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Modock Road Springs/DLS Sand and Gravel, Inc. Site (HW 8-35-013)
Victor, New York

Focused Feasibility Study for Groundwater Interim Remedial Measure

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1.1. Introduction

1.1.1. Purpose

This Focused Feasibility Study (FFS) has been developed to evaluate Interim Remedial Measures (IRMs) for chlorinated volatile organic compounds (CVOCs) in groundwater at the Modock Road Springs/DLS Sand and Gravel, Inc. site in the Town of Victor, New York (Figure 1). This FFS describes the screening of potential IRMs for the site (the 169 acre DLS Sand and Gravel, Inc. property located at 1389 Malone Road). The purpose of this report is to:

- Identify interim in-situ plume containment/control remedial technologies;
- Evaluate these technologies based on their feasibility/implementability and cost; and
- Recommend potential IRMs that could be implemented to meet preliminary Remedial Action Objectives (PRAOs) and provide site-specific information on performance of the remedial technology.

The IRM for groundwater at the site will not be selected until this evaluation, and subsequent NYSDEC assessments, have been thoroughly reviewed and presented to the public. The goal of an IRM would be to limit the migration of the dissolved phase CVOC plume from the suspected area of origin.

1.1.2. Site Description

1.1.2.1. Physical Setting

The site is located in a rural portion of Ontario County in the Town of Victor, New York (Figure 1). A dissolved phase CVOC plume extends from the DLS Sand & Gravel, Inc (located on Malone Road) property approximately one mile to the north where groundwater discharges to a spring directly to the south of Modock Road. Land use is agricultural and residential adjacent to and north of the DLS Sand & Gravel, Inc. property, in the area of the dissolved phase CVOC plume. Farther to the north, between Dryer Road and Modock Road, land use is rural/suburban with some recent home construction. A second sand and gravel mine is located on Malone Road directly west of the DLS Sand & Gravel, Inc. property.

The topography in the area of the dissolved phase CVOC plume generally slopes downward to the north, but consists of rolling hills with elevations varying from approximately 620 feet above mean sea level (AMSL) near the Modock Road Springs to approximately 900 feet AMSL near the DLS Sand & Gravel, Inc. property.

1.1.2.2. Hydrogeology

The Modock Road Springs, located in the transition zone between the Erie-Ontario Lake Plain and the Appalachian Upland Physiographic Provinces, are situated along the lower slope of a large kame moraine complex formed by meltwater issuing from a stagnating continental glacier more than 10,000 years ago. Aggregate mining operations (DLS Sand & Gravel, Inc. and second sand and gravel mine located on Malone Road directly west of the site) along the crest of this kame moraine complex have exposed thick sequences of stratified sands, gravels, and occasional clay layers which underlie the hummocky topography. A west-east geologic cross section at the northern boundary of the DLS Sand & Gravel, Inc. property is shown on Figure 2. The permeable soils of this moraine complex provide groundwater recharge areas for regional aquifer systems, such as the Irondogenesee Aquifer (incised buried valley of the pre-glacial Genesee River; coincident with present-day Irondequoit Creek). At distinct changes in topography (e.g., toe of slope) and stratigraphy (e.g., clay layers), groundwater may discharge to the surface as springs and wetlands. Small spring-fed streams, which originate at Modock Road Springs and other springs in the area, form the headwaters of Irondequoit Creek. These wetlands are part of the headwaters of a tributary of the Irondequoit Creek.

Past investigations indicate that groundwater flows from the south near the DLS Sand & Gravel, Inc. property to the north toward the Modock Road Springs (Figure 3). The depth to groundwater varies considerably depending upon location within the hummocky kame deposits. Specifically, at MW-5, the watertable is at a depth of approximately 10 feet below ground surface. At MW-10 along Surrey Lane and at MW-14, just north of the DLS Sand & Gravel, Inc. property, groundwater occurs at a depth of approximately 80 feet and 60 feet below ground surface respectively. Available data indicate that the uppermost water-table aquifer is affected by CVOC contamination. A low permeability clay layer of appears to restrict groundwater contamination to the uppermost, approximately 10- to 50-foot thick, zone of saturated sand. Based on information from residential wells, depth to bedrock (Bertie Formation/Onondaga Limestone) varies from roughly 150 to 200 feet below ground surface. Water samples from bedrock residential wells have not shown CVOC contamination.

1.1.3. Site History

The site is located in a rural/suburban area in the Town of Victor, Ontario County, New York. Previous investigations have documented the presence of CVOCs, including trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethene (1,1-DCE), in groundwater. Data (analytical sampling results, groundwater elevations, hydraulic gradients, and groundwater flow direction) indicate that the upgradient portion of the dissolved phase CVOC plume is located on the DLS Sand & Gravel, Inc. property.

Groundwater contamination was initially discovered in February 1990 during a New York State Department of Health (NYSDOH) initiative to sample small community water supplies across New York State. During this community water supply sampling, TCE, 1,1-DCE, and 1,1,1-TCA were detected in the Modock Road Springs. Both TCE and 1,1,1-TCA were detected in the spring water at concentrations greater than the NYSDOH Part 5 drinking water standards of 5 ppb. As a result, the use of the springs as a public water supply ceased and the Village of Victor connected to the Monroe County Water Authority as a source of supply. Surface water total VOC concentrations in the wetland/stream that originates from the Modock Road Springs decrease from about 50 ppb to near undetectable levels within a quarter mile downstream (north) of the springs.

The DLS Sand & Gravel, Inc. property was listed on the New York State Registry of Inactive Hazardous Waste Disposal Sites as Class 2. A site is listed as a Class 2 when a consequential quantity of hazardous waste has been confirmed and the presence of such hazardous waste or its components or breakdown products represent a significant threat to the environment or to health as described in 6 NYCRR Part 375-1.4. In August 2006, the site was referred to the NYSDEC Division of Environmental Remediation for the completion of a state-funded Remedial Investigation/Feasibility Study (RI/FS). The goal of the RI/FS, which is currently being conducted, is to evaluate and characterize the suspected source of the groundwater contamination, better define the extent of the dissolved phase CVOC plume, determine whether actions are needed to address exposures related to soil vapor intrusion, and assess remedial alternatives to address the source area and dissolved phase CVOC plume.

Based on the results of soil vapor intrusion sampling completed at 64 residential properties between February 2007 and May 2007 as part of an Immediate Investigation Work Assignment (IIWA), NYSDEC funded the installation of soil vapor intrusion mitigation systems in six residences.

1.1.4. Conceptual Site Model

A conceptual site model was developed to facilitate the evaluation of potential remedial measures and data gaps and provide an organizational structure for data collected at the site. These data include site-specific information on CVOCs in soil, groundwater, soil gas, sub-slab vapor, and indoor and outdoor air. The conceptual site model summarizes the site-specific geology, the depth and flow of groundwater, and the characteristics of the potential CVOC sources.

As shown on Figure 2, the uppermost portion of the water-table aquifer consists of sand with some gravel and silt. A low permeability clay layer appears to restrict groundwater contamination to the uppermost, approximately 10- to 50-foot thick, zone of saturated sand. At the northern boundary of the DLS Sand & Gravel, Inc. property the top of this clay layer is approximately 80 feet below ground surface. Information from residential wells indicate that the top of bedrock (Bertie Formation/Onondaga Limestone) is approximately 150 to 200 feet below ground surface.

Based on water level measurements in DLS Sand & Gravel, Inc. and NYSDEC groundwater monitoring wells, an east-west groundwater divide is present in the southern portion of the DLS Sand & Gravel, Inc. property (Figure 3). South of this divide overburden groundwater flows to the south and north of this divide groundwater flows to the north. Groundwater samples in wells SS&G MW-10 and SS&G MW-11 to the south of the groundwater divide do not contain CVOCs. A dissolved phase CVOC plume extends from the DLS Sand & Gravel, Inc. property approximately one mile to the north where groundwater discharges to a spring directly to the south of Modock Road. Preliminary data indicates that no continuing sources of CVOCs in the unsaturated zone have been identified. Analysis of groundwater collected from residential bedrock wells indicate that the bedrock groundwater quality has not been impacted by the dissolved phase CVOC plume.

2. Preliminary Remedial Action Objectives and Evaluation Criteria

This section outlines the Preliminary Remedial Action Objective (PRAO) proposed for the groundwater IRM at the Modock Road Springs/DLS Sand and Gravel, Inc. site, and the standards, criteria, and guidance to be considered in addressing the PRAO. This objective is considered preliminary because information obtained from the RI/FS and IRM will be used to better define the Remedial Action Objectives for a final site-wide remedy.

2.1. Preliminary Remedial Action Objectives

For the purposes of this report, the PRAO for the IRM is to reduce the concentration of site-related contaminants (e.g., TCE, 1,1-DCE, and 1,1,1-TCA) downgradient from the DLS Sand and Gravel, Inc. property to the extent feasible or until groundwater standards are achieved..

2.2. Evaluation Criteria

Due to the nature of the contaminants at the site, and the NYSDEC's desire to expeditiously implement an IRM at the site, this report will limit evaluation of potential IRMs to their technical feasibility/implementability and their overall cost. These criteria are considered to be the most important for selecting an interim remedial alternative. The final remedy for the site will be selected based on an evaluation of additional criteria.

2.2.1. Feasibility/Implementability

IRM alternatives will be evaluated based on their technical and administrative feasibility for implementation, and the availability of the technology and materials required during implementation. The following will be considered:

- Technical aspects of construction, operation, and monitoring;
- Reliability of technology;
- The activities related to obtaining necessary approvals from government agencies;
- The availability of services and materials, including the availability of specialists and the ability to obtain competitive bids; and
- The availability of adequate off-site treatment, storage, and disposal services, if needed.

2.2.2. Cost

The relative capital costs and annual operations, maintenance, and monitoring (OM&M) costs for remedial alternatives will be assessed. The cost analysis will include an assessment of the range of costs for materials provided by remediation vendors.

3. Preliminary Screening of Interim Remedial Technologies

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

Technology types include such general categories as treatment or containment, whereas process options are specific processes within the general technology types (e.g., treatment via chemical oxidation, or containment using a treatment barrier). This section develops a list of potential technology types and process options for treatment of groundwater impacted by VOCs in groundwater at the site. The retained technologies and process options are subsequently evaluated in Section 4 of this report based on the evaluation criteria discussed in Section 2.

GRAs identified for evaluation include:

- No Further Action
- In-situ Chemical Oxidation
- In-Situ Bioremediation
- Permeable Reactive Barriers
- Air Sparging/Soil Vapor Extraction

Descriptions, evaluations, and preliminary screening of each of these potential interim remedial technologies are provided below.

3.1. No Further Action

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

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

3.2. In-situ Chemical Oxidation

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

ISCO is defined as the delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants of concern into innocuous end products such as carbon dioxide (CO_2), water, and inorganic compounds. A chemical oxidant is injected in areas where a reduction in groundwater contaminant concentration is desired. Injection locations can be either permanently installed wells or temporary injection points installed using direct-push methods. When oxidants come in contact with chlorinated VOCs they are broken down into non-toxic components. However, contact between the oxidant and contaminant required to facilitate the reaction 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 chlorinated VOCs without the generation of potentially more toxic degradation products (although not all chlorinated VOC mass may break down).

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.

3.2.1. 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 would be required to sustain the oxidant in the subsurface compared to injections of other oxidants.

3.2.2. Sodium and Potassium Permanganate

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

Sodium permanganate has a much higher solubility in water than potassium permanganate, allowing it to be used for ISCO at higher concentrations, compared to two to five percent for potassium permanganate. Since it is supplied in liquid form, the use of sodium permanganate commonly requires no on-site mixing. Permangenate will not be considered further because it is ineffective at treating groundwater containing 1,1,1-TCA.

3.2.3. Sodium Persulfate

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

In-situ chemical oxidation using sodium persulfate or Fenton's reagent is retained for evaluation as a potential IRM alternative for the site because is can be used to treat site-related dissolved phase contaminants.

3.3. Enhanced In-situ Bioremediation

Bioremediation is the controlled management of microbial processes in the subsurface. This differs from monitoring of bioremediation processes under monitored natural attenuation (MNA) by being an active, designed, and managed process. Some microorganisms, such as Dehalococcoides (DHC), break down VOCs to the end products ethane and ethene. Therefore, bioremediation can often be enhanced through biostimulation (substrates injected in-situ to promote microbial activity) or bioaugmentation (increasing of bioremediation by adding microbial cultures). Biostimulation is used to set the proper conditions for increased microbial activity and may be all that is needed for satisfactory remediation. Biostimulation is often focused in areas where microbial populations are marginal and/or under conditions that are insufficient to support practical biodegradation rates.

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.

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

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

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

A disadvantage of a biological barrier is the possible increase of DCE and vinyl chloride (VC) downgradient of the treatment area. This is due to the TCE byproduct's (DCE and vinyl chloride) slower reduction rates. Heterogeneity in the soil can disrupt continuity of the wall resulting in gaps that can transmit contaminated water. Increased biofouling can also reduce the permeability of the barrier, potentially causing water to flow around the treatment zone. 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.

In the right conditions, chlorinated ethenes can be degraded under anaerobic conditions through reductive dechlorination. Reductive dechlorination is a reaction catalyzed by microorganisms in which a hydrogen atom replaces the chlorine atom on CVOCs such as TCE. The resulting hydrogen is then used by reductive dehalogenators to strip the solvent molecules of their chlorine atoms which allows for further degradation. Though this can occur naturally, it may not happen within an adequate time frame to meet remedial goals. The injection of hydrogen-releasing compounds can be used to enhance dechlorination processes. Anaerobic conditions can be created through the introduction of large amounts of carbon sources, and monitored by measuring dissolved oxygen (DO) to determine if anaerobic conditions have been achieved.

Advantages of anaerobic degradation typically include:

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

Disadvantages of anaerobic degradation typically include:

- The presence of DO at levels greater than 1 part-per-million (ppm) limit anaerobic degradation and would require the introduction of a carbon source to reduce DO levels.
- Depending on soil type, degree of heterogeneity, and groundwater depth, this technology may require closely spaced injection sites and can be cost prohibitive.
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient.

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

3.4. Permeable Reactive Barrier

Permeable Reactive Barriers (PRBs) are vertical zones of material (typically zero-valent iron, mulch, or some other reducing agent) that are installed in the subsurface to passively intercept groundwater flow. PRBs are installed in or down gradient of a contaminant plume by excavating a trench across the path of a migrating VOC 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 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.

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

3.4.1. Zero-valent Iron

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

PRB longevity using zero-valent iron is dependent on contaminant concentration, groundwater flow velocity, and the geochemical makeup of the groundwater. The oldest full-scale PRB was installed in February 1995 at a site in Sunnyvale, California. This PRB has successfully reduced the concentrations of TCE, DCE, VC, and Freon throughout its 11 years of operation (ETI, 2006). Since the age of the oldest PRB is only approximately 12 years, bench scale studies using reactive iron columns (from both cores obtained from emplaced reactive walls and from virgin reactive iron) have been conducted to evaluate long-term PRB longevity. These tests have shown that, although the reactivity of the iron declines with long-term exposure to groundwater, conditions promoting the dehalogenation of chlorinated solvents are maintained over the long term. Based on these studies, the expected life of a typical reactive wall (where life is defined as the period over which the reactivity of the iron declines by a factor of two) is approximately 30 years (ESTCP, 2003). However, these studies also indicated that groundwater geochemistry, specifically the concentration and resulting flux of natural organic matter (NOM), total dissolved solids (TDS), and carbonate, along with the distribution of VOC concentrations, greatly influences the lifetime of the reactive iron and should be considered in the reactive wall design process (Klausen et al., 2003).

Zero-valent iron PRBs can be installed by direct-injection of iron or iron substrate into a series of injection wells or boreholes along the barrier alignment. The iron particles are injected into the subsurface to form a continuous barrier between the wells/boreholes. During injection, the barrier geometry can be monitored in real-time to ensure fracture coalescence or overlap using resistivity sensors in the subsurface. Once installed, the hydraulic continuity of the PRB can also be verified using pulse interference testing. PRBs have been installed to depths exceeding 100 feet below grade and barrier lengths exceeding 1,000 feet. This trenchless method generates almost no waste that would require disposal or treatment.

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

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 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; and
- Relatively high capital costs.

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

3.4.2. Mulch and Chitin Barriers

A form of in-situ bioremediation is a biological barrier which acts as a passive control to plume flow when microorganisms break down VOCs that pass by them in groundwater. A biological barrier treats VOC containing groundwater biologically, which is different than most PRB technologies where a chemically reactive treatment barrier is utilized. As with chemical barriers, care must be taken to ensure the wall is constructed to the correct thickness so that the contaminated plume has enough time to biodegrade. 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 mulch or chitin barrier cannot be installed without excavation. Mulch can be used to turn aquifers anaerobic and provide a source of electron donors for reductive dechlorination of CVOCs. Mulch is inexpensive, long-lasting, and is naturally present in the environment. A mulch barrier will not be considered further because of the inability to trench down to or deliver the mulch to the required depths.

3.4.3. Electrically-induced Redox Barrier

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

Advantages of an electrically-induced redox barrier typically include:

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

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

Disadvantages of an electrically-induced redox barrier typically include:

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

Although an electrically-induced redox barrier may be feasible for site treatment, it will not be retained for future consideration. This technology is an unproven technology that has had limited field testing at F.E. Warren Air Force Base and would be difficult to implement due to the depth to groundwater.

3.5. 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 system would be designed so that the area of influence of the systems overlap, ensuring that all areas are treated. 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:

- Can be installed relatively easily with readily available equipment;
- Can be installed with minimal disturbance to site activities; and
- Air can be injected at the exact location desired.

Disadvantages of air sparging with soil vapor extraction typically include:

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

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

4. Analysis of Interim Remedial Measure Alternatives

The IRM alternatives to be evaluated are described below. Each alternative would treat an approximately 35-foot thick by 400-foot wide portion of saturated sand with CVOC-containing groundwater downgradient of MW-14. This treatment area was selected because the highest CVOC groundwater concentrations in the plume have been detected at MW-14. The results of the selected IRM alternative will be used in the evaluation of final site-wide remedies to address a larger portion of the plume.

4.1. No Further Action

4.1.1. Approach

A no further action alternative would involve no monitoring or remediation and is considered to be ineffective because the groundwater would not be remediated. This alternative will be retained for comparison to other technologies.

4.1.2. Feasibility/Implementability

A no further action alternative would require no effort to implement.

4.1.3. Cost

There are no costs associated with a no further action alternative.

4.2. In-situ Chemical Oxidation

4.2.1. Approach

Although there are several chemical oxidants capable of treating TCE and 1,1-DCE, the most commonly used chemical oxidant for CVOC remediation is permanganate because it is stable in the subsurface and relatively easier and safer to handle than other oxidants. However, since permanganate does not treat 1,1,1-TCA, sodium persulfate and Fenton's reagent will be considered in the following alternative. Implementation of an ISCO treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of ISCO treatment and the amount of oxidant required for treatment.
- Implementation and evaluation of a field pilot test to evaluate oxidant distribution and persistence in the subsurface.

- Injection of oxidant into either temporary direct-push injection points or permanent injection wells into the subsurface.
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

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 PRAO for the site. The ISCO injections would be located in a linear treatment zone generally perpendicular to groundwater flow downgradient of MW-14. Groundwater monitoring both upgradient and downgradient from the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations and protecting downgradient areas from further plume migration. Multiple injections are required to sustain the oxidants in the subsurface. It is common to space injections 3 to 6 months apart, although this spacing would most likely be less at this site due to relatively high hydraulic conductivity and hydraulic gradient.

ISCO would treat the groundwater plume as the affected groundwater flows through the treatment area. This would limit migration of the plume from its source. However, areas of the plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient of the ISCO treatment area would be addressed during the development of the final remedy for the site. An ISCO pilot study would be conducted to evaluate the implementability, effectiveness, cost, and feasibility of this technology at the site.

4.2.2. Feasibility/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.

As the proposed location for the ISCO injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the ISCO injection locations. As discussed in Section 3, ISCO injections do not generate significant waste, so treatment and disposal considerations are negligible.

4.2.3. Cost

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

4.3. Enhanced In-situ Bioremediation

4.3.1. Approach

Implementation of an in-situ bioremediation treatment program would include the following:

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

Since in-situ bioremediation relies on direct contact between bacteria and the contaminant, the success of the in-situ bioremediation treatment would be highly dependent on the ability to effectively distribute the biostimulant or bacteria through the treatment area. If such distribution can be achieved, it is anticipated that in-situ bioremediation is capable of meeting the PRAO for the site. Biostimulants are typically emulsified oils, lactate, or molasses. The injection of biostimulant or bacteria would be in a linear treatment zone generally perpendicular to groundwater flow downgradient of MW-14. This orientation would be similar to that from ISCO. Groundwater monitoring both upgradient and downgradient from 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 plume migration. Multiple injections, commonly one to two years apart for emulsified oils or lactate and up to monthly for molasses, are required to sustain anaerobic conditions and microbial populations in the subsurface.

In-situ bioremediation would treat the plume as the affected groundwater flows through the treatment area, which would limit migration of the plume from its source. There would also be limited downgradient treatment because the bioremediation amendments would flow with groundwater downgradient. However, areas of the plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient of the in-situ bioremediation treatment area would be addressed during the development of the final remedy for the site. An in-situ bioremediation pilot study would be conducted to evaluate the implementability, effectiveness, and feasibility of this technology at the site.

4.3.2. Feasibility/Implementability

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

As the proposed location for the in-situ bioremediation injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the in-situ bioremediation injection locations. It is assumed that access agreements could be obtained from adjacent property owners as necessary. In-situ bioremediation injections do not generate significant waste, so treatment and disposal considerations are negligible.

4.3.3. Cost

Maintaining an in-situ bioremediation barrier for five years or less, with or without bioaugmentation, is more expensive than no further action and air sparging with soil vapor extraction. In-situ bioremediation is more expensive than the PRB, no further action, and air sparging alternatives if implemented for more than five years.

4.4. ISCO and Enhanced In-situ Bioremediation

4.4.1. Approach

ISCO would be used to treat the highest groundwater CVOC concentration areas and enhanced bioremediation would be used to treat the lower concentration areas and as a barrier to minimize plume migration. An ISCO injection would significantly reduce the source concentrations, and then residual concentrations would be treated with enhanced bioremediation.

ISCO and in-situ bioremediation would treat the plume as the affected groundwater flows through the treatment area, which would limit migration of the plume from its source. There would also be limited downgradient treatment because the bioremediation amendments would flow with groundwater downgradient. However, areas of the plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient of the treatment area would be addressed during the development of the final remedy for the site. A pilot study would be conducted to evaluate the implementability, effectiveness, and feasibility of this technology at the site.

4.4.2. Feasibility/Implementability

Attainment of PRAO goals would be achieved in a shorter time frame than enhanced bioremediation itself. As stated above, both ISCO and enhanced bioremediation could be implemented using readily available technologies and there does not appear to be any significant obstacles to implementing these technologies at the site.

As the proposed location for the injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the injection locations. Injections do not generate significant waste, so treatment and disposal considerations are negligible.

4.4.3. Cost

This remedial alternative would cost less than using ISCO only but more than using enhanced bioremediation only. ISCO, which costs more than enhanced bioremediation per volume of aquifer treated, would only be used to treat the area with the highest groundwater CVOC concentrations resulting in lower costs than if ISCO is injected over the entire treatment area.

4.5. Enhanced In-situ Bioremediation and Zero Valent Iron

4.5.1. Approach

Zero valent iron would be used to treat the highest groundwater CVOC concentration areas and enhanced bioremediation would be used to treat the lower concentration areas and as a barrier to minimize plume migration. Zero valent iron injection could significantly reduce the groundwater concentrations, and then residual concentrations would be treated with enhanced bioremediation. 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 and in-situ bioremediation would treat the plume as the affected groundwater flows through the treatment area, which would limit migration of the plume from its source. There would also be limited downgradient treatment because the bioremediation amendments would flow with groundwater downgradient. However, areas of the plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient of the treatment area would be addressed during the development of the final remedy for the site. A pilot study would be conducted to evaluate the implementability, effectiveness, and feasibility of this technology at the site.

4.5.2. Feasibility/Implementability

Attainment of PRAO goals would be achieved in a shorter time frame than enhanced bioremediation itself. As stated above, both zero valent iron and enhanced bioremediation could be implemented using readily available technologies and there does not appear to be any significant obstacles to implementing these technologies at the site.

As the proposed location for the injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the injection locations. Injections do not generate significant waste, so treatment and disposal considerations are negligible.

4.5.3. Cost

This remedial alternative would cost more than using enhanced bioremediation, air sparging with soil vapor extraction, and PRBs but less than ISCO and enhanced bioremediation with ISCO. Zero valent iron, which costs more than enhanced bioremediation per volume of aquifer treated, would only be used to treat the area with the highest groundwater CVOC concentrations resulting in lower costs than if zero valent iron is injected over the entire treatment area (as in a PRB).

4.6. Permeable Reactive Barrier

4.6.1. Approach

Zero-valent iron PRBs would be installed by direct-injection as discussed in Section 3. The PRB would be constructed using a series of injection wells or boreholes oriented generally perpendicular to groundwater flow downgradient of MW-14. The PRB would extend vertically from approximately 60 feet bgs (average depth of the water table) to an approximate average depth of 100 feet bgs. Assuming a 400 foot long PRB, the treatment area would contain approximately 350 to 600 tons of iron, depending on the barrier thickness. 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 plume migration.

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 and east and west of the PRB would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient and east and west of the PRB would be addressed during the development of the final remedy for the site.

4.6.2. Feasibility/Implementability

Trenchless technologies for the installation of PRBs (Section 3) are relatively simple and technically feasible processes for the site. The uncertainties associated with PRB construction consist of minimizing gaps in the barrier and sufficient barrier thickness. These uncertainties could be mitigated using the testing and monitoring procedures discussed in Section 3. The effectiveness of the PRB could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the PRB.

As the proposed location for the PRB may not be owned by the State, an access agreement may need to be obtained from the property owner(s) to allow access to and from the PRB location. As discussed in Section 3, PRB installation using direct injection does not generate significant waste, so treatment and disposal considerations are negligible.

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

4.6.3. Cost

The PRB alternative has a higher capital cost (excluding the first year OM&M) but lower OM&M cost than all other alternatives. Over a five year time period, the PRB alternative would be more expensive than the air sparging and in-situ bioremediation alternatives but less than the ISCO injection alternatives because of the large number of ISCO injections required to maintain an effective treatment zone. Over a five year or longer time period, the PRB alternative becomes less expensive than the other IRM alternatives with the exception of air sparging with soil vapor extraction.

4.7. Air Sparging/Soil Vapor Extraction

4.7.1. Approach

Air sparging wells would be installed using a series of injection wells oriented generally perpendicular to groundwater flow downgradient of MW-14. Soil vapor extraction wells would be installed in the vadose zone in the vicinity of the air sparging wells. Air would be injected from approximately 60 feet bgs (average depth of the water table) to an approximate average depth of 100 feet bgs, although the majority of air would be injected in the lower 20 feet of this interval. Soil vapor extraction wells would be installed to within 10 feet above the water table. The volume of extracted soil vapor is typically two to three times more than the air injected into the aquifer.

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

Air sparging 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 and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the plume downgradient and to the east and west of the air sparging wells would be addressed during the development of the final remedy for the site.

4.7.2. Feasibility/Implementability

An air sparging and soil vapor extraction system could be installed relatively easily with readily available equipment. It is anticipated that the necessary specialists and equipment are available to complete the project. There does not appear to be any significant obstacles to implementing this technology at the site.

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

An air sparging and soil vapor extraction system could be installed with minimal disturbance to the site. However, at a minimum, an injection pump, vacuum extractor and surface treatment structures would be located above ground. As the proposed location for the air sparging injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the air sparging and soil vapor extraction well locations.

4.7.3. Cost

Capital costs (excluding the first year of OM&M) for air sparging and soil vapor vapor extraction are typically more than for injection technologies but less than PRB installations. However, OM&M costs could be substantial if the system is operated for many years. OM&M costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks. Capital costs would include construction of the treatment shed, running electrical lines to the treatment shed, and installation of the PVC piping, monitoring wells, and injection wells.

5. Comparative Evaluation of Interim Remedial Alternatives

5.1. Feasibility/Implementability

The no further action alternative was retained for evaluation to facilitate the comparison of the other interim remedial alternatives. In-situ bioremediation, ISCO, and PRBs have been selected as technologies that are capable of meeting the PRAO for the site while eliminating the need for ex-situ treatment facilities and minimizing disposal issues. The air sparging and soil vapor extraction alternative is also capable of meeting the PRAO for the site, however, it would require above-ground structures. There does not appear to be significant obstacles to implementing these technologies at the site, although providing power for air sparging equipment would be relatively more difficult because the other technologies do not require a sustainable power supply. The alternatives are all technically feasible and may be affected differently by site-specific geologic and hydrogeologic characteristics. As such, predesign studies or pilot tests are recommended prior to IRM implementation. Obtaining access will be necessary for all alternatives.

Each of the IRM alternatives would require installation of monitoring and injection wells. In-situ bioremediation and ISCO are more flexible than PRBs or air sparging as the results of initial injections may be used to guide, focus, and/or modify subsequent injection strategies. PRB bench scale studies indicate that the barrier would be effective for up to 30 years (ESTCP, 2003); however, a PRB cannot be moved once installed. The air sparging and soil vapor extraction remedial alternative is the only alternative considered which would include OM&M costs (excluding groundwater sampling). Air sparging requires aboveground structures and equipment, which would need to be maintained. An air sparging and soil vapor extraction system would need to be operated and maintained continuously until it is determined that it is no longer needed.

Based on information provided from bioremediation vendors, it is expected that one bioremediation injection would be effective for one to two years. Because of the relatively high hydraulic conductivity and gradient downgradient of MW-14, ISCO vendors expect that ISCO injections would be required every four weeks to maintain an effective barrier. For costing purposes, it is assumed that two bioremediation injections per year and one ISCO injection per month would be required. The need for more frequent injections would be evaluated as part of IRM performance monitoring.

A PRB would most likely need to be installed along Dryer Road as the relatively high groundwater seepage velocity and hydraulic gradient along the tree line near MW-14 may make this alternative infeasible in this area. The relatively high groundwater seepage velocity and hydraulic gradient along the tree line near MW-14 complicates the effectiveness of injection technologies. The time between injections using enhanced bioremediation would be approximately two to eight times longer than if an ISCO technology were selected. IRM performance monitoring would be used to evaluate the frequency of injections if an injection technology is selected as the IRM for groundwater. The groundwater seepage velocity and hydraulic gradient would have less of an effect on air sparging and soil vapor extraction as they would be continuous operations.

5.2. Cost

The costs for implementing the IRM alternatives are shown in Tables 1 through 6 and are summarized in Tables 7 and 8. Figure 4 shows a graph of the probable 30-year present value of each of the IRM alternatives. The relative order of probable present value for the seven IRM alternatives over a two year period are, from least to most expensive:

- No further action;
- Air sparging with soil vapor extraction;
- Bioremediation;
- Bioremediation and zero valent iron;
- PRB;
- ISCO and bioremediation; and
- ISCO.

If these IRM alternatives are operated for more than five years the PRB alternative would become the less expensive than all other alternatives other than air sparging with soil vapor extraction and no further action. OM&M costs for air sparging with soil vapor extraction are significant, but this alternative is less expensive than all other alternatieve (other than no further action) because the capital costs are lower than multiple enhanced bioremediation, ISCO, and PRB injections. The injection costs for in-situ bioremediation and ISCO are expected to be similar per event, however ISCO would require more injection events to maintain the oxidant in the subsurface. Based on remediation costs at 36 sites, McDade et al. (2005) calculated that the median cost per treatment volume using ISCO is approximately four times more expensive than using in-situ bioremediation. The PRB alternative has a higher capital cost (when excluding the first year of OM&M) than the other remedial alternatives. The injection material costs for as many as 10 enhanced bioremediation injections are comparable to the cost of the installation of one PRB. Although a PRB would have the highest capital cost, there are no OM&M costs other than groundwater monitoring.

5.3. IRM Alternative Advantages and Disadvantages

The IRM alternatives that are capable of meeting the PRAO with a reasonable cost are in-situ bioremediation, air sparging with soil vapor extraction, and a PRB. A list of advantages and disadvantages for each of these alternatives is below:

In-situ bioremediation advantages:

- More flexible than PRBs or air sparging as the results of initial injections may be used to guide, focus, and/or modify subsequent injection strategies.

In-situ bioremediation disadvantages:

- Requires multiple injections to maintain the treatment zone;
- Site conditions may dictate the need for closely spaced injection wells;
- Anaerobic degradation could be limited if elevated DO levels are present;
- A carbon source may be required to create anaerobic conditions;
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient.

Air sparging with soil vapor extraction advantages:

- Groundwater seepage velocity and hydraulic gradient would have less of an effect than on other alternatives; and
- Lower capital costs than a PRB.

Air sparging with soil vapor extraction disadvantages:

- Only IRM alternative considered which would include OM&M costs (excluding groundwater sampling);
- Requires maintenance of aboveground structures and equipment;
- Requires continuous operation and maintenance until the system is no longer needed;
- Heterogeneities or stratified soils would cause air flow to not flow uniformly through the subsurface causing some zones to be less treated; and
- Effective vapor extraction is needed to prevent fugitive vapors.

PRB advantages:

- Higher confidence of maintaining a complete barrier than other IRM alternatives;

- Does not require multiple injections;
- One-time installation with up to 30-year lifespan;
- No OM&M costs other than groundwater monitoring; and
- Lower long term costs than other alternatives;

PRB disadvantages:

- Once emplaced the PRB is expensive to adjust, re-locate or remove;
- May not be able to be installed along the tree line near MW-14 due to the relatively high groundwater seepage velocity and hydraulic gradient; and
- Relatively high capital costs.

6. References

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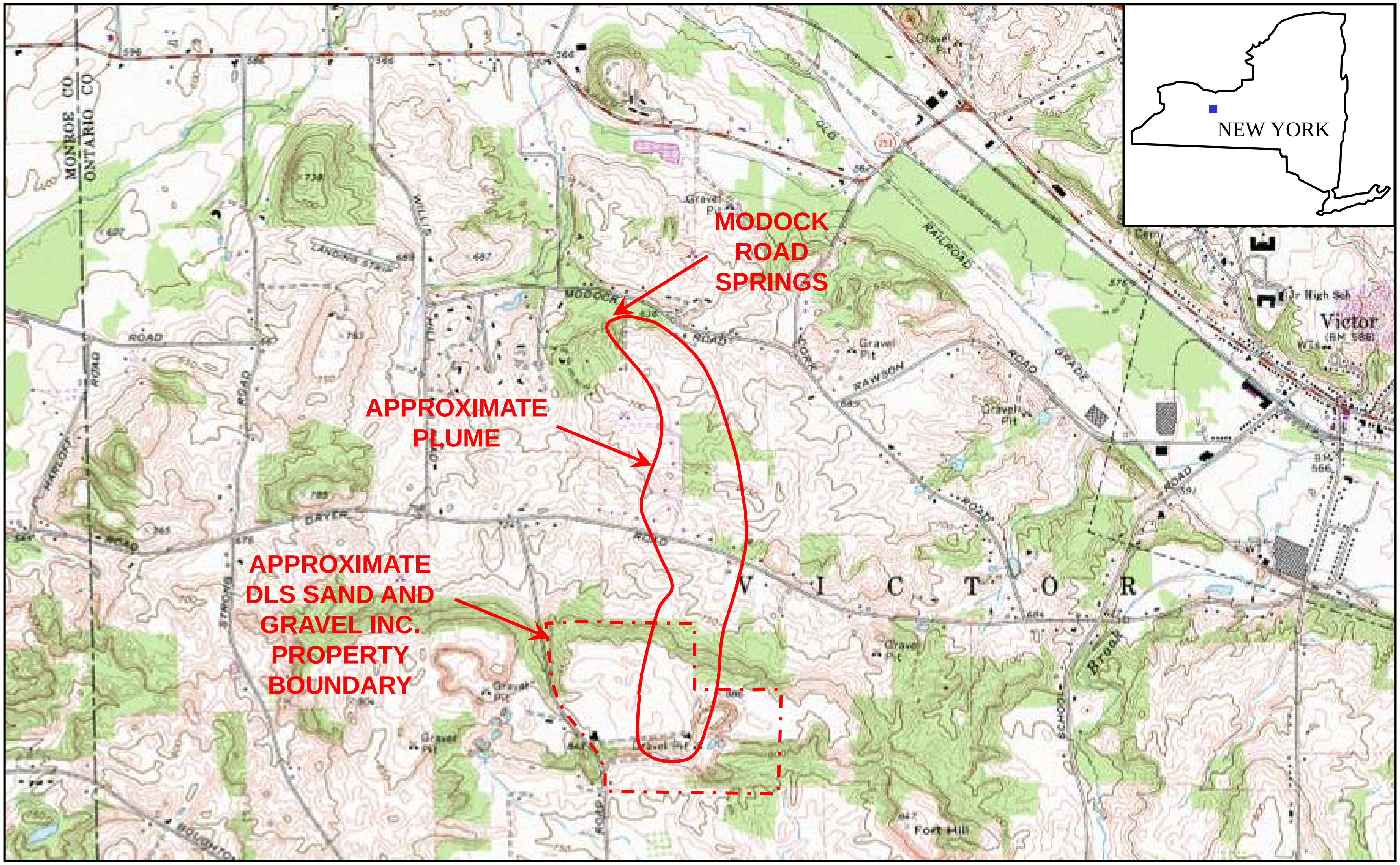
New York State Department of Environmental Conservation
Focused Feasibility Study for Groundwater
Interim Remedial Measure

Figures

0266361 / ALB

MALCOLM PIRNIE



MAP SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC SERIES, VICTOR QUADRANGLE (PHOTOREVISED 1978)

APPROXIMATE SCALE IN FEET

0 1200 2400 4800

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL REMEDIATION

FOCUSED FEASIBILITY STUDY

WORK ASSIGNMENT # D-004439 - 9

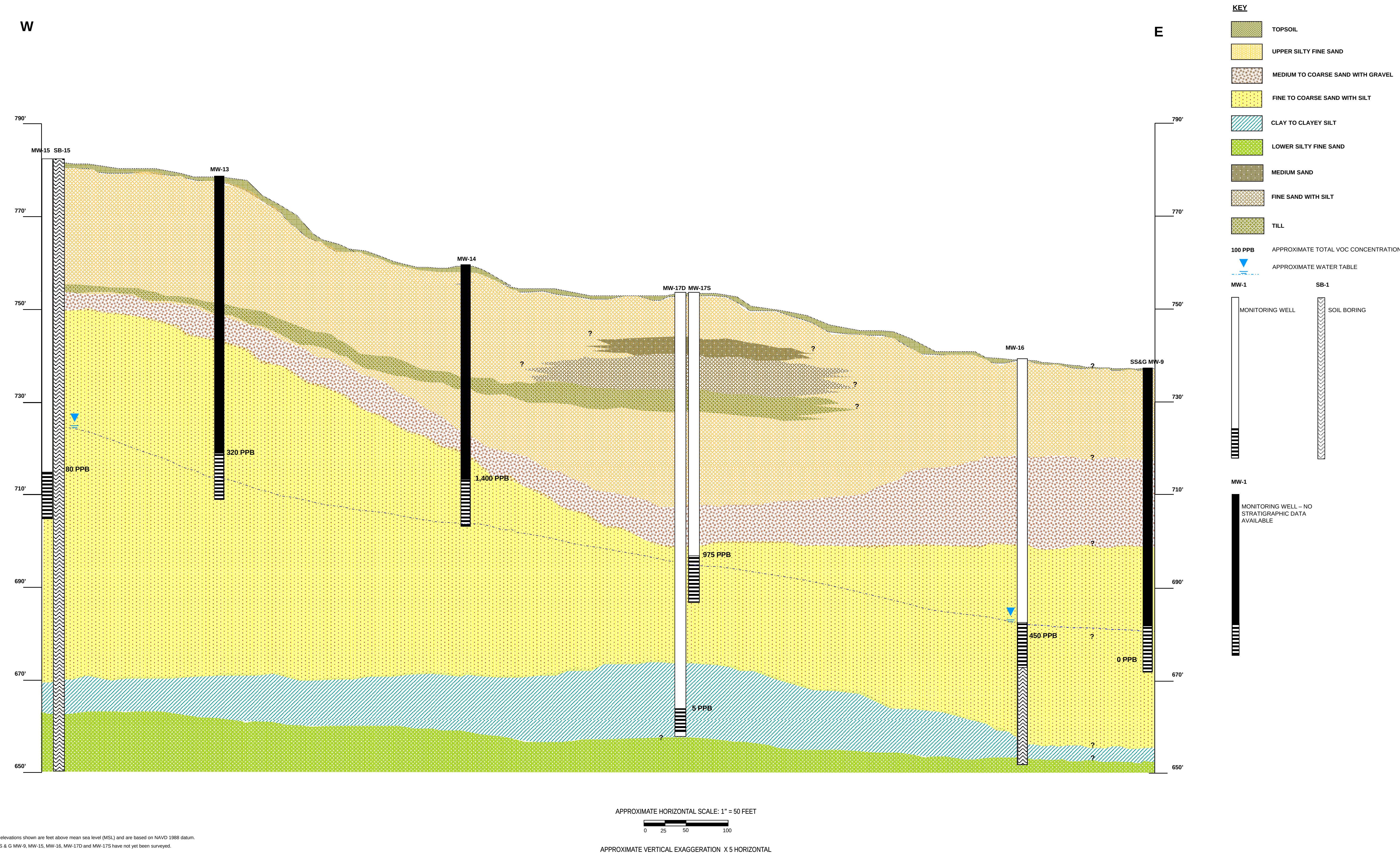
MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

FIGURE 1

SITE MAP

MALCOLM PIRNIE

F:\PROJECT\0266361\FILE\IRM FFS\Figure 1.ppt



NOTE: Vertical elevations shown are feet above mean sea level (MSL) and are based on NAVD 1988 datum.
Wells SS & G MW-9, MW-15, MW-16, MW-17D and MW-17S have not yet been surveyed.

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION DIVISION OF ENVIRONMENTAL REMEDIATION

FOCUSED FEASIBILITY STUDY

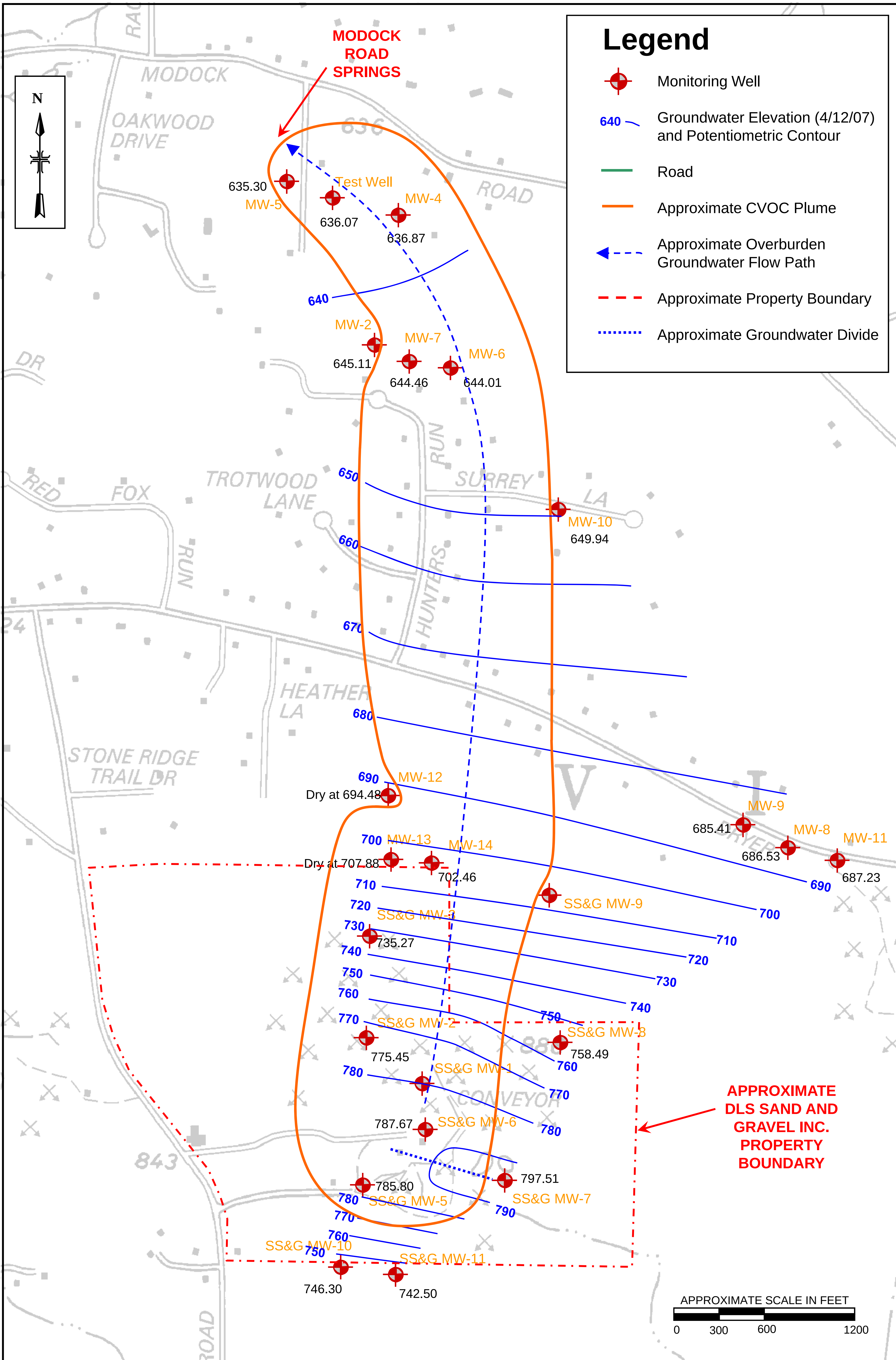
WORK ASSIGNMENT # D-004439 - 9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

FIGURE 2

WEST – EAST SIMPLIFIED GEOLOGIC CROSS-SECTION

MALCOLM PIRNIE

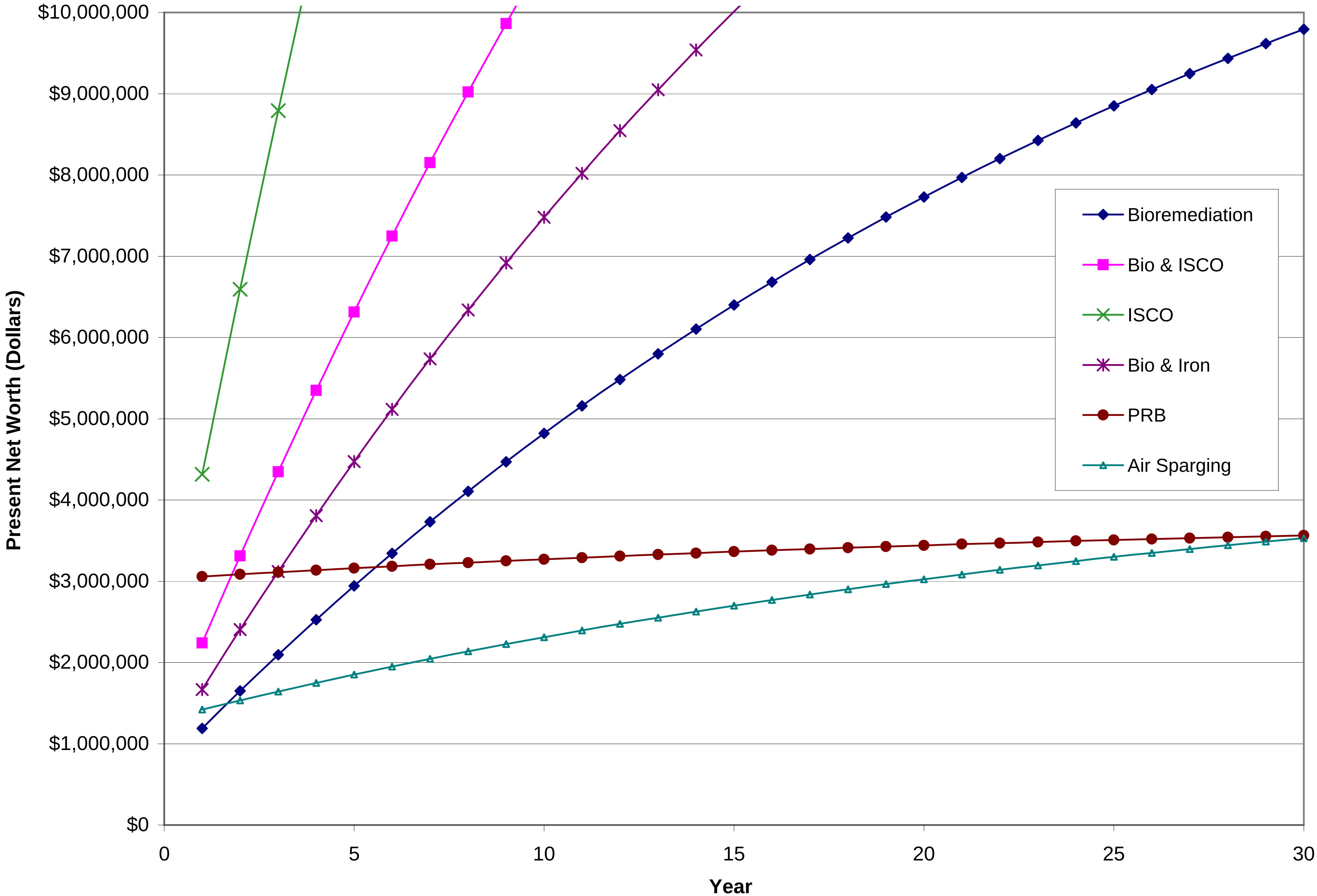


Basemap source: NYSDOT Quadrangle

F:\PROJECT\0266361\FILE\IRM FFS\Figure 3 Potentiometric Map.ppt

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION DIVISION OF ENVIRONMENTAL REMEDIATION FOCUSED FEASIBILITY STUDY WORK ASSIGNMENT # D-004439 - 9	MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013) TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK FIGURE 3 POTENTIOMETRIC CONTOUR MAP	MALCOLM PIRNIE

Figure 4
IRM Alternatives 30-year Present Net Worth
for a 400-foot wide treatment barrier



New York State Department of Environmental Conservation
Focused Feasibility Study for Groundwater
Interim Remedial Measure

Tables

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MALCOLM PIRNIE

Table 1
Remedial Alternative Opinion of Probable Cost

Alternative 1
IN-SITU BIOREMEDIATION

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Description: Alternative 1 consists of in-situ bioremediation to treat groundwater in a 400 foot width of the plume. Assuming 2 injections per year for 2 or 3 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Injection Well Drilling	2,000	linear feet	$40.00	$80,000	Sonic Drilling, 20 wells to 100 feet
Injection Well Installation	2,000	linear feet	$23.00	$46,000	2" PVC, Schedule 40
Stick-up Injection Well Casing	20	wells	$235.00	$4,700	20 Injection Wells
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
First year operation and maintenance	1	lump sum	$477,000.00	$477,000	
SUBTOTAL				$715,680	
Contingency	25%			$178,920	10% scope + 15% Bid
SUBTOTAL				$894,600	
Project Management	8%			$71,568	
Remedial Design	15%			$134,190	
Construction Management	10%			$89,460	
TOTAL CAPITAL COST				$1,190,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	8	samples	$250.00	$2,000	Biological indicators
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
SUBTOTAL				$21,500	
Bioremediation Injections					
Injection Materials	2	Lump Sum	$110,000.00	$220,000	2 Injections per year over 400 feet
Vendor/Subcontractor Field Support	2	lump sum	$40,000.00	$80,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$310,000	
SUBTOTAL				$331,500	
Contingency	25%			$82,875	
SUBTOTAL				$414,375	
Project Management	5%			$20,719	
Technical Support	10%			$41,438	
TOTAL ANNUAL O&M COST				$477,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,190,000	$1,190,000	1.00	$1,190,000	
Annual O&M	2	$477,000	$477,000	0.97	$460,870	2 years, 3.5 %
		$1,667,000			$1,650,870	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$1,651,000	
Capital	1	$1,190,000	$1,190,000	1.00	$1,190,000	
Annual O&M	2-3	$954,000	$477,000	1.90	$906,154	3 years, 3.5 %
		$2,144,000			$2,096,154	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$2,096,000	

Table 2
Remedial Alternative Opinion of Probable Cost

Alternative 2
IN-SITU BIOREMEDIATION AND ISCO

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Description: Alternative 2 consists of in-situ bioremediation and ISCO to treat groundwater in a 400 foot width of the plume. Assuming 2 injections per year for 2 or 3 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Injection Well Drilling	2,000	linear feet	$40.00	$80,000	Sonic Drilling, 20 wells to 100 feet
Injection Well Installation	2,000	linear feet	$23.00	$46,000	2" PVC, Schedule 40
Stick-up Injection Well Casing	20	wells	$235.00	$4,700	20 Injection Wells
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
First year operation and maintenance	1	lump sum	$1,109,000.00	$1,109,000	
SUBTOTAL				$1,347,680	
Contingency	25%			$336,920	10% scope + 15% Bid
SUBTOTAL				$1,684,600	
Project Management	8%			$134,768	
Remedial Design	15%			$252,690	
Construction Management	10%			$168,460	
TOTAL CAPITAL COST				$2,241,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	8	samples	$250.00	$2,000	Biological indicators
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
SUBTOTAL				$21,500	
Bioremediation Injections					
Injection Materials	2	Lump Sum	$330,000.00	$660,000	2 Injections per year over 400 feet
Vendor/Subcontractor Field Support	2	lump sum	$40,000.00	$80,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$750,000	
SUBTOTAL				$771,500	
Contingency	25%			$192,875	
SUBTOTAL				$964,375	
Project Management	5%			$48,219	
Technical Support	10%			$96,438	
TOTAL ANNUAL O&M COST				$1,109,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$2,241,000	$2,241,000	1.00	$2,241,000	
Annual O&M	2	$1,109,000	$1,109,000	0.97	$1,071,498	2 years, 3.5 %
		$3,350,000			$3,312,498	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$3,312,000	
Capital	1	$2,241,000	$2,241,000	1.00	$2,241,000	
Annual O&M	2-3	$2,218,000	$1,109,000	1.90	$2,106,761	3 years, 3.5 %
		$4,459,000			$4,347,761	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$4,348,000	

Table 3
Remedial Alternative Opinion of Probable Cost

Alternative 3
IN-SITU CHEMICAL OXIDATION

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Description: Alternative 3 consists of in-situ chemical oxidation to treat groundwater in a 400 foot width of the plume. Assumes 12 injections of RegenOx per year for 2 or 3 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Injection Well Drilling	2,000	linear feet	$40.00	$80,000	Sonic Drilling, 20 wells to 100 feet
Injection Well Installation	2,000	linear feet	$23.00	$46,000	2" PVC, Schedule 40
Stick-up Injection Well Casing	20	wells	$235.00	$4,700	20 Injection Wells
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
First year operation and maintenance	1	lump sum	$2,357,000.00	$2,357,000	
SUBTOTAL				$2,595,680	
Contingency	25%			$648,920	10% scope + 15% Bid
SUBTOTAL				$3,244,600	
Project Management	8%			$259,568	
Remedial Design	15%			$486,690	
Construction Management	10%			$324,460	
TOTAL CAPITAL COST				$4,315,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
SUBTOTAL				$19,500	
ISCO Injections					
Injection Materials	12	lump sum	$135,000.00	$1,620,000	12 Injections per year over 400 feet
Vendor/Subcontractor Field Support	1	lump sum	$40,000.00	$40,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$1,620,000	
SUBTOTAL				$1,639,500	
Contingency	25%			$409,875	
SUBTOTAL				$2,049,375	
Project Management	5%			$102,469	
Technical Support	10%			$204,938	
TOTAL ANNUAL O&M COST				$2,357,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$4,315,000	$4,315,000	1.00	$4,315,000	
Annual O&M	2	$2,357,000	$2,357,000	0.97	$2,277,295	2 years, 3.5 %
		$6,672,000			$6,592,295	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$6,592,000	
Capital	1	$4,315,000	$4,315,000	1.00	$4,315,000	
Annual O&M	2-3	$4,714,000	$2,357,000	1.90	$4,477,579	3 years, 3.5 %
		$9,029,000			$8,792,579	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$8,793,000	

Table 4
Remedial Alternative Opinion of Probable Cost

Alternative 4
BIOREMEDIATION AND ZERO VALENT IRON

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Description: Alternative 2 consists of in-situ bioremediation and zero valent iron to treat groundwater in a 400 foot width of the plume. Assuming 2 injections per year for 2 or 3 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Injection Well Drilling	2,000	linear feet	$40.00	$80,000	Sonic Drilling, 20 wells to 100 feet
Injection Well Installation	2,000	linear feet	$23.00	$46,000	2" PVC, Schedule 40
Stick-up Injection Well Casing	20	wells	$235.00	$4,700	20 Injection Wells
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
First year operation and maintenance	1	lump sum	$764,000.00	$764,000	
SUBTOTAL				$1,002,680	
Contingency	25%			$250,670	10% scope + 15% Bid
SUBTOTAL				$1,253,350	
Project Management	8%			$100,268	
Remedial Design	15%			$188,003	
Construction Management	10%			$125,335	
TOTAL CAPITAL COST				$1,667,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	8	samples	$250.00	$2,000	Biological indicators
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
SUBTOTAL				$21,500	
Bioremediation Injections					
Injection Materials	2	Lump Sum	$210,000.00	$420,000	2 Injections per year over 400 feet
Vendor/Subcontractor Field Support	2	lump sum	$40,000.00	$80,000	
Vendor/Subcontractor Reporting	1	lump sum	$10,000.00	$10,000	
SUBTOTAL				$510,000	
SUBTOTAL				$531,500	
Contingency	25%			$132,875	
SUBTOTAL				$664,375	
Project Management	5%			$33,219	
Technical Support	10%			$66,438	
TOTAL ANNUAL O&M COST				$764,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,667,000	$1,667,000	1.00	$1,667,000	
Annual O&M	2	$764,000	$764,000	0.97	$738,164	2 years, 3.5 %
		$2,431,000			$2,405,164	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$2,405,000	
Capital	1	$1,667,000	$1,667,000	1.00	$1,667,000	
Annual O&M	2-3	$1,528,000	$764,000	1.90	$1,451,366	3 years, 3.5 %
		$3,195,000			$3,118,366	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$3,118,000	

Table 5
Remedial Alternative Opinion of Probable Cos

Alternative 5
PERMEABLE REACTIVE BARRIER

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Description: Alternative 5 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 Geosierra. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	40	Drums	$55.00	$2,200	
Purge Water and Cuttings Disposal	40	Drums	$250.00	$10,000	
First year operation and maintenance	1	lump sum	$28,000.00	$28,000	
SUBTOTAL				$135,980	
PRB Installation					
Subcontractor and Material Costs	400	feet	$4,500.00	$1,800,000	PRB installed
ETI Patent License Fee	1	lump sum	$120,000.00	$120,000	
SUBTOTAL				$1,920,000	
SUBTOTAL				$2,055,980	
Contingency	25%			$513,995	10% scope + 15% Bid
SUBTOTAL				$2,569,975	
Project Management	5%			$128,499	
Remedial Design	8%			$205,598	
Construction Management	6%			$154,199	
TOTAL CAPITAL COST				$3,058,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
SUBTOTAL				$19,500	
SUBTOTAL				$19,500	
Contingency	25%			$4,875	
SUBTOTAL				$24,375	
Project Management	5%			$1,219	
Technical Support	10%			$2,438	
TOTAL ANNUAL O&M COST				$28,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$3,058,000	$3,058,000	1.00	$3,058,000	
Annual O&M	2	$28,000	$28,000	0.97	$27,053	2 years, 3.5 %
		$3,086,000			$3,085,053	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$3,085,000	
Capital	1	$3,058,000	$3,058,000	1.00	$3,058,000	
Annual O&M	2-3	$56,000	$28,000	1.90	$53,191	3 years, 3.5 %
		$3,114,000			$3,111,191	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$3,111,000	

Table 6
Remedial Alternative Opinion of Probable Cost

Alternative 6
AIR SPARGING AND SOIL VAPOR EXTRACTION

COST ESTIMATE SUMMARY

Site:	Modock Road Springs
Location:	Victor, New York
Phase:	IRM Focused Feasability Study
Base Year:	2008
Date:	January 21, 2008

Description: Alternative 6 consists of an Air Sparge and Soil Vapor Extraction Unit. Assuming a 10 ft radius of influence for Air Sparge and Soil Vapor Exctraction Wells. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-2 or Years 1-3.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Work					
Drilling Mobilization	1	lump sum	$11,000.00	$11,000	
Decon Pad	1	lump sum	$500.00	$500	
Monitoring Well Drilling	800	linear feet	$40.00	$32,000	Sonic Drilling, 8 wells to 100 feet
Monitoring Well Installation	800	linear feet	$23.00	$18,400	2" PVC, Schedule 40
Stick-up Monitoring Well Casing	8	wells	$235.00	$1,880	8 Monitoring Wells
Air Sparge Well Drilling	2,000	linear feet	$40.00	$80,000	Sonic Drilling, 20 wells to 100 feet
Air Sparge Well Installation	2,000	linear feet	$23.00	$46,000	2" PVC, Schedule 40
SVE Well Drilling	1,000	linear feet	$40.00	$40,000	Sonic Drilling, 20 wells to 50 feet
SVE Well Installation	1,000	linear feet	$23.00	$23,000	2" PVC, Schedule 40
Well Install. & Development Oversight	400	hours	$80.00	$32,000	
Drums	50	Drums	$55.00	$2,750	
Purge Water and Cuttings Disposal	50	Drums	$250.00	$12,500	
SVE/AS Mobilization, Bond, and Insurance	1	lump sum	$60,000.00	$60,000	
Trench for piping	1	lump sum	$6,000.00	$6,000	
Above ground PVC piping	1	lump sum	$14,000.00	$14,000	
Tees, elbows, reducers, and ball valves	1	lump sum	$20,000.00	$20,000	
Valve Vaults	1	lump sum	$105,000.00	$105,000	40 Vaults
Electrical Service	1	lump sum	$60,000.00	$60,000	
Treatment Shed, Blowers, and Controls	1	lump sum	$220,000.00	$220,000	
First year operation and maintenance	1	lump sum	$117,000.00	$117,000	
SUBTOTAL				$902,030	
Contingency	25%			$225,508	10% scope + 15% Bid
SUBTOTAL				$1,127,538	
Project Management	6%			$67,652	
Remedial Design	12%			$135,305	
Construction Management	8%			$90,203	
TOTAL CAPITAL COST				$1,421,000	

OPERATION & MAINTENANCE COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Site Monitoring					
Groundwater Sampling	200	hours	$80.00	$16,000	
Groundwater Laboratory Analysis	50	samples	$70.00	$3,500	VOC analysis
OM&M Inspection	300	hours	$80.00	$24,000	
SUBTOTAL				$43,500	
Misc.					
Electrical	1	Lump Sum	$15,000.00	$15,000	
System effluent sampling	12	samples	$300.00	$3,600	
OM&M Equipment and Materials	1	Lump Sum	$10,000.00	$10,000	
SUBTOTAL				$28,600	
SUBTOTAL				$72,100	
Contingency	25%			$18,025	
SUBTOTAL				$90,125	
Project Management	10%			$9,013	
Technical Support	20%			$18,025	
TOTAL ANNUAL O&M COST				$117,000	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	NOTES
Capital	1	$1,421,000	$1,421,000	1.00	$1,421,000	
Annual O&M	2	$117,000	$117,000	0.97	$113,043	2 years, 3.5 %
		$1,538,000			$1,534,043	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR TWO YEARS					$1,534,000	
Capital	1	$1,421,000	$1,421,000	1.00	$1,421,000	
Annual O&M	2-3	$234,000	$117,000	1.90	$222,264	3 years, 3.5 %
		$1,655,000			$1,643,264	
TOTAL PRESENT VALUE OF ALTERNATIVE FOR THREE YEARS					$1,643,000	

Table 7
Remedial Alternative Opinion of Probable Cost

COST ESTIMATE SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

Alternative	Description	Capital Costs	Annual OM&M Costs	Total Present Value
Alternative 1	IN-SITU BIOREMEDIATION			
	2 injections per year for 2 years	$1,190,000	$477,000	$1,651,000
	2 injections per year for 3 years	$1,190,000	$477,000	$2,096,000
Alternative 2	IN-SITU BIOREMEDIATION AND ISCO			
	2 injections per year for 2 years	$2,241,000	$1,109,000	$3,312,000
	2 injections per year for 3 years	$2,241,000	$1,109,000	$4,348,000
Alternative 3	IN-SITU CHEMICAL OXIDATION			
	12 injections per year for 2 years	$4,315,000	$2,357,000	$6,592,000
	12 injections per year for 3 years	$4,315,000	$2,357,000	$8,793,000
Alternative 4	BIOREMEDIATION AND ZERO VALENT IRON			
	2 injections per year for 2 years	$1,667,000	$764,000	$2,405,000
	2 injections per year for 3 years	$1,667,000	$764,000	$3,118,000
Alternative 5	PERMEABLE REACTIVE BARRIER			
	1 time installation OM&M for 2 years	$3,058,000	$28,000	$3,085,000
	1 time installation OM&M for 3 years	$3,058,000	$28,000	$3,111,000
Alternative 6	AIR SPARGING AND SOIL VAPOR EXTRACTION			
	1 time installation OM&M for 2 years	$1,421,000	$117,000	$1,534,000
	1 time installation OM&M for 3 years	$1,421,000	$117,000	$1,643,000
Alternative 7	NO FURTHER ACTION	$0	$0	$0

Table 8
Remedial Alternative 30-Year Cost Summary

OPINION OF PROBABLE COST SUMMARY

Site: Modock Road Springs
Location: Victor, New York
Phase: IRM Focused Feasability Study
Base Year: 2008
Date: January 21, 2008

	1	2	3	4	5	6
Alternative	Bio	Bio & ISCO	ISCO	Bio & Iron	PRB	Air Sparging
Capital Cost	$1,190,000	$2,241,000	$4,315,000	$1,667,000	$3,058,000	$1,421,000
Annual O&M	$477,000	$1,109,000	$2,357,000	$764,000	$28,000	$117,000
Year	Present Net Worth					
1	$1,190,000	$2,241,000	$4,315,000	$1,667,000	$3,058,000	$1,421,000
2	$1,650,870	$3,312,498	$6,592,295	$2,405,164	$3,085,053	$1,534,043
3	$2,096,154	$4,347,761	$8,792,579	$3,118,366	$3,111,191	$1,643,264
4	$2,526,381	$5,348,015	$10,918,458	$3,807,451	$3,136,446	$1,748,792
5	$2,942,059	$6,314,445	$12,972,448	$4,473,233	$3,160,846	$1,850,750
6	$3,343,680	$7,248,193	$14,956,978	$5,116,500	$3,184,421	$1,949,261
7	$3,731,720	$8,150,365	$16,874,399	$5,738,015	$3,207,199	$2,044,441
8	$4,106,637	$9,022,029	$18,726,980	$6,338,512	$3,229,207	$2,136,402
9	$4,468,877	$9,864,217	$20,516,913	$6,918,702	$3,250,471	$2,225,253
10	$4,818,866	$10,677,924	$22,246,317	$7,479,272	$3,271,015	$2,311,099
11	$5,157,021	$11,464,115	$23,917,239	$8,020,886	$3,290,865	$2,394,043
12	$5,483,740	$12,223,720	$25,531,656	$8,544,185	$3,310,043	$2,474,181
13	$5,799,410	$12,957,638	$27,091,479	$9,049,787	$3,328,573	$2,551,610
14	$6,104,406	$13,666,737	$28,598,555	$9,538,292	$3,346,477	$2,626,420
15	$6,399,088	$14,351,857	$30,054,666	$10,010,277	$3,363,775	$2,698,701
16	$6,683,805	$15,013,809	$31,461,537	$10,466,302	$3,380,488	$2,768,537
17	$6,958,894	$15,653,376	$32,820,833	$10,906,905	$3,396,635	$2,836,012
18	$7,224,680	$16,271,315	$34,134,163	$11,332,609	$3,412,237	$2,901,205
19	$7,481,478	$16,868,357	$35,403,080	$11,743,917	$3,427,311	$2,964,193
20	$7,729,592	$17,445,210	$36,629,087	$12,141,316	$3,441,875	$3,025,051
21	$7,969,316	$18,002,555	$37,813,635	$12,525,276	$3,455,947	$3,083,851
22	$8,200,934	$18,541,053	$38,958,125	$12,896,252	$3,469,543	$3,140,663
23	$8,424,719	$19,061,341	$40,063,913	$13,254,683	$3,482,679	$3,195,554
24	$8,640,936	$19,564,035	$41,132,307	$13,600,994	$3,495,371	$3,248,588
25	$8,849,841	$20,049,730	$42,164,572	$13,935,593	$3,507,634	$3,299,829
26	$9,051,682	$20,519,000	$43,161,930	$14,258,877	$3,519,482	$3,349,337
27	$9,246,698	$20,972,401	$44,125,560	$14,571,229	$3,530,930	$3,397,171
28	$9,435,119	$21,410,469	$45,056,604	$14,873,018	$3,541,990	$3,443,388
29	$9,617,168	$21,833,724	$45,956,163	$15,164,602	$3,552,677	$3,488,041
30	$9,793,061	$22,242,666	$46,825,303	$15,446,326	$3,563,001	$3,531,185

Notes:

Present Net Worth is based on a 3.5% discount rate.

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

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