) Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation (DER-10), NYSDEC DER program policy for Presumptive/Proven Remedial Technologies (DER-15), and other appropriate NYSDEC guidance.

1.1. Site History

The site is approximately one acre and contains a one-story cinder block and brick building, which houses two businesses, an auto repair facility and a commercial (water-based) cleaner. S&W Commercial Laundry, a water-based cleaning operation occupies approximately 6,000 square feet of the northern end of the building (**Figure 2**). S&W reportedly does not use solvents in their cleaning processes. ARAW, a Volvo auto repair business, occupies approximately 5,500 square feet of the southern portion of the building. A portion of the Volvo repair facility located in the southwestern area of the building is used as an office and for storage (**Figure 2**).

The site is bordered to the west by the Li Tungsten Parcel B United States Environmental Protection Agency (USEPA) Superfund site, to the south by the former Li Tungsten Parcel A USEPA Superfund site, and to the north by the Konica Minolta property. The Powers Chemco and Columbia Ribbon and Carbon Disposal Company (Powers

Chemco), located within the Konica Minolta property, is a NYSDEC Superfund Class 2 Site. The site is located in a generally commercial and light industrial area of Glen Cove.

Dykman Laundry and Cleaners occupied the property from 1932 to 1975 (Roy F. Weston, 1997). Crown Uniform Service, a dry cleaner and uniform service, occupied the building from 1975 to 1983. Crown Uniform Service used both Stoddard Solvent (a petroleum-based mixture also known as varnoline) and tetrachloroethene (PCE) during its operational history. After 1983, a number of different commercial tenants occupied the building, including auto repair businesses (F.B. Filpse Auto and Northbound Motors), S&W Cleaners, and a woodworking shop (Proyarq 4-5, Inc.). Proyarq reportedly stored and used various lacquers and thinners at the site (NYSDEC, 1993).

1.2. Site Geology and Hydrogeology

The site and its surrounding areas are underlain by the Harbor Hill ground moraine, which consist of a mixture of clay, silt, sand, and boulders. The Harbor Hill ground moraine is typically 5 to 10 feet thick, but can be up to 40 feet thick. Upper Pleistocene age deposits associated with the Ronkonkoma glaciation are deposited beneath the Harbor Hill ground moraine deposits. The Ronkonkoma layer consists of interlayered glacial till and outwash deposits. The glacial sediments associated with both layers range in thickness from less than 10 feet to over 200 feet in the northern part of Long Island (Kilburn and Krulikas, 1987).

Beneath the Upper Pleistocene age deposits is an extensive unit (Port Washington confining unit) comprised of clay, silt, and a few layers of sand that correlates to the Pleistocene and Holocene epochs (Kilburn, 1972). Underlining these sediments is the unnamed clay member of the Raritan Formation. The lower unit of the Raritan Formation is the Lloyd Sand Member, which is approximately 125 feet thick and lies above the bedrock, which is encountered at depths of approximately 400 to 500 feet below mean sea level (Smolensky et al., 1989). Cross-section A-A' is shown on **Figure 3**.

Water levels are approximately five to 10 feet below grade level in the vicinity of the site. Groundwater is assumed to generally flow south-southwest toward the Glen Cove Creek (**Figure 4**).

1.3. Summary of Remedial Investigation

The results of the Remedial Investigation (RI) and an evaluation of available documents and previous investigations, indicate that past releases of CVOCs and petroleum have impacted groundwater at the Crown Dykman Site and adjacent former Li Tungsten Parcels A and B to the south and west of the site, respectively. Based on the sampling and analysis performed during the RI, and an evaluation of past uses and investigations, the following conclusions are supported by the RI:

- The former excavation area in the southwestern portion of the building and adjacent former UST excavation area are likely a potential source of groundwater and soil vapor impacts at the site as discussed in the RI. Historical data indicates that soil near the building foundation may be a continuing source of groundwater and soil vapor impacts. AN SVE system was installed in 2008/2009 as an interim remedial measure to address this contamination.
- The greatest groundwater concentrations of PCE and its degradation products are present in samples downgradient from the southwestern corner of the site building extending off-site to northern portions of the former Li Tungsten Parcel A, and on the eastern portion of the former Li Tungsten Parcel B. PCE in groundwater extends to a depth of up to 35 feet bgs
- No significant impacts to soil or groundwater from petroleum-related compounds or CVOCs were present in the northern portion of the site. PCE and trichloroethene (TCE) were not detected in monitoring wells located upgradient of the site building.
- The extent of CVOCs in groundwater, including PCE, TCE, cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride (VC) have not been fully delineated to the south and west on former Li Tungsten Parcels A and B, respectively. It is likely that concentrations of PCE and related CVOCs in groundwater are moving to the south and southwest, toward Glen Cove Creek.
- Dewatering operations on the former Li Tungsten Parcel B may have caused migration of groundwater contaminants from the southwestern area of the Crown Dykman property toward the former Li Tungsten Parcel B.
- Concentrations of 1,1,2-trichloroethane (1,1,2-TCA) exceeding the respective Class GA Groundwater Standard were present on the former Li Tungsten Parcel B. However, no source on the Crown Dykman property was identified for this compound during the RI, and 1,1,2-TCA was not detected in soil samples from Crown Dykman or the former Li Tungsten Parcel B during the RI.
- Concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX) and other petroleum compounds exceeding their respective NYSDEC Class GA Groundwater Standards or Guidance Values and measurable LNAPL in monitoring wells MW-6R and MW-8 indicate a petroleum release at the site.
- Impacts to soil and groundwater from CVOCs and petroleum are a source of soil vapor contamination contributing to the degradation of indoor air quality within the site building via the soil vapor intrusion pathway. Based on the NYSDOH guidance, action is recommended to reduce the current impact, and the potential for these volatile organic compounds in soil vapor to continue to impact indoor air. While operation of the current SVE system may be addressing the soil vapor intrusion pathway, additional sampling will be necessary.

- The presence of petroleum in groundwater at the site may be contributing to conditions favorable to the natural attenuation of CVOCs present in groundwater. Degradation and natural attenuation of CVOCs present in the groundwater was evident in the analytical data, and evaluation of natural attenuation parameters and the presence of *Dhc* under anaerobic conditions suggest that subsurface conditions are conducive to biodegradation at the site.

1.4. Nature and Extent of Contamination

Based on the information collected during the RI (Malcolm Pirnie, 2009) as well as the historical data collected, chemical compounds of potential concern have been identified in sub-slab vapor, indoor air, soil, and groundwater. Compounds of potential concern were selected based on frequency of detection, range of concentration, and potential for migration. The following are the media which were investigated and a summary of the findings of the investigation.

Soil

Based on previous investigations at the site, past activities at the site have contributed to significant past impacts to soil and groundwater at the site. Most significantly, during a period between August 1997 and July 1999, investigations at the site indicated that floor drains in the southwestern area of the building and a former solvent tank area were potential sources of contamination. Additional sub-slab soil sampling and soil samples collected from a trench area in the southwestern corner of the building in January 2000 showed significant concentrations of PCE present below the floor slab to a maximum depth of approximately 5 feet (Walden Associates, 2006).

Based on this information, a limited remedial action was performed at the site in 2004 in the southwestern corner of the building that included excavation of soil in the southwestern corner of the building, and installation of sub-slab piping intended for a depressurization system to mitigate contamination not removed during the excavation. However, subsequent confirmation sampling of the excavation showed that not all of the contaminated soil was removed. One soil sample collected within the excavated area near the southern building foundation footing (SS-2) contained a PCE concentration of 290,000 ug/kg (Walden Associates, 2006).

Based on data collected during past investigations at the site and the results of groundwater sampling and soil vapor sampling during the RI, the southwestern area of the building is likely a potential source of groundwater and soil vapor intrusion impacts at the site. However, past releases at the site do not appear to have significantly impacted subsurface soil outside of this area.

The RI soil analytical data was compared to 6 NYCRR Part 375 soil cleanup objectives (SCOs), which were developed for individual compounds for various land use categories as well as for the protection of ecological resources and groundwater. During the RI, samples were not collected within the southwestern area of the building where contamination was noted during the excavation confirmation sampling due to obstructions from the SVE system. However, subsurface soil samples were collected outside of the area adjacent to the previously noted residual contamination. The results of the soil sampling and analysis did not yield significant concentrations of VOCs in subsurface soil (sample locations SB-16 and SB-17). The concentrations of VOCs detected did not exceed their respective unrestricted use or commercial SCOs, with the exception of VC in sample SB-5 (an estimated 84 ug/kg) near the western side of the building, at a depth of 2-5 feet. Only acetone and two petroleum-based compounds (1,2,4 trimethylbenzene and n-propylbenzene) were detected at concentrations exceeding their respective unrestricted use SCOs. Non chlorinated VOCs detected in soil samples below the respective SCOs were primarily petroleum and BTEX compounds. No semivolatile organic compounds (SVOCs) were detected in subsurface soil samples exceeding their respective unrestricted use or commercial SCOs. As such, no further remedial alternatives (except continued operation of the SVE system) for soil are considered in this FS Report.

Groundwater

Previous groundwater investigations at the site provided information that indicated impacts to groundwater resulting from past site activities and releases of both CVOCs (including PCE) and petroleum compounds likely associated with former underground storage tanks (USTs) present at the site. Previous groundwater samples collected from MW-1 in 1992 and 1999 contained concentrations of PCE ranging from 11,000 ug/l to 12,100 ug/l, and TCE concentrations ranging from 4,000 ug/l to 6,900 ug/l respectively. PCE and TCE were present in the sample from well MW-1D taken in 1999 at concentrations of 7,000 ug/l and 2,400 ug/l, respectively.

The RI groundwater monitoring program was conducted to determine if previously noted contamination is still present and further delineate the extent of contamination. The results of the groundwater RI show that the greatest concentrations of PCE and its degradation products are present in samples downgradient from the southwestern corner of the site building extending off-site to northern portions of the former Li Tungsten Parcel A, and on the eastern portion of the former Li Tungsten Parcel B. Concentrations in wells down-gradient from the site building correlate with a release and subsequent groundwater impacts from the area where CVOC contaminated soils were removed during 2004. However, the concentrations to the west of the site building and on the adjacent former Li Tungsten Parcel B sampling locations indicate off-site activities that have affected groundwater flow and contaminant migration in groundwater at the site. The groundwater PCE, TCE, cis-1,2-DCE, and VC concentrations are summarized on **Figures 5 through 8**.

PCE and its degradation products were not present in samples from monitoring wells located on the former Li Tungsten Parcel B (wells GM-7 and GM-9) taken during previous investigations prior to 2007. However, as discussed in Section 3, dewatering was underway on the former Li Tungsten Parcel B from circa 2006 until the summer of 2007. Groundwater from well GM-9 and direct push locations SB-07 and SB-06 sampled during and after this time (June 2007 and September-October 2007, respectively) showed significant concentrations of CVOCs including PCE, TCE, cis-1,2-DCE and VC in groundwater between the assumed source area and the former Li Tungsten Parcel B. Based on data from the RI and previous investigations, dewatering operations on the former Li Tungsten Parcel B have likely caused migration of groundwater contaminants from the source area toward the former Li Tungsten Parcel B.

Sampling results from September 2008 show that concentrations of PCE and its degradation products are greatest in the shallow monitoring well (MW-10) just outside and down-gradient of the area of remediated soils within the southern corner of the site building. Concentrations of PCE in groundwater are greatest between this area and well GM-9 on the eastern side of the former Li Tungsten Parcel B. The distribution of TCE, cis-1,2-DCE, and VC are similar to that of PCE.

Based on the results of the September 2008 sampling event, the extent of CVOCs in groundwater, including PCE, TCE, cis-1,2-DCE, and VC have not been fully delineated to the south and west on former Li Tungsten Parcels A and B, respectively. Based on groundwater sampling data from the 2006 and 2008 sampling events, it is likely that concentrations of PCE and related CVOCs in groundwater are moving to the south, toward Glen Cove Creek.

Concentrations of BTEX and other petroleum compounds exceeding their respective NYSDEC Class GA Groundwater Standards or Guidance Values and measurable LNAPL in monitoring wells MW-6R and MW-8 indicate a petroleum release at the site. Former USTs at the site include those that contained solvents, fuel oil, and gasoline. According to a report submitted by Roy F. Weston (1997), two 550-gallon and two 2,000-gallon solvent USTs were present where MW-8 is located. The presence of petroleum in groundwater at the site may be contributing to conditions favorable to the natural attenuation of CVOCs present in groundwater, as discussed below.

Surface Soil and Surface Water

The results of surface soil sampling at the site did not indicate the presence of VOCs in surface soil. SVOCs exceeding their respective unrestricted use SCO were present in four of the 12 surface soil samples, and only one sample contained concentrations of benzo(a)pyrene that exceeded its respective commercial use SCO. These results are consistent with observations of surface soil staining related to a current uses at the site, including automotive repair and the presence of vehicular traffic at the site.

No pesticides or PCBs were detected in surface soil samples at concentrations exceeding their respective commercial use SCOs. Concentrations of 4,4 DDT and its derivatives (including 4,4-DDD and 4,4-DDE) exceeding their respective unrestricted use SCOs were present in all of the surface soil samples, likely related to historic application of DDT on Long Island. PCBs were not detected at concentrations exceeding their respective unrestricted use SCOs.

The surface water sample from the storm water cistern at the intersection of Herb Hill Road and Dickson Street (SW-01) did not contain VOCs at concentrations greater than the respective GA Standard. However, this cistern was observed to be flowing continuously during site activities. Concentrations of PCE, TCE, and cis-1,2-DCE were present at concentrations below the Class GA Standard (all detected at an estimated 1 ug/l).

Sub-slab Soil Vapor and Indoor Air

Consistent with groundwater sampling results, PCE, TCE and cis-1,2-DCE were the primary constituents in sub-slab soil vapor samples collected from the areas adjacent to the former excavation area in the southwestern portion of the site building. These CVOCs were also present in indoor air samples, with the greatest concentrations of PCE in indoor air detected in the sample from inside the storage area adjacent to the Volvo Repair Shop. A soil vapor extraction system has been installed at the site and will continue to be operated as part of the selected site remedy.

Sub-slab Piping System Evaluation and Sampling

As discussed previously, a limited remedial action was performed at the site in 2004 in the southwestern corner of the building that included excavation of soil in the southwestern corner of the building, and installation of sub-slab piping intended for a depressurization system to mitigate contamination not removed during the excavation. However, subsequent confirmation sampling of the excavation showed that not all of the contaminated soil was removed. Based on the results of the investigation, a “sub-slab venting system” (Walden Associates, 2006) was installed prior to installing a new floor slab in the excavated area, which consisted of 2-inch perforated PVC piping. However, no subsequent sub-slab soil vapor or indoor air sampling was performed, and the piping system was never utilized.

In 2008, the existing sub-slab piping system in the southwestern area of the site building was connected to a temporary collection and treatment system after completion of the sub-slab soil vapor sampling to assess the potential effectiveness of a future soil vapor extraction system using existing sub-slab piping. This information was also used to evaluate potential soil vapor intrusion issues at the site, and to develop a response to potential soil vapor intrusion issues as discussed in the Remedial Investigation (RI) Report.

As described in the RI Report, the temporary collection system was sampled in accordance with the procedures outlined in the Generic QAPP for Work Assignments, in accordance with the NYSDOH Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York, dated October 2006. Each air sample was analyzed for VOCs by USEPA Method Low Level TO-15 Selective Ion Mode (SIM). In addition to sampling the air discharged from the collection system prior to treatment, the system was monitored by connecting manometers to the sub-slab soil vapor sampling points installed during the sub-slab soil vapor sampling round. The vacuum below the building was monitored at these points to assess the performance of the piping system. The results of the sub-slab piping system evaluation and sampling are presented in the RI Report.

Based on the results of the sub-slab piping system evaluation, Malcolm Pirnie developed a depressurization system to operate at the site that utilized the existing sub-slab piping system. The system was installed in December 2008, after review and approval of the system design by the NYSDEC. The system consists of a regenerative blower, control equipment, and a carbon canister effluent treatment system installed on a skid-mounted platform outside of the building adjacent to the western wall inside a fenced storage area. The system is connected to the existing sub-slab piping system by piping installed through the building.

Prior to full system operation, the system was tested, and vacuum was measured at six of the seven previously-installed sub-slab soil vapor sampling points, as discussed in the RI Report. System operation was started on December 30, 2008. During a site visit to assess system performance and check system operation in April 2009, Malcolm Pirnie collected a sample from the system influent. The sample was collected from the system influent sampling port over a half-hour period using a 6-liter Summa canister, and sent to an analytical laboratory for analysis using USEPA Method TO-15. The results of the system performance sample analysis indicate that PCE and related degradation products are present in the soil vapor beneath the site building slab, as discussed in the RI Report.

2. Identification of RAOs, SCGs, and GRAs

This section outlines the Remedial Action Objectives (RAOs) proposed for the final site-wide remedy, and the standards, criteria, and guidance (SCGs) to be considered in addressing the RAOs. General response actions (GRAs) are medium-specific actions that could be taken to address the RAOs.

2.1. Remedial Action Objectives

RAOs are goals set for environmental media, such as soil, groundwater, sediment, surface water, soil vapor, and indoor air that are intended to provide protection for human health and the environment. RAOs form the basis for the FS by providing overall goals for site remediation. The RAOs are considered during the identification of appropriate remedial technologies and formulation of alternatives for the site, and later during the evaluation of remedial alternatives. RAOs are based on engineering judgment, risk-based information established in the risk assessment, and potentially applicable or relevant and appropriate SCGs. 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, exposures to volatile organic compounds in the indoor air originating from groundwater and soil contamination as a result of soil vapor intrusion;
- Reduce, to the extent practicable, on-site groundwater concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values;
- Reduce, to the extent practicable, off-site groundwater concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values; and
- Remove, to the extent practicable, LNAPL from the subsurface and prevent its migration from the site.

2.2. Applicable Standards, Criteria, and Guidance

6 NYCRR Part 375 requires that SCGs are identified and that remedial actions conform with SCGs unless "good cause exists why conformity should be dispensed with". Standards and Criteria are cleanup 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, or location. Guidance includes non-promulgated criteria and guidelines that are not legal requirements; however, the site's remedial program should be designed

with consideration given to guidance that, based on professional judgment, is determined to be applicable to the site.

The principle SCGs for the site are listed below:

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

Soil:

- 6 NYCRR Part 375 – Soil Cleanup 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:

- Air Guide 1 – Guidelines for Control of Toxic Ambient Air Contaminants
- NYSDOH October 2006 Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York

There are three types of SCGs: chemical-, location-, and action-specific SCGs. Chemical-specific SCGs are health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to the ambient environment. Location-specific SCGs set restrictions on activities based on the characteristics of the site or immediate environs. Action-specific SCGs set controls or restrictions on particular types of remedial actions once the remedial actions have been identified as part of a remedial alternative. The identification of potential SCGs is summarized in **Table 1**.

2.3. General Response Actions for Groundwater

NYSDEC Program Policy DER-15: *Presumptive /Proven Remedial Technologies*, provides generally accepted presumptive remedies for various site media which comply with 6 NYCRR section 375-1.8. Presumptive remedies for VOC contaminated site media are presented in Section 4 of the DER-15 guidance document. The purpose of the presumptive remedy approach is to streamline the remedy selection process by providing remedies which have been proven to be both feasible and cost-effective for specific site types and/or contaminants. In accordance with DER-10, Section 4.2(a)3 the use of presumptive remedies eliminates the need to screen the selected technologies and to proceed directly to the evaluation of the presumptive alternatives.

In accordance with DER-10, Section 4.2(a)3 GRAs have been identified for groundwater which may be effective remedies for the remediation of groundwater at site. The GRAs identified include:

- **No Action -** A no action response, required by DER-10 provides a baseline for comparison with other alternatives.
- **Institutional Controls -** Institutional controls are applied when active remedial measures do not achieve cleanup limits. Human exposure and potential health risk are reduced by limiting public access to site contaminants. Institutional controls such as environmental easements can also apply through an extended remediation period, or to sites where cleanups are completed up to feasible levels but still leave residual contamination greater than background levels.
- **Monitored Natural Attenuation (MNA)** - MNA, also known as intrinsic remediation, bioattenuation, or intrinsic bioremediation, refers 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
- **In-situ Treatment**- In-situ treatment for groundwater uses various technologies including biological, thermal, and reactive materials. In-situ treatment is effective in treating source areas of contamination but can be prohibitively expensive for treatment of large areas of groundwater contamination
- **Removal Measures-** Removal measures provide for the removal of contaminants or contaminated materials from their existing location for treatment (on-site or off-site) or disposal. Groundwater extraction systems are typically used to remove groundwater and are combined with various ex-situ treatment technologies including UV oxidation, air stripping, and granular activated carbon. The effluent treated water is often returned to the subsurface through injection wells, released to surface water bodies, or released to the local Publicly-Owned Treatment Works (POTW).

- **Containment/Barrier** - Containment for groundwater includes remedial measures that contain or isolate contaminants on-site. Containment prevents migration of contaminants from the site and attempts to prevent direct human and ecological exposure to contaminated media. Examples of containment technologies are grout slurry walls, sheet piling, hydraulic control by pumping, and reactive barriers. Containment technologies are often combined with other treatment technologies to remove contamination.

3. Identification and Selection of Remedial Technologies

Based on the GRAs for groundwater at the site the following treatment technologies have been identified for evaluation:

- No Further Action
- Monitored Natural Attenuation
- Biodegradation/ Bioenhancement
- In-situ Chemical Oxidation
- In-situ Thermal
- Groundwater Extraction and Treatment
- Zero-Valent Iron
- Barrier Technologies
- Air Sparging/Soil Vapor Extraction

3.1. No Further Action

A no further action alternative for groundwater will be considered further. As indicated by the name, under this alternative no work will be completed at the site. This alternative will serve as a baseline for comparison for all other remedial alternatives considered for the site.

3.2. Monitored Natural Attenuation

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 evaluation of contaminant degradation rates and pathways, and predicting contaminant concentrations at downgradient receptor points. The primary objective of this evaluation would be to demonstrate that the natural processes of contaminant degradation will reduce contaminant concentrations to less than regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long term monitoring must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with the eventual attainment of RAOs.

Based on observed concentrations of CVOCs, the RAOs for the site cannot be met by MNA alone in a reasonable time period. MNA will not be considered further as a primary remedial alternative for the site. However, MNA will be considered as a secondary or polishing remedial technology.

3.3. Biodegradation/Enhanced Biodegradation

Biodegradation, or bioremediation, is the controlled management of microbial processes in the subsurface. Enhanced bioremediation is accomplished through the addition of organic carbon source, nutrients (including phosphate, nitrate, and potassium), electron acceptors, and/or microbial cultures to stimulate degradation. This differs from monitoring of bioremediation processes under MNA as it is an active, designed, and managed process. 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.

A key factor in the design of bioremediation programs 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 high concentration 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.

Enhanced bioremediation is appropriate for sites in which natural biological activity has been confirmed. Anaerobic conditions are generally required for heavily chlorinated compounds including PCE, TCE, 1,1,1-TCA, and 1,2-DCE. Carbon sources used at anaerobic sites include molasses, edible oils, lactic acid, sodium benzoate, methane, and yeast extract. Because naturally occurring bacteria are the primary degradation mechanism, enhanced bioremediation can be less expensive than chemical or physical treatment technologies.

The presence of Dehalococcoides bacteria can be quantified to evaluate if bioaugmentation with Dehalococcoides 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, it is likely that sufficient reductive dechlorinators are already present and bioaugmentation may not be necessary.

A disadvantage of a biodegradation is the possible increase of 1,2-DCE and VC within and downgradient of the treatment area. This is due to the TCE byproducts' (DCE and VC) slower anaerobic reduction rates. Additional byproducts of bioremediation 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.

Advantages of biodegradation and/or enhanced biodegradation typically include:

- effective reduction of CVOC concentrations under the right conditions;
- in-situ degradation of CVOCs; and
- generally less expensive than other remedial technologies.

Disadvantages of biodegradation and/or enhanced biodegradation typically include:

- High levels of contamination can kill the organisms needed for remediation;
- Depending on soil type, degree of heterogeneity, and groundwater depth, this technology may be cost prohibitive;
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient;
- When adding nutrients, biofouling of any injection or extraction wells may occur;
- Not all compounds are equally amenable to biological degradation;
- Some intermediate compounds in the biodegradation pathway are more mobile and/or toxic than their parent compounds (i.e., VC is 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.

As degradation byproducts are present in site groundwater, enhanced bioremediation will be considered further as a secondary remedial technology for the site.

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., BTEX and methyl tertiary-butyl ether (MTBE)] and semi-volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and pesticides.

ISCO is defined as the delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants of concern into innocuous end products such as carbon dioxide (CO_2), water, and inorganic compounds. Injection locations can be either permanently installed wells or temporary injection points installed using direct-push methods. When oxidants come in contact with contaminants they are broken down into non-toxic components. However, contact between the oxidant and contaminant required to facilitate the reaction 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 typically include:

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

Disadvantages of ISCO 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;
- The difficulty of contacting oxidants with groundwater contaminants intended for destruction 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;
- Relatively high costs per volume treated; and
- 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. Soluble iron (ferrous iron), the transition metal catalyst added to the subsurface during injection of the oxidant mixture, is precipitated out of solution during conversion to ferric iron.

  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 may be required to sustain the oxidant in the subsurface compared to injections of other oxidants. As such, Fenton's reagent will not be considered further.

- **Sodium and Potassium Permanganate-** Permanganate is an oxidizing agent with a unique affinity for oxidizing organic compounds with carbon-carbon double bonds (ethenes), 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 (up to 40 percent, 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. The U.S. Department of Homeland Security (DHS), in accordance with securing the nation's chemical facilities, has placed potassium permanganate on a list with other chemical substances determined to be potentially dangerous. Because of the homeland security issues, paperwork, and restrictions placed on the use of potassium permanganate, potassium permanganate will not be considered further in a potential ISCO remedial alternative. However, sodium permanganate will be retained for further consideration.

- **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 and will not be considered further as a potential ISCO remedial alternative.

- **Regenox-** RegenOx is a proprietary mixture of oxidants used to treat VOCs in groundwater. A RegenOx application will remove significant amounts of contamination from the subsurface and is typically applied using direct-injection techniques. The application process enables the two part product to be combined, then pressure injected into the zone of contamination and moved out into the aquifer media. Once in the subsurface, RegenOx produces a cascade of efficient oxidation reactions via a number of mechanisms including: surface mediated oxidation, direct oxidation and free radical oxidation. These reactions eliminate contaminants and can be propagated in the presence of RegenOx for periods of up to 30 days on a single injection. RegenOx produces minimal heat and is highly compatible with follow-on enhanced bioremediation applications. Regenox will not be considered further as an ISCO remedial alternative.

ISCO, using sodium permanganate, will be considered further as a remedy.

3.5. Groundwater Extraction and Treatment

Groundwater extraction and treatment, 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 control 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 evaluated to characterize transport of the contaminant and evaluate the feasibility of groundwater pumping. To determine if groundwater extraction is appropriate for a site, the following information is needed:

- Properties of the subsurface including aquifer characteristics which would affect groundwater recovery rates and radius of influence; and
- The biological and chemical characteristics of the groundwater.

The following factors may limit the applicability and effectiveness of groundwater pumping as a 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 or rock pores cannot be removed effectively by groundwater pumping. Contaminants tend to be sorbed in the soil or rock matrix. Groundwater pumping is generally not applicable as a remedial technology for contaminants with high residual saturation, contaminants with high sorption capabilities, and aquifers 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 spent carbon and the handling of other treatment residuals and wastes; and
- Bio-fouling of the extraction wells, and associated treatment stream, is a common problem which can severely affect system performance.

Despite the potential drawbacks related to installation, operation, and maintenance, groundwater extraction with ex-situ treatment has the potential to quickly control dissolved-phase plume migration. Following treatment, the water would be re-injected into the subsurface or discharged to a sanitary sewer or surface water body in accordance with SPDES requirements. Extracted groundwater is generally treated by granular activated carbon (GAC), air stripping, or ultraviolet (UV) oxidation. Extracted vapors may also need to be treated. A description of several ex-situ groundwater treatment technologies is provided below:

3.5.1. Advanced Oxidation Process

Advanced oxidation processes are similar to in-situ chemical oxidation in that oxidants are used to degrade contaminants to carbon dioxide, water, and simple organic and inorganic compounds. The process typically uses ozone, hydrogen peroxide, and ultraviolet light (UV) in some combination to form hydroxyl radicals (OH^-). Hydroxyl radicals have the highest oxidation potential and readily breakdown contaminants such as TCE.

Advanced oxidation processes are available in many forms and generally are used in treatment systems for groundwater that contain higher concentrations of CVOCs. The most widely used products are systems using hydrogen peroxide/UV, ozone/UV, and hydrogen peroxide/ozone. For evaluation purposes, the hydrogen peroxide/ozone system has been selected. This system is effective in treating VOCs and is not significantly affected by turbidity as are processes using UV due to the need to keep UV lamps clean. Ozone is readily mixed with groundwater in the controlled environment of the treatment piping. Although it is effective at treating a wide variety of compounds, oxidation will not be considered further because of its high costs relative to granular activated carbon and air stripping.

3.5.2. Air Stripping

Air stripping involves the mass transfer of VOCs from water to air. In the air stripping process, VOCs are partitioned from extracted groundwater by increasing the surface area of the water containing TCE exposed to air. 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.

Aeration methods include packed towers, diffused aeration, tray aeration, venturi aeration, and spray aeration. For groundwater remediation, the most widely used process typically involves use of a packed tower or tray aeration. The typical packed tower air stripper includes a spray nozzle at the top of the tower to distribute water containing VOCs over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect treated water. Packed tower air strippers can be installed as either permanent structures on concrete pads or as temporary structures on a skid or trailer, mainly depending on the volume of water treated. Low-profile air strippers, or tray aerators, include a number of trays in a very small chamber to maximize air-water contact. These systems are easier to install and operate than other air strippers, but have a somewhat larger footprint. Air strippers commonly use vapor-phase activated carbon systems to capture VOCs in off-gases, especially in early stages of remediation when VOC concentrations are higher. Air stripping will not be considered further because of its high costs relative to granular activated carbon.

3.5.3. Carbon Adsorption

Carbon adsorption is most appropriate for low concentrations and/or low flow rates of contaminated water. Liquid phase carbon adsorption typically involves pumping groundwater through one or more vessels in series containing activated carbon to which dissolved TCE adsorbs. When the concentration of contaminants in the effluent from the treatment vessel exceeds a certain level, the carbon is typically removed and regenerated off site or disposed. The most common reactor configuration for carbon adsorption systems involving groundwater is the fixed bed approach with two vessels in series. The fixed-bed configuration is the most widely used for adsorption from liquids. The duration of operation and maintenance (O&M) is dependent upon the contaminant type, concentration, mass treated, other organics or metals that occupy adsorption sites, and the clean-up requirements. It should be noted that several compounds, including VC, TCA, DCA, chloroform, methylene chloride, and alcohols, have a poor affinity for carbon absorption. Because several of these compounds are present in site groundwater, carbon adsorption will not be considered further.

Groundwater extraction and treatment will not be considered further because it is not cost effective compared to other technologies and implementation of the groundwater extraction would require significant operation and maintenance effort over an extended time period.

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. 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. As such, a physical wall will not be considered further.

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. A biological barrier will not be considered further because of the difficulties associated with maintaining an effective biological barrier.

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. Groundwater monitoring systems are typically installed to monitor the effectiveness of a PRB (or other remedial technology) over the long term.

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.

Advantages of zero-valent iron PRBs typically include:

- The zero-valent iron PRB is a passive method of treatment and long-term operations, maintenance, and monitoring (OM&M) 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.

The use of a zero-valent iron PRB will be considered further.

3.7. Zero-Valent Iron Injections

Zero-valent iron can be injected into the subsurface to degrade chlorinated VOCs via abiotic reductive dehalogenation. The degradation processes are the same as during the treatment of contaminated groundwater with a zero-valent iron PRB. Zero-valent iron can be injected into the subsurface using a gas- or liquid-based delivery system. The path of the zero-valent iron in the subsurface can be monitored to ensure fracture coalescence or overlap using resistivity sensors. In low permeability or heterogeneous formations, pneumatic or hydraulic fracturing can be used prior to injection of the zero-valent iron to increase the permeability of the formation and radius of influence. Zero-valent iron is often combined with controlled-release carbon or other substances to more fully degrade contaminants in groundwater.

Zero-valent iron would be used to treat the area of highest groundwater CVOC concentration, in the vicinity of MW-1, MW-7, MW-8, and MW-10. It is anticipated that injecting a 2-4 micron zero-valent iron colloidal suspension will reduce the time required to create dechlorinating conditions and may also reduce the time needed to completely dechlorinate CVOCs. In the presence of zero-valent iron, oxidation of the dissolved phased CVOCs will occur while initiating the production of hydrogen for microbial mineralization processes. Zero-valent iron would be used to treat dissolved-phased CVOCs while acting in synergy with anaerobic degradation processes. Zero-valent iron injections will be considered further as a remedy.

3.8. 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; and
- Relatively low cost compared to other remedial technologies.

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, manifold, piping, and injection structures are needed; and
- Cannot be used for treating confined aquifers.

Air sparging and soil vapor extraction will not be considered further because of the heterogeneous nature of the aquifer and difficulties associated with extraction of soil vapor, designing an effective vapor control, and implementation next to and under the site building. However, soil vapor extraction, which is not a viable technology to treat groundwater, is currently being used at the site to treat residual soil contamination and soil vapor.

3.9. Summary of Selected Technologies

Based on the extent and magnitude of contamination and the physical and hydrogeologic characteristics of the site, the following technologies have been selected for further evaluation as remedial alternatives.

1. NFA
2. ISCO with sodium permanganate
3. Zero-Valent Iron PRB
4. Zero-Valent Iron Injections

4. Development and Screening of Alternatives

Medium-specific Remedial Action Alternatives (RAAs) for the protection of public health and the environment were developed based on a comparison of the results of the RI to SCGs. Potential RAAs for the site were identified by:

- Developing RAOs that specify the contaminants and media of interest, potential exposure pathways, and remediation goals. The objectives developed were based on contaminant-specific cleanup criteria and SCGs;
- Developing general response actions for each medium of interest that may be taken to satisfy the RAOs for the site;
- Identifying volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the RAOs and the chemical and geological characterization of the site;
- Identifying and screening the technologies applicable to each medium of interest to eliminate those technologies that cannot be implemented technically at the site; and,
- Assembling the selected representative technologies into appropriate alternatives.

An evaluation of each of the RAAs is provided in Section 4.2.

4.1. Evaluation Criteria

The remedial alternatives were evaluated based on the following criteria, as outlined DER#10 Section 4.1(e):

- Overall protectiveness of the public health and the environment;
- Compliance with SCGs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term impacts and effectiveness;
- Implementability;
- Cost; and
- Community Acceptance.

Overall protectiveness of the public health and the environment

This criterion assesses whether each alternative is 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 SCGs. 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 SCGs

This evaluation criterion assesses how each alternative complies with applicable or relevant and appropriate SCGs, as discussed and identified in Section 3. If an SCG is not met, the basis for one of the four waivers allowed under 6 NYCRR Part 375-1.10(c)(1) is discussed. If an alternative does not meet the SCGs and a waiver is not appropriate or justifiable, it should not be considered further.

Short-term Impacts and 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 RAOs 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 compounds remaining in environmental media at the site and operating systems 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 contaminant's 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, OM&M, and future capital costs. A cost analysis is performed which includes the following factors: the effective life of the remedial action, the OM&M costs, the duration of the cleanup, 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).

Community Acceptance

This evaluation criterion addresses the public participation program that was followed for the project. The public's comments, concerns and overall perception of the proposed remedial alternative are evaluated in a format that responds to all questions that are raised. Community acceptance of the proposed remedy for the Crown Dykman Site will be evaluated after the public comments have been received.

4.2. Common Components of Remedial Alternatives

The elements common to each of the alternatives being evaluated for the site are discussed below and summarized in the description of each remedial alternative in Section 4.3.

4.2.1. Site Management Plan

A Site Management Plan would guide future activities at the site by addressing property and groundwater use restriction and by developing requirements for periodic site management reviews. The periodic site management reviews would focus on evaluating the site with regard to the continuing protection of human health and the environment as provided by information such as indoor air and groundwater monitoring results and documentation of field inspections.

4.2.2. Environmental Easement

Building/property use restrictions and groundwater use restrictions would be placed on the site property through an environmental easement that would require compliance with the approved site management plan. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. In addition a site management plan could preclude excavation and construction activities that would expose workers without proper protective equipment to affected groundwater. Costs for an environmental easement were not included in the remedial alternative cost estimates.

4.2.3. Soil Vapor Intrusion Mitigation

A soil vapor intrusion mitigation plan would be developed to assess the effectiveness of the soil vapor extraction (SVE) system. This SVE system would be operated continuously until NYSDEC determines that it is no longer necessary. Periodic SVE system inspections would be conducted to confirm that it is functioning as intended and designed. For costing purposes, it is assumed that the SVE system would be operated for ten years, during which time it would be inspected monthly and a carbon drum would be replaced once per month.

4.2.4. Monitored Natural Attenuation

Monitored natural attenuation (MNA) would be implemented as part of each active remedial alternative in areas outside of the treatment zone. The MNA alternative would involve periodic sampling and analysis of site groundwater. To further delineate the extent of groundwater contamination, 6 additional monitoring wells would be installed. Groundwater from approximately 14 wells in the site monitoring well network would be sampled annually and analyzed for VOCs, field parameters, and natural attenuation (NA) parameters. Field parameters will include oxidation/reduction potential (ORP), DO, pH, temperature, and specific conductance. NA parameters will include chloride, nitrite, nitrate, sulfate, ferrous iron, ferric iron, alkalinity, dissolved sulfide, dissolved organic carbon, methane, ethane, ethene, and carbon dioxide.

No active groundwater remediation is included in MNA. If MNA alone is implemented, the dissolved-phase CVOC plume would not be remediated other than with natural processes (i.e. dilution, dispersion, natural attenuation, etc.). For this reason, MNA alone would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume. MNA would be protective of human health and the environment because groundwater containing site-related CVOCs is not being used as a water supply and exposures resulting from soil vapor intrusion would be mitigated. MNA requires minimal effort to implement and would have significantly lower capital and OM&M costs than technologies that include active treatment of the dissolved-phase CVOC plume. MNA would be implemented for a period of five years as a secondary component of the selected groundwater treatment remedial alternative.

4.2.5. LNAPL Recovery

The selected remedial alternative for light non-aqueous phase liquid (LNAPL) is separate phase recovery, which is described and evaluated below.

The separate phase recovery alternative would consist of a network of approximately four LNAPL recovery wells screened across the groundwater-LNAPL interface. A pre-design investigation would be performed to assess the lateral extent of the LNAPL and the possible source area to effectively locate the recovery wells. Recovery wells would be constructed of 4’’ PVC and would be placed in subgrade vaults with manholes. LNAPL recovery would be performed with the use of an automated LNAPL pumping system with a motorized reel capable of tracking the rise and fall of the groundwater- LNAPL interface. The recovered LNAPL would be contained on-site in 55 gallon drums stored within secondary confinement. Overflow sensors would be installed on the containment drums. An O&M plan would be developed for the system. This action would be incorporated with the potential alternates for groundwater remediation without affecting their effectiveness.

Overall protectiveness of the public health and the environment

The LNAPL recovery system would be effective at removing LNAPL from the subsurface therefore reducing a source of groundwater contamination at the site. The system would achieve the RAO for LNAPL by actively removing LNAPL from the subsurface.

Compliance with SCGs

Compliance with SCGs would be attained through the implementation of LNAPL recovery. LNAPL would be removed from the subsurface and would no longer act as a continuing source of dissolved-phase groundwater contamination.

Long-term effectiveness and permanence

This alternative effectively and permanently reduces long-term impacts from LNAPL to groundwater at the site.

Reduction of toxicity, mobility, and volume

This alternative would reduce the mobility and volume of LNAPL through its physical removal from the subsurface.

Short-term impacts and effectiveness

LNAPL removal would be effective in the short-term. The greatest amount of LNAPL is typically recovered by such systems at the outset of their operation.

Implementability

LNAPL recovery is a presumptive remedy for groundwater contaminated with NAPL (Section 3.2.5 of Attachment to DER-15 NYSDEC Program Policy). LNAPL recovery utilizing mechanical pumping is a common practice which has been used at many sites. A pre-design investigation would be necessary to design a LNAPL recovery system which would target the source area as well as control further LNAPL migration.

Based on the final LNAPL delineation, it may be necessary to install extraction wells inside the existing site building. If this is warranted, the wells would be installed in sub-slab vaults with manhole covers. The wells, controls, and drums containing LNAPL would be placed out of the way of day-to-day business operations in the building.

Cost

The opinion of probable cost for LNAPL recovery, with an expected accuracy range of –30 to +50 percent, is presented in Table 2. The cost opinion is based on the installation and operation of a LNAPL extraction system including four 4-inch diameter PVC recovery wells. The capital costs include the costs for the LNAPL recovery system components, a shed to house the treatment system, installation of the recovery wells. The total assumed capital costs including the first year of OM&M is approximately $275,000. Annual OM&M cost including maintenance of the LNAPL recovery system is estimated to be approximately $28,000. The total present value of this alternative based on a 5% discount rate over a 5-year period is approximately $375,000.

4.3. Remedial Alternatives

The remedial alternatives for groundwater are:

- No Further Action
- ISCO with sodium permanganate
- Zero-Valent Iron PRB
- Zero-Valent Iron Injections
- Return to Pre-Disposal conditions

These alternatives are described and evaluated below.

4.3.1. No Further Action

Under the no further action (NFA) alternative no work will be completed at the site. This alternative will serve as a baseline for comparison for all other remedial alternatives considered for the site.

This alternative is considered to be ineffective because groundwater contamination would not be remediated.

Compliance with SCGs

SCGs would not be met through the implementation of the NFA alternative. This alternative does not meet the RAOs for the site.

Long-term effectiveness and permanence

The NFA alternative would provide minimal long term protection of sensitive receptors, as it does not remediate the contaminants in groundwater.

Reduction of toxicity, mobility, and volume

The NFA does not directly influence the toxicity, mobility, or volume of contaminants within groundwater at the site. However, over time the concentrations of contaminants may decrease due to natural attenuation.

Short-term impacts and effectiveness

There would have no short term impacts due to the implementation of this alternative. This alternative does not actively address groundwater contamination at the site and would not be effective in the short-term.

Implementability

This alternative requires no effort to implement.

Cost

There are no costs associated with the NFA alternative.

4.3.2. In-Situ Chemical Oxidation

Sodium permanganate will be considered in the following alternative. Implementation of an ISCO treatment program would include the following:

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

The oxidant would be injected into the subsurface within the treatment zone, which is shown on **Figure 9** and is bounded by Crown Dykman building, Herb Hill Road, Dickson Street, MW-7, and MW-8. Groundwater monitoring upgradient, downgradient, and within the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase plume migration. 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 Glen Cove Creek.

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.

As discussed in Section 4.2, an environmental easement, an MNA program, LNAPL recovery, and development and implementation of site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the site property that would require compliance with the approved site management plan. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. The SVE system would be operated in accordance with the soil vapor intrusion mitigation plan and continue until NYSDEC, in conjunction with NYSDOH, determines that it is no longer necessary. MNA would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of site groundwater. To further delineate the extent of groundwater contamination, six monitoring wells would be installed. LNAPL would be removed from the subsurface using a network of approximately four LNAPL recovery wells screened across the groundwater-LNAPL interface.

Overall protectiveness of the public health and the environment

The implementation of the ISCO alternative would be protective of human health by reducing concentrations of VOCs in groundwater.

Compliance with SCGs

The implementation of ISCO as a remedy would be in compliance with SCGs because there would be a reduction of VOC concentrations within the treatment area.

Long-term effectiveness and permanence

ISCO is considered to be effective in the long-term because further migration of the dissolved phase plume could be minimized and the groundwater VOC concentrations in the treatment area would be reduced. 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 contact can be achieved.

Short-term impacts and 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. Implementation and initial operation of this alternative is not expected to pose significant risk to the community. Risks to workers, which include potential exposure to oxidants and to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls. Air emissions during implementation are also monitored and can be controlled within acceptable levels with standard work practices and engineering controls.

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. Utility clearance confirmation is necessary prior to conducing any subsurface drilling.

Cost

The cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table 3. The cost assumes that three injection events would be conducted during the first year with five years of groundwater monitoring. The estimated capital cost including the first year of O&M is approximately $1.1 million. Annual O&M cost are estimated to be approximately $119,000 for the first five years (post injection groundwater monitoring/MNA and laboratory analysis and operation of the LNAPL extraction and SVE systems) and $71,000 from years six to 10 (SVE system O&M only). The total present value of this alternative based on a 5% discount rate over a 10-year period is approximately $1.8 million.

4.3.3. Zero-Valent Iron PRB

A zero-valent iron PRB would be installed using trenching techniques discussed in Section 3.7. The PRB would be constructed using two trenches both originated at the southwestern corner of the site and extending along Herb Hill Road to MW-7 and along Dickson Street to MW-8 (**Figure 10**). The PRB would extend vertically from approximately 10 feet bgs (average depth of the water table) to the low-permeability clay layer at an approximate average depth of 45 feet bgs. Assuming a 220-foot long PRB, the treatment area would contain approximately 200 to 250 tons of iron, depending on the barrier thickness.

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 Glen Cove Creek. Groundwater monitoring both upgradient and downgradient of the PRB would be required to evaluate the effectiveness of the PRB at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase plume migration.

As discussed in Section 4.2, an environmental easement, an MNA program, LNAPL recovery, and development and implementation of site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the site property that would require compliance with the approved site management plan. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. The SVE system would be operated in accordance with the soil vapor intrusion mitigation plan and continue until NYSDEC, in conjunction with NYSDOH, determines that it is no longer necessary. MNA would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of site groundwater. To further delineate the extent of groundwater contamination, six monitoring wells would be installed. LNAPL would be removed from the subsurface using a network of approximately four LNAPL recovery wells screened across the groundwater-LNAPL interface.

Overall protectiveness of the public 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 (with the exception of excavated soil) 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 SCGs

It is anticipated that the PRB would effectively treat contaminated groundwater as it flows through the PRB. The off-site plume migration RAO would be met because the mass discharge of the contaminants to downgradient areas would be reduced. With time, groundwater downgradient of the PRB would be in compliance with SCGs. 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. The one exception is the soil excavated during the PRB installation, which would need to be disposed of properly.

A PRB would be effective at meeting the off-site plume migration RAO 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 addressed with MNA.

Short-term impacts and effectiveness

A PRB would be effective in the short-term because 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. Installation of a PRB is not expected to pose significant risk to the community. Risks to workers, which include potential exposure to contaminated soils and groundwater during trenching activities, are readily controlled using standard work practices and engineering controls. Air emissions during implementation are also monitored and can be controlled within acceptable levels with standard work practices and engineering controls.

Implementability

Trenching technologies for the installation of PRBs are relatively simple and technically feasible processes for the site. PRB installation by trenching can generate significant waste, so treatment and disposal options must be considered. It is anticipated that the necessary specialists and equipment are available to complete the PRB installation. Utility clearance confirmation is necessary prior to conducing any subsurface drilling or trenching. The PRB would need to be designed so as not to affect adjacent roadways.

Cost

The cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table 4. This cost is based on the installation of a 220-linear foot PRB. Capital costs include the installation of the PRB and the first year of O&M. The capital cost for the PRB alternative is approximately $1.4 million. Annual O&M cost for 30 years of groundwater sampling and laboratory analysis is estimated at $20,000. Additional annual O&M costs are estimated to be approximately $99,000 for the first five years (operation of the LNAPL extraction, MNA, and SVE systems) and $71,000 from years six to 10 (SVE system O&M only). The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $2.3 million.

4.3.4. Zero-Valent Iron Injections

Implementation of a zero-valent iron injection treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of zero-valent iron treatment.
- Implementation and evaluation of a field pilot test to evaluate injection efficacy, distribution, and persistence in the subsurface.
- Injection of zero-valent iron injection into either temporary direct-push injection points or permanent injection wells.
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

The process by which zero-valent iron breaks down VOCs is sometimes referred to as in-situ chemical reduction. Since VOC treatment by zero-valent iron injection relies on direct contact between iron and the contaminant, the success of this treatment would be highly dependent on the ability to effectively distribute the iron through the treatment area. If such distribution can be achieved, it is anticipated that the zero-valent iron injection alternative is capable of meeting the RAOs for the site.

Zero-valent iron would be injected into the subsurface within the treatment zone, which is shown on **Figure 9** and is bounded by Crown Dykman building, Herb Hill Road, Dickson Street, MW-7, and MW-8. The zero-valent iron would be injected from the watertable down to the low-permeability clay (approximately 45 feet bgs) throughout the treatment area. Groundwater monitoring 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. Areas of the plume downgradient of the treatment area would continue to migrate toward the Glen Cove Creek. A pilot study would be conducted to evaluate the injection spacing, implementability, effectiveness, and feasibility of this technology at the site.

As discussed in Section 4.2, an environmental easement, an MNA program, LNAPL recovery, and development and implementation of site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the site property that would require compliance with the approved site management plan. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. The SVE system would be operated in accordance with the soil vapor intrusion mitigation plan and continue until NYSDEC, in conjunction with NYSDOH, determines that it is no longer necessary. MNA would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of site groundwater. To further delineate the extent of groundwater contamination, six monitoring wells would be installed. LNAPL would be removed from the subsurface using a network of approximately four LNAPL recovery wells screened across the groundwater-LNAPL interface.

Overall protectiveness of the public 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. Zero-valent iron has been shown to be effective at meeting MCLs for organic contaminants, and is likely to reduce contaminant concentrations within the treatment area to below applicable MCLs. The objective of the remedial alternative is to reduce contaminant concentrations in the treatment area, thereby reducing the mass discharge of the contaminants to downgradient areas.

It is anticipated that the zero-valent iron would effectively treat groundwater contamination as it comes into contact with the iron. 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.

Contaminated groundwater present downgradient from the proposed injection area would not be treated, resulting in continued plume migration to the north and east of the site. MNA would be implemented in areas downgradient of the PRB to monitor the reduction of contaminant levels over time.

Compliance with SCGs

The implementation of in-situ chemical reduction using zero-valent iron would result in a reduction of VOC concentrations within the treatment area.

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). Although a permeable reactive wall is not proposed as part of this alternative, it is anticipated that the zero-valent iron will be effective in treating the plume for up to a 30-year evaluation period. There are no maintenance requirements for zero-valent iron injections although additional injections may be needed.

Reduction of toxicity, mobility, and volume

It is anticipated that injection of zero-valent iron will significantly and permanently reduce the toxicity, mobility, and volume of contaminants in the treatment area. 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.

In-situ chemical reduction using zero-valent iron would be effective at meeting the RAO for the site by reducing contaminant concentrations in the source zone and minimizing off-site migration of contaminated groundwater. Zero-valent iron would reduce the mobility of the plume by treating the plume’s source. Plume areas downgradient from the proposed PRB location would not be addressed.

Short-term impacts and effectiveness

In-situ chemical reduction using zero-valent iron will have significant short-term effectiveness. Once the zero-valent iron is injected, it will begin reducing contaminant concentrations within the radius of influence of the injection points. Implementation and initial operation of the bioremediation alternative is 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. Air emissions during implementation are also monitored and can be controlled within acceptable levels with standard work practices and engineering controls.

Implementability

In-situ chemical reduction using zero-valent iron could be implemented using readily available technologies and is considered easy to implement. This remedial technology has been implemented at more than 30 sites (Personal communication with ARS Technologies, Inc., 2009). However, the success of the treatment would be dependent on the degree to which the iron is able to come into contact with the contaminants and the number of injections required. Zero-valent iron injections do not generate significant waste, so treatment and disposal considerations are negligible. Utility clearance confirmation is necessary prior to conducing any subsurface drilling.

Cost

The estimated cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table 5. Capital costs include the injection of 105,000 pounds of zero-valent iron powder during one injection event and the first year of O&M. The capital cost for this alternative is approximately $1.2 million. There are no ongoing consistent annual O&M costs for this alternative. Annual O&M costs are estimated to be approximately $119,000 for the first five years (MNA groundwater sampling and operation of the LNAPL extraction and SVE systems) and $71,000 from years six to 10 (SVE system O&M only). The total present value of this alternative based on a 5% discount rate over a 10-year period is approximately $1.8 million.

4.3.5. Return Site to Pre-disposal Conditions

ISCO would be employed to restore the site to pre-disposal conditions by reducing groundwater contaminant concentrations so as to be in compliance with SCGs. Because the southern limit of the dissolved-phase plume is not delineated, it is assumed that groundwater contamination extends to Glen Cove Creek, approximately 575 feet south of the site building. Oxidants would be injected over an approximately 144,000 square foot area. For the purposes of the cost estimate, it is assumed that saturated thickness above the clay in the area between the site building and Glen Cove Creek is 7 feet.

As discussed in Section 4.2, an environmental easement, an MNA program, LNAPL recovery, and development and implementation of site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the site property that would require compliance with the approved site management plan. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. The SVE system would be operated in accordance with the soil vapor intrusion mitigation plan and continue until NYSDEC, in conjunction with NYSDOH, determines that it is no longer necessary. MNA would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of site groundwater. To further delineate the extent of groundwater contamination, six monitoring wells would be installed. LNAPL would be removed from the subsurface using a network of approximately four LNAPL recovery wells screened across the groundwater-LNAPL interface.

Overall protectiveness of the public health and the environment

This alternative would be protective of the public health and the environment because the contamination related to the site would be removed or treated.

Compliance with SCGs

Implementation of this alternative would result in a reduction of VOC concentrations within the treatment area to less than SCGs.

Long-term effectiveness and permanence

This alternative would be effective in the long-term and permanent because groundwater contaminant concentrations on and downgradient of the site would be reduced, including within the source area.

Reduction of toxicity, mobility, and volume

The toxicity, mobility, and volume of contaminants in the treatment area would be reduced.

Short-term impacts and effectiveness

This alternative would be effective in the short-term because ISCO treatment oxidizes VOCs almost immediately upon contact. Implementation and initial operation of the bioremediation alternative is 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. Air emissions during implementation are also monitored and can be controlled within acceptable levels with standard work practices and engineering controls.

Implementability

Although each component of this alternative could be implemented using readily available technologies that are easy to implement, the alternative as a whole would be difficult to implement because of the size of the treatment area. ISCO is commonly used as a remedial technology. 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. Utility clearance confirmation is necessary prior to conducing any subsurface drilling.

Cost

The estimated cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table 6. Capital costs include ISCO injections over an approximately 144,000 square foot area and the installation of 12 monitoring wells. The capital cost for this alternative is approximately $8.8 million. There are no ongoing consistent annual O&M costs for this alternative. Annual O&M costs are estimated to be approximately $119,000 for the first five years (MNA groundwater sampling and operation of the LNAPL extraction and SVE systems) and $71,000 from years six to 10 (SVE system O&M only). The total present value of this alternative based on a 5% discount rate over a 10-year period is approximately $9.5 million.

5. Comparison of Alternatives

The five remedial alternatives summarized in Section 4.3 are evaluated below relative to each other and the criteria summarized in Section 4.1. As part of each remedial alternative, with the exception of no further action, 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. The no further action alternative was retained for evaluation to facilitate the comparison of the other remedial alternatives and involves no monitoring, institutional controls, or remediation.

The no further action alternative requires no costs or effort to implement and would not be protective of human health and the environment, would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume. In contrast, the pre-disposal conditions alternative would have the highest costs, would be the most protective of human health and the environment, and would be the most effective in the short- or long-term. Additionally, the pre-disposal conditions alternative would be in compliance with SCGs and would reduce the toxicity, mobility, and volume of VOCs in the entire dissolved-phase VOC plume. Because the no further action alternative would not treat the dissolved-phase VOC plume and the cost to implement the pre-disposal conditions alternative would make it infeasible, these two alternatives are not evaluated further in this section.

Overall Protection of Human Health and the Environment

With the exception of the no further action alternative, each alternative would be effective at minimizing further off-site migration of contaminated groundwater by removing contaminant mass and controlling migration of the dissolve-phase CVOC plume. Because it does not include active treatment, the no further action alternative not protective of human health and the environment. The groundwater extraction alternative physically removes contaminant mass from the groundwater and includes ex-situ treatment and disposal. In contrast, ISCO, PRB, and zero-valent iron injections are in-situ alternatives that chemically degrade VOCs to non-toxic byproducts (e.g., ethane, ethane, and/or chloride ions). There is less risk for exposure to soil, groundwater, and soil vapor during implementation of the injection alternatives (ISCO and zero-valent iron injection alternatives) and therefore they are slightly more protective of human health and the environment than those with ex-situ components. As the RAOs would be met, each remedial alternative, excluding no further action, would be protective of human health and the environment. Of all the remedial alternatives, returning the site to pre-disposal conditions would be the most protective of human health and the environment.

Compliance with SCGs

The no further action would not actively treat the dissolved-phase VOC plume and would therefore not be in compliance with SCGs. It is anticipated that the four groundwater treatment alternatives would effectively reduce groundwater VOC concentrations within the treatment area. Each of these alternatives would also reduce the mass discharge of site contaminants to areas downgradient of the treatment area. However, the ISCO, PRB, and zero-valent iron alternatives will only treat the on-site portion of the dissolved-phase VOC plume, leaving the plume downgradient of the treatment area to naturally attenuate. The return the site to pre-disposal conditions alternative would achieve compliance with SCGs faster than the other alternatives because the dissolved-phase VOC plume would be treated both on- and off-site.

Short-Term Effectiveness

Once any of the groundwater treatment remedial alternatives is implemented, contaminant concentrations will begin to be reduced within the treatment area. The PRB alternative would not be as effective in the short-term as other alternatives because contaminants would be treated as groundwater flows through the PRB; the PRB alternative would only treat groundwater on the downgradient border of the site. The ISCO and zero-valent iron injection alternatives would 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 would be assessed using standard groundwater monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area.

Implementation and operation of these alternatives 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 standard work practices and engineering controls. Air emissions, which could impact the community, during implementation are also monitored and can be controlled within acceptable levels with standard work practices and engineering controls. There is less risk for exposure to soil, groundwater, and soil vapor during implementation of the injection alternatives, which do not include ex-situ treatment or soil/groundwater disposal.

Long-Term Effectiveness and Permanence

The no further action alternative is not effective in the long-term. 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 and/or the migration of the dissolve-phase VOC plume would be controlled.

The ISCO and zero-valent iron injection alternatives would effectively reduce groundwater VOC concentrations quickly. However, additional injection events may be necessary if there is incomplete treatment or to treat upgradient groundwater that flows into the treatment area. Remedy performance monitoring would be used to evaluate the frequency of injections if an injection technology is selected as the remedy for groundwater.

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 potential for incomplete contaminant degradation would be evaluated using available data, including those from pilot studies. As discussed in Section 3.7, the continuity of a PRB can be verified using pulse interference testing. 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 return the site to pre-disposal conditions alternative would be the most effective in the long-term because groundwater and soil that has been contaminated from the site will be treated.

Reduction of Toxicity, Mobility, or Volume

The four groundwater treatment remedial alternatives would reduce the mobility of the plume by treating the groundwater within the treatment area, thereby minimizing off-site migration of contaminated groundwater. With the exception of the alternative in which the site would be returned to pre-disposal conditions, these alternatives will not affect distal portions of the plume and portions of the plume downgradient of the treatment area would continue to migrate toward Glen Cove Creek. These alternatives would limit plume migration and reduce contaminant concentrations in the treatment area, thereby reducing the toxicity, mobility, and volume of the plume. The no further action alternative would not reduce the toxicity, mobility or volume of site contaminants.

If the ISCO, zero-valent iron injection, and PRB alternatives are implemented, VOCs would be chemically degraded to non-toxic byproducts (e.g., ethane, ethane, and/or chloride ions), which do not pose significant risk to human health or the environment. The amount of reduction of the toxicity, mobility, or volume of the plume is dependent on the 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.

Implementability

The ISCO and zero-valent iron injection alternatives are capable of reducing groundwater VOC concentrations while eliminating the need for ex-situ treatment facilities and minimizing disposal issues. PRB installation by trenching can generate significant waste, so soil treatment and disposal options must be considered.

There does not appear to be significant obstacles to implementing these remedial technologies at the site, although obtaining access will be necessary for all groundwater treatment alternatives. Utility clearance confirmation is necessary prior to conducting any subsurface drilling or trenching. The PRB would need to be designed so as not to affect adjacent roadways.

The remedial alternatives are all technically feasible and may be affected differently by site-specific geologic and hydrogeologic characteristics. As such, predesign studies and/or pilot tests are recommended prior to remedy implementation to evaluate the feasibility of the selected remedial alternative and to finalize design of the remedy.

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 a PRB. Despite this, PRBs have successfully been installed at numerous sites.

The ISCO and zero-valent iron injection alternatives do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruptions to site activities during implementation of these alternatives because no surface structures, other than possibly injection wells, are needed. No subsurface structures are needed to implement the PRB alternative. However, implementation of the PRB alternative could temporarily disrupt site activities because a portion of the site would be disturbed during the trenching and PRB installation.

Cost

A summary of opinion of probable costs for each remedial alternative is provided in Tables 7 and 8. A graph of the probable present value of each of the alternatives is included in Figure 11. The relative order of probable present value for the six alternatives over a 30 year period are, from least to most expensive:

- No Further Action;

- ISCO;
- Zero-valent Iron Injections;
- PRB;
- Return site to pre-disposal conditions.

There are no costs associated with the no further action alternative. Returning the site to pre-disposal conditions would be more expensive than all other alternatives.

Although the PRB alternative would have the highest capital cost, there are no OM&M costs other than groundwater monitoring. The PRB alternative OM&M costs are less than all other groundwater treatment alternatives. Over a 30 year time period, the PRB alternative is only slightly more expensive than the ISCO and zero-valent iron alternatives. If more than one zero-valent iron or three ISCO injection events are needed, these alternatives would be more expensive than the PRB alternative.

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Crown Dykman (Site #130054)
Feasibility Study Report

Figures

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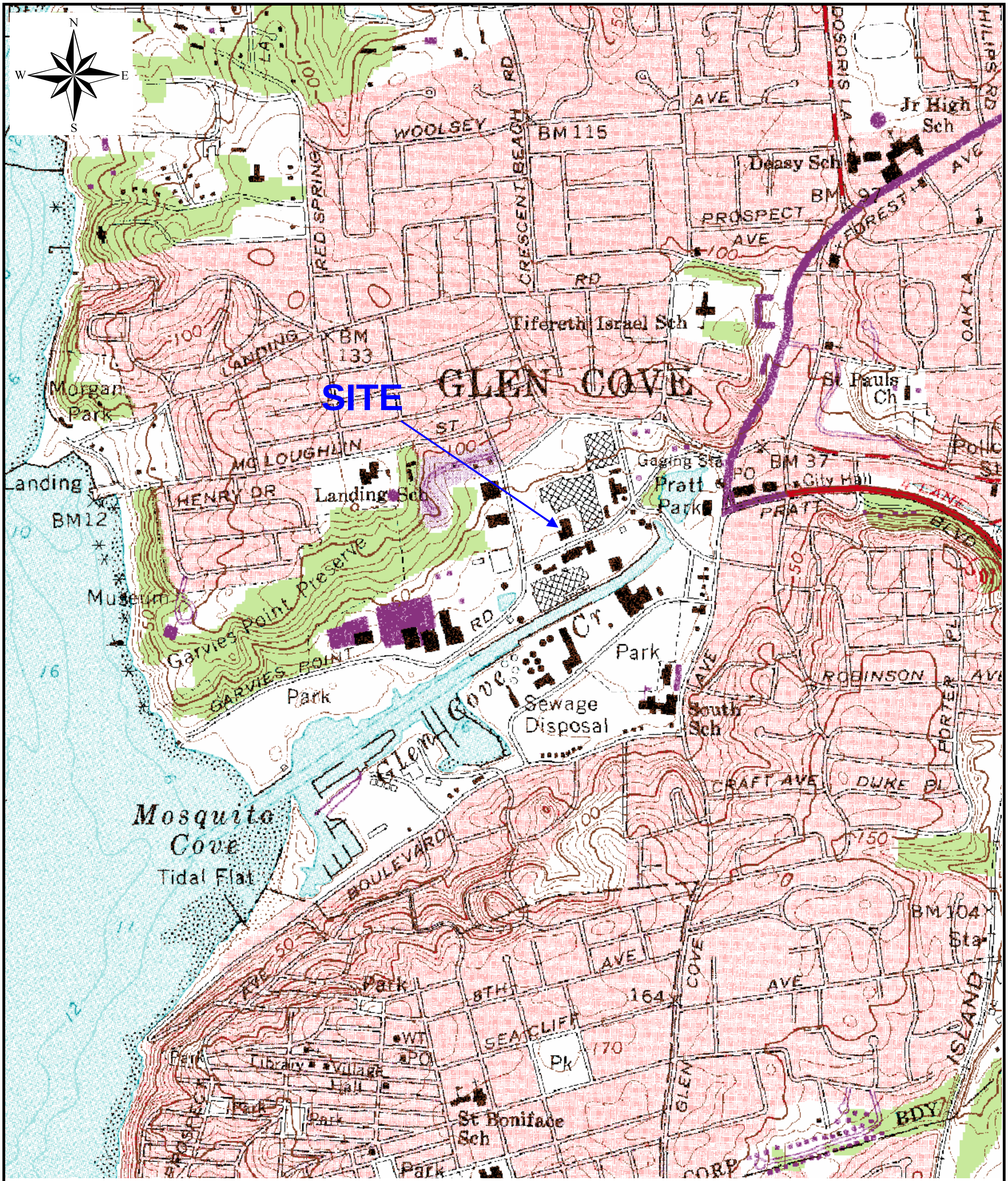

0 295 590 1,180 1,770 2,360

SCALE IN FEET

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NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

SITE LOCATION

DECEMBER 2009

FIGURE 1

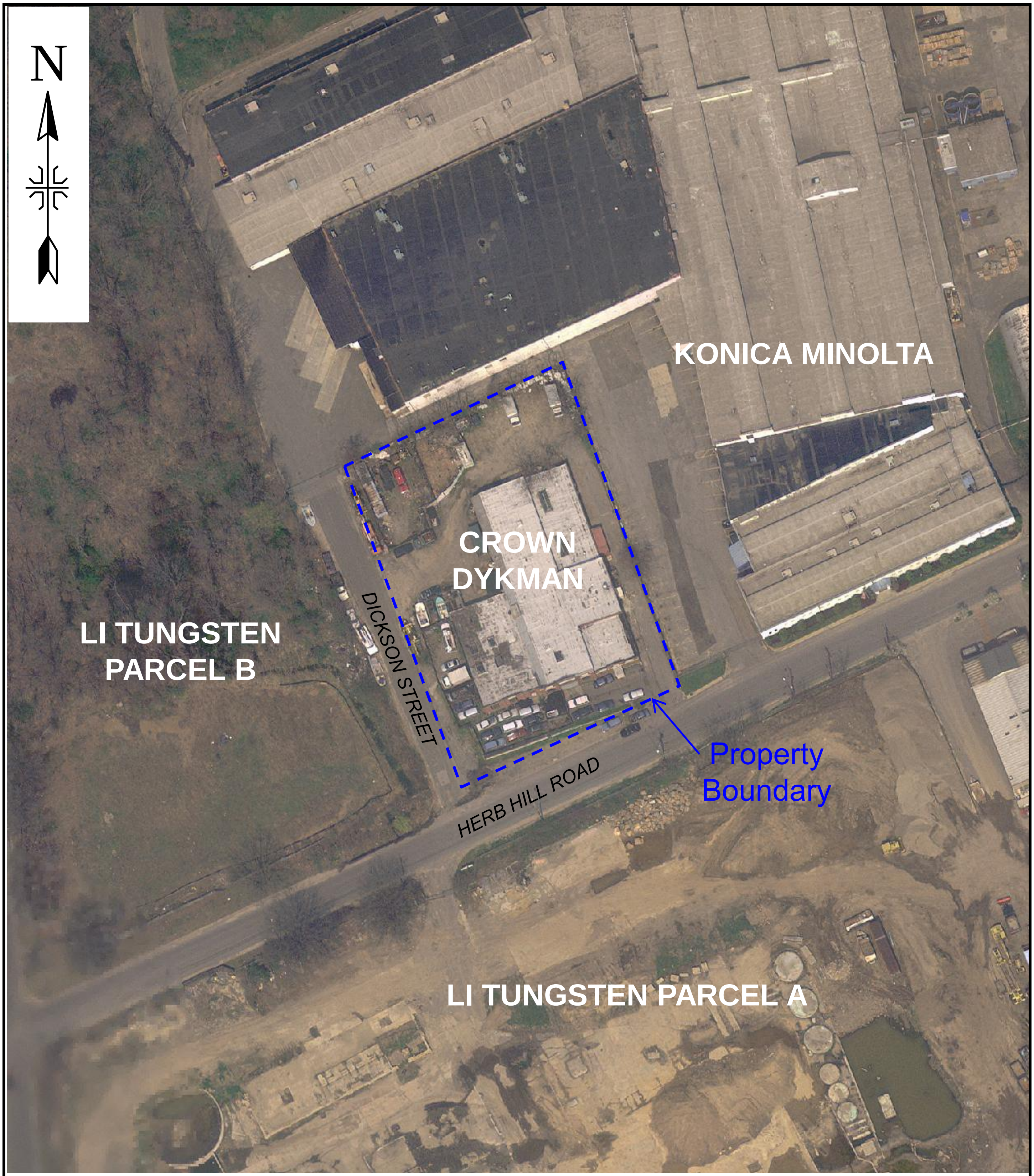

IMAGE SOURCE: NYS OCSCIC. *Nassau County 12-inch Resolution Natural Color Orthoimagery* [image]. August 2001. State Plane Coordinate System 1983 (NAD83). NYS Digital Orthoimagery Program. NYS GIS Clearinghouse http://www.nysgis.state.ny.us/ (6 Sept. 2006)

0 50 100 200
SCALE IN FEET

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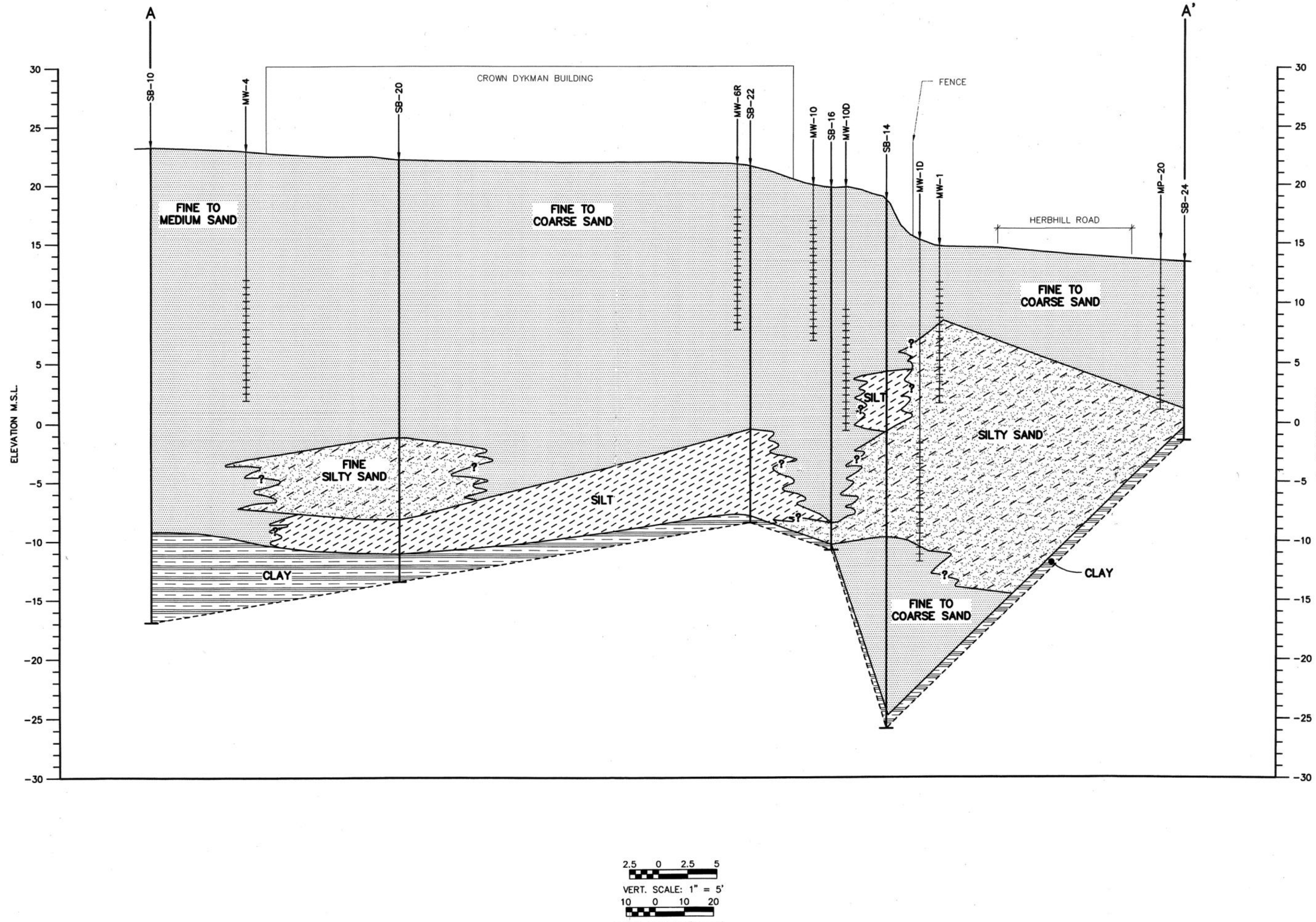
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

SITE OVERVIEW AND ADJACENT PROPERTIES

DECEMBER 2009

FIGURE 2



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REVISIONS			
NO.	BY	DATE	REMARKS

DES —
DWN SMH
CKD —

NYSDEC 1-30-054
GLEN COVE, NEW YORK

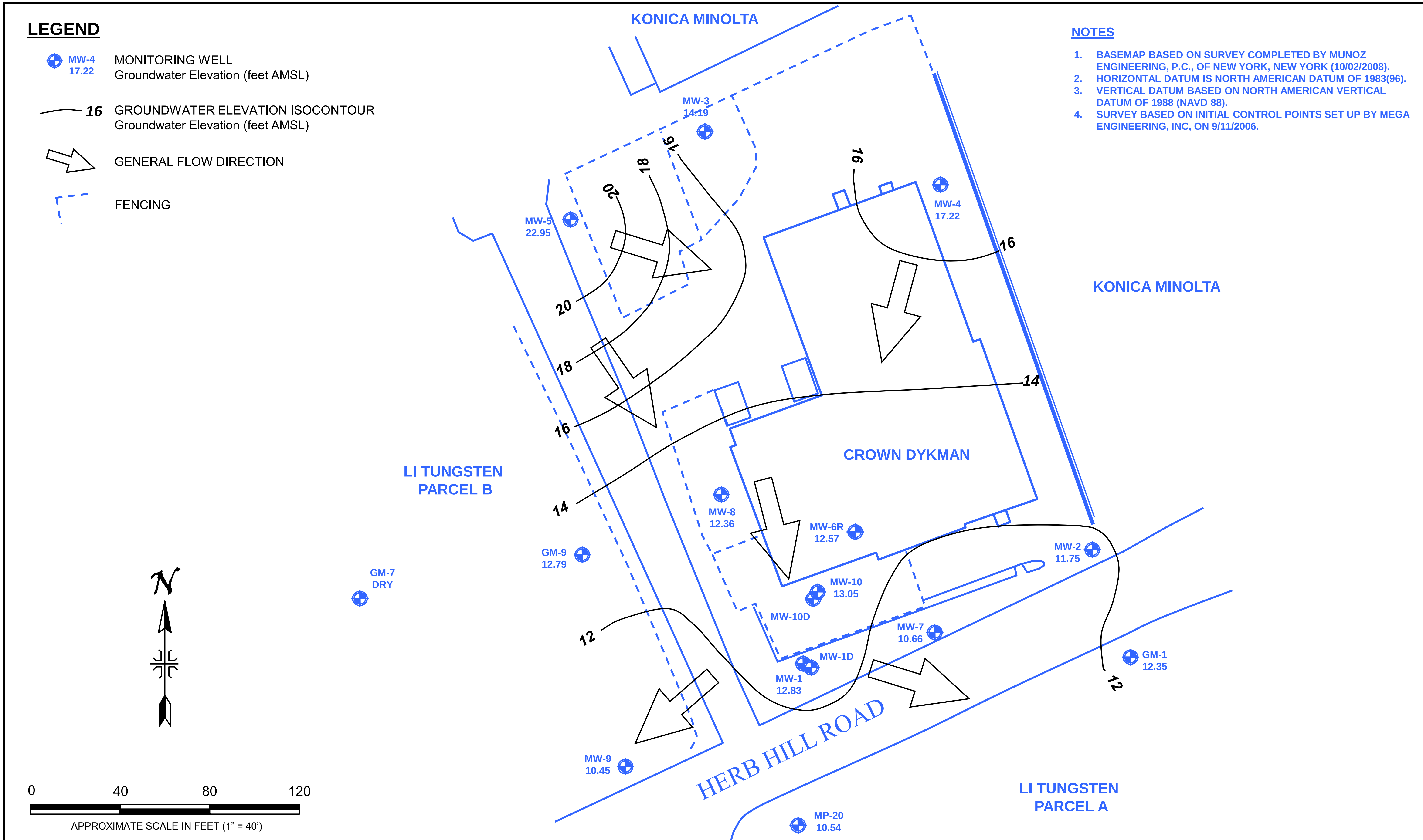
CROWN DYKMAN

FIGURE 3
GEOLOGIC
CROSS SECTION A-A'
SCALE: AS SHOWN

DATE NOVEMBER 2008

SHEET 1 OF 1

CAD REF. NO. 0266351



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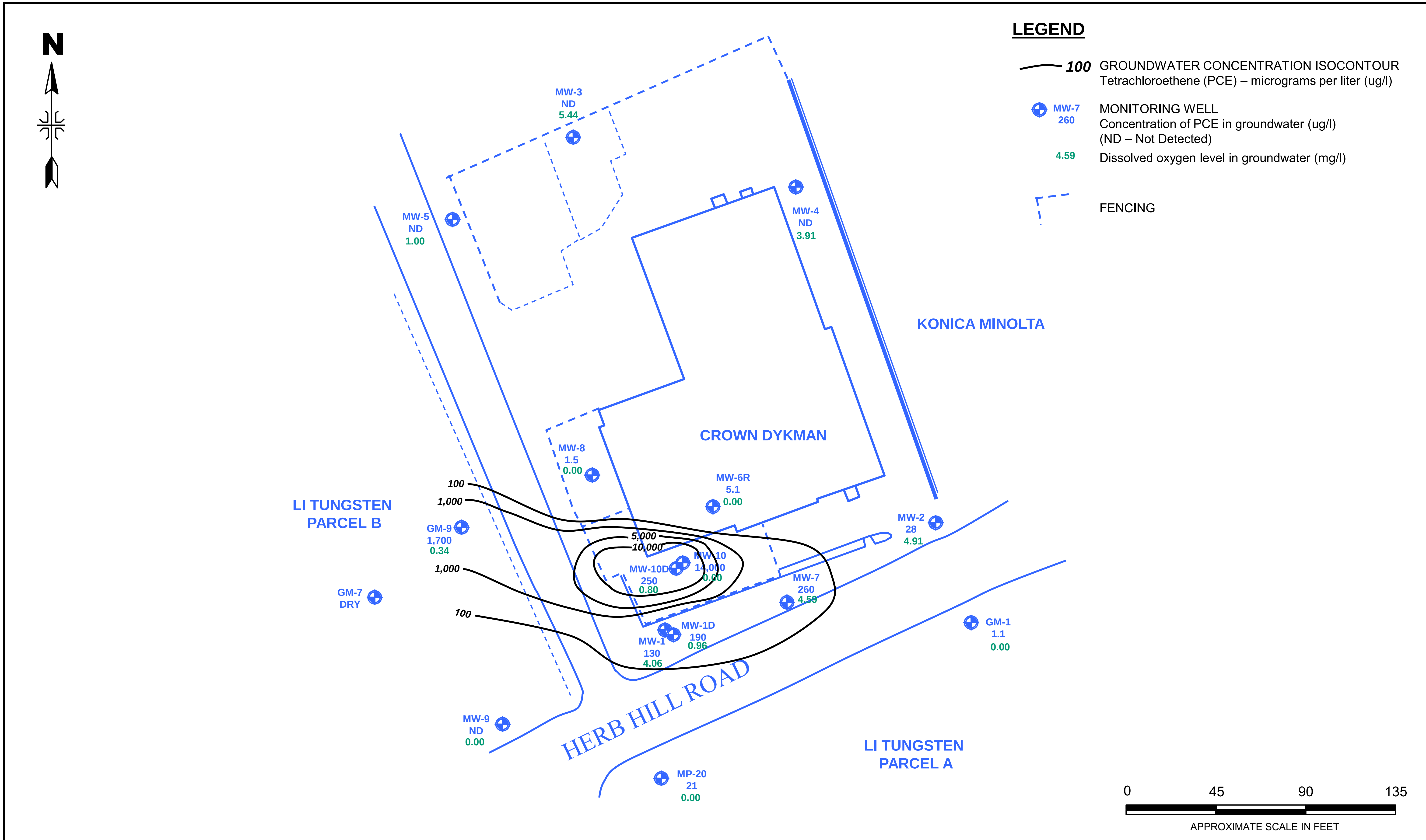
NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

GROUNDWATER ELEVATION AND FLOW DIRECTION (SEPTEMBER 2008)

DECEMBER 2009

FIGURE 4



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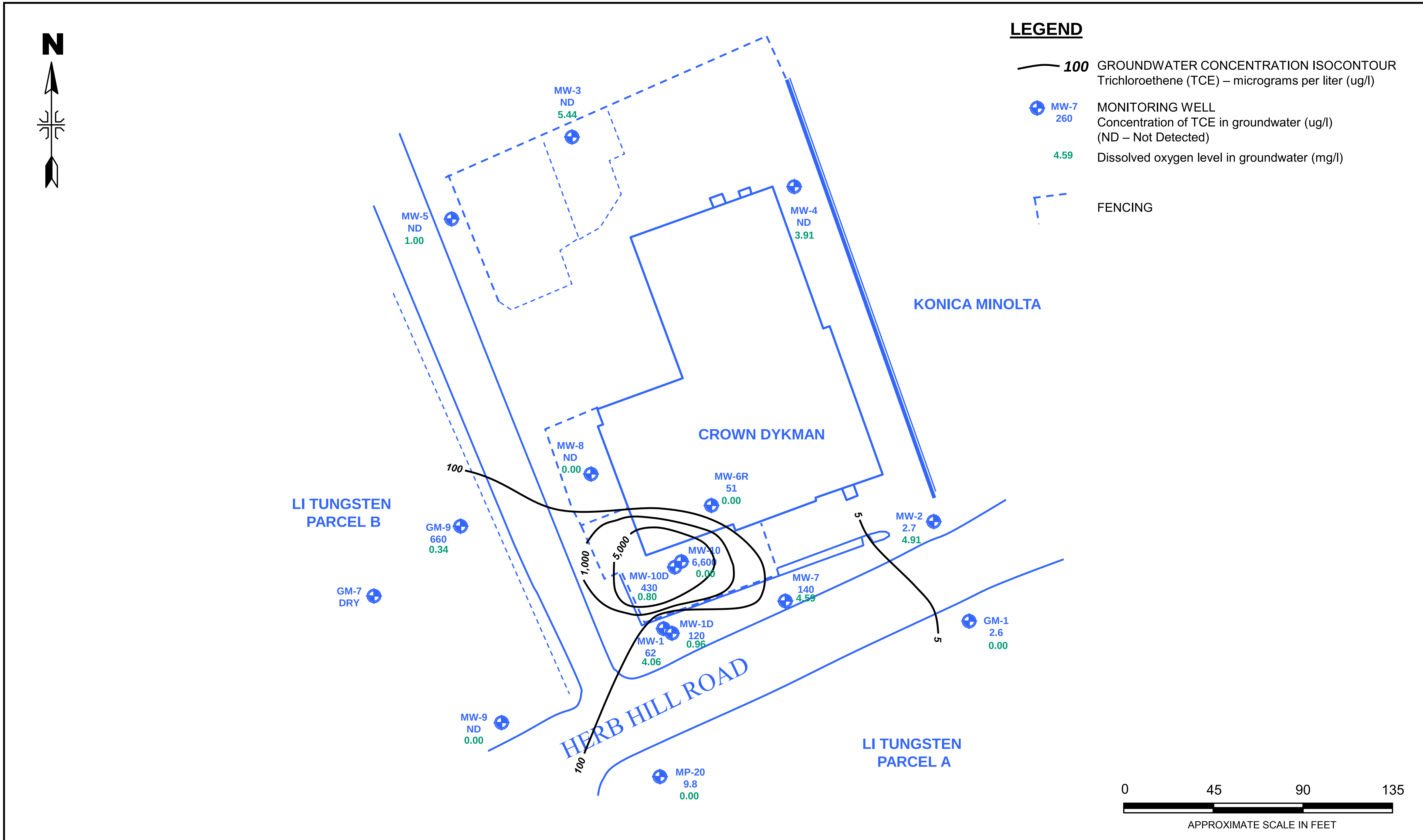
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

CONCENTRATION OF TETRACHLOROETHENE (PCE) IN GROUNDWATER SAMPLES (SEPTEMBER 2008)

DECEMBER 2009

FIGURE 5



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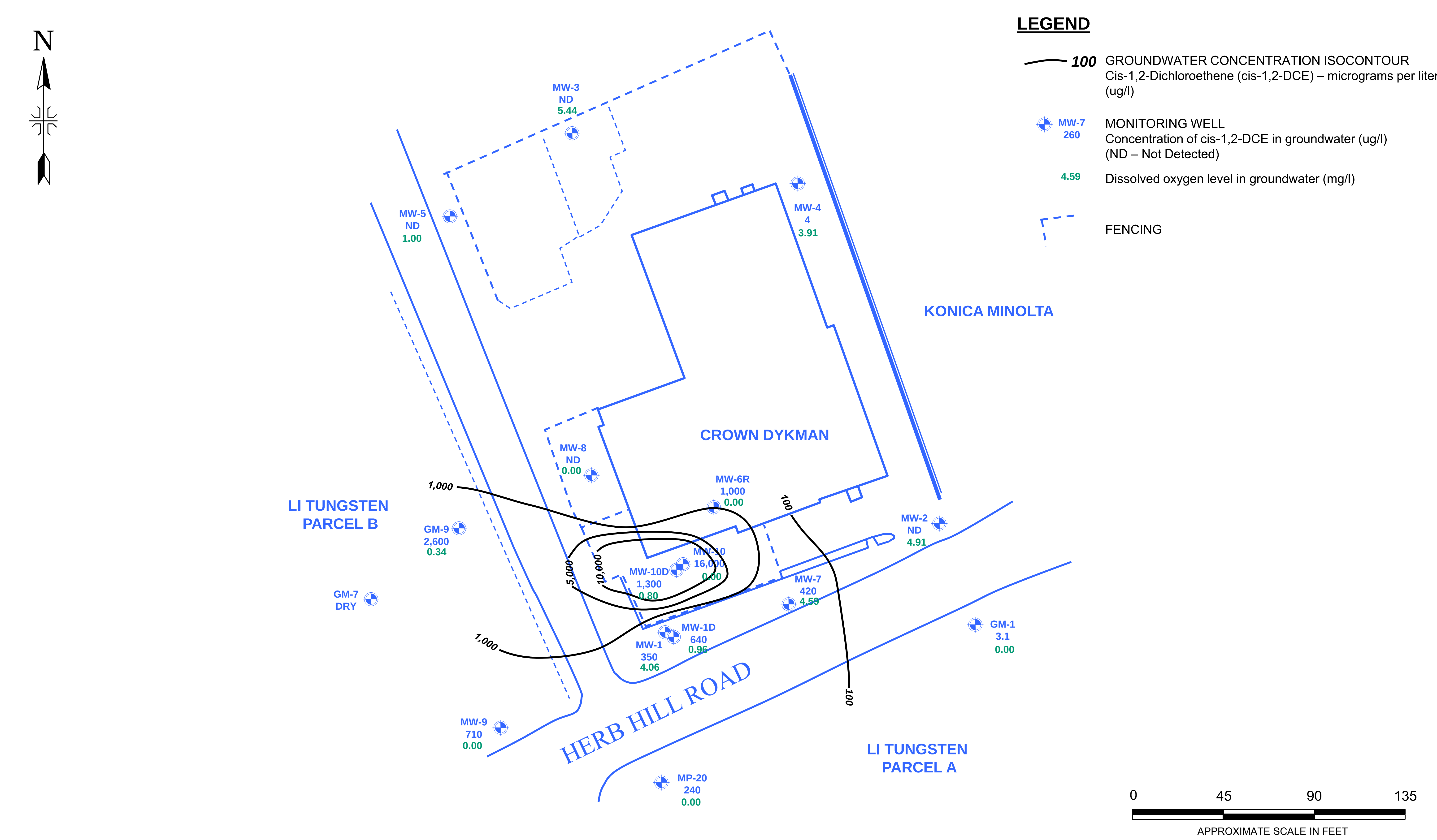
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

CONCENTRATION OF TRICHLOROETHENE (TCE) IN GROUNDWATER SAMPLES (SEPTEMBER 2008)

DECEMBER 2009

FIGURE 6



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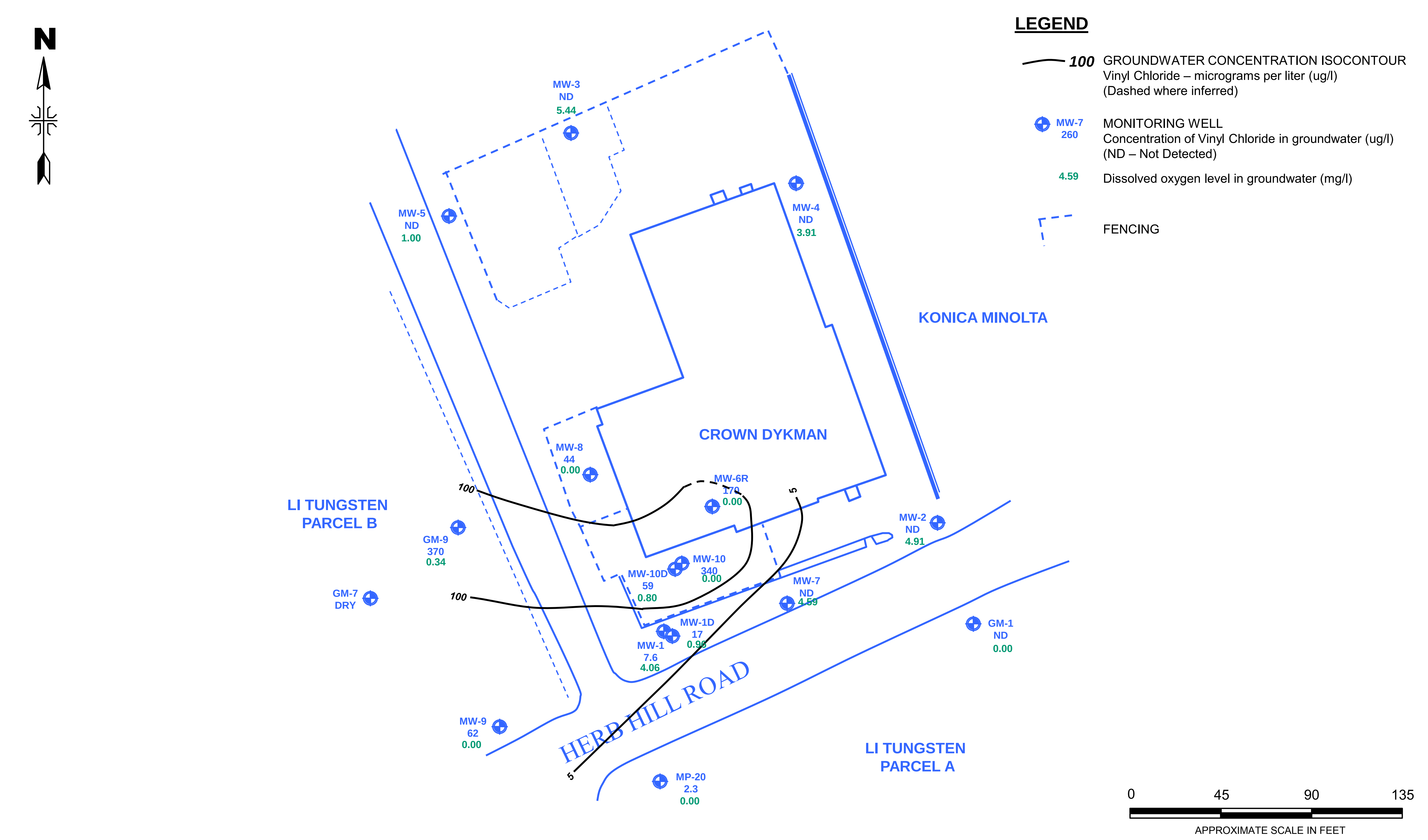
NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

CONCENTRATION OF cis-1,2-DICHLOROETHENE (cis-1,2-DCE) IN GROUNDWATER SAMPLES (SEPTEMBER 2008)

DECEMBER 2009

FIGURE 7



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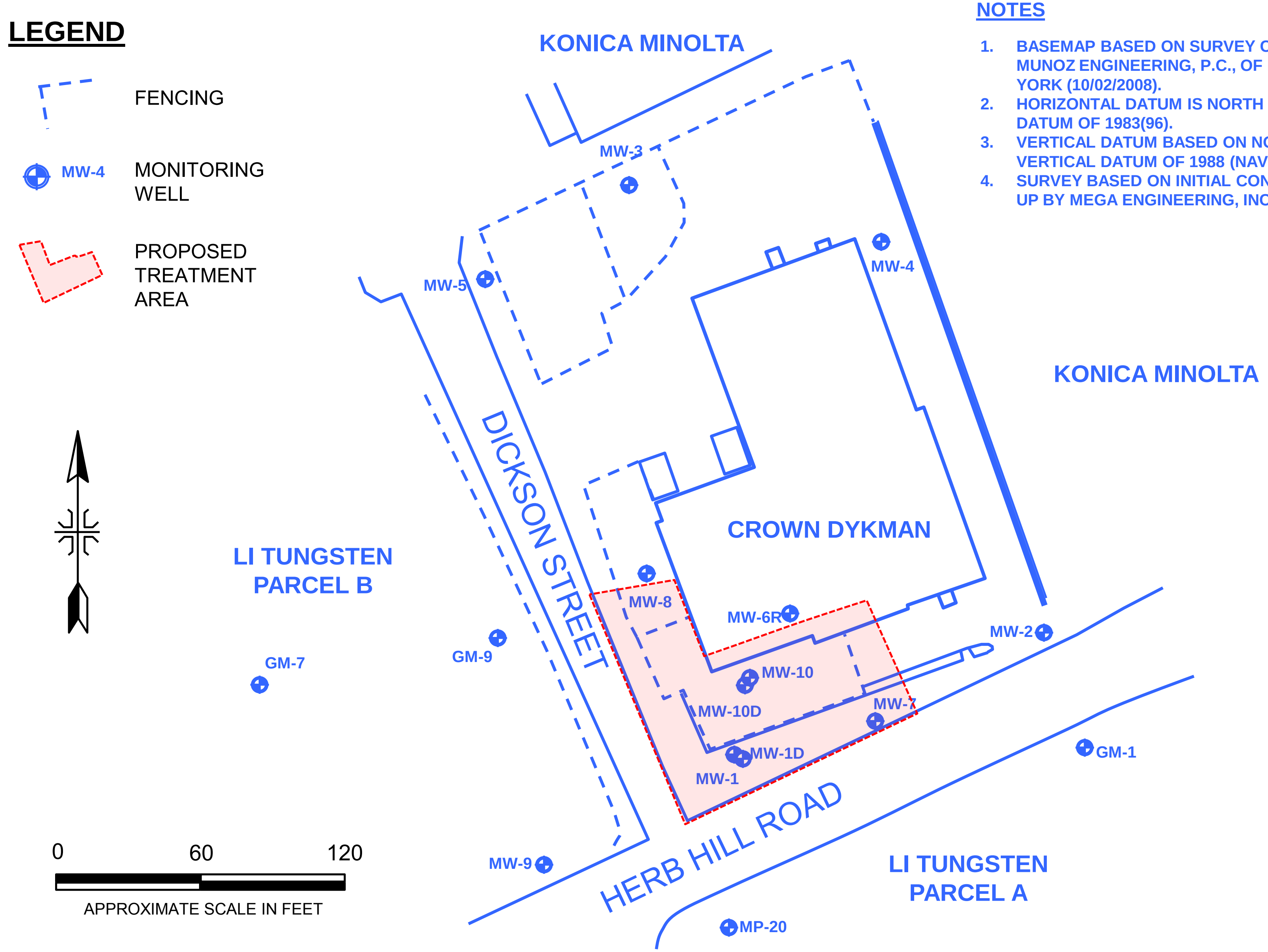
NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
FEASIBILITY STUDY - CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

CONCENTRATION OF VINYL CHLORIDE IN GROUNDWATER SAMPLES (SEPTEMBER 2008)

DECEMBER 2009

FIGURE 8



NOTES

1. BASEMAP BASED ON SURVEY COMPLETED BY MUNOZ ENGINEERING, P.C., OF NEW YORK, NEW YORK (10/02/2008).
2. HORIZONTAL DATUM IS NORTH AMERICAN DATUM OF 1983(96).
3. VERTICAL DATUM BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).
4. SURVEY BASED ON INITIAL CONTROL POINTS SET UP BY MEGA ENGINEERING, INC, ON 9/11/2006.

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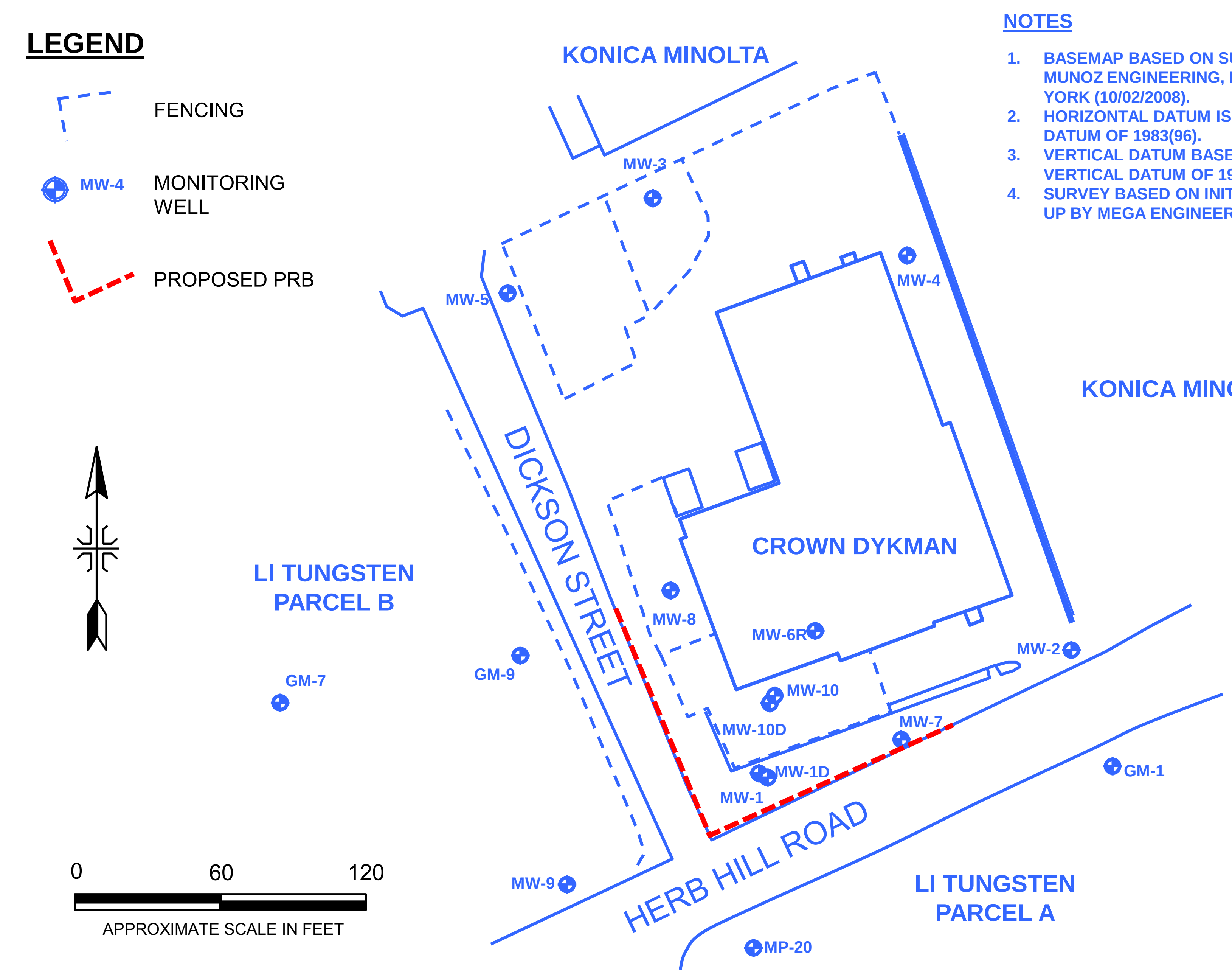
FEASIBILITY STUDY
CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

PROPOSED SOURCE TREATMENT AREA

DECEMBER 2009

FIGURE 9

\\ALBANY\Data\PROJECT\0266351\FILE\Feasibility Study\ FIGURES.ppt



NOTES

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\\ALBANY\Data\PROJECT\0266351\FILE\Feasibility Study\ FIGURES.ppt

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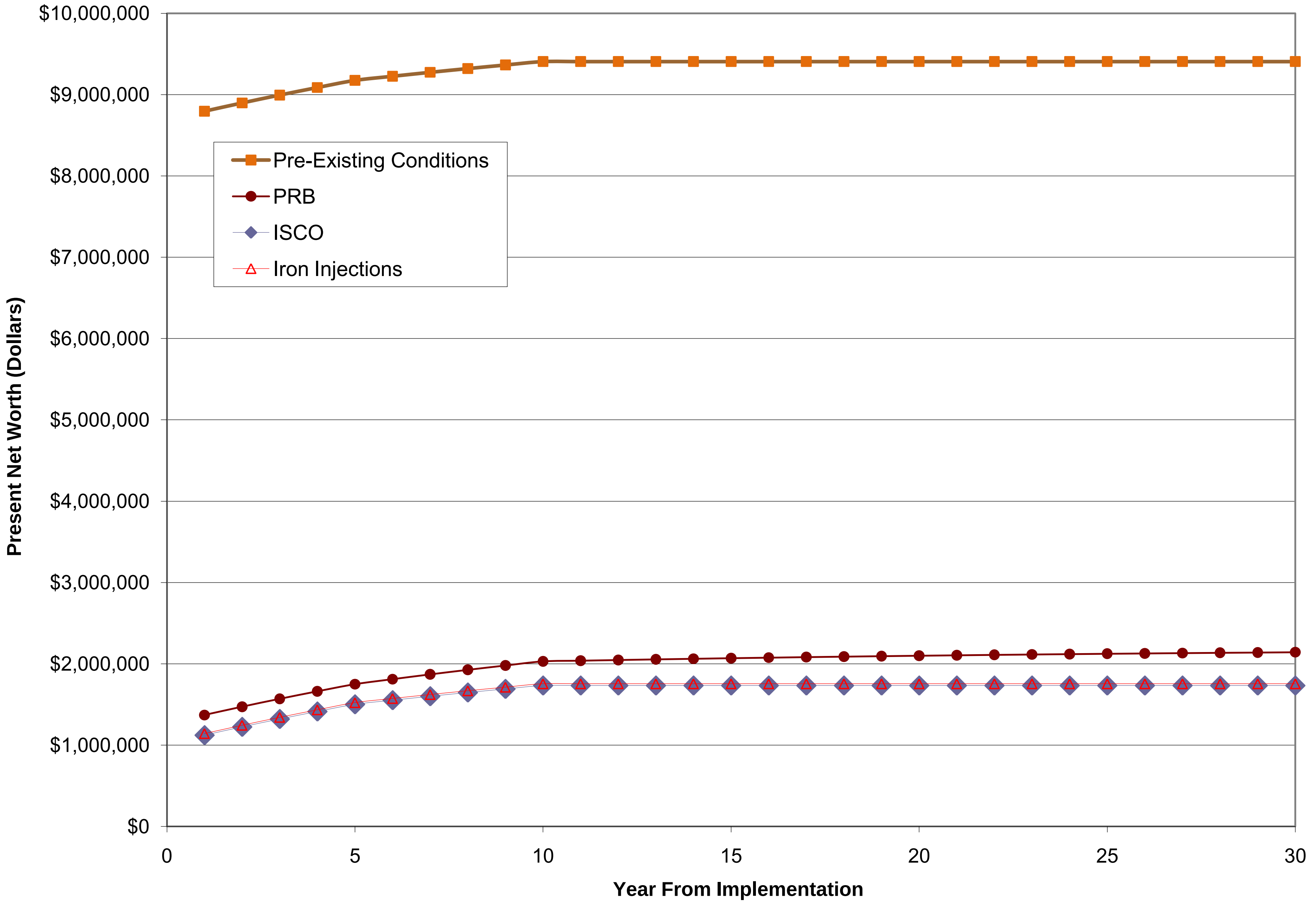
FEASIBILITY STUDY
CROWN DYKMAN (SITE # 1-30-054)
GLEN COVE, NEW YORK

PROPOSED PERMEABLE REACTIVE BARRIER LOCATION

DECEMBER 2009

FIGURE 10

Figure 11
Crown Dykman Remedial Alternatives Present Net Worth



New York State Department of Environmental Conservation
Crown Dykman (Site #130054)
Feasibility Study Report

Tables

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Table 1
EVALUATION OF POTENTIAL SCGs
Crown Dykman Site
(NYSDEC HW ID 1-30-054)
Glen Cove, New York

Medium/Location/Action	Citation	Requirements	Comments	Potential SCG
Potential chemical-specific SCGs				
Ground water	6 NYCRR 703 - Class GA ground water quality standards	Promulgated state regulation that requires that fresh ground waters of the state must attain Class GA standards	Potentially applicable to site ground water.	Yes
Indoor Air	NYSDOH - Guidance for Evaluating Soil Vapor Intrusion	Guidance that provides action levels for mitigation of indoor air influences	Potentially applicable to all occupied structures affected soil vapor intrusion as a result of the dissolve-phase CVOC plume.	Yes
Soil	NYSDEC 6 NYCRR Part 375-2 Inactive Hazardous Waste Disposal Site Remedial Program	Regulation that provides guidance for soil cleanup objectives for various property uses.	Potentially applicable to site soil.	Yes
Potential location-specific SCGs				
Wetlands	6 NYCRR 633 - Freshwater wetland permit requirements	Actions occurring in a designated freshwater wetland (within 100 ft) must be approved by NYSDEC of its designee. Activities occurring adjacent to freshwater wetlands must: be compatible with preservation, protection, and conservation of wetlands and benefits; result in no more than insubstantial degradation to or loss of any part of the wetland; and be compatible with public health and welfare.	Not applicable or relevant and appropriate. No wetlands within 100 feet of the Site.	No
	Executive Order 11990 - Protection of Wetlands	Activities occurring in wetlands must avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction or modification of wetlands. The procedures also require USEPA to avoid direct or indirect support of new construction in wetlands wherever there are practicable alternatives or minimal potential harm to wetlands when there are no practicable alternatives.	Not applicable or relevant and appropriate. No wetlands within 100 feet of the Site.	No
100-year flood plain	6 NYCRR 373-2.2 - Location standards for hazardous waste treatment, storage, and disposal facilities - 100-yr floodplain	Hazardous waste treatment, storage, or disposal facilities located in a 100-yr floodplain must be designed, constructed, operated and maintained to prevent washout of hazardous waste during a 100-yr flood.	Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain.	No
	Executive Order 11988 - Floodplain Management	EPA is required to conduct activities to avoid, to the extent possible, the long- and short- term adverse impacts associated with the occupation or modification of floodplain. The procedures also require EPA to avoid direct or indirect support of floodplain development wherever there are practicable alternatives and minimize potential harm to floodplains when there are no practicable alternatives..	Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain.	No
Within 61 meters (200 ft) of a fault displaced in Holocene time	40 CFR Part 264.18	New treatment, storage, or disposal of hazardous waste is not allowed.	Not applicable or relevant and appropriate. Site is not located within 200 ft of a fault displaced in Holocene time, as listed in 40 CFR 264 Appendix VI.	No
River or stream	16 USC 661 - Fish and Wildlife Coordination Act	Required protection of fish and wildlife in a stream when performing activities that modify a stream or river.	Not applicable or relevant and appropriate. No modification to river or stream .	No
Habitat of an endangered or threatened species	6 NYCRR 182	Provides requirements to minimize damage to habitat of an endangered species.	Not applicable or relevant and appropriate. No habitat of endangered species identified at the Site.	No

Table 1
EVALUATION OF POTENTIAL SCGs
Crown Dykman Site
(NYSDEC HW ID 1-30-054)
Glen Cove, New York

Medium/Location/Action	Citation	Requirements	Comments	Potential SCG
Habitat of an endangered or threatened species	Endangered Species Act	Provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction.	Not applicable or relevant and appropriate. No endangered species identified at the Site.	No
Historical property or district	National Historic Preservation Act	Remedial actions are required to account for the effects of remedial activities on any historic properties included on or eligible for inclusion on the National Register of Historic Places.	Not applicable or relevant and appropriate. Site not identified as a historic property.	No
Potential action-specific SCGs				
Treatment actions	6 NYCRR 373- Hazardous waste management facilities	Provides requirements for managing hazardous wastes.	Not applicable. No hazardous waste anticipated to be produced.	No
Construction	29 CFR Part 1910 - Occupational Safety and Health Standards - Hazardous Waste Operations and Emergency Response	Remedial activities must be in accordance with applicable OSHA requirements.	Applicable for construction and monitoring phase of remediation.	Yes
	29 CFR Part 1926 - Safety and Health Regulations for Construction	Remedial construction activities must be in accordance with applicable OSHA requirements.	Applicable for construction and monitoring phase of remediation.	Yes
Transportation	6 NYCRR 364 - Waste Transporter Permits	Hazardous waste transport must be conducted by a hauler permitted under 6 NYCRR 364.	Potentially applicable for treatment residuals.	Yes
	6 NYCRR Part 372- Hazardous Waste Manifest System and Related Standards for Generators, Transporters, and Facilities	Substantive hazardous waste generator and transportation requirements must be met when hazardous waste is generated for disposal. Generator requirements include obtaining an EPA Identification Number and manifesting hazardous waste for disposal.	Potentially applicable for treatment residuals.	Yes
	49 CFR 172-174 and 177-179 - Department of Transportation Regulations	Hazardous waste transport to offsite disposal facilities must be conducted in accordance with applicable DOT requirements.	Potentially applicable for treatment residuals.	Yes
Generation of air emissions	NYS Air Guide 1	Provides annual guideline concentrations (AGCs) and short-term guideline concentrations (SGCs) for specific chemicals. These are property boundary limitations that would result in no adverse health effects.	Potentially applicable for treatment residuals.	Yes
	NYS TAGM 4031- Dust Suppressing and Particle Monitoring at Inactive Hazardous Waste Disposal Sites	Provides limitations on dust emissions.	Potentially applicable. Dust emissions may be anticipated depending on remedy selected.	Yes
Construction storm water management	NYSDEC General permit for storm water discharges associated with construction activities. Pursuant to Article 17 Titles 7 and 8 and Article 70 of the Environmental Conservation Law.	The regulation prohibits discharge of materials other than storm water and all discharges that contain hazardous substance in excess of reportable quantities established by 40 CFR 117.3 or 40 CFR 302.4, unless a separate NPDES permit has been issued to regulate those discharges. A permit must be acquired if activities involve the disturbance of 5 acres or more. If the project is covered under the general permit, the following are required: development and implementation of a monitoring program; all records must be retained for a period of at least 3 years after construction is complete.	Not applicable. Construction disturbances will not exceed the limits.	No
Underground Injection	40 CFR 144 and 146 USEPA Underground Injection Control Regulations	This regulation sets forth minimum requirements for the UIC program promulgated under Part C of the Safe Drinking Water Act and describes the technical standards to follow when implementing the UIC program.	Applicable for the installation of injection wells.	Yes

Table 2
Remedial Alternative Opinion of Probable Cost

Component Common to Each Alternative
LNAPL EXTRACTION

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Description: The LNAPL extraction alternative is a common component of all remedial alternatives. It consists of the installation of four LNAPL recovery wells with LNAPL pumps. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5. Assumes remediation of LNAPL completed in 5 years.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pre-Design Investigation					
LNAPL Investigation Costs	1	lump sum	$25,000.00	$25,000	
LNAPL Extraction System Installation					
Mobilization, Bond, and Insurance	1	lump sum	$60,000.00	$60,000	
4-inch Vertical Extraction Wells x 4 (installed)	60	LF	$125	$7,500	4" PVC to 15 Feet
Spillbuster System	4	EA	$6,000	$24,000	Spillbuster with Autoseeker
Power and data line conduit	500	LF	$30	$15,000	See Note 1
Spill Deck, LNAPL Containment	1	EA	$500.00	$500	
2x4x2 Concrete Vaults	4	LS	$1,500	$6,000	Installed with traffic rated lid
10x12 Shed	1	LS	$7,000	$7,000	
Electrical Hook Up	1	LS	$2,000	$2,000	
Disposal of Excess Soils					
Drums	35	Drums	$55.00	$1,925	
Purge Water and Cuttings Disposal	35	Drums	$250.00	$8,750	
SUBTOTAL				$157,675	
Contingency	25%			$39,419	10% scope + 15% Bid
SUBTOTAL				$197,094	
Project Management	6%			$11,826	
Remedial Design	12%			$23,651	
Construction Management	8%			$15,768	
First year operation and maintenance	1	lump sum		$28,000	See cost breakdown below
TOTAL CAPITAL COST				$276,000	

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) Includes 4" diam. rigid galvanized conduit (RSM BC 16120 120 0350)

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Activities					
O&M Labor	150	hours	$100	$15,000	Monthly Visits
System Repair, Misc Parts	1	LS	$2,000	$2,000	
LNAPL Disposal	8	ea	$160	$1,280	Assumes Haz, per drum
Electrical Consumption	12	months	$100	$1,200	
SUBTOTAL				$19,480	
Contingency	25%			$4,870	
SUBTOTAL				$24,350	
Project Management	5%			$1,218	
Technical Support	10%			$2,435	
TOTAL ANNUAL O&M COST				$28,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (5%)	PRESENT VALUE	NOTES
Capital	1	$276,000	$276,000	1.00	$276,000	
Annual O&M	2-5	$112,000	$28,000	3.55	$99,287	5 years, 5 %
		$388,000			$375,287	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS					$375,000	

Table 3
Remedial Alternative Opinion of Probable Cost

Alternative 2
IN-SITU CHEMICAL OXIDATION

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Description: Alternative 2 consists of in-situ chemical oxidation to treat the area of the plume with the highest concentrations. Assumes 3 injections of permangenate in year 1. Includes five years of LNAPL extraction and groundwater monitoring and 10 years of sub-slab depressurization system operation. Capital costs and first year O&M costs occur in Year 1.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Report Preparation					
Site Management Plan	60	hours	$100.00	$6,000	
Site Work					
Monitoring Well Drilling and Installation	6	well	$4,000.00	$24,000	6 - 2" Schedule 40 PVC Wells to 20 feet
Drums	12	Drums	$55.00	$660	
Purge Water and Cuttings Disposal	12	Drums	$250.00	$3,000	
Bench scale and pilot test	1	lump sum	$60,000.00	$60,000	Hydraulic and geochemical analyses
ISCO Injections					
Injection Materials	58,000	pounds	$3.10	$179,800	3 Injection events
Vendor/Subcontractor Field Support/Drilling	3	lump sum	$45,000.00	$135,000	
Vendor/Subcontractor Reporting	1	lump sum	$5,000.00	$5,000	
SUBTOTAL				$413,460	
Contingency	25%			$103,365	10% scope + 15% Bid
SUBTOTAL				$516,825	
Project Management	8%			$41,346	
Remedial Design/Bid Assistance	25%			$129,206	
Construction Management	10%			$51,683	
First Year O&M and Periodic Costs	1	lump sum		$107,000	See cost breakdown below
LNAPL Recovery	1	lump sum		$276,000	See cost breakdown on Table 2
TOTAL CAPITAL COST				$1,122,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
O&M	0	hours	$80.00	$0	
Contingency	25%			$0	
Project Management	5%			$0	
Technical Support	10%			$0	
TOTAL ANNUAL O&M COST				$0	

PERIODIC COSTS IN YEARS 1 THROUGH 5:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week per year
Groundwater Laboratory Analysis	15	samples	$100.00	$1,500	VOC analysis: 15 samples/year
SUBTOTAL				$9,500	
Contingency	25%			$2,375	
SUBTOTAL				$11,875	
Project Management	5%			$594	
Technical Support	10%			$1,188	
LNAPL Recovery O&M	1	Lump Sum		$28,000	See cost breakdown on Table 2
TOTAL PERIODIC COST				$42,000	

PERIODIC COSTS IN YEARS 1 THROUGH 10:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Carbon Drums for SVE System	8	drums	$1,000.00	$8,000	
Air and Sub-slab Vapor Sampling and O&M	240	hours	$80.00	$19,200	20 hours/month
Air and Sub-slab Vapor Laboratory Analysis	10	samples	$300.00	$3,000	TO-15 VOC analysis
Reporting	100	hours	$100.00	$10,000	
SVE System Electrical	20,000	kilowatt hours	$0.15	$3,000	
SUBTOTAL				$43,200	
Contingency	25%			$10,800	
SUBTOTAL				$54,000	
Project Management	10%			$5,400	
Technical Support	10%			$5,400	
TOTAL PERIODIC COST				$65,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,122,000	$1,122,000	1.00	$1,122,000	
Annual O&M	2-10	$0	$0	1.00	$0	10 years, 5 %
Periodic Cost	2	$107,000	$107,000	0.95	$101,905	
Periodic Cost	3	$107,000	$107,000	0.91	$97,052	
Periodic Cost	4	$107,000	$107,000	0.86	$92,431	
Periodic Cost	5	$107,000	$107,000	0.82	$88,029	
Periodic Cost	6	$65,000	$65,000	0.78	$50,929	
Periodic Cost	7	$65,000	$65,000	0.75	$48,504	
Periodic Cost	8	$65,000	$65,000	0.71	$46,194	
Periodic Cost	9	$65,000	$65,000	0.68	$43,995	
Periodic Cost	10	$65,000	$65,000	0.64	$41,900	
		$1,875,000			$1,732,938	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TEN YEARS					$1,733,000	

Table 4
Remedial Alternative Opinion of Probable Cost

Alternative 3
PERMEABLE REACTIVE BARRIER

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Description: Alternative 4 consists of installation of a permeable reactive barrier to treat groundwater in a 400 foot width of the plume . Assumes one time installation based on a quote from ARS. Includes five years of LNAPL extraction, 10 years of sub-slab depressurization system operation, and 30 years of groundwater monitoring. Capital costs and first year O&M costs occur in Year 1.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Report Preparation					
Site Management Plan	60	hours	$100.00	$6,000	
Site Work					
Monitoring Well Drilling and Installation	6	well	$4,000.00	$24,000	6 - 2" Schedule 40 PVC Wells to 20 feet
Drums	50	Drums	$55.00	$2,750	
Purge Water and Cuttings Disposal	50	Drums	$250.00	$12,500	
Bench scale test	1	lump sum	$20,000.00	$20,000	Hydraulic and geochemical analyses
PRB Installation					
Zero-valent iron	250	tons	$800.00	$200,000	
Subcontractor construction costs	1	lump sum	$180,000.00	$180,000	
ETI Patent License Fee	1	percent	15%	$57,000	
Utility Protection	1	lump sum	$50,000.00	$50,000	
SUBTOTAL				$552,250	
Contingency	25%			$138,063	10% scope + 15% Bid
SUBTOTAL				$690,313	
Project Management	8%			$55,225	
Remedial Design/Bid Assistance	25%			$172,578	
Construction Management	10%			$69,031	
First Year O&M and Periodic Costs	1	lump sum		$107,000	See cost breakdown below
LNAPL Recovery	1	lump sum		$276,000	See cost breakdown on Table 2
TOTAL CAPITAL COST				$1,370,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week per year
Groundwater Laboratory Analysis	15	samples	$100.00	$1,500	VOC analysis: 15 samples/year
SUBTOTAL				$9,500	
Contingency	25%			$2,375	
SUBTOTAL				$11,875	
Project Management	5%			$594	
Technical Support	10%			$1,188	
TOTAL ANNUAL O&M COST				$14,000	

PERIODIC COSTS IN YEARS 1 THROUGH 5:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
LNAPL Recovery O&M					
O&M	1	Lump Sum		$28,000	See cost breakdown on Table 2
SUBTOTAL				$28,000	
TOTAL PERIODIC COST				$28,000	

PERIODIC COSTS IN YEARS 1 THROUGH 10:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Carbon Drums for SVE System	8	drums	$1,000.00	$8,000	
Air and Sub-slab Vapor Sampling and O&M	240	hours	$80.00	$19,200	20 hours/month
Air and Sub-slab Vapor Laboratory Analysis	10	samples	$300.00	$3,000	TO-15 VOC analysis
Reporting	100	hours	$100.00	$10,000	
SVE System Electrical	20,000	kilowatt hours	$0.15	$3,000	
SUBTOTAL				$43,200	
Contingency	25%			$10,800	
SUBTOTAL				$54,000	
Project Management	10%			$5,400	
Technical Support	10%			$5,400	
TOTAL PERIODIC COST				$65,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,370,000	$1,370,000	1.00	$1,370,000	
Annual O&M	2-30	$406,000	$14,000	15.14	$211,975	30 years, 5 %
Periodic Cost	2	$93,000	$93,000	0.95	$88,571	
Periodic Cost	3	$93,000	$93,000	0.91	$84,354	
Periodic Cost	4	$93,000	$93,000	0.86	$80,337	
Periodic Cost	5	$93,000	$93,000	0.82	$76,511	
Periodic Cost	6	$65,000	$65,000	0.78	$50,929	
Periodic Cost	7	$65,000	$65,000	0.75	$48,504	
Periodic Cost	8	$65,000	$65,000	0.71	$46,194	
Periodic Cost	9	$65,000	$65,000	0.68	$43,995	
Periodic Cost	10	$65,000	$65,000	0.64	$41,900	
		$2,473,000			$2,143,270	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$2,143,000	

Table 5
Remedial Alternative Opinion of Probable Cost

Alternative 4
ZERO-VALENT IRON INJECTIONS

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Description: Alternative 3 consists of 1 injection of zero valent iron to treat the area of the plume with the highest concentrations. Includes five years of LNAPL extraction and groundwater monitoring and 10 years of sub-slab depressurization system operation. Capital costs and first year O&M costs occur in Year 1.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Report Preparation					
Site Management Plan	60	hours	$100.00	$6,000	
Site Work					
Monitoring Well Drilling and Installation	6	well	$4,000.00	$24,000	6 - 2" Schedule 40 PVC Wells to 20 feet
Drums	12	Drums	$55.00	$660	
Purge Water and Cuttings Disposal	12	Drums	$250.00	$3,000	
Bench scale and pilot test	1	lump sum	$20,000.00	$20,000	Hydraulic and geochemical analyses
Zero-valent Iron Injections					
Subcontractor Design, Planning and H&S Plan	1	lump sum	$9,000.00	$9,000	
Mobe/Demobe and Setup	1	lump sum	$15,000.00	$15,000	
Zero-valent iron	1	lump sum	$72,000.00	$72,000	1 Injection event, 105,000 pounds of iron
Subcontractor labor, equipment, drilling and materi	1	lump sum	$230,000.00	$230,000	
ETI License Fee	1	percent	15%	$45,300	
SUBTOTAL				$424,960	
Contingency	25%			$106,240	10% scope + 15% Bid
SUBTOTAL				$531,200	
Project Management	8%			$42,496	
Remedial Design/Bid Assistance	25%			$132,800	
Construction Management	10%			$53,120	
First Year O&M and Periodic Costs	1	lump sum		$107,000	See cost breakdown below
LNAPL Recovery	1	lump sum		$276,000	See cost breakdown on Table 2
TOTAL CAPITAL COST				$1,143,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
O&M	0	hours	$80.00	$0	
SUBTOTAL				$0	
Contingency	25%			$0	
Project Management	5%			$0	
Technical Support	10%			$0	
TOTAL ANNUAL O&M COST				$0	

PERIODIC COSTS IN YEARS 1 THROUGH 5:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week per year
Groundwater Laboratory Analysis	15	samples	$100.00	$1,500	VOC analysis: 15 samples/year
SUBTOTAL				$9,500	
Contingency	25%			$2,375	
SUBTOTAL				$11,875	
Project Management	5%			$594	
Technical Support	10%			$1,188	
LNAPL Recovery O&M	1	Lump Sum		$28,000	See cost breakdown on Table 2
TOTAL PERIODIC COST				$42,000	

PERIODIC COSTS IN YEARS 1 THROUGH 10:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Carbon Drums for SVE System	8	drums	$1,000.00	$8,000	
Air and Sub-slab Vapor Sampling and O&M	240	hours	$80.00	$19,200	20 hours/month
Air and Sub-slab Vapor Laboratory Analysis	10	samples	$300.00	$3,000	TO-15 VOC analysis
Reporting	100	hours	$100.00	$10,000	
SVE System Electrical	20,000	kilowatt hours	$0.15	$3,000	
SUBTOTAL				$43,200	
Contingency	25%			$10,800	
SUBTOTAL				$54,000	
Project Management	10%			$5,400	
Technical Support	10%			$5,400	
TOTAL PERIODIC COST				$65,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,143,000	$1,143,000	1.00	$1,143,000	
Annual O&M	2-10	$0	$0	1.00	$0	10 years, 5 %
Periodic Cos	2	$107,000	$107,000	0.95	$101,905	
Periodic Cos	3	$107,000	$107,000	0.91	$97,052	
Periodic Cos	4	$107,000	$107,000	0.86	$92,431	
Periodic Cos	5	$107,000	$107,000	0.82	$88,029	
Periodic Cos	6	$65,000	$65,000	0.78	$50,929	
Periodic Cos	7	$65,000	$65,000	0.75	$48,504	
Periodic Cos	8	$65,000	$65,000	0.71	$46,194	
Periodic Cos	9	$65,000	$65,000	0.68	$43,995	
Periodic Cos	10	$65,000	$65,000	0.64	$41,900	
		$1,896,000			$1,753,938	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TEN YEARS					$1,754,000	

Table 6
Remedial Alternative Opinion of Probable Cost

Alternative 5
PRE-DISPOSAL CONDITIONS

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Description: Alternative 5 consists ISCO injections over a 250 foot width between the site building and Glen Cove. Assumes one time installation based on a quote from ARS. Includes five years of LNAPL extraction, 10 years of sub-slab depressurization system operation, and 30 years of groundwater monitoring. Capital costs and first year O&M costs occur in Year 1.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Report Preparation					
Site Management Plan	60	hours	$100.00	$6,000	
Site Work					
Monitoring Well Drilling and Installation	12	well	$4,000.00	$48,000	6 - 2" Schedule 40 PVC Wells to 20 feet
Drums	24	Drums	$55.00	$1,320	
Purge Water and Cuttings Disposal	24	Drums	$250.00	$6,000	
Bench scale and pilot test	1	lump sum	$20,000.00	$20,000	Hydraulic and geochemical analyses
ISCO Injections					
ISCO injections	37,000	cubic yards	$125.00	$4,625,000	Unit cost from McDade et al. (2005)
SUBTOTAL				$4,706,320	
Contingency	25%			$1,176,580	10% scope + 15% Bid
SUBTOTAL				$5,882,900	
Project Management	8%			$470,632	
Remedial Design/Bid Assistance	25%			$1,470,725	
Construction Management	10%			$588,290	
First Year O&M and Periodic Costs	1	lump sum		$107,000	See cost breakdown below
LNAPL Recovery	1	lump sum		$276,000	See cost breakdown on Table 2
TOTAL CAPITAL COST				$8,796,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
O&M	0	hours	$80.00	$0	
Contingency	25%			$0	
Project Management	5%			$0	
Technical Support	10%			$0	
TOTAL ANNUAL O&M COST				$0	

PERIODIC COSTS IN YEARS 1 THROUGH 5:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	100	hours	$80.00	$8,000	2 people, 1 week per year
Groundwater Laboratory Analysis	15	samples	$100.00	$1,500	VOC analysis: 15 samples/year
SUBTOTAL				$9,500	
Contingency	25%			$2,375	
SUBTOTAL				$11,875	
Project Management	5%			$594	
Technical Support	10%			$1,188	
LNAPL Recovery O&M	1	Lump Sum		$28,000	See cost breakdown on Table 2
SUBTOTAL				$41,656	
TOTAL PERIODIC COST				$42,000	

PERIODIC COSTS IN YEARS 1 THROUGH 10:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Carbon Drums for SVE System	8	drums	$1,000.00	$8,000	
Air and Sub-slab Vapor Sampling and O&M	240	hours	$80.00	$19,200	20 hours/month
Air and Sub-slab Vapor Laboratory Analysis	10	samples	$300.00	$3,000	TO-15 VOC analysis
Reporting	100	hours	$100.00	$10,000	
SVE System Electrical	20,000	kilowatt hours	$0.15	$3,000	
SUBTOTAL				$43,200	
Contingency	25%			$10,800	
SUBTOTAL				$54,000	
Project Management	10%			$5,400	
Technical Support	10%			$5,400	
TOTAL PERIODIC COST				$65,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$8,796,000	$8,796,000	1.00	$8,796,000	
Annual O&M	2-30	$0	$0	#DIV/0!	$0	30 years, 5 %
Periodic Cost	2	$107,000	$107,000	0.95	$101,905	
Periodic Cost	3	$107,000	$107,000	0.91	$97,052	
Periodic Cost	4	$107,000	$107,000	0.86	$92,431	
Periodic Cost	5	$107,000	$107,000	0.82	$88,029	
Periodic Cost	6	$65,000	$65,000	0.78	$50,929	
Periodic Cost	7	$65,000	$65,000	0.75	$48,504	
Periodic Cost	8	$65,000	$65,000	0.71	$46,194	
Periodic Cost	9	$65,000	$65,000	0.68	$43,995	
Periodic Cost	10	$65,000	$65,000	0.64	$41,900	
		$9,549,000			$9,406,938	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS					$9,407,000	

Table 7
Remedial Alternative Opinion of Probable Cost Summary

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Alternative	Description	Capital Costs	Annual O&M Costs	Periodic Year 1-5 Annual Costs	Periodic Year 6-10 Annual Costs	Total Present Value
Alternative 1	NO FURTHER ACTION	$0	$0	$0	$0	$0
Alternative 2	IN-SITU CHEMICAL OXIDATION	$1,122,000	$0	$107,000	$65,000	$1,733,000
Alternative 3	PERMEABLE REACTIVE BARRIER	$1,370,000	$14,000	$93,000	$65,000	$2,143,000
Alternative 4	ZERO-VALENT IRON INJECTIONS	$1,143,000	$0	$107,000	$65,000	$1,754,000
Alternative 5	PRE-DISPOSAL CONDITIONS	$8,796,000	$0	$107,000	$65,000	$9,407,000

Note:
Capital costs include the first year of O&M and first year periodic cost.

Table 8
Remedial Alternative 30-Year Cost Summary

OPINION OF PROBABLE COST SUMMARY

Site: Crown Dykman
Location: Glen Cove, New York
Phase: Feasability Study (-30% to +50%)
Base Year: 2009
Date: June 8, 2009

Alternative	1	2	3	4	5
	No Action	ISCO	PRB	Iron Injections	Pre-existing Conditions
Capital Cost	$0	$1,122,000	$1,370,000	$1,143,000	$8,796,000
Annual O&M	$0	$0	$14,000	$0	$0
Periodic Cost Years 1-5	$0	$107,000	$93,000	$107,000	$107,000
Periodic Cost Years 6-10	$0	$65,000	$65,000	$65,000	$65,000
Year	Present Net Worth				
1	$0	$1,122,000	$1,370,000	$1,143,000	$8,796,000
2	$0	$1,223,905	$1,471,905	$1,244,905	$8,897,905
3	$0	$1,320,957	$1,568,957	$1,341,957	$8,994,957
4	$0	$1,413,388	$1,661,388	$1,434,388	$9,087,388
5	$0	$1,501,417	$1,749,417	$1,522,417	$9,175,417
6	$0	$1,552,346	$1,811,315	$1,573,346	$9,226,346
7	$0	$1,600,850	$1,870,266	$1,621,850	$9,274,850
8	$0	$1,647,044	$1,926,410	$1,668,044	$9,321,044
9	$0	$1,691,039	$1,979,880	$1,712,039	$9,365,039
10	$0	$1,732,938	$2,030,805	$1,753,938	$9,406,938
11	$0	$1,732,938	$2,039,399	$1,753,938	$9,406,938
12	$0	$1,732,938	$2,047,585	$1,753,938	$9,406,938
13	$0	$1,732,938	$2,055,381	$1,753,938	$9,406,938
14	$0	$1,732,938	$2,062,805	$1,753,938	$9,406,938
15	$0	$1,732,938	$2,069,876	$1,753,938	$9,406,938
16	$0	$1,732,938	$2,076,610	$1,753,938	$9,406,938
17	$0	$1,732,938	$2,083,024	$1,753,938	$9,406,938
18	$0	$1,732,938	$2,089,132	$1,753,938	$9,406,938
19	$0	$1,732,938	$2,094,949	$1,753,938	$9,406,938
20	$0	$1,732,938	$2,100,490	$1,753,938	$9,406,938
21	$0	$1,732,938	$2,105,766	$1,753,938	$9,406,938
22	$0	$1,732,938	$2,110,791	$1,753,938	$9,406,938
23	$0	$1,732,938	$2,115,577	$1,753,938	$9,406,938
24	$0	$1,732,938	$2,120,135	$1,753,938	$9,406,938
25	$0	$1,732,938	$2,124,476	$1,753,938	$9,406,938
26	$0	$1,732,938	$2,128,610	$1,753,938	$9,406,938
27	$0	$1,732,938	$2,132,548	$1,753,938	$9,406,938
28	$0	$1,732,938	$2,136,297	$1,753,938	$9,406,938
29	$0	$1,732,938	$2,139,869	$1,753,938	$9,406,938
30	$0	$1,732,938	$2,143,270	$1,753,938	$9,406,938

Notes:
NA - Not applicable
Present Net Worth for PRB O&M is based on a 5% discount rate.
Capital costs, which include the first year of O&M and first year periodic cost, occur in year 1.
Assumes O&M and periodic costs incurred at the end of each year.
Periodic costs years 1 to 5 include post injection groundwater monitoring and laboratory analysis and SVE system monitoring
Periodic costs years 6 to 10 include SVE system monitoring only.