FEASIBILITY STUDY REPORT

Site:
Crystal Cleaners (Site No. 851022)
343 West Pulteney Street
City of Corning, New York 14830

Prepared for:
NYSDEC
625 Broadway
Albany, New York 12233

Prepared by:
AECOM
300 Broadacres Drive
Bloomfield, New Jersey 07003

February 2011

AECOM Project No. 60134118

Table of Contents

FIGURES

TABLES

APPENDICES

1 INTRODUCTION

This report presents the results of a Feasibility Study prepared by AECOM Technical Services Northeast, Inc. (AECOM) of alternatives for the environmental remediation of the Crystal Cleaners, Corning, New York, located in Steuben County. The Crystal Cleaners Site is listed as a Class 2 site on the New York State Department of Environmental Conservation (NYSDEC) Registry of Inactive Hazardous Waste Sites, Site No. 851022. The general location of the site is presented on Figure 1-1.

1.1 Background

In response to documented groundwater contamination at the site, NYSDEC commissioned a Remedial Investigation/Feasibility Study (RI/FS) for groundwater. The objective of the RI was to characterize the nature and extent of contamination of groundwater and to provide data for completing the FS. The scope of work for the RI is described in the final work plan submitted in November 2008. The RI included a qualitative risk assessment to identify potential risks to human health and the environment due to contaminants present on site. The results of the RI (Final Remedial Investigation Report, Crystal Cleaners, Steuben County, NY; AECOM, January 2011) are summarized in, and serve as the basis for, this FS report. The general site layout is presented on Figure 1-2.

This FS does not address remedial actions related to soil vapor intrusion. The NYSDEC and New York State Department of Health (NYSDOH) determined that remedial action was required to address soil vapor intrusion at one structure. Installation of a sub-slab depressurization system was completed on December 29, 2010 at this structure.

1.2 Report Organization

The purpose of the FS is to identify and evaluate technologies that are available to remediate the contaminated groundwater as identified in the RI. The technologies most appropriate for the Site conditions are then developed into Remedial Action Alternatives that are evaluated based on their environmental benefits and cost. The information presented in the FS will be used by NYSDEC to select remedial action(s). The remedial action(s) selected for the site will be summarized by NYSDEC in a Proposed Remedial Action Plan (PRAP), which will be released for public comment. After receipt of public comments, NYSDEC will issue a Record of Decision (ROD).

The FS is organized in accordance with the outline provided in Section 4.4 of DER-10 (NYSDEC, 2010):

1. Introduction
2. Site Description and History
3. Summary of Remedial Investigation and Exposure Assessment
4. Remedial Goals and Remedial Action Objectives
5. General Response Actions

6. Identification and Screening of Technologies
7. Development and Analysis of Alternatives (assembly of a technologies into alternatives, evaluation of alternatives, and evaluation of institutional/engineering controls for the selected remedy)
8. Recommended Remedy and Rationale for Selection

Additional supporting material is provided in the Appendices.

AECOM completed the following scope of work for the FS, in accordance with DER-10 Guidance and the November 2008 final dynamic work plan incorporating NYSDEC comments.

2 SITE DESCRIPTION AND HISTORY

Site description and historical information developed from the draft RI (AECOM, 2011) is presented below.

2.1 Site Description

The former Crystal Cleaners is located at 343 West Pulteney Street, in the City of Corning, Steuben County, New York (Figure 1-1). The site is approximately 0.58 acres including a retail building and a large parking lot. The current one-story site building was constructed in 1970 and included a mini-mart, a service station, a dry cleaning business and a laundromat. The building is constructed on a slab with the exception of the dry cleaners, which has a basement (Figure 1-2).

2.1.1 Land Use

The site is located in a mixed commercial and residential area near the western boundary of the City of Corning, New York. The site consists of a single story building with parking spaces in the front. The building is oriented east-west and is separated into three sections. All sections are currently vacant, but previously were occupied by a mini mart/gas station, a dry cleaners and a laundromat.

Adjacent properties include residences to the north, northeast, and northwest, a bank to the east across Cutler Avenue, a liquor store to the southeast across West Pulteney Street, a retail business to the southwest across West Pulteney Street, and a used car lot to the west across Townsend Avenue.

2.1.2 Topography

The site is located in the Cohocton/Chemung River Valley, which runs east-west. The site property is located at 940 ft above mean sea level (amsl), sloping slightly to the south. The surrounding area slopes slightly to the south, before reaching the Chemung River, located 900 ft south of the site. The Chemung River is located at an elevation of approximately 930 ft amsl, just south of the dike. The topography to the northeast of the site is relatively flat for approximately 0.7 miles, and then rises to a ridge at 1600 ft amsl approximately 1.5 miles from the site.

2.1.3 Surface Water Hydrology

The site is not located in an area mapped as either a 100 year or 500 year flood zone (EDR, 2006). Surface drainage from the site generally follows the topography, flowing toward the municipal storm drains located on West Pulteney Street. These storm drains flow to a treatment plant located approximately 2.4 miles east of the site (MACTEC, 2007). The treatment plant discharges to the Chemung River downstream of the site.

2.1.4 Groundwater Hydrology

Groundwater at the site was encountered at approximately 10 to 12 ft bgs, and is interpreted to flow south towards the Chemung River. Potentiometric contours for the greater Corning area prepared by the United States Geological Survey (USGS) indicate that groundwater at the site flows to the southeast (USGS, 1982).

2.1.5 Local and Site Geology and Hydrogeology

The site is located in Cohocton/Chemung River Valley, which runs east-west. Overburden soils at the site consisted primarily of fluvial silts, sands and gravel. Surficial geology is mapped as oxidized, non calcareous, fine sand to gravel (Muller, 1986). A Phase II Site Assessement (Teeter, 2005) described site soils as varying horizontally and vertically generally consisting of brown and reddish brown gravelly silt with varying amounts of sand, sandy gravel with little silt and clayey silt with some sand and gravel. Based on regional geologic mapping (Rickard and Fisher, 1970), bedrock consists of shale and siltstones associated with the Upper Devonian West Falls Group; specifically, the Gardeau formation, consisting of shale and siltstone; and/or Toricks Glen shale (Rickard and Fisher, 1970).

2.2 Site History

The property lot was purchased from Corning Inc., in December 1969. The property has contained a gas station since at least 1974, when four 4,000 gallon gasoline tanks were installed at the site. An additional 1,000 gallon kerosene tank was installed in 1984. The gasoline tanks were removed in 1992 and replaced with two 8,000 gallon gasoline tanks. These tanks were removed in 2008. The 1,000 gallon kerosene tank was abandoned in place and a new 1,000 gallon kerosene tank was installed.

The date of the first dry cleaner is not known, but Corning One Hour Martinizing at 343 West Pulteney appeared in the 1981 Corning City Guide. The 1989 Corning City Guide lists the property as One Hour Tecni Clean. The manager of the dry cleaner, who was interviewed by MACTEC in 2006 as part of the site characterization, took over lease of the property in 1994 and changed the name to Crystal Cleaner. He stated the original operation was a wet to dry system. (The manager is likely referring to a transfer system which consists of two machines: a washer and a dryer. Clothing is transferred from the washer to the dryer resulting in a source of tetrachloroethene (PCE) emissions.) This was converted to a dry to dry system (materials are cleaned and dried in the same machine) in the mid 1980s. He updated the equipment and added spill protection in the mid-1990s. Crystal Cleaners has always been serviced by public water and sewer because, according to the City of Corning Department of Public Works, the water main along West Pulteney Street was installed in 1907 and the sewer line was installed around 1908 and no evidence of a water supply well or septic tanks exist.

Prior Investigations Conducted at the Site

Chlorinated solvents were first detected in the City of Corning's water supply wells (SW) 1 and 2 in the early 1980s (Figure 1-1). These wells are located approximately 950 feet (ft) and 1300 ft southeast of Crystal Cleaners, respectively, along the banks of Chemung River. Well SW-1 is screened from approximately 50 to 70 ft below ground surface (bgs). Well SW-2 is screened from approximately 43 to 63 ft bgs. PCE was detected at low concentrations in both wells. Concentrations typically range from non-detect to 14 micrograms per liter (µg/L), with slightly higher concentrations detected in SW-2 than SW-1 (MACTEC, 2007).

In preparation for selling the property, the owner of the plaza that includes Crystal Cleaner hired Teeter Environmental Services, Inc. to conduct a Phase II Site assessment in 2005, primarily for the purpose of determining the condition of the underground fuel tanks for the gas station (Teeter, 2005). The investigation included the completion of six soil borings (BS-1 to BS-6) to approximately 16 ft bgs and collection of groundwater grab samples. The investigation found concentrations above the NYS groundwater criteria for PCE at two borings on the site (7 µg/L and 43.1 µg/L). Naphthalene, toluene, and m,p-xylenes were also detected at concentrations above the applicable regulatory standards.

During the Final Site Characterization conducted by MACTEC Engineering and Consulting, PC (MACTEC) in March 2007, 35 groundwater, four soil, and three soil vapor samples were collected from the areas around the site. PCE was detected at concentrations above the New York State (NYS) Class GA groundwater standards in groundwater samples collected on site and downgradient. PCE detections in groundwater from borings on the Crystal Cleaners site ranged from 0.88 µg/L to 610 µg/L. Sub-slab soil gas/vapor samples taken adjacent to the dry cleaner had elevated levels above NYSDOH guidance values of trichloroethene (TCE) and PCE. Shallow contaminated groundwater was found off-site under a densely populated residential neighborhood and present in a downgradient public supply well above NYS Class GA groundwater standards. A water treatment system is currently in place on the public supply wells to remove VOCs from drinking water to meet drinking water standards.

3 REMEDIAL INVESTIGATION – IMPLEMENTATION AND RESULTS

This section summarizes the findings of the RI conducted at the site (AECOM, 2011). The RI was conducted to determine the sources of contamination within the site and its threat to human health and the environment. The scope and execution of the RI is discussed below. The field work consisted of six efforts:

- Membrane interface probe investigation
- Direct push soil sampling and groundwater sampling

- Soil sampling at the Crystal Cleaners facility
- Direct push sampling for soil classification
- Groundwater monitoring well installation and sampling
- Soil Vapor Intrusion Investigation

In January 2009, MIP borings were advanced in the immediate vicinity of the Crystal Cleaners facility to collect remote sensing data indicating the possible presence of chlorinated solvents in the soils or groundwater based on the response of the ECD. No samples were collected for laboratory analysis during the initial phase of the investigation.

In March 2009, Hydropunch groundwater and soil samples were collected using direct push drilling. Groundwater and soil samples were shipped to Chemtech in Mountainside, New Jersey for VOC analysis. The Hydropunch data were used as a screening tool to determine the appropriate screened interval for permanent monitoring well installation.

Soil samples were collected from within the Crystal Cleaners facility on June 22, 2009. Samples were collected with a hand auger at a depth of 4-5 ft bgs beneath the concrete slab. The soil samples were shipped to Chemtech in Mountainside, New Jersey for VOC analysis.

Direct push borings were advanced at three locations to determine soil classification in the vicinity of the site and PCE groundwater plume. Soil samples were collected in macrocores using a direct push rig. The Unified Soil Classification System (USCS) was used to describe the soil. No soil samples were collected for laboratory analysis.

Six monitoring wells were installed in October 2009. Groundwater samples collected from the monitoring wells in December 2009 were analyzed by Hampton-Clarke Veritech for VOCs, metals (whole water and field filtered, ferrous iron, biochemical oxygen demand, chemical oxygen demand, alkalinity, ammonia, nitrate, chloride, sulfate, phosphorous, sulfide, total organic carbon, methane, ethane, and ethane).

Soil vapor intrusion sampling was conducted at 17 structures in 2009. The air samples include sub-slab soil vapor samples, indoor air samples, and outdoor air samples. In 2010, five of these structures were resampled. All air samples were analyzed for VOCs.

3.1 Geology and Hydrogeology

The Corning aquifer is a valley-fill glacial aquifer. The aquifer overlies four deeply incised bedrock valleys located at the intersection of the Chemung River, Canisteo, Tioga, and Cohocton Rivers. The bedrock valleys are partially filled with sand and gravel intermixed with fine grained glacial-lake deposits. Outwash and alluvial sand and gravel cover the valley floors as a result of redeposition by the streams. Soil was classified as predominantly gravel and sand. A thick clay layer was identified within the area sampled during the investigation.

The saturated thickness of the aquifer typically ranges between 20 ft and 60 ft. In the vicinity of the site; the saturated zone is approximately 60 ft. The groundwater surface is typically at the level of the stream traversing the area. Groundwater is found near ground level in some locations. Aquifer recharge consists of precipitation and inflow from the adjacent bedrock and by downvalley movement of water through the aquifer. The direction of groundwater flow is generally downvalley toward the principal streams. Groundwater provides base flow to the streams. In areas with losing tributary streams, groundwater flow is away from the tributary into the aquifer. Near the Crystal Cleaners site, groundwater flow is toward the southeast. The two public wells, each producing up to 700 gpm, are located southeast of the site.

3.2 Nature Contamination

The principle contaminants detected were chlorinated aliphatics. Principle chlorinated aliphatics include PCE and infrequent detection of the degradation products TCE, cis-1,2-dichloroethene (DCE), and vinyl chloride. The identity of the contaminants is well-established, with data collected from the permanent monitoring wells confirming findings from the MIP investigation and Hydropunch sampling in terms of compounds detected (PCE, TCE and DCE), and the spatial distribution of the contamination.

3.3 Extent of Contamination

The PCE groundwater plume is centered at the Crystal Cleaners site. The plume extends downgradient towards the southeast toward the two public wells. The plume concentrations are expected to drop below the NYS Class GA groundwater criteria to the southeast of SW-2..

Elevated levels of iron, manganese, sulfide, and sodium, which exceed the NYS Class GA groundwater criteria but are considered background for this aquifer, were not assessed further in the RI.

3.4 Contaminant Transport

Groundwater flow is generally to the southeast. The process by which a solute (dissolved phase contaminant) is transported by the bulk movement of groundwater flow is referred to as advection. The average linear velocity of groundwater through a porous aquifer is determined by the hydraulic conductivity, effective porosity of the aquifer formation, and hydraulic gradient.

Adsorption of chlorinated aliphatics at the site may be an important process influencing the movement of contaminants in groundwater. The importance of adsorption depends significantly upon the characteristics of the aquifer matrix material, which acts as the adsorbing medium. In particular, adsorption of hydrophobic organic compounds has been shown to be a function of the amount of natural organic carbon in the aquifer matrix. PCE is slightly hydrophobic and, therefore, will be adsorbed/retarded to a degree.

The estimated seepage velocities are calculated as 488 ft/yr for PCE, 465 ft/yr for TCE, 256 ft/yr for DCE, and 1,280 ft/yr for vinyl chloride assuming degradation begins near the site. Using these estimates, the PCE-contaminated groundwater from Crystal Cleaners would reach public well SW-2 in three years from the time of the release. PCE contaminated groundwater would reach the Chemung River, which is approximately 2,100 ft southeast of the site in four years. These seepage velocities based on the coarse-grained material identified during the investigation.

3.5 Contaminant Fate

The fate of organic chemicals in the subsurface environment is affected by a variety of physiochemical and biological processes. Abiotic transformations such as hydrolysis, oxidation, and volatization are not significant factors in contaminant fate. Biological transformation activity does not appear to be significant at this time. This finding is consistent with the VOC concentrations detected in the monitoring wells which shown infrequent detections of the daughter products TCE and DCE, at low concentrations, relative to the PCE concentrations.

4 REMEDIAL GOALS AND REMEDIAL ACTION OBJECTIVES

4.1 Remedial Goals

For the State Superfund program, 6 NYCRR Part 375-2.8, “The goal of the remedial program for a specific site is to restore that site to pre-disposal conditions, to the extent feasible. At a minimum, the remedy selected shall eliminate or mitigate all significant threats to the public health and to the environment presented by contaminants disposed at the site through the proper application of scientific and engineering principles.”

Per Environmental Conservation Law (ECL) Article 27 Title 13, “The goal of any such remedial program shall be a complete cleanup of the site through the elimination of the significant threat to the environment posed by the disposal of hazardous wastes at the site and of the imminent danger of irreversible or irreparable damage to the environment caused by such disposal.”

4.2 Standards, Criteria and Guidelines (SCGs)

The applicable SCGs for the site are described below. SCG selection is based on the following:

- The current, intended and reasonably anticipated future use of the site and its surroundings (mixed residential and non-residential);
- All contaminants exceeding applicable SCGs (PCE, TCE, cis-1,2-DCE, and vinyl chloride);
- The environmental media impacted by the contaminants exceeding the SCGs (groundwater);
- The extent of the impact to the environmental media;
- All actual or potential human exposures and/or environmental impacts resulting from the contaminants in environmental media; and
- No site-specific human health or environmental SCGs.

Chemical-specific SCGs are typically technology or health-risk based numerical limitations on the contaminant concentrations in the ambient environment. They are used to assess the extent of the remedial action required and to establish cleanup goals for a site. Chemical-specific SCGs may be directly used as actual cleanup goals, or as a basis for establishing appropriate cleanup goals for the contaminants of concern at a site. Chemical-specific SCGs for groundwater at the site are identified in Table 4-1.

Action-specific SCGs are usually administrative or activity-based limitations that guide how remedial actions are conducted. These may include record-keeping and reporting requirements; permitting requirements; design and performance standards for remedial actions; and treatment, storage and disposal practices. Action-specific SCGs identified for the site are provided in Table 4-2. Soil vapor intrusion related action-specific SCGs are not listed in Table 4-2 since this FS only addresses groundwater contamination.

Location-specific SCGs apply to sites that contain features such as wetlands, floodplains, sensitive ecosystems, or historic buildings that are located on, or in close proximity to the site. Based on the RI, wetlands, floodplains, sensitive ecosystems or historic buildings are not located on, or in close proximity to the site. Thus, no location-specific SCGs were identified for this site.

4.3 Contaminated Groundwater Exposure Pathways

Exposure to groundwater, if used as a drinking water supply, includes ingestion, dermal contact and inhalation of vapors. Two public water supply wells are located downgradient; the closest is about 1,000 feet away from the site. PCE was detected in one of the two down gradient public wells above the NYS Class GA criterion at 15 µg/L during the RI.

Groundwater flows approximately in a south-easterly direction, towards the Chemung River. Potential human exposure may occur at the point of groundwater contact. Potential human exposure may occur at the point of groundwater contact. The likelihood of exposure to groundwater due to construction activities is considered to be low since the groundwater is generally encountered at 10 to 12 ft bgs and the area is serviced by public water. Potential human exposures include ingestion and dermal contact. Ingestion of groundwater (as drinking water), dermal contact and vapor inhalation scenarios are potential future exposure scenarios. Potential human exposure by inhalation of vapors was mitigated by installation of a sub-slab depressurization system at a structure in December 2010.

4.4 Contaminants of Concern and SCGs

Table 4-3 lists the contaminants detected in samples collected on-site and the chemical-specific SCGs (risk-based exposure limits) that apply to the likely exposure routes for the environmental media of interest. Proposed cleanup goals for each contaminant were developed in accordance with the procedures described below.

Proposed SCGs for organic compounds were selected by identifying the chemical-specific SCGs appropriate to the likely exposure pathways. The cleanup SCG was then selected based on the potential exposure scenarios and contaminated media encountered within the study area.

Contaminants of concern were identified for on-site environmental media by identifying the contaminants that exceeded the proposed cleanup SCGs and then evaluating the frequency that cleanup goals were exceeded and the relative toxicity of the contaminant. In general, contaminants of concern were established based on the exceedance of SCGs, frequency of detection, and being site-related.

The site-related contaminants exceeding the applicable chemical-specific SCGs were identified in the groundwater only. These contaminants are PCE, TCE, cis-1,2-DCE, and vinyl chloride with the extent as described in Section 3.3 of this document. The groundwater flow direction is generally to the southeast toward the Chemung River. This water body is classified as class C, fresh surface water. Of the contaminants of concern in groundwater, there is a class C criterion for TCE only at 40 µg/L. If the contaminated groundwater discharges to the Chemung River, concentrations of TCE in the groundwater from the Crystal Cleaners site as characterized by the RI would not exceed the class C criterion, having a maximum detected concentration of 15 µg/L at the location sampled farthest to the southeast during the RI (SW-2). Potential impacts to surface water are not considered for this FS.

5 GENERAL RESPONSE ACTIONS

In keeping with the requirements of DER-10, the general response actions based on the RAOs for this site were developed with the following considerations:

- Include an estimate of the areas and volumes for the contaminated groundwater.
- Are specific to the impacted medium, contaminants, and geologic characterization of the site;
- Eliminate technologies that are not appropriate for the site due to site-specific factors or constraints;
- Include non-technology specific categories;
- Give preference to presumptive remedies; and
- Consider the use of innovative technologies where available and applicable.

As described in the RI, the estimated area and volume of contaminated groundwater to assist in evaluating remedial alternatives are 16 acres and 33 million gallons (MG). The horizontal extent exceeding the 5 µg/L NYS Class GA groundwater criterion for PCE is shown on Figure 4-1.

The non-technology specific remedial categories defined in Section 4.1 of DER-10 are as follows:

- Removal and/or treatment
- Containment
- Elimination of Exposure
- Treatment of source at the point of exposure

Elimination of exposure is not considered further in this FS because groundwater is a primary source of water supply in the area.

Presumptive remedies defined in DER-15 (NYSDEC, 2007) for VOCs contamination in groundwater include containment and treatment responses. The presumptive remedies are as following:

- Extraction and Treatment
- Air Stripping
- Granular Activated Carbon
- Chemical/Ultraviolet (UV) Oxidation
- Separate-Phase Recovery
- Air Sparging
- In-Well Air Stripping (Groundwater Recirculation)
- Bioremediation

Separate-phase recovery is not considered in this FS because this technology is primarily used for petroleum hydrocarbon contamination and a separate phase of contamination was not observed in the groundwater samples.

The general response actions evaluated in this FS include the following:

- Monitored Natural Attenuation;
- Ex-situ treatment (air stripping, granular activated carbon (GAC), or chemical/ultraviolet (UV) oxidation);
- In-situ treatment (air sparging, in-well air stripping, enhanced bioremediation or chemical oxidation);
- Containment (extraction wells or physical barrier); and

6 SCREENING OF TECHNOLOGIES

This section presents the results of the preliminary screening of the associated remedial technologies that may be used to control the contaminants of concern and to achieve the RAOs. The technologies associated with the general response actions have been evaluated during the preliminary screening on the basis of effectiveness and implementability. The purpose of the preliminary screening is to eliminate remedial technologies that may not be effective based on anticipated on-site conditions, or that cannot be implemented technically at the site; and, to more narrowly focus the list of alternatives that will be developed and evaluated in greater detail.

6.1 Monitored Natural Attenuation

Monitored Natural Attenuation involves taking no further action to remedy groundwater conditions at the site with the exception of conducting annual long term monitoring. Groundwater monitoring tracks the progress of natural attenuation of the contaminant plume. For this FS, the maximum concentration of PCE has been assumed to fall below the NYS Class GA groundwater criterion of 5 ug/L after 30 years.

6.2 Ex Situ Treatment

This general response action involves aboveground treatment of groundwater removed from the subsurface and discharge/disposal of the treated effluent. The extraction wells would be placed on the dry cleaner property. The groundwater would be extracted at a sufficient rate to capture the area where the highest concentrations have been detected (i.e., beneath the dry cleaner property). The extraction rate and estimated contaminant concentration within the extracted groundwater would be required to design the system, through a pumping test as part of the remedial design. The treatment facility would be located in the parking lot of the dry cleaner. Disposal of the treated water would comply with the requirements listed in TOGS 2.1.2. This could involve:

1. Treating the groundwater to the cleanup goals and discharging the treated water into the site groundwater via injection or diffusion wells;
2. Treating the groundwater and discharging the treated water to a stormwater sewer or water body in conformance with State Pollutant Discharge Elimination System (SPDES) permit requirements; or
3. Treating the water sufficiently for discharge to the sanitary sewer system.

The groundwater treatment technologies will remove VOC contamination to below the NYS Class GA groundwater criteria.

The following subsections describe the results of preliminary screening of technologies that were considered for ex situ treatment of groundwater.

6.2.1 Air Stripping

Air stripping involves passing air through the contaminated groundwater to induce volatilization and removal of VOCs. If necessary to comply with permit requirements, air that contains organic vapors stripped from the groundwater can be treated by either filtration with activated carbon, or another appropriate method, prior to discharge to the atmosphere. Air stripping is most appropriate for situations where the contaminants to be treated are volatile and where there are no significant concentrations of dissolved metals that may precipitate (e.g., iron).

Effectiveness – Air stripping is expected to be an effective technology for treating the groundwater to less than the NYS Class GA groundwater criteria. This is a proven and reliable technology for treatment of water containing VOCs. An air stripper would be used to treat the groundwater prior to discharge to the storm sewer or sanitary sewer system, or injected into the aquifer. Air emissions may need to be treated prior to discharge, based on the anticipated levels, for protection of human health and the environment, or compliance with an air emissions permit. Elevated levels of iron and manganese were detected in the groundwater samples collected for the RI. Therefore, pretreatment of the groundwater for metals may be required.

Implementability – The labor, equipment and materials for installation of an air stripper at the site are readily available. Air emissions from the stripper may require treatment by activated carbon, or appropriate method to meet NYSDEC requirements for allowable concentrations of PCE and other VOCs in air.

The process equipment that may be required to implement an air stripping treatment system includes construction of a shelter building, an electrical power source, instrumentation and controls system equipment, an equalization tank to receive influent water from the groundwater extraction well, potential metals treatment process, an air stripper unit with an air blower, an off gas treatment system to remove organic vapors from air prior to discharge to the atmosphere, activated carbon for polishing of the groundwater, and discharge piping for effluent water leading to the existing stormwater sewer system. In addition, effluent discharge or SPDES permit would be required. Alternatively, the treated water could be discharged to the sanitary sewer. The system will need to substantially comply with appropriate State and Federal air permit requirements. Once the system is operational, typically, limited maintenance of the system would be required.

Air stripping appears to be an effective and implementable technology for ex situ treatment of contaminated groundwater prior to discharge, when used in conjunction with other technologies for pre-treatment and post-treatment of the effluent. Ex situ treatment by air stripping is retained for further evaluation in this FS.

6.2.2 Granular Activated Carbon

Liquid phase carbon adsorption is used to remove organic compounds from groundwater by adsorbing the organic compounds onto the surface of GAC. Contaminants are removed by adsorption as the water flows through the GAC. Granular activated carbon can be packed into a treatment column or placed in properly sized drums or pressure vessels connected in series. On a regular basis, the granular activated carbon would be changed as the adsorption capacity is depleted with use.

Effectiveness – Use of carbon may be an effective method of primary groundwater treatment of groundwater. However, the carbon usage rate for groundwater treatment is expected to be high, particularly during initial startup when higher flow rates are anticipated. Thus, significant quantities of activated carbon are anticipated to be consumed, that would result in the need for frequent carbon change-out. Carbon may also be utilized in a treatment process for the purposes of final polishing following the use of one of the other treatment technologies. Disposal of the spent carbon and system maintenance related to the carbon change-outs would be required.

Implementability – Granular activated carbon treatment columns or containers are readily available and relatively simple to install and replace.

This technology is retained as a potential secondary treatment to be used in conjunction with air stripping.

6.2.3 Ex Situ Oxidation

Ex situ oxidation processes include the use of ultraviolet (UV) radiation, ozone, or hydrogen peroxide to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect or escape.

UV oxidation is a destruction process that oxidizes organic and explosive constituents in water by the addition of strong oxidizers and irradiation with UV light. Oxidation of target contaminants is caused by direct reaction with the oxidizers, UV photolysis, and through the synergistic action of UV light, in combination with ozone and/or hydrogen peroxide. If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of UV oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase. UV oxidation processes can be configured in batch or continuous flow modes, depending on the throughput under consideration.

UV oxidation differs from UV photolysis, a related process but one which does not typically fully convert organic contaminants to carbon dioxide, hydrogen peroxide, and salts (chlorides in the case of chlorinated compounds).

For the discussion below, oxidation by UV radiation in conjunction with peroxide is assumed.

Effectiveness – Ex situ oxidation is effective at remediating sites with chlorinated aliphatic contamination. Ex situ treatment is not hindered by subsurface heterogeneities that affect in situ options. Organic compounds with double bonds (e.g., TCE, PCE, and vinyl chloride) are rapidly destroyed in UV/oxidation processes. However, ex situ oxidation is subject to the same limitations as all pump and treat options, in that complete remediation may be time-consuming and often becomes ineffective or inefficient as the final remediation criteria are approached.

Implementability – Ex situ oxidation is readily implemented. It requires groundwater extraction and pumping to a treatment location, followed by discharge of treated water. Remediation systems capable of treating as much as 1,000,000 gpd have been installed. Issues related to UV/oxidation include:

- The influent may require treatment to provide for good transmission of UV light (high turbidity causes interference). This factor can be more critical for UV/hydrogen peroxide than UV/ozone. (Turbidity does not affect direct chemical oxidation of the contaminant by hydrogen peroxide or ozone).
- Free radical scavengers can inhibit contaminant destruction efficiency. Excessive dosages of chemical oxidizers may act as a scavenger.
- The aqueous stream to be treated by UV/oxidation should be relatively free of metals (less than 10 mg/L) to minimize the potential for fouling of the quartz sleeves.
- Some VOC contaminants may be volatilized (e.g., “stripped”) rather than destroyed; therefore, off-gas treatment (by activated carbon adsorption or catalytic oxidation) may be necessary.

Ex situ oxidation is retained for further evaluation in the FS.

6.3 In Situ Treatment

6.3.1 Air Sparging

The technology of air sparging involves contaminant reduction primarily by volatilization and biodegradation. Sparging is conducted by injecting air into the subsurface below the water table under controlled pressure and volume. Contaminants, such as dissolved phase chlorinated aliphatics in the groundwater and adsorbed onto soil are volatilized (or stripped) when in contact with the injected air. Air containing stripped contaminants migrates upward through the groundwater into and through the unsaturated zone, where it is ultimately collected in vacuum/vapor extraction wells, in order to capture volatilized chemicals prior to discharge into the atmosphere. The air is then treated and discharged to the atmosphere.

In addition to the stripping process that occurs on contaminants in the groundwater, it has been shown that air sparging provides for enhanced biodegradation under certain conditions. However, PCE is degraded anaerobically in the subsurface environment. Therefore, sparging is not expected to significantly enhance biodegradation of site contaminants.

Effectiveness - This technology is generally effective in removal of VOCs from groundwater, especially highly volatile compounds such as chlorinated VOCs. The effectiveness of this technology is based in part on the site geology. Higher removal efficiencies are generally accomplished in coarse-grained soils, as airflow channels are more evenly distributed both laterally and vertically. However, subsurface heterogeneities may inhibit the sparged air from contacting dissolved phase contamination in groundwater. Air sparging is anticipated to reduce VOC concentrations (by about one order of magnitude), but is not believed to be able to meet the groundwater remediation objective for PCE (5 µg/L).

Implementability – An air sparging system is potentially implementable at the site, although the layout of the injection wells and vapor extraction wells would need to consider current land usage (e.g., roadways and residences within the footprint of the plume). The materials, equipment and labor for installation of a sparging system are available and can be readily implemented. Sparge wells can be reliably installed to the required depth and the screened interval can be installed to meet the subsurface conditions. The system requirements include a blower/air compressor system, and a vapor extraction/treatment system. Pilot testing may be necessary to evaluate the required design parameters (e.g., sparge well spacing, injection flow rate), relative to the desired remediation of chlorinated aliphatics in groundwater. Installation of the vapor extraction system typically requires at least 5 ft of unsaturated thickness above the overburden aquifer.

Because air sparging may result in vapor migration, this technology is eliminated from further consideration in this FS.

6.3.2 In-Well Air Stripping (Groundwater Recirculation)

The in-well groundwater circulation well system creates in situ vertical groundwater circulation cells by drawing groundwater from the aquifer through the lower screen of a double-screened well and discharging it through the second screen (upper) section. While groundwater circulates in and out of the stripping cell, no groundwater is removed from the ground. Air is injected into the well through a gas injection line and diffuser, releasing bubbles into the contaminated groundwater. These bubbles aerate the water and form an air-lift pumping system (due to an imparted density gradient) that causes groundwater to flow upward in the well. As the bubbles rise, VOC contamination in the groundwater is transferred from the dissolved state to the vapor state through an air stripping process. Groundwater may be polished at the well head through carbon adsorption or injection of a chemical oxidant prior to recirculation.

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

Effectiveness – The effectiveness of in-well recirculation is dependent on the groundwater velocity and the contaminant concentrations within the treatment zone along with the air injection rate. The greater the concentrations and velocities, the more recirculation wells will be required along the axis of groundwater flow. A pilot test would be required prior to full scale implementation.

Implementability – For the subsurface conditions at the site, recirculation wells are an implementable technology to treat the plume and prevent further migration of the plume. The materials, equipment, and labor necessary to install extraction wells are readily available. Fouling of the system may occur by precipitation of oxidized constituents. The technology is not recommended for sites with low-conductivity deposits which may be present in this aquifer. Wells and screens must be placed to prevent spreading the contamination. Treatment is likely to require a long period of time to achieve the RAOs.

In-well recirculation will not be considered further due to limited available data on performance, and possible fouling of the system from elevated iron levels measured in the site groundwater.

6.3.3 Enhanced Bioremediation

Enhanced bioremediation refers to the addition of substrates, microbes, and/or electron acceptors to the groundwater through injection wells. Biodegradation occurs when indigenous microorganisms consume organic compounds to obtain energy for reproduction and growth. Microorganisms obtain this energy by facilitating the transfer of electrons from an electron donor (organic substrate) to an electron acceptor (typically native inorganics). Common electron donors at contaminated sites can be natural organic carbon or fuel hydrocarbons. Electron acceptors commonly found in groundwater include oxygen, nitrate, manganese, ferric iron, sulfate, and carbon dioxide. Under anaerobic conditions, contaminants may be used as an electron acceptor, as in the reductive dechlorination of TCE.

Effectiveness – Bioremediation can be effective for the destruction of chlorinated VOCs in groundwater; and a properly designed enhanced bioremediation system can be effective at the complete oxidation of chlorinated VOCs. The effectiveness of bioremediation could be tested prior to implementation using biotraps as an alternative to pilot or bench testing.

Implementability – Enhanced bioremediation is implementable but is limited by the presence of roadways and residences. To counter these impediments, injections could target the area of the plume with highest measured concentrations at the dry cleaner and a line of injections could be installed along West Pultney and West William southeast of the site to create a barrier to contaminant migration for PCE and target the highest concentrations of the contaminants of concern. Lower concentrations south and southeast of these barriers would naturally attenuate.

Enhanced bioremediation is retained for further evaluation as a potential remedial technology in this FS.

6.3.4 Chemical Oxidation

In situ chemical oxidation is a technology whereby an oxidant is injected into an aquifer or subsurface soils. Common oxidants include peroxide, ozone, and permanganate. These compounds cause rapid and complete chemical destruction of many organic chemicals. The process includes placing injection points throughout the area to be treated, and injection of the selected oxidant into the aquifer/subsurface.

Effectiveness – High treatment efficiencies have been demonstrated for unsaturated aliphatics. Chemical oxidants are capable of oxidizing chlorinated VOCs such as PCE.

Implementability – Implementation of this technology is limited by the presence of residences and roadways. Injections could target the area of the plume with highest measured concentrations as described for bioremediation in Section 6.3.3. The materials, equipment and labor necessary to implement this technology are available from several vendors.

Application of an in situ oxidant is retained for further evaluation as a potential remedial technology in this FS.

6.4 Containment

6.4.1 Groundwater Extraction

Groundwater extraction is a commonly used method to control the migration of contaminated groundwater and to collect contaminated groundwater for subsequent (ex situ) treatment. Groundwater extraction wells are generally installed with a drill rig. Well screens and filter packs are generally installed to intercept the saturated thickness of the contaminated water-bearing zone. Extraction wells can be installed to provide a hydraulic barrier for control of migration of contaminated groundwater, or at specific locations for source area remediation.

Effectiveness – Groundwater extraction wells are an effective remedy that could be used in conjunction with other technologies to meet the RAOs. Extraction wells, in conjunction with an ex situ groundwater treatment system, would reduce the mobility, toxicity, and volume of contaminated groundwater. Extraction wells can be installed with limited site disturbance and relatively low potential for impacts to human health and the environment during installation, as compared to other technologies that are more intrusive. Extraction wells are a proven and reliable technology for removal of groundwater for remediation.

Implementability – Complete capture of the plume may not be practical. The soil in the aquifer is predominantly sand with gravel. The hydraulic conductivity is likely to be at least 175 ft/day (USGS, 1995). For this aquifer, the pumping rate to achieve a 100 ft capture zone extending throughout the dry cleaners site where the highest concentrations were observed is likely to be in excess of 650 gpm. There are limitations on well placement due to the existence of residences and roadways. The materials, equipment and labor necessary to install extraction wells are readily available. Extraction wells can be reliably installed to the required depth and the screened interval can be installed to meet the subsurface conditions.

Groundwater extraction for containment is not considered further in this FS due to limitations on well placement which are likely to prohibit the complete capture of the plume. Groundwater extraction for source removal with ex situ treatment is retained assuming the highest concentrations of PCE in groundwater can be targeted.

6.4.2 Physical Barriers

The purpose of groundwater containment is to restrict the flow of contaminated groundwater. This is generally accomplished by a physical barrier (slurry wall, sheet piling), hydraulic control (removing water from the ground, such as by pumping from extraction wells), or reactive barriers. Containment technologies that rely on groundwater extraction are occasionally supplemented with a low permeability subsurface barrier wall to improve the effectiveness of the extraction system. Another groundwater containment technology includes groundwater collection trenches, which are constructed for the purpose of collecting groundwater.

Effectiveness – Physical barriers could contain the contaminated groundwater. A geotechnical study would be required. Long term monitoring to document the effectiveness of the technology would be recommended.

Groundwater extraction wells may be used to exert hydraulic control to prevent the migration of the groundwater. Prior to the design of such a system a thorough analysis of the aquifer properties including pump tests would need to be performed to ensure an adequate array of extraction wells are installed. The extracted groundwater would be routed to in an ex situ treatment unit.

Implementability – While construction of physical barriers is possible, significant disruption to the community is anticipated, e.g. construction noise in the immediate vicinity of a residential community. Current land use would limit placement of the barrier walls.

Groundwater extraction wells are an implementable technology for exerting hydraulic control to prevent further migration of the plume. The materials, equipment, and labor necessary to install extraction wells are readily available.

Physical barriers will not be considered further in this FS due to limits on placement.

7 DEVELOPMENT AND ANALYSIS OF ALTERNATIVES

Based on the technology review and screening (as summarized in Section 6.3), four remedial alternatives have been developed for the remediation of contaminated groundwater. The selected alternatives include presumptive remedies specified in DER-15. These alternatives include readily available technologies which have been proven to be effective at similar sites with VOC contamination in groundwater.

The selected alternatives include:

Alternative 1 – Monitored natural attenuation
Alternative 2 – Groundwater extraction and ex situ treatment
Alternative 3 – In situ treatment

7.1 Remedial Action Alternatives

As described above, site remedial action alternatives have been assembled using general response actions and remedial technologies that passed the preliminary screening. An expanded description of each of the alternatives is provided below. The following information is provided for each alternative:

- Size and configuration of process options
- Time for remediation
- Spatial requirements
- Options for disposal
- Substantive technical permit requirements
- Limitations or other factors necessary to evaluate the alternatives
- Beneficial and /or adverse impacts on fish and wildlife resources
- Cost

Capital costs, O&M costs, and present worth costs were estimated for each alternative. All direct and indirect capital costs and engineering costs for the construction of all facilities and process equipment, labor, materials, construction equipment and services were estimated for the alternatives. The estimates included herein assume contingencies, engineering costs, project management costs, and construction management. Costs for system start up and testing, facility operation, maintenance and repair, continuous performance and effectiveness monitoring, and periodic site condition reviews were estimated. A present worth analysis is made to compare the remedial alternatives on the basis of a single dollar amount for the base year. For the present worth analysis, assumptions are made regarding the interest rate applicable to borrowed funds and the average inflation rate. The period of performance evaluated does not exceed 30 years. Construction will be completed in a single year. Cost sheets are provided in Appendix A. Supporting information (calculations and vendor information) is provided in Appendix B.

7.1.1 Alternative 1 – Monitored Natural Attenuation

Alternative 1 would involve performing groundwater monitoring. This alternative allows for natural attenuation of impacted groundwater. This alternative assumes that annual groundwater monitoring would be conducted every year for five years then once every five years. The six existing monitoring wells shown on Figure 7-1 would be sampled using low flow sampling. All wells would be sampled for VOCs by EPA method 8260 and water levels in the wells would be measured. Three of the groundwater samples would also be analyzed for monitored natural attenuation parameters. Costs also include an environmental easement/deed restriction and preparation of a report summarizing the monitoring data following each sampling event.

Size and configuration of process options - Not applicable.

Time for remediation - groundwater concentrations would remain above the NYS Class GA groundwater criteria for more than 30 years.

Spatial requirements - Not applicable.

Options for disposal - Not applicable.

Substantive technical permit requirements – No permit requirements were identified for this alternative.

Limitations or other factors necessary to evaluate the alternatives – No limitations or other factors necessary to evaluate the alternative were identified.

Beneficial and /or adverse impacts on fish and wildlife resources – No beneficial and/or adverse impacts to fish and wildlife resources were identified.

Cost - A cost estimate is provided in Appendix A. The costs for this option are: present worth capital costs of $54,231, present worth O&M costs for 30 years of $599,248, and total present worth for 30 years of $653,479.

7.1.2 Alternative 2 – Groundwater Extraction and Ex Situ

This alternative includes groundwater extraction for source removal treatment of extracted groundwater by air stripping. Other treatment alternatives are viable, but this technology is selected for evaluation as representative of ex situ treatment options. Air stripping uses volatilization to transfer contaminants from groundwater to air. In general, water is contacted with an air stream to volatilize dissolved contaminants into the air stream. Depending on the level of contaminants in the air discharge, the contaminated air stream may need further treatment. This alternative would include pre-treatment (filtering) to address elevated iron and manganese levels in the groundwater prior to air stripping. The treated groundwater would comply with the NYS Class GA groundwater criteria. No treatment is included for the air effluent. If necessary, the facility would be heated adequately to allow year-round operation.

Figure 7-2 presents a conceptual sketch of Alternative 3. Pilot testing would be conducted during a pre-design study to better define the radius of influence and capture zone of the wells and optimize the location of the extraction and injection wells. Pilot testing would be completed using the existing wells. The extraction well(s) would be screened within the impacted aquifer approximately 15 to 35 feet bgs. The extraction system would consist of two wells. The extent of the capture zone may be limited due to the relatively high hydraulic conductivity of the aquifer and limitations on locating the extraction wells because of current land use. The treatment system would extract and treat groundwater from the most highly contaminated region of the plume and the remainder would be subject to monitored natural attenuation.

The groundwater treatment system would consist of an equalization tank, bag filters, an air stripper, and an effluent holding tank. The treatment system would be located in a new structure located behind the dry cleaner.

Periodic groundwater sampling would be required to evaluate the effectiveness of the treatment. Groundwater sampling would be conducted as described for Alternative 1 every year for five years then at ten, 20, and 30 years from the time the treatment started.

Size and configuration of process options - For an influent flow rate of 500 gpm, a packed tower with a 54” diameter and a 23 ft packing depth is assumed. Alternatively, an appropriately sized tray tower could be used. The groundwater would be filtered (bag filter) initially to address elevated metals concentrations. No treatment of the air effluent is assumed.

Time for remediation - Reduction of PCE concentrations in the source area to the SCGs is expected within the first two to three years of treatment. The remainder of the plume is expected to attenuate within 30 years.

Spatial requirements – The treatment facility is expected to be approximately 6 ft by 8 ft. The extraction wells would be flush mounted. Land on the dry cleaner property would be disturbed during construction for installation of the wells and to install the piping and electrical conduit below ground surface.

Options for disposal – Because the treated groundwater would comply with NYS Class GA groundwater criteria, disposal to the local POTW, storm drains, or re-injection to the aquifer are viable options. For costing, treated groundwater is partially re-injected to the aquifer and the remainder is discharged to the nearest stormwater catch basin.

Substantive technical permit requirements - The air releases must comply with the substantive requirements of DAR-1. However, this system is exempt for state air permit requirements because the work is performed at a State Superfund site, but would comply with the substantive requirements of state and federal permits. The underground injection/recirculation system must comply with the substantive requirements of a SPDES permit and the NYS Class GA groundwater criteria. Discharge to the stormwater catch basis must comply with the substantive requirements of a SPDES permit.

Limitations or other factors necessary to evaluate the alternatives – This alternative assumes a stormwater catch basin is present in the area surrounding the dry cleaner for disposal of a portion of the groundwater effluent. A pump test using the existing wells would be conducted in pre-design to provide field measurements to better define the radius of influence and capture zone for the extraction wells.

Beneficial and /or adverse impacts on fish and wildlife resources – No beneficial and/or adverse impacts to fish and wildlife resources were identified.

Cost - A cost estimate is provided in Appendix A. The costs for this option are: present worth capital costs of $428,196, present worth O&M costs for 30 years of $701,177, and present worth for 30 years of $1,129,373.

7.1.3 Alternative 3 – In Situ Treatment

This alternative would implement in situ treatment by chemical oxidation as the primary treatment. This in situ treatment would be used to reduce PCE levels in the area under the dry cleaner where the highest PCE levels were detected. Additionally, a downstream barriers would be implemented along a portion of West Pulteney Street and West William Street to capture contamination migrating to the southeast and target the highest detections downstream of the source area. A pilot study would be conducted pre-design.

Size and configuration of process options - Injections would be made on approximately a grid with spacing of 15 feet by 15 feet for a total of 49 injection points from 15 to 40 ft bgs on the dry cleaner property. Twenty barrier injections would be installed from 15 to 45 ft bgs along West Pulteney Street and West William Street. The proposed injection locations are shown on Figure 7-3.

Periodic groundwater sampling would be required to evaluate the effectiveness of the treatment. Groundwater sampling would be conducted as described for Alternative 1 every year for five years then at ten, 20, and 30 years from the time the treatment started.

Time for remediation - Reduction of PCE concentrations in the source area to SCGs is expected within the two years from the initial time of application. The remainder of the plume is expected to attenuate within 30 years.

Spatial requirements – Not applicable.

Options for disposal – Not applicable.

Substantive technical permit requirements – No permits are required for chemical oxidant injections in New York. Roadway opening permits would be required for the injections along West Pulteney Street and West William Street.

Limitations or other factors necessary to evaluate the alternatives – The area of the plume where injections can be made is limited to the dry cleaner and roadways.

Beneficial and /or adverse impacts on fish and wildlife resources – No beneficial and/or adverse impacts to fish and wildlife resources were identified.

Cost - A cost estimate is provided in Appendix A. The costs for this option are: present worth capital costs of $404,133, present worth O&M costs for 30 years of $445,643, and present worth for 30 years of $849,776.

7.2 Detailed Analysis of Alternatives – General

The purpose of the detailed analysis of remedial action alternatives is to present the relevant information to select an on-site remedy. During the detailed analysis, the alternatives established in Section 7.1 are compared on the basis of environmental benefits and costs using criteria established by NYSDEC in DER-10 (NYSDEC, 2010). This approach is intended to provide needed information to compare the merits of each alternative and select an appropriate remedy that satisfies the RAOs for the site.

7.2.1 Description of Evaluation Criteria

The alternatives were evaluated against the following remedy selection evaluation criteria. Of these criteria, the first two are threshold criteria that must be satisfied in order for an alternative to be considered for selection. The remaining seven criteria are balancing criteria used to compare the positive and negative aspects of the alternatives. Community acceptance is evaluated after completion of the proposed remedial action plan by NYSDEC.

1 <u>Overall Protection of Human Health and the Environment:</u> This criterion is an evaluation of the ability of the alternative to protect public health and the environment: the ability of the alternative to eliminate, reduce or control any existing or potential human exposures or environmental impacts identified in the RI and to achieve the RAOs identified in Section 4. This assessment considers other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with SCGs.
2 <u>SCGs:</u> This criterion is used to evaluate the extent to which each alternative conforms to the SCGs identified in Section 4.
3 <u>Long-Term Effectiveness and Permanence:</u> This criterion addresses the long-term effectiveness and permanence of the alternative after implementation. If contamination remains after implementation, this criterion requires evaluation of human exposures, ecological receptors or impacts to the environment. In addition, long-term impacts to the community may occur through the consumption of materials, resources, and energy and gas emissions (including carbon dioxide, nitrogen oxides, and sulfur oxides) associated with the operation and maintenance following construction of a remedy.
4 <u>Reduction of Toxicity, Mobility, and Volume:</u> This criterion is an evaluation of the ability of the alternatives to reduce the toxicity, mobility and volume of site contamination. Alternatives that permanently or significantly reduce the toxicity, mobility or volume of the contamination at the site are preferred.
5 <u>Short-Term Impacts and Effectiveness:</u> This criterion is an evaluation of potential short-term adverse environmental impacts and human exposures during construction or implementation

of the alternative. Short-term impacts are conditions which may cause human exposures, adverse environmental impacts and nuisance conditions. Means of controlling short-term impacts are identified. The effectiveness of these controls is evaluated. Examples of short-term impacts include increased truck traffic, odors, vapors, dust, habitat disturbance, run off, consumption of materials, resources, and energy, gas emissions (including carbon dioxide, nitrogen oxides, and sulfur oxides), and noise. In general, the longer the construction schedule at a site the greater the short-term impacts.

6 Implementability: This criterion evaluates the technical and administrative feasibility of implementing an alternative. Technical feasibility includes difficulties associated with construction and the ability to monitor the effectiveness of the alternative. Administrative feasibility includes the availability of the necessary personnel and material and potential difficulties in obtaining approvals, access, etc.

7 Cost Effectiveness: An evaluation of the overall cost effectiveness of an alternative. An assessment is made as to whether the cost is proportional to the overall effectiveness of the alternative.

8 Land Use: This criterion is an evaluation of the current, intended and reasonable anticipated future use of the site and its surroundings as it relates to the alternative when unrestricted levels are not achieved.

9 Community Acceptance: This criterion is evaluated after the public review of the remedy selection process as part of the final DER selection/approval of the remedy for the site.

7.3 Detailed Analysis of Site Alternatives

Alternatives 1 through 3 are evaluated individually in terms of the seven environmental and one cost criteria described above. Descriptions of the alternatives are provided in Section 7.1.

7.3.1 Alternative 1 – Monitored Natural Attenuation

1 Overall Protection of Human Health and the Environment: This alternative is not protective of human health and the environment, since the site would remain in its present condition. Groundwater can continue to migrate off site, potentially impacting both downgradient public wells. Public supply well SW-2 has been impacted and is currently treated prior to distribution.

2 Compliance with Applicable or Relevant and Appropriate SCGs and Remediation Goals: Reduction in PCE contamination below the chemical-specific SCGs for the site is not expected for several decades. No location-specific SCGs were identified. Action-specific SCGs (e.g., OSHA regulations) can be met during sampling activities.

3 Long-Term Effectiveness and Permanence: Because this alternative does not involve removal or treatment of the contaminated groundwater, the risks involved with the migration of contaminants and direct contact with contaminants remain essentially the same over a long period of time. In addition, an estimated 11 trips will be made to the site to collect groundwater samples throughout the estimated 30 year maintenance period. Each trip to the site will consume fuel and release green-house gases into the atmosphere.

4 Reduction of Toxicity, Mobility, and Volume: This alternative does not involve the removal or treatment of the source of on-site contamination. Therefore, neither the toxicity, nor mobility, nor volume of contamination is expected to be reduced significantly. Natural

attenuation of contaminants is expected to reduce the concentration in groundwater over time.

5 Short-Term Impacts and Effectiveness: No short-term impacts are anticipated during the implementation of this alternative, since no construction activities are involved, only sampling. Field personnel wear appropriate personal protective equipment during groundwater sampling in order to limit health risks due to exposure to contaminants and physical hazards. In addition, equipment used for sampling purposes is decontaminated prior to leaving the site, as needed, in order to avoid the transport of contaminants. This alternative does not involve any additional activities on-site and, therefore, can be considered a baseline case for the environmental impacts of a remedy at the site.

6 Implementability: This alternative is readily implementable. Groundwater sampling can be performed without sophisticated equipment, and the necessary services and equipment are readily available.

7 Cost Effectiveness: The present work (30 year life) cost for this alternative is estimated to total approximately $653,479. This alternative does not effectively mitigate risk from contamination at the site, and the costs are lower than alternatives providing active remediation of treatment at the public wells.

8 Land Use: Institutional controls (e.g., deed or access restrictions) would be required for the on-site property to preclude contact with contaminated media (i.e., groundwater withdrawal or use restrictions).

7.3.2 Alternative 2 – Groundwater Extraction and Treatment

1 Overall Protection of Human Health and the Environment: This alternative is considered to be protective of human health and the environment. Implementation of this alternative would result in remediation of groundwater. Although the alternative will not meet the SCGs throughout the site, this alternative for groundwater remediation is considered to be protective of human health since PCE concentrations in groundwater are expected to reach the chemical SCGs within 30-years.

2 SCGs: It is expected that this alternative will meet the chemical-specific SCGs for on-site groundwater between the source area and the downgradient property line within a 10-year timeframe. No location-specific SCGs were identified. Action-specific SCGs (e.g., OSHA regulations) will be met during construction activities.

3 Long-Term Effectiveness and Permanence: Chemical-specific SCGs are expected to be achieved within 30 years. Therefore, this alternative is considered an adequate and reliable remedy for mitigating human health and environmental impacts due to groundwater. Operation of the groundwater extraction and treatment system will consume energy. In addition, an estimated 36 trips will be made to the site to install and maintain the groundwater extraction and treatment system and to collect groundwater samples throughout the estimated 30 year maintenance period. Each trip to the site will consume fuel and release green-house gases into the atmosphere. Best Management Practices (BMPs) identified in NYSDEC's DER-31 will be utilized to reduce energy consumption and gas emissions including limiting the amount of trips to the site, the purchase of Renewable Energy Credits (RECs), and reducing the energy consumption of the groundwater extraction and treatment system through site optimization(s).

4 Reduction of Toxicity, Mobility, and Volume: The toxicity, mobility and volume of on-site groundwater contamination are expected to be reduced significantly through the use of extraction wells, ex situ treatment, and natural attenuation at the fringe of the plume.

5 Short-Term Impacts and Effectiveness: There are minimal short-term effects related to the installation and construction of this type of treatment system. Potential exists for worker exposure to contaminated groundwater during the installation of the extraction wells and during the startup of the system. Extraction well(s) will be installed by a drill rig. The drill rig will consume fuel and release gas emissions into the atmosphere. Workers and construction vehicles will be present on active businesses to perform the remedy. Some flexibility in the work schedule (e.g., working weekends) may be required. Construction equipment used to transport and install on-site equipment will increase traffic to/from the site, consume fuel, and release gas emissions into the atmosphere. Field personnel would wear appropriate personal protective equipment during groundwater sampling in order to limit health risks due to exposure to contaminants and physical hazards. In addition, equipment used for sampling purposes would be decontaminated prior to leaving the site, as necessary, in order to avoid the transport of contaminants.

6 Implementability: This alternative is readily implementable on a technical basis. Construction and installation of the groundwater extraction/treatment systems would involve standard construction methods and equipment; and materials and services necessary for construction are readily available. With regard to O&M, the materials and services required for the systems are also readily available. Groundwater sampling can be performed without sophisticated equipment, and the necessary services and equipment are readily available.

In terms of administrative concerns, this alternative is also considered to be implementable. Implementation of this alternative would require coordination with and approval by municipal agencies (e.g., city of Corning, NY) as well as coordination with the owners/occupants of the dry cleaner facility. However, no specific problems are anticipated in obtaining permits or approvals from the various agencies and other concerns. A thorough survey of utilities and piping traversing the properties would need to be conducted prior to the installation of the injection/extraction wells and the associated infrastructure.

7 Cost Effectiveness: The present work cost for this alternative is estimated to total approximately $1,129,373. This alternative effectively mitigates risk from contamination at the site.

8 Land Use: This alternative is expected to achieve the chemical-specific SCGs for this site within a reasonable timeframe. No changes to land use are anticipated.

7.3.3 Alternative 3 – In Situ Treatment by Chemical Oxidation/Monitored Natural Attenuation

1 Overall Protection of Human Health and the Environment: This alternative is considered to be protective of human health and the environment. Implementation of this alternative would result in remediation of groundwater within the area of higher contamination and create a barrier to contaminant migration from the area of highest contamination.

2 SCGs: This alternative is expected to meet the chemical-specific SCGs for on-site groundwater between the source area and the plume limits within a 30-year timeframe for the

majority of the site areas. No location-specific SCGs were identified. Action-specific SCGs (e.g., OSHA regulations) will be met during construction activities.

3 Long-Term Effectiveness and Permanence: This alternative is considered an adequate and reliable remedy for mitigating human health and environmental impacts (in terms of affecting habitat or vegetation) due to groundwater. The injections have the potential to eliminate impacts within the region of the plume with highest PCE concentrations, allowing the lower concentrations of VOCs to further dissipate through bioremediation and natural attenuation. In addition, 18 trips will be made to the site for injections and to collect groundwater samples throughout the estimated 30 year maintenance period. Each trip to the site will consume fuel and release green-house gases into the atmosphere. Best Management Practices (BMPs) identified in NYSDEC's DER-31 will be utilized to reduce chemical consumption and gas emissions including limiting the amount of trips to the site and reducing the chemical consumption of the injections through site optimization(s).

4 Reduction of Toxicity, Mobility, and Volume: The injections will reduce the concentration of VOCs within the injected area. The injections will target groundwater impacts beneath the dry cleaner property. Injections along West Pulteney Street and West William Street create a barrier to migration in this area; eventually reducing the toxicity and limiting mobility of the contaminated groundwater. The remainder of the plume is expected to reduce in concentration over time by natural attenuation.

5 Short-Term Impacts and Effectiveness: Short-term impacts associated with the injected chemicals include risks to workers during handling of the solution. Injections will be accomplished with a drill rig. The drill rig will consume fuel and release gas emissions into the atmosphere. Workers and construction vehicles will be present on active businesses potentially causing some disruption. Some flexibility in the work schedule (e.g., working weekends) may be considered. Construction equipment used to transport and install on-site equipment will increase traffic to/from the site, consume fuel, and release gas emissions into the atmosphere. Field personnel would wear appropriate personal protective equipment during groundwater sampling in order to limit health risks due to exposure to contaminants and physical hazards. In addition, equipment used for sampling purposes would be decontaminated prior to leaving the site, as necessary, in order to avoid the transport of contaminants.

6 Implementability: This alternative is readily implementable on a technical basis. Construction and installation of the injection systems would involve standard construction methods and equipment; and materials and services necessary for construction are readily available. Several vendors supply the chemicals. Confirmatory groundwater sampling would be performed to monitor the effectiveness of injections. A pilot study may be implemented as part of pre-design work. Modification of the construction schedule to minimizing disruptions to the dry cleaner facility will be considered.

7 Cost Effectiveness: The present work cost for this alternative is estimated to total approximately $849,776. This alternative effectively mitigates risk from contamination at the site.

8 Land Use: This alternative is expected to achieve the chemical-specific SCGs for this site within a reasonable timeframe. No changes to land use are anticipated.

8 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents a comparative analysis of remedial alternatives. The alternatives are compared below on the basis of criteria defined in Section 7.2.1. The cost comparison is provided on Table 8-1, and the overall comparative analysis is summarized on Table 8-2.

8.1 Overall Protection of Human Health and the Environment

Alternative 2 and 3 are protective of human health and the environment. Alternative 1 provides adequate protection of human health and the environment with regard to the contaminated environmental media.

8.2 SCGs

Alternatives 2 and 3 are expected to achieve substantial compliance with the chemical-specific SCGs/remediation action objectives for groundwater. Alternative 1 is not expected to achieve compliance within 30 years. Each of the alternatives evaluated is considered to be in compliance with action-specific SCGs; permits and approvals necessary for implementing these alternatives will be obtained prior to initiating the remedial action. No location-specific SCGs were identified.

8.3 Long-Term Effectiveness and Permanence

Alternatives 2 and 3 are considered to be adequate, reliable and permanent remedies for the remediation of groundwater. Alternative 1 is not considered an adequate, reliable, or permanent long-term remedy for groundwater at the site.

Alternatives 1 and 3 will require the least amount of trips to the site and Alternative 2 will require the greatest amount of trips to the site over a 30 year operational period. Each trip to the site will consume fuel and release gas emissions into the atmosphere. Alternatives 1 and 3 will consume the least amount of energy on-site; Alternative 2 will consume the most. For each Alternative, Best Management Practices (BMPs) identified in NYSDEC's DER-31 will be utilized to reduce energy consumption and gas emissions including limiting the amount of trips to the site, the purchase of RECs, and reducing the energy consumption of the remedy through site optimization(s).

8.4 Reduction of Toxicity, Mobility, and Volume

Alternatives 2 and 3 provide for the reduction of toxicity, mobility and volume of impacted groundwater. Alternative 1 is expected to provide for the reduction of toxicity, mobility and volume of impacted groundwater over an extended period of time (greater than 30 years).

8.5 Short-Term Impacts and Effectiveness

No significant short-term impacts are identified for Alternative 1. Alternatives 2 and 3 involve intrusive work which may provide some disruption at the dry cleaner facility during construction activities.

Alternative 1 is not effective at reducing risks from the groundwater contamination in the short-term. Alternatives 2 and 3 are expected to realize significant reductions in the groundwater contaminant levels within the first year after construction.

Alternative 1 does not require the use of a drill rig unlike Alternatives 2 and 3. A drill rig consumes fuel/energy, releases gas emissions into the atmosphere, and consumes PVC material. Alternative 2 requires the delivery and installation of treatment equipment. Construction equipment used to transport and install on-site equipment will increase traffic to/from the site, consume fuel, and release gas emissions into the atmosphere.

8.6 Implementability

Alternatives 1, 2, and 3 are technically implementable with readily available methods, equipment, materials, and services. Alternatives 1, 2, and 3 are also administratively implementable. Property owners or tenants may object to the intrusive work required for Alternatives 2 and 3.

8.7 Cost Effectiveness

The estimated costs associated with the implementation of each alternative are summarized on Table 8-1. The lowest present worth cost of $653,479 is for Alternative 1 which does not include remedial actions for groundwater; rather, this alternative only includes long-term groundwater monitoring. Alternatives 2 and 3 are expected to provide effective remediation of groundwater. The present worth costs for Alternatives 2 and 3 are $1,129,373 and $849,776, respectively.

8.8 Land Use

Deed restrictions are required for Alternative 1 because groundwater contamination is expected to remain above the NYS Class GA groundwater criteria for an extended period of time.

9 REFERENCES

AECOM Technical Services, Inc. (AECOM), 2011. Final Remedial Investigation Report. Crystal Cleaners Site. January.

New York State Department of Environmental Conservation (NYSDEC), 2007. Presumptive/Proven Remedial Technologies. February.

NYDEC, 2010. Technical Guidance for Site Investigation and Remediation. DER-10. Division of Environmental Remediation. May.

NYSDEC, 2010. Green Remediation. DER-31. Division of Environmental Remediation. August.

USGS, 1995. Ground Water Atlas of the United States, Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, HA 730-M. by Perry G. Olcott

Table 4-1
Chemical-Specific Standards, Criteria, and Guidance

Title	Citation	Description/applicability
Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations	6 NYCRR 700-706 Water Quality Regulations; especially Part 703.5; summarized in TOGS 1.1.1.	Groundwater (Class GA) standards and guidance values; applicable. Establishes long-term remediation goals. PCE: 5 ug/L, TCE: 5 ug/L, cis-1,2-DCE: 5 ug/L, and vinyl chloride: 2 ug/L
New York Public Water Supplies	10 NYCRR 5-1.52 (Tables); 10 NYCRR 170.4 (Standards for Raw Water)	Drinking Water standards; relevant. May be used where groundwater standard may not be protective of aquifer use for potable water supply. Principle Organic Contaminant Maximum Contaminant Level: 5 ug/L (Table 3)
Primary Drinking Water Regulations – Maximum Contaminant Levels	40 CFR 141.61	Establishes federal maximum contaminant levels for organic contaminants in drinking water; relevant where it addresses contaminants not included in state standards, or has more stringent criteria. PCE: 5 ug/L, TCE: 5 ug/L, cis-1,2-DCE: 70 ug/L, and vinyl chloride: 2 ug/L
Ambient (Surface Water) standards and guidance values	NYCRR 700-706; especially Part 701 (establishes water classes); 6 NYCRR 811 Table I (designates Chemung River between Painted Post, NY and Big Flats, NY as Class C)	Surface Water Standards (Class C); potentially applicable to discharge to Chemung River. PCE: none, TCE: 40 ug/L, cis-1,2-DCE: none, and vinyl chloride: none

Table 4-2
Action-Specific Standards, Criteria, and Guidance

Title	Citation	Description/applicability
Hazardous Waste Regulations	6 NYCRR Part 370	Potentially applicable for off-site disposal of contaminated groundwater classified as hazardous waste
Solid Waste Regulations	6 NYCRR Part 360	Potentially applicable for off-site disposal of contaminated groundwater classified as hazardous waste
Selection of remedial actions at hazardous waste disposal sites	NYSDEC TAGM 4030	This TAGM provides guidelines to select an appropriate remedy at State Superfund sites, and sets forth a hierarchy of remedial technology treatments consistent with SARA and RCRA land disposal restrictions.
Guidelines for the Control of Toxic Ambient Air Contaminants	Air Guide 1	Potentially applicable for alternatives with discharges to air (e.g., air stripping)
Underground Injection/ Recirculation at Groundwater Remediation Sites	NYSDEC T.O.G.S. 2.1.2	Potentially applicable for alternatives involving re-injection of groundwater
Surface water standards	6 NYCRR 701.8 (best uses for Class C); 6 NYCRR 703.5; TOGS 1.1.1.	Potentially applicable for alternatives with discharges to surface water
Municipal Code Discharge Restrictions	City of Corning Municipal Code	Potentially Applicable for alternatives with discharges to sanitary sewer system
Stormwater discharge permit	State Pollutant Discharge Elimination System (SPDES); Steuben County Code; City of Corning Municipal Code	Potentially applicable for discharges to stormwater sewer system

Table 4-3
Groundwater Concentration Summary Statistics

Parameter	CAS	Detection Frequency	Detection Limit Range	Minimum Detected Value	Maximum Detected Value	Maximum Detected Sample	NYSDEC Class GA Groundwater Criteria	EPA RSL Screening Toxicity Values	EPA MCL	Used for Screening	Number of Exceed-ances
VOCs (ug/L)											
cis-1,2-Dichloroethene	156-59-2	12 / 35	1 - 5	1.6	120	HP-6-B	5	37	70	GA	4
Cyclohexane	110-82-7	1 / 35	1 - 5	1.3	1.3	MW-2	NL	1300	NL	RSL	0
Methyl tert-butyl Ether	1634-04-4	1 / 35	1 - 5	0.82	0.82	MW-5	NL	12	NL	RSL	0
Methylcyclohexane	108-87-2	3 / 35	1 - 5	1.1	4.3	HP-1-AA	NL	NL	NL	NL	
Tetrachloroethene (PCE)	127-18-4	17 / 35	1 - 5	3.9	430	HP-3-A	5	0.11	5	RSL	17
Toluene	108-88-3	1 / 35	1 - 5	1.2	1.2	HP-1-A	5	230	1000	GA	0
Trichloroethene (TCE)	79-01-6	8 / 35	1 - 5	0.57	34	HP-6-B	5	2	5	RSL	6
Vinyl Chloride	75-01-4	2 / 35	1 - 5	1.6	4.5	HP-6-B	2	0.016	2	RSL	2
Inorganics (ug/L)											
Aluminum	7429-90-5	5 / 6	50 - 50	53.2	6700	MW-6	NL	3700	NL	RSL	2
Barium	7440-39-3	6 / 6	50 - 50	192	447	MW-6	1000	730	2000	RSL	0
Calcium	7440-70-2	6 / 6	1000 - 1000	70800	109000	MW-6	NL	NL	NL	NL	
Chromium	7440-47-3	3 / 6	5 - 5	4.51	10.8	MW-6	50	NL	100	GA	0
Copper	7440-50-8	3 / 6	10 - 10	5.5	13.5	MW-6	250	150	1300	RSL	0
Iron	7439-89-6	5 / 6	50 - 50	72.3	11800	MW-6	300	2600	NL	GA	3
Lead	7439-92-1	3 / 6	6 - 6	3.32	14.9	MW-6	25	NL	15	MCL	0
Magnesium	7439-95-4	6 / 6	1000 - 1000	15000	31900	MW-5	35000	NL	NL	GA	0
Manganese	7439-96-5	6 / 6	10 - 10	8.49	859	MW-6	300	88	NL	RSL	5
Nickel	7440-02-0	3 / 6	20 - 20	5.18	13.2	MW-6	100	73	NL	RSL	0
Potassium	7440-09-7	6 / 6	1000 - 1000	1990	5751.45	MW-3	NL	NL	NL	NL	
Sodium	7440-23-5	6 / 6	1000 - 1000	41200	223025	MW-3	20000	NL	NL	GA	6
Vanadium	7440-62-2	3 / 6	20 - 20	5.78	10.8	MW-6	NL	0.26	NL	RSL	3
Zinc	7440-66-6	4 / 6	20 - 20	6.03	198	MW-4	2000	1100	NL	RSL	0

Table 4-3
Groundwater Concentration Summary Statistics

Parameter	CAS	Detection Frequency	Detection Limit Range	Minimum Detected Value	Maximum Detected Value	Maximum Detected Sample	NYSDEC Class GA Groundwater Criteria	EPA RSL Screening Toxicity Values	EPA MCL	Used for Screening	Number of Exceed-ances
Inorganics-Filtered (ug/L)											
Aluminum	7429-90-5	3 / 6	50 - 50	34	2010	MW-3F	NL	3700	NL	RSL	0
Barium	7440-39-3	6 / 6	50 - 50	184	362	MW-5F	1000	730	2000	RSL	0
Calcium	7440-70-2	6 / 6	1000 - 1000	68000	99700	MW-3F	NL	NL	NL	NL	
Chromium	7440-47-3	1 / 6	5 - 5	2.8	2.8	MW-3F	50	NL	100	GA	0
Copper	7440-50-8	1 / 6	10 - 10	3.87	3.87	MW-3F	250	150	1300	RSL	0
Iron	7439-89-6	4 / 6	50 - 50	67.9	2260	MW-3F	300	2600	NL	GA	2
Lead	7439-92-1	3 / 6	6 - 6	2.77	3.27	MW-5F	25	NL	15	MCL	0
Magnesium	7439-95-4	6 / 6	1000 - 1000	14300	27600	MW-5F	35000	NL	NL	GA	0
Manganese	7439-96-5	6 / 6	10 - 10	6.33	554	MW-5F	300	88	NL	RSL	5
Potassium	7440-09-7	6 / 6	1000 - 1000	1990	4880	MW-3F	NL	NL	NL	NL	
Sodium	7440-23-5	6 / 6	1000 - 1000	40000	220000	MW-3F	20000	NL	NL	GA	6
Zinc	7440-66-6	3 / 6	20 - 20	10.5	22.3	MW-3F	2000	1100	NL	RSL	0

Notes:
1. Background values are Eastern USA background values from New York State TAGM 4046, Table 4.
2. Screening toxicity values are the EPA Regional Screening Level (RSL) Resident Tap (May 2010).
3. RSLs correspond to 1E-6 of a hazard quotient of 0.1 or MCL, whichever is lower.

Table 8-1
Remedial Action Alternatives-Cost Estimate Summary

Summary of Costs	Alternative 1	Alternative 2	Alternative 3
Captial Costs (000)			
Total Construction Cost	$45,000	$262,421	$247,674
Contingencies (20%)	$2,250	$52,484	$49,535
Engineering (15%)	$0	$39,363	$37,151
Project Management (8%)	$3,600	$20,994	$19,814
Construction Management (10%)	$0	$26,242	$24,767
Total Capital Cost	$50,850	$401,504	$378,941
Present Worth Capital Costs	$54,231	$428,196	$404,133
Annual O&M Costs	$0	$0	$0
Total Annual O&M Cost	$23,706	$117,449	$48,706
Contingency (20%)	$1,185	$5,872	$2,435
Project Management (8%)	$1,896	$9,396	$3,896
Total Annual O&M Cost	$26,787	$132,717	$55,037
Present Worth of O&M Costs (30 year life)	$599,248	$701,177	$445,643
Present Worth of Total Costs	**$653,479**	**$1,129,373**	**$849,776**

Table 8-2

Detailed Evaluation of Alternatives Summary

Alternative	Compliance with SCGs	Protection of Human Health and Environment	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost Effectiveness	Land Use
Alternative 1 – Monitored Natural Attenuation	Non-compliant	None; contamination remains in groundwater.	Little or none; some natural attenuation may occur.	No short term impacts.	Not effective; PCE levels expected to remain over SCG more than 30 years after release.	Readily implementable	Low cost but limited effectiveness.	Deed or access restrictions.
Alternative 2– Groundwater Extraction with Ex Situ Treatment by Air Stripping/ Monitored Natural Attenuation	Expected to meet SCGs throughout most of site but some areas of non-compliance likely to persist.	Expected to provide protection of human health and the environment.	Expected to achieve significant reductions in contaminant concentrations and toxicity. May also reduce off-site migration (to north) based on positioning of extraction wells.	Requires coordination with owner/tenants to minimize disruptions of current operations.	Expected to effectively lower PCE levels within 10 years.	Implementable. Coordination with government agencies and owners/tenants required.	High cost but effective remediation expected.	No land use restrictions required.
Alternative 3– In Situ Treatment/ Monitored Natural Attenuation	Expected to meet SCGs throughout most of site but some areas of non-compliance likely to persist.	Expected to provide protection of human health and the environment.	Expected to achieve significant reductions in contaminant concentrations and toxicity.	Requires coordination with owner/tenants to minimize disruptions of current operations; and town and DOT for right of way access.	Expected to effectively lower PCE levels within 10 years.	Implementable. Coordination with government agencies and owners/tenants required.	Moderate cost and effective remediation expected.	No land use restrictions required.

AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

0 100 200 400 Feet

Supply Well
Site Boundary

Site Location Map

Project No: 106774

Figure No: 1-1

February 25, 2011

AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

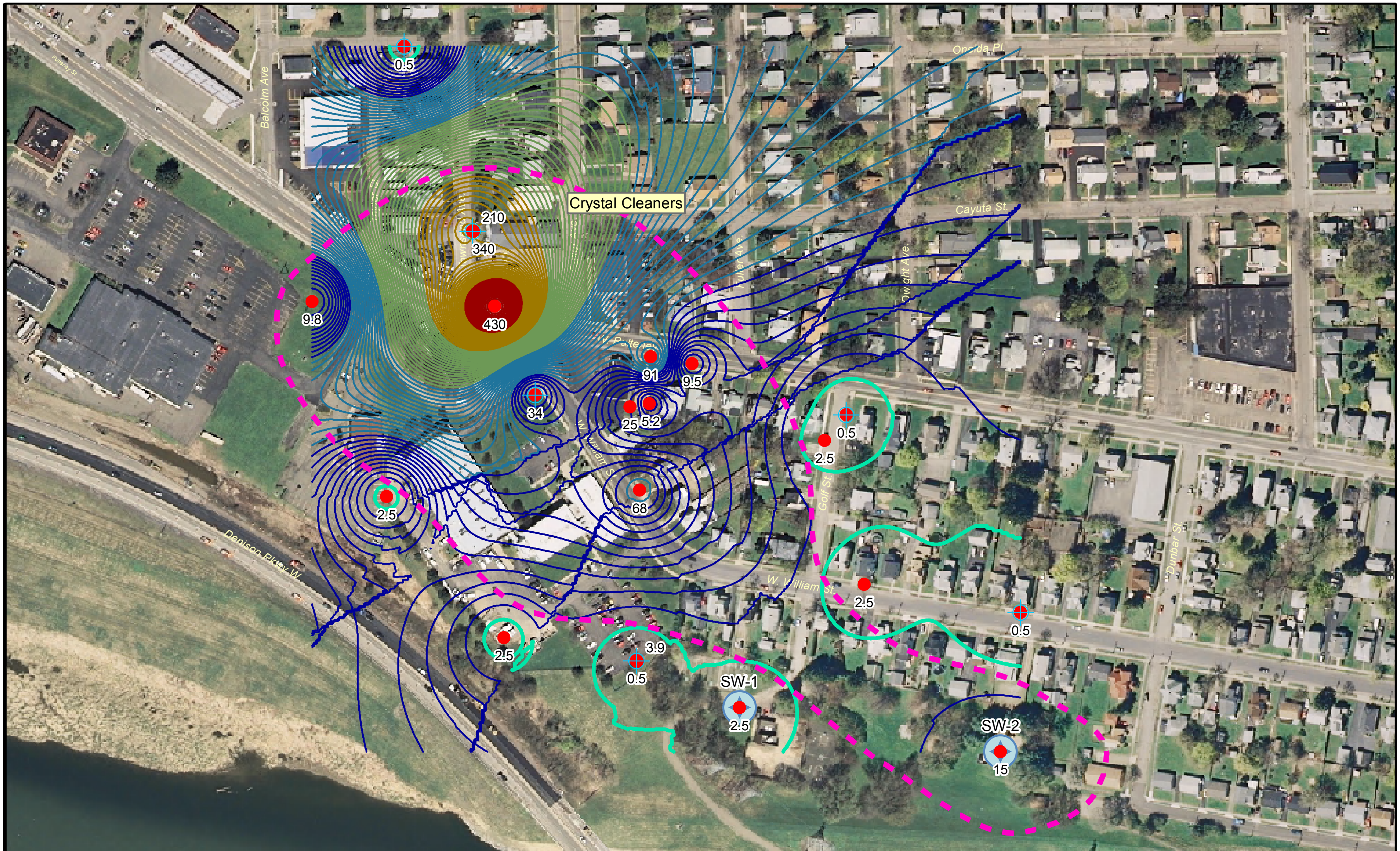
Feet
0 15 30 60

Site Layout

Project No: 106774

Figure No: 1-2

October 20, 2010



AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

0 62.5 125 250
Feet

Legend

- HP - Hydropunch Locations
- Permanent Monitoring Wells
- SW - Supply Well

PCE - Tetrachloroethene

PCE Contours (ug/L)

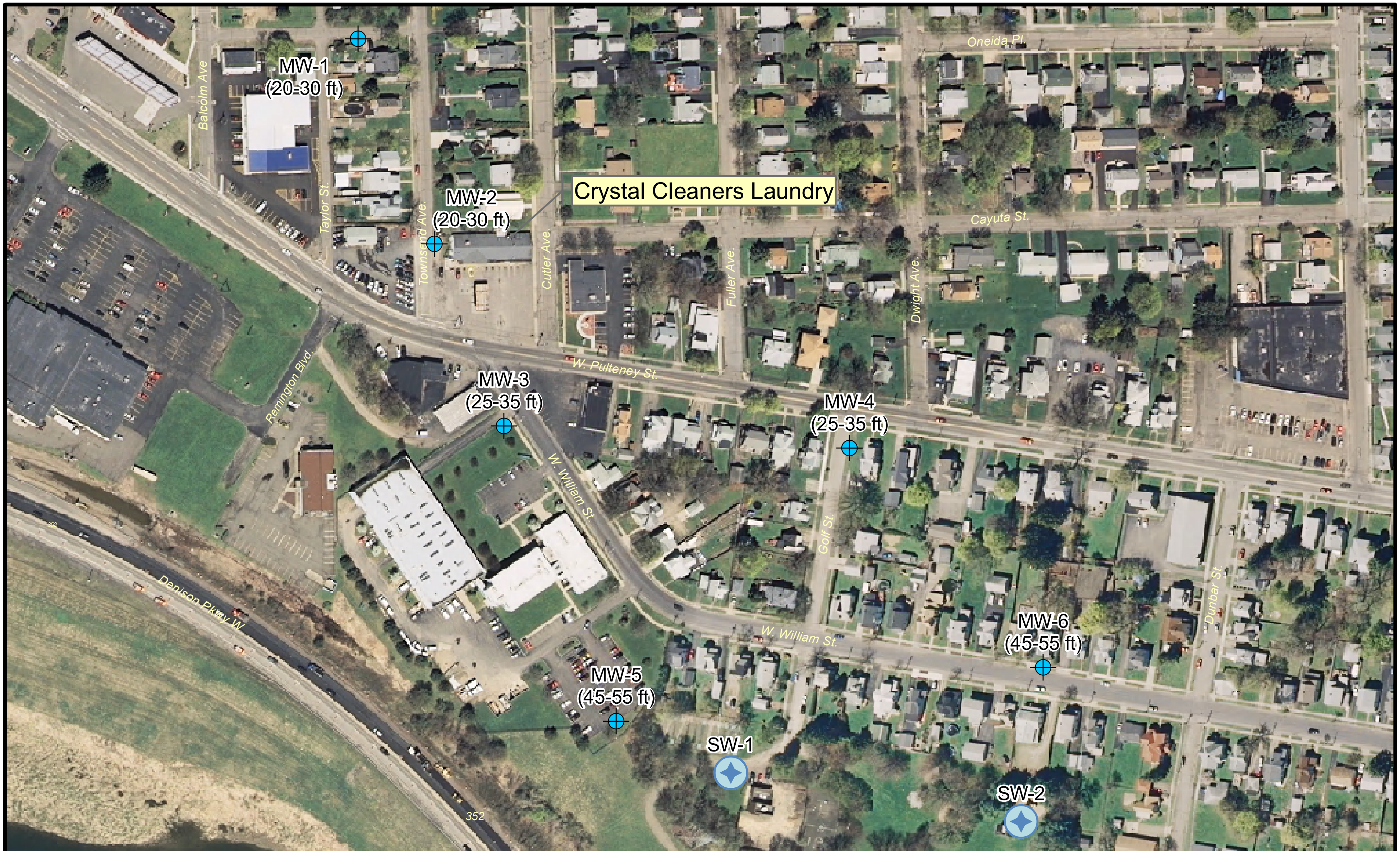
- 5
- 10 - 60
- 61 - 140
- 141 - 235
- 236 - 330
- 331 - 425
- Approximate Extent of PCE >5 ug/L

Groundwater PCE Contours

Project No: 106774

Figure No: 4-1

October 20, 2010



AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

0 50100 200
Feet

Legend

Permanent Monitoring Wells

Supply Well

Alternative 1 -
Monitoring Well Locations

Project No: 106774

Figure No: 7-1

October 20, 2010

AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

0 12.5 25 50
Feet

Legend

- Extraction Wells
- Injection Wells
- Pipes (buried)
- Treatment System

Alternative 2 - Conceptual Layout

Project No: 106774

Figure No: 7-2

October 1, 2010

AECOM

Crystal Cleaners Site
Site No. 8-51-022
Corning, NY

0 25 50 100
Feet

Legend

Injection Points

Alternative 3 - Conceptual Layout

Project No: 106774

Figure No: 7-3

October 1, 2010

Appendix A
Cost Estimates

1. Component	APPENDIX A: COST ESTIMATE				2. Date
SUMMARY OF COSTS					JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY			
5. Program Element ALTERNATIVE 1 - MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60134118	8. Project Cost ($000) $653		

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
SUMMARY OF COSTS				
CAPITAL COSTS				
Total Construction Cost				$45
Contingencies (20%)				$2
Engineering (0%)				$0
Project Management (8%)				$4
Construction Management (0%)				$0
Total Capital Cost				**$51**
Present Worth Capital Costs				**$54**
Annual O&M Costs				
Total Annual O&M Cost				$24
Contingency (5%)				$1
Project Management (8%)				$2
Total Annual O&M Cost				**$27**
Present Worth of O&M Costs (30 year life)				**$599**
Present Worth of Total Costs				**$653**
Guidance Cost Analysis				

10. Description of Proposed Construction:

Notes:

1. The escalation factor for construction costs is 4.2% from ENR (November 2010).
2. The discount factor from Circular-94 Dec 2009 ranged from 0.9% (3-year) to 2.7% (30+years).
4. The construction period is assumed to occur in 2012

1. Component CAPITAL COSTS	APPENDIX A: COST ESTIMATE			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 1 - MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60133623	8. Project Cost ($000) $653	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
COST DETAILS				
CAPITAL COSTS				
Deed Restriction - Environmental Easement	LS	1	25,000	$25
Site Management Plans	LS	1	20,000	$20
Total Construction Cost				$45
Contingency (5%)				$2
Engineering (0%)				$0
Project Management (8%)				$4
Construction Management (0%)				$0
2010 Construction Costs				**$51**
2012 Construction Costs (4.2% Escalation)				**$55**
Present Worth Construction Costs (0.9% discount)				**$54**

1. Component O&M COSTS	**APPENDIX A: COST ESTIMATE**			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 1 - MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60134118		8. Project Cost ($000) $653

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
O&M COSTS				
Groundwater Sampling Event	LS	1	23,706	$24
Events -				
2012-2017				
2022				
2027				
2032				
2037				
2042				
Periodic Review Reports	EA	1	25,000	$25
Total Annual Cost				$24
Contingency (5%)				$1
Project Management (8%)				$2
Total Annual O&M Cost				$27
Future O&M Costs (2012 to 2042)				**$941**
Present Worth of O&M Costs (0.9 to 2.7% Discounts)				**$599**

1. Component SUMMARY OF COSTS	APPENDIX A: COST ESTIMATE			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 2 - EX SITU TREATMENT/MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60134118	8. Project Cost ($000) $1,129	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
SUMMARY OF COSTS				
CAPITAL COSTS				
Total Construction Cost				$262
Contingencies (20%)				$52
Engineering (15%)				$39
Project Management (8%)				$21
Construction Management (10%)				$26
Total Capital Cost				**$402**
Present Worth Capital Costs				**$428**
Annual O&M Costs				
Total Annual O&M Cost				$117
Contingency (5%-20%)				$6
Project Management (8%)				$9
Total Annual O&M Cost				**$133**
Present Worth of O&M Costs (30 year life)				**$701**
Present Worth of Total Costs				**$1,129**
Guidance Cost Analysis				

10. Description of Proposed Construction:

Notes:

1. The escalation factor for construction costs is 4.2% from ENR (November 2010).
2. The discount factor from Circular-94 Dec 2009 ranged from 0.9% (3-year) to 2.7% (30+years).
4. The construction period is assumed to occur in 2012

1. Component CAPITAL COSTS	APPENDIX A: COST ESTIMATE			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 2 - EX SITU TREATMENT/MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60133623	8. Project Cost ($000) $1,129	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
COST DETAILS				
CAPITAL COSTS				
Pre-Design Study, Well Installation - 2 Extractions Wells, 2 Injection Wells	LS	1	69,342	$69
Electrical and Plumbing, connection to stormwater basin	LS	1	72,160	$72
Treatment Equipment and Installation	LS	1	100,919	$101
Site Management Plans	LS	1	20,000	$20
Total Construction Cost				$262
Contingency (20%)				$52
Engineering (15%)				$39
Project Management (8%)				$21
Construction Management (10%)				$26
2010 Construction Costs				**$402**
2012 Construction Costs (4.2% Escalation)				**$436**
Present Worth Construction Costs (0.9% discount)				**$428**

1. Component O&M COSTS	APPENDIX A: COST ESTIMATE			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 2 - EX SITU TREATMENT/MONITORED NATURAL ATTENUATION	6. Category Code	7. Project Number 60134118	8. Project Cost ($000) $1,129	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
O&M COSTS				
Assume three years of operation				
Energy	kW	113880	0.14	$16
Site Visits	LS	20	2640	$53
Groundwater Sampling Event	LS	1	23,706	$24
Events -				
2012-2017, 2022, 2032, 2042				
Periodic Review Reports	EA	1	25,000	$25
Total Annual Cost				$117
Contingency (5%)				$6
Project Management (8%)				$9
Total Annual O&M Cost				$133
Future O&M Costs (2012 to 2042)				**$927**
Present Worth of O&M Costs (0.9 to 2.7% Discounts)				**$701**

1. Component SUMMARY OF COSTS	APPENDIX A: COST ESTIMATE				2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY			
5. Program Element ALTERNATIVE 3 - IN SITU TREATMENT	6. Category Code	7. Project Number 60134118	8. Project Cost ($000) $850		

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
SUMMARY OF COSTS				
CAPITAL COSTS				
Total Construction Cost				$248
Contingencies (20%)				$50
Engineering (15%)				$37
Project Management (8%)				$20
Construction Management (10%)				$25
Total Capital Cost				**$379**
Present Worth Capital Costs				**$404**
Annual O&M Costs				
Total Annual O&M Cost				$49
Contingency (5%-20%)				$2
Project Management (8%)				$4
Total Annual O&M Cost				**$55**
Present Worth of O&M Costs (30 year life)				**$446**
Present Worth of Total Costs				**$850**
Guidance Cost Analysis				

10. Description of Proposed Construction:
Notes:
1. The escalation factor for construction costs is 4.2% from ENR (November 2010).
2. The discount factor from Circular-94 Dec 2009 ranged from 0.9% (3-year) to 2.7% (30+years).
4. The construction period is assumed to occur in 2012.

1. Component CAPITAL COSTS	APPENDIX A: COST ESTIMATE			2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY		
5. Program Element ALTERNATIVE 3 - IN SITU TREATMENT	6. Category Code	7. Project Number 60133623	8. Project Cost ($000) $850	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
COST DETAILS				
CAPITAL COSTS				
Pilot Study, Data Evaluation and Reporting	LS	1	20,000	$20
Drilling	LS	1	132,484	$132
Chemicals	LS	1	75,189	$75
Site Management Plans	LS	1	20,000	$20
Total Construction Cost				$248
Contingencies (20%)				$50
Engineering (15%)				$37
Project Management (8%)				$20
Construction Management (10%)				$25
2010 Construction Costs				**$379**
2012 Construction Costs (4.2% Escalation)				**$411**
Present Worth Construction Costs (0.9% discount)				**$404**

1. Component O&M COSTS	**APPENDIX A: COST ESTIMATE**				2. Date JAN 2010
3. Site CRYSTAL CLEANERS, CORNING, NY SITE NO. 851022		4. Project Title CRYSTAL CLEANERS FEASIBILITY STUDY			
5. Program Element ALTERNATIVE 3 - IN SITU TREATMENT	6. Category Code	7. Project Number 60134118		8. Project Cost ($000) $850	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
O&M COSTS				
Groundwater Sampling Event	LS	1	23,706	$24
Events -				
2012-2017, 2022, 2032, 2042				
Periodic Review Reports	EA	1	25,000	$25
Total Annual Cost				$49
Contingency (5%)				$2
Project Management (8%)				$4
Total Annual O&M Cost				$55
Future O&M Costs (2012 to 2042)				**$663**
Present Worth of O&M Costs (0.9 to 2.7% Discounts)				**$446**

Appendix B
Supporting Calculations

Air Stripper Calculations

Table of Contents

1 TECHNOLOGY DESCRIPTION

As the process name implies, volatile contaminants are "stripped" from the pumped groundwater and into the air. The two most commonly used air stripper systems are packed column and low profile. In a packed tower air stripping system, contaminated water flows down through a column that is filled with randomly packed or structured packing material while air is introduced below the packed bed and flows upward through the column countercurrent to the flow of water. In a low profile aeration system, contaminated water flows down over baffled aeration trays while air is forced upward through the perforations in the trays.

Air stripping is used to separate VOCs from water and is ineffective for inorganic contaminants. Henry's law constant is used to determine whether air stripping will be effective. Generally, organic compounds with constants greater than 0.01 atmospheres - m^3/mol are considered amenable to stripping. Some compounds that have been successfully separated from water using air stripping include BTEX, chloroethane, TCE, DCE, and PCE.

2 INPUTS AND ASSUMPTIONS

In order to model an air stripper and get a preliminary estimate of the size requirements several inputs must be determined. The main inputs listed in Table B-1 are the minimum and maximum volume of water to be air stripped, the minimum temperature of water, the maximum concentration of VOCs in the untreated water, the desired concentrations in the treated water and Henry's constant for the VOCs. In addition, the operation schedule, range of air temperatures, and mineral content, must be considered. It is assumed to run full time for the entire year. The influent air conditions and mineral content are listed in Table B-1.

Table B-1 – Site Information

System	Crystal On-site 1	Crystal On-site 2	Crystal On-site 3
Water Influent			
Max PCE (ug/L)	350	350	350
Min Liquid Temp (deg.F)	60	60	60
Flow Rate (gpm)	500	1,000	2,000
Water Effluent			
PCE (ug/L) less than	5	5	5
Air Influent			
PCE less than	0	0	0
Water Quality			
Iron (unfiltered) ug/L	70-7,000	70-7,000	70-7,000
Iron (filtered) ug/L	70-2,000	70-2,000	70-2,000
Manganese (unfiltered) ug/L	200-300	200-300	200-300
Manganese (filtered) ug/L	200-600	200-600	200-600
Calcium ug/L	70,000-100,000	70,000-100,000	70,000-100,000
Magnesium ug/L	15,000-30,000	15,000-30,000	15,000-30,000

2.1 Air Flow Rates

The air flow rate for a given VOC concentration is generally lower for a packed column air stripper than a low profile air stripper. The range of air flow rates for the two types of air strippers is 5 to 250 cfm/ft^2 for a packed column and 30 to 60 cfm/ft^2 (US Army Corps of Engineers [USACE], 2001). Thus the tray area for a low profile air stripper will be greater than the tower cross sectional area for the same conditions. For both types of air strippers if the air flow rate is too high flooding may occur, in which case the water floods the top of the air stripper. There is a narrow range of possible air flow rates for the low profile air stripper since a rate that is too high will force the air through the holes in the trays too quickly forming a jet and dispersing the water and if the air flow rate is too low the water will drip through the holes in the trays. Both of these conditions negatively affect the efficiency of the stripper.

2.2 Water Flow Rates

Based on the hydraulic conductivity of the area and the desired capture water flow rates ranging from 500 to 2,000 gpm were examined. The range of water flow rates for the two types of air strippers is 20 to 45 gpm/ft^2 for a packed column and 1 to 15 cfm/ft^2 (USACE, 2001).

2.3 Other Inputs

All the values used in the calculations are provided in the attached calculations sheets.

3 RESULTS

For the packed column analysis, the on-site well packing depths ranged from 18 to 32 ft with diameters ranging from 4 to 10 ft. The on-site wells would require low profile systems with at least 4 trays with areas ranging from 20 to 265 ft^2.

For the emissions analysis, for an added measure of conservatism, the air stripper is assumed to be 100% efficient, and therefore, all of the VOCs are emitted into the air. This analysis uses worst-case values. Actual air emissions will be less than in this conservative analysis. The on-site wells were estimated to emit between 0.4 and 1.5 tons per year.

4 FURTHER CONSIDERATIONS

Air strippers may become fouled by mineral deposits. In cases of high metal concentrations pre-treatment of the water prior to stripping may be necessary. In general fouling is a concern when the calcium levels are greater than 40 mg/L, iron is greater than 0.3 mg/L, magnesium is greater than 10 mg/L or manganese is greater than 0.05 mg/L. Fouling may also occur if there is excessive biological growth. After fouling has occurred and compromised the effectiveness of the air stripper, maintenance is required. For packed column air strippers the packing must either be removed for cleaning or washed with an acid solution. Since these operations are both costly, low profile air strippers are often desirable when fouling is expected (USACE, 2001). Low profiles generally are easier to clean after fouling.

The following factors may limit the applicability and effectiveness of the process:

- The potential exists for inorganic (e.g., iron greater than 5 ppm, hardness greater than 800 ppm) or biological fouling of the equipment, requiring pretreatment or periodic column cleaning.
- Off-gases may require treatment based on mass emission rates.

5 REFERENCES

US Army Corps of Engineers, 2001. Engineer Design Guide, DG 1110-1-3, Engineering and Design-Air Stripping, October 31, 2001.

System	Crystal On-site 1	Crystal On-site 2	Crystal On-site 3
Water Influent			
Max PCE (ug/L)	350	350	350
Min Liquid Temp (deg.F)	60	60	60
Flow Rate (gpm)	500	1,000	2,000
Water Effluent			
PCE (ug/L) less than	5	5	5
Air Influent			
PCE less than	0	0	0
Water Quality			
Iron (unfiltered) ug/L	70-7,000	70-7,000	70-7,000
Iron (filtered) ug/L	70-2,000	70-2,000	70-2,000
Manganese (unfiltered) ug/L	200-300	200-300	200-300
Manganese (filtered) ug/L	200-600	200-600	200-600
Calcium ug/L	70,000-100,000	70,000-100,000	70,000-100,000
Magnesium ug/L	15,000-30,000	15,000-30,000	15,000-30,000
Air Emissions (tons/year)	0.384	0.768	1.535
Air Emissions (lbs/hr)	0.088	0.175	0.350

PCE Henry's Constant H (atm) @ 60F =	800
PCE Henry's Constant H (unitless) @ 60F =	0.6

		Packed Column	Low Profile
min air flow rate	cfm/ft^2	5	30
max air flow rate	cfm/ft^2	250	60
min water flow rate	gpm/ft^2	20	1
max water flow rate	gpm/ft^2	45	15
Min A/W ratio	cfm/gpm	0.11	2.00
Max A/W ratio	cfm/gpm	12.50	7.50

PACKED COLUMN EQUATIONS (page 1 of 2)

From USACE, 2001.

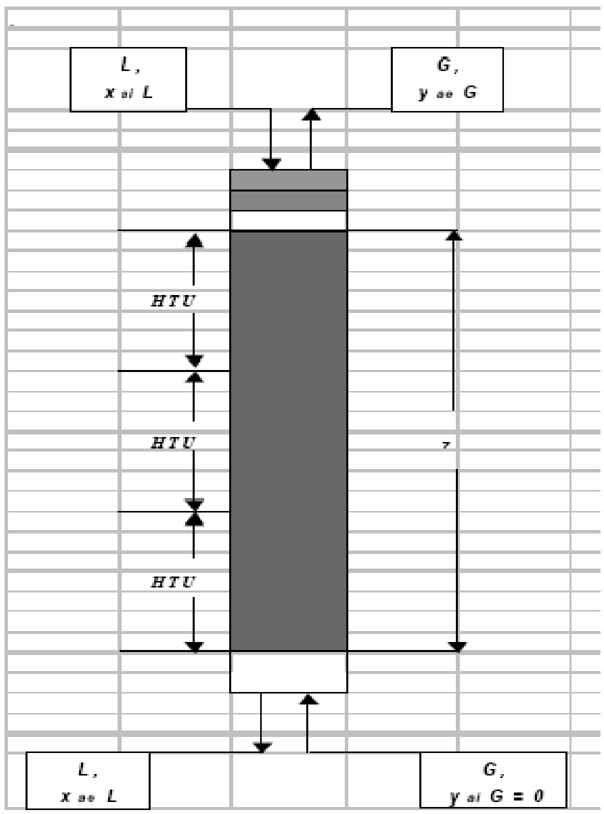


Figure D-1. Random "dumped" packed tower.

Table D-5
Water at 20°C (293.16 K)

s	$= 0.072764 \dfrac{\mathrm{N}}{\mathrm{m}} = \dfrac{\mathrm{kg}}{\mathrm{s}^2}$	liquid surfacetension
μ_L	$= 0.0010042 \dfrac{\mathrm{kg}}{\mathrm{m\,s}}$	liquidviscosity
ρ_L	$= 998.20 \dfrac{\mathrm{kg}}{\mathrm{m}^3}$	liquid density

Table D-7
Air at 20°C (293.16 K) and 1 atm

μ_G	$= 1.773 \times 10^{-5} \dfrac{\mathrm{kg}}{\mathrm{m\,s}}$	gasviscosity
ρ_G	$= 1.2046 \dfrac{\mathrm{kg}}{\mathrm{m}^3}$	gasdensity

Table D-6
Packing Characteristics

d_p	$= 0.0508\ \mathrm{m}$	nominal diameter
a_t	$= 157 \dfrac{\mathrm{m}^2}{\mathrm{m}^3}$	totalsurfacearea
s_c	$= 0.033 \dfrac{\mathrm{kg}}{\mathrm{s}^2}$	criticalsurfacetension for polyethylenepacking
c_f	$= 15$	packing factor

PACKED COLUMN EQUATIONS (page 2 of 2)

From USACE, 2001.

Assuming influent air has not PCE:

$$\frac{Q_{G\,\min}}{Q_L} = \frac{(C_{ai} - C_{ae})}{H_a C_{ai}}$$

$$L = \rho_L \frac{Q_L}{A} \left[\frac{\text{kg}}{\text{m}^2\ \text{s}} \right]$$

$$N_{Re} = \frac{V_L \rho_L}{a_t\ \mu_L} \quad \text{(Reynolds Number)}$$

$$N_{Fr} = \frac{a_t V_L^2}{g_c} \quad \text{(FroudeNumber)}$$

$$N_{We} = \left(\frac{1}{a_t}\right) \frac{V_L^2 \rho_L}{g_c s} \quad \text{(Weber Number)}$$

Calculate the wetted area of the packing, a_w from the dimensionless relation:

$$\frac{a_w}{a_t} = 1 - \exp\left[-1.45 \left(\frac{s_c}{s} \right)^{0.75} \left(N_{Re}^{\ 0.1} N_{Fr}^{\ -0.05} N_{We}^{\ 0.2} \right) \right]$$

k. Calculate the liquid phase mass transfer coefficient, Onda K_L from the following relationship:

$$K_L \left(\frac{\rho_L}{\mu_L g_c} \right)^{\frac{1}{3}} = 0.0051 \left(\frac{V_L\ \rho_L}{a_w\ \mu_L} \right)^{\frac{2}{3}} \left(\frac{\mu_L}{\rho_L D_L} \right)^{-0.5} (a_t d_p)^{0.4}$$

l. Calculate the gas phase mass transfer coefficient, Onda K_G, using a stripping factor (R) between 2 and 5. Try $R = 2.5$ if air pollution control is required, $R = 4.5$ if it isn't.

$$\frac{K_G}{(a_t D_G)} = 5.23 \left(\frac{G}{a_t\ \mu_G} \right)^{0.7} \left(\frac{\mu_G}{\rho_G D_G} \right)^{\frac{1}{3}} (a_t d_p)^{-2.0}$$

q. Calculate the overall mass transfer coefficient, Onda K_{LA}.

$$\frac{1}{K_{LA}} = \frac{1}{H'_a\ K_G\ a_w} + \frac{1}{K_L\ a_w}$$

$$HTU = \frac{V_L}{K_{LA}}$$

$$NTU = \left(\frac{R}{R-1} \right) \ln \left(\frac{\left[\left(\frac{x_{ai}}{x_{ae}} \right) (R-1) \right] + 1}{R} \right)$$

$$Z = NTU \times HTU \text{ packingdepth[m]}$$

LOW PROFILE EQUATIONS (page 1 of)

From USACE, 2001.

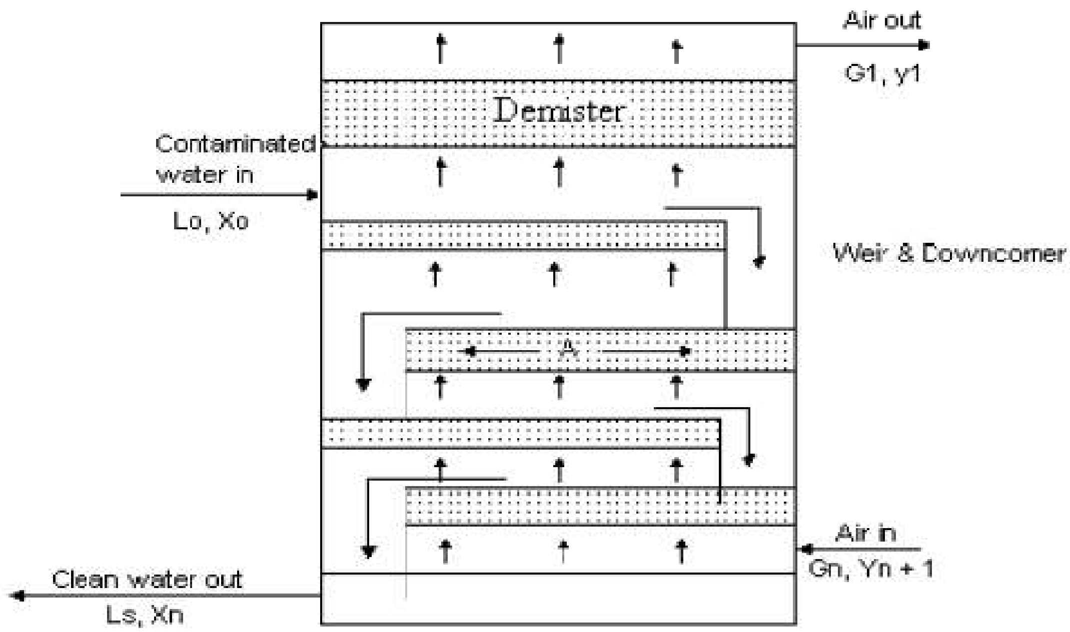


Figure C-1. Cross-sectional area of perforated plate section.

$$N_{\text{theoretical}} = \frac{\log\left[\dfrac{\left(X_0 - \dfrac{Y_{n+1}}{m}\right)}{\left(X_n - \dfrac{Y_{n+1}}{m}\right)}\left(1-\dfrac{1}{S}\right) + \dfrac{1}{S}\right]}{\log S}$$

where

X_0	=	concentration of contaminant (TCE) in the inlet water phase: 10 mg/L
X_n	=	concentration of contaminant (TCE) in the treated water phase: 0.1 mg/L
N	=	number of theoretical plates. Assumes that the liquid on each plate is completely mixed and that the vapor leaving the plates is in equilibrium with the liquid.
H	=	Henry's Constant (atm)
m	=	slope of equilibrium curve (H/Pt)
G	=	lb-moles air/min
L	=	lb-moles of water/min
S	=	stripping factor (mG/L)
Pt	=	ambient pressure (atm)
Y_{n+1}	=	concentration of volatiles in the air entering the air stripper.

		Reference Values	Crystal 1-lower	Crystal 1-upper	Crystal 2-lower	Crystal 2-upper	Crystal 3-lower	Crystal 3-upper
Preliminary Stripper Cross Section								
water flow rate per cross section	gpm/ft^2		26	45	26	45	26	45
Water flow rate	gpm		500	500	1,000	1,000	2,000	2,000
total cross section	ft2		19.2	11.1	38.5	22.2	76.9	44.4
Number of Strippers			1	1	1	1	1	1
prelim cross section per stripper	ft2		19.2	11.1	38.5	22.2	76.9	44.4
prelim diameter of strippers	ft		4.95	3.76	7.00	5.32	9.90	7.52
Standard Diameter Stripper								
diameter (d)	**ft**		**5**	**4**	**7**	**6**	**10**	**8**
packing material diameter	in		5	4	7	6	10	8
water flow rate per stripper (QL)	gpm		500	500	1000	1000	2000	2000
cross section per stripper (A)	ft2		19.6	12.6	38.5	28.3	78.5	50.3
water flow rate per cross section (VL)	gpm/ft2	20-45	25.5	39.8	26.0	35.4	25.5	39.8
water flow rate per stripper (QL)	m3/s		0.0315	0.0315	0.0631	0.0631	0.1262	0.1262
diameter (d)	m3/s		1.52	1.22	2.13	1.83	3.05	2.44
cross section per stripper (A)	m2		1.82	1.17	3.58	2.63	7.30	4.67
water flow rate per cross section (VL)	m/s		0.0173	0.0270	0.0176	0.0240	0.0173	0.0270
Untreated Water Conc. (Cai)	ug/L		350	350	350	350	350	350
Treated Water Conc. (Cae)	ug/L		5	5	5	5	5	5
Henry's Constant (H')	unitless	0.6						
A/W ratio minimum (Qgmin/QL)	m3/m3		1.64	1.64	1.64	1.64	1.64	1.64
gravitational constant (gc)	m/s2	9.807						
liquid surfacetension of water at 60 F (s)	kg/s2	0.072764						
liquid viscosity of water at 60 F (μ_L)	kg/ms	0.0010042						
liquid density of water at 60 F (ρ_L)	kg/m3	998.2						
Liquid Diffusivity of PCE at 60 F (DL)	m2/s	5.86E-10						

		Reference Values	Crystal 1-lower	Crystal 1-upper	Crystal 2-lower	Crystal 2-upper	Crystal 3-lower	Crystal 3-upper
nominal diameter (d_p)	m	0.0508						
total surface area (a_t)	m2/m3	157						
critical surface tension for polyethylene packing (s_c)	kg/s2	0.033						
packing factor (c_f)	unitless	15						
Liquid mass velocity	kg/m2s		17.3	27.0	17.6	24.0	17.3	27.0
Reynolds Number (Nre)			109.5	171.1	111.7	152.1	109.5	171.1
Nre^0.1			1.60	1.67	1.60	1.65	1.60	1.67
Froude Number (NFr)			0.00479	0.01169	0.00498	0.00924	0.00479	0.01169
NFr^-0.05			1.31	1.25	1.30	1.26	1.31	1.25
Weber Number (Nwe)			0.00266	0.00651	0.00277	0.00514	0.00266	0.00651
Nwe^0.2			0.306	0.365	0.308	0.348	0.306	0.365
wetted area (aw)	m2/m3		62.9	71.8	63.3	69.4	62.9	71.8
Liquid phase mass transfer coefficient (KL)	m/s		0.00026	0.00031	0.00026	0.00030	0.00026	0.00031
gasviscosity of air at 60 F (μ_G)	kg/ms	1.77E-05						
gas density of air at 60 F (ρ_G)	kg/m3	1.2046						
Gas Diffusivity of PCE at 60 F (Dg)	m2/s	7.13E-06						
Gas flow rate (VGmin=QGmin/QL*VL)	m/s		0.028	0.044	0.029	0.039	0.028	0.044
Stripping Factor (R)	unitless	2.5 to 4.5 or	15	2.5	15	2.5	15	2.5
Gas flow rate (VG=Vgmin*R)	m/s		0.426	0.111	0.435	0.099	0.426	0.111
Gas flow rate (QG)	m3/s		0.777	0.130	1.555	0.259	3.109	0.518
Gas flow rate (G=VG*ρG)	kg/sm2		0.513	0.134	0.524	0.119	0.513	0.134

		Reference Values	Crystal 1-lower	Crystal 1-upper	Crystal 2-lower	Crystal 2-upper	Crystal 3-lower	Crystal 3-upper
Gas phase mass transfer coefficient (KG)	m/s		4.52E-03	1.76E-03	4.58E-03	1.62E-03	4.52E-03	1.76E-03
Overall Mass Transfer Coefficient (KLA)	s^-1		0.015	0.017	0.015	0.016	0.015	0.017
Height of transfer unit (HTU)	m		1.2	1.6	1.2	1.5	1.2	1.6
Number of Transfer Units (NTU)	unitless		4.5	6.2	4.5	6.2	4.5	6.2
Packing depth (Z)	m		5.3	9.7	5.3	9.5	5.3	9.7
Packing depth (Z)	**ft**		**17.3**	**31.8**	**17.4**	**31.1**	**17.3**	**31.8**
Air to Water Ratio (A/W)	m3 air/m3 H2O		24.6	4.1	24.6	4.1	24.6	4.1
Air to Water Ratio (A/W)	cfm/gpm		3.29446	0.54908	3.29446	0.54908	3.29446	0.54908
Air to Water Ratio (A/W)	cfm/cfm		24.6425	4.10709	24.6425	4.10709	24.6425	4.10709
Air flow rate	cfm		1647.23	274.538	3294.46	549.076	6588.92	1098.15
Air flow rate (cfm/ft2 packed column)			83.8927	21.8471	85.6048	19.4196	83.8927	21.8471
Water flow rate (gpm/ft2 packed column)			25.4648	39.7887	25.9845	35.3678	25.4648	39.7887

		Crystal	Crystal	Crystal	Crystal	Crystal	Crystal
Scenario		1-lower	1-upper	2-lower	2-upper	3-lower	3-upper
Untreated Water Conc. (Xo)	ug/L	350	350	350	350	350	350
Treated Water Conc. (Xn)	ug/L	5	5	5	5	5	5
Air In conc. (Yn+1)	ug/L	0	0	0	0	0	0
Henry's Constant (H)	atm	800	800	800	800	800	800
Ambient Pressur (Pt)	atm	1	1	1	1	1	1
Slope of Equilibrium curve (m=H/Pt)		800	800	800	800	800	800
Water Flowrate (L)	gpm	500	500	1,000	1,000	2,000	2,000
	Conversion to lb-mol/min	0.46	0.46	0.46	0.46	0.46	0.46
L	lb-mol/min	231.69	231.69	463.39	463.39	926.78	926.78
A/W Ratio	cfm/gpm	2.00	3.30	2.00	3.30	2.00	3.30
Air Flowrate (G)	cfm	1,000	1,650	2,000	3,300	4,000	6,600
	Conversion to lb-mol/min	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
G	lb-mol/min	2.63	4.34	5.26	8.68	10.53	17.37
Stripping Factor (S)		9.09	14.99	9.09	14.99	9.09	14.99

N(theoretical)		1.87	1.54	1.87	1.54	1.87	1.54
Tray Efficiency E		0.5	0.5	0.5	0.5	0.5	0.5
N(actual)		**4**	**4**	**4**	**4**	**4**	**4**
Exchange Tray area min	ft2	17	28	33	55	67	110
Exchange Tray area max	ft2	33	55	67	110	133	220

Tray Area with weir/downcomer	ft2	20	33	40	66	80	132
Tray Area with weir/downcomer	ft2	40	66	80	132	160	264

pressure drop per tray (estimated)	in wc	4	4	4	4	4	4
pressure drop across piping (estimated)	in wc	10	10	10	10	10	10
Total pressure drop	in wc	26	26	26	26	26	26

GW TECHNOLOGY:	Ex Situ Air Stripping--Packed Tower			
RACER PARAMETERS	Scenario A	Scenario B	Scenario C	Scenario D
	Small Site		Large Site	
Remedial Action:	**Easy**	**Difficult**	**Easy**	**Difficult**
Media/Waste Type	Groundwater	Groundwater	Groundwater	Groundwater
Contaminant	VOCs	VOCs	VOCs	VOCs
Approach	Ex Situ	Ex Situ	Ex Situ	Ex Situ
System Definition:				
Type of Air Stripper	Packed Tower	Packed Tower	Packed Tower	Packed Tower
Influent Flow Rate (GPM)	50	50	500	500
Volatility of Contaminants	High	Low	High	Low
Removal Percentage	98%	98%	98%	98%
Safety Level	D	D	D	D
Configuration (Packed Tower):				
Number of Towers in Series	1	2	1	2
Packed Tower Diameter (ft)	2	2	6	6
Packed Tower Height (ft)	25	20	25	20
Low Profile Stripper Number of Trays	0	0	0	0
Number of Strippers	1	1	1	1
Configuration (Low profile tray stack):				
Packed Tower Diameter (ft)	N/A	N/A	N/A	N/A
Packed Tower Height (ft)	N/A	N/A	N/A	N/A
Low Profile Stripper Number of Trays	N/A	N/A	N/A	N/A
Number of Strippers	N/A	N/A	N/A	N/A
O&M:				
Assign Startup Costs	Exclude from estimate	Exclude from estimate	Exclude from estimate	Exclude from estimate
Duration (YR)	2	2	5	5
Treatment Train Systems Maintenance Level	Moderate	Moderate	Moderate	Moderate
Sampling Frequency	Monthly	Monthly	Monthly	Monthly
Ex Situ Air Stripping Marked-up Costs	$56,304	$105,433	$124,371	$301,156
Additional Costs:				
O&M	$60,346	$60,346	$388,942	$388,942
Remedial Design (10% or 10K)	$6,756	$11,598	$13,681	$30,116
TOTAL MARKED-UP COSTS	$123,406	$177,377	$526,994	$720,214
GALLONS TREATED	**52,560,000**	**52,560,000**	**1,314,000,000**	**1,314,000,000**
COST PER GALLON	**$0.0023**	**$0.0034**	**$0.0004**	**$0.0005**
COST PER 10,000 GALLONS	**$23**	**$34**	**$4**	**$5**

Stripper Data

Stripper	Select	Max Liquid Flow	Air Flow	4-Tray Height	6-Tray Height	Width	Length	Diameter	Tray Area
Model	**Model**	**(gpm)**	**(cfm)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(ft2)**
EZ-Stacker 2.xp		25	140	83	103	0	0	27	2
EZ-Stacker 4.xp		40	280	83	103	0	0	37	4
EZ-Tray 4.x		50	210	82	102	26	29	0	4
EZ-Tray 6.x		65	320	82	102	26	37	0	6
EZ-Tray 8.x		75	420	82	102	26	49	0	8
EZ-Tray 12.x		120	600	82	102	26	73	0	12
EZ-Tray 16.x		150	850	84	104	52	49	0	16
EZ-Tray 24.x		250	1300	84	104	52	73	0	24
EZ-Tray 36.x		375	1900	100	120	100	73	0	36
EZ-Tray 48.x		500	2600	110	130	124	73	0	48
EZ-Tray 72.x		750	3800	110	130	100	146	0	72
EZ-Tray 96.x		1000	5200	110	130	124	146	0	96

QED Air Stripper Model ver. 2.01	11/9/2010

Site Data

Name: Crystal

e-mail: celeste.foster@aecom.com

Project: On 1

Units: English

Altitude: 50 ft

Air Temp: 50 F

Flow: 500 gpm

Water Temp: 50 F

Stripper: EZ-Tray 48.x - Click for details

Stripper Air Flow: 2600 cfm

Stripper Max Flow: 500 gpm

Water Results

Contaminant	Influent (ppb)	Target (ppb)	4-Tray Results (ppb)	4-Tray % Removal	6-Tray Results (ppb)	6-Tray % Removal
tetrachloroethylene (PERC,PCE)	350	5	< 1	100.000	< 1	100.000

Air Results

Contaminant	4-Tray (ppmV)	4-Tray (lb/hr)	6-Tray (ppmV)	6-Tray (lb/hr)
tetrachloroethylene (PERC,PCE)	1.2596	0.08756	1.2606	0.08762

Notes

PH-> 1-800-624-2026 or 1-734-995-2547, FX-> 1-734-995-1170. E-mail->info@qedenv.com. WEB->www.qedenv.com.

The QED modeler estimates unit performance for the listed contaminants. ***Results assume -***

1. *dissolved-phase contaminant within a water matrix*
2. *clean stripper air*
3. *no surfactants, oil, grease or other immiscible phase(s) in the influent*
4. *unit operated within the given parameters and as instructed in the O&M manual*

Stripper performance shall meet or exceed either the required effluent concentration(s) or effluent estimates, whichever is greater, for the conditions supplied and assumes the influent concentrations of each contaminant are less than 25% solubility in water. QED makes no claim of the model's accuracy beyond the 25% solubility in water limit.

QED Air Stripper Model ver. 2.01	11/9/2010

Site Data

Name: Crystal

e-mail: celeste.foster@aecom.com

Project: On 2

Units: English

Altitude: 50 ft

Air Temp: 50 F

Flow: 1000 gpm

Water Temp: 50 F

Stripper: EZ-Tray 96.x - Click for details

Stripper Air Flow: 5200 cfm

Stripper Max Flow: 1000 gpm

Water Results

Contaminant	Influent (ppb)	Target (ppb)	4-Tray Results (ppb)	4-Tray % Removal	6-Tray Results (ppb)	6-Tray % Removal
tetrachloroethylene (PERC,PCE)	350	5	< 1	100.000	< 1	100.000

Air Results

Contaminant	4-Tray (ppmV)	4-Tray (lb/hr)	6-Tray (ppmV)	6-Tray (lb/hr)
tetrachloroethylene (PERC,PCE)	1.2596	0.17512	1.2606	0.17525

Notes

PH-> 1-800-624-2026 or 1-734-995-2547, FX-> 1-734-995-1170. E-mail->info@qedenv.com. WEB->www.qedenv.com.

The QED modeler estimates unit performance for the listed contaminants. ***Results assume -***

1. *dissolved-phase contaminant within a water matrix*
2. *clean stripper air*
3. *no surfactants, oil, grease or other immiscible phase(s) in the influent*
4. *unit operated within the given parameters and as instructed in the O&M manual*

Stripper performance shall meet or exceed either the required effluent concentration(s) or effluent estimates, whichever is greater, for the conditions supplied and assumes the influent concentrations of each contaminant are less than 25% solubility in water. QED makes no claim of the model's accuracy beyond the 25% solubility in water limit.

QED Air Stripper Model ver. 2.01	11/9/2010

Site Data

Name: Crystal

e-mail: celeste.foster@aecom.com

Project: Off

Units: English

Altitude: 50 ft

Air Temp: 50 F

Flow: 700 gpm

Water Temp: 50 F

Stripper: EZ-Tray 72.x - Click for details

Stripper Air Flow: 3800 cfm

Stripper Max Flow: 750 gpm

Water Results

Contaminant	Influent (ppb)	Target (ppb)	4-Tray Results (ppb)	4-Tray % Removal	6-Tray Results (ppb)	6-Tray % Removal
tetrachloroethylene (PERC,PCE)	15	5	< 1	100.000	< 1	100.000

Air Results

Contaminant	4-Tray (ppmV)	4-Tray (lb/hr)	6-Tray (ppmV)	6-Tray (lb/hr)
tetrachloroethylene (PERC,PCE)	0.0517	0.00525	0.0517	0.00526

Notes

PH-> 1-800-624-2026 or 1-734-995-2547, FX-> 1-734-995-1170. E-mail->info@qedenv.com. WEB->www.qedenv.com.

The QED modeler estimates unit performance for the listed contaminants. ***Results assume -***

1. *dissolved-phase contaminant within a water matrix*
2. *clean stripper air*
3. *no surfactants, oil, grease or other immiscible phase(s) in the influent*
4. *unit operated within the given parameters and as instructed in the O&M manual*

Stripper performance shall meet or exceed either the required effluent concentration(s) or effluent estimates, whichever is greater, for the conditions supplied and assumes the influent concentrations of each contaminant are less than 25% solubility in water. QED makes no claim of the model's accuracy beyond the 25% solubility in water limit.

Contact Us

Fill out your contact and project information and click Send to have a QED Treatment *application specialist contact you.*

Name -	Crystal		
Company -	Company		
Phone -	Phone	**Fax -**	Fax
e-mail -	celeste.foster@aecom.com	**Project -**	Off

Application Notes

Send Reset

Save Data

Use the following URL to reconstruct your data form for future remodeling with changes. This URL can be saved in any text file for record keeping and later retrieval. This run's URL:

```
http://64.9.214.199/cgi-bin/remodel.pl?
u=e&tw=50&ta=50&f=700&a=50&s=72.x&n=Cryst&e=celeste.foster@aecom.com&
p=Off&c=182,15;
```

VANGUARD®

Delta Cooling Towers, Inc.
41 Pine Street
Rockaway, New Jersey 07866-0315
Telephone 973-586-2201x116
Fax 973-586-2243
Email: sales@deltacooling.com
Web Address: www.deltacooling.com

Delta Cooling Towers

October 28, 2010

Claire Hunt
claire.hunt@aecom.com

AECOM
100 Red Schoolhouse Road, Suite B-1
Chestnut Ridge , NY 10977-6715
T 845.425.4980 x21 F 845.425.4989
www.aecom.com

Subject: Delta Project # B10-056

Dear Ms. Hunt,

Thank you for the opportunity to submit this Delta Air Stripper proposal for your consideration. In response to your request, Delta recommends the following equipment for this application.

THIS SCOPE IS TYPICAL FOR ALL 9 OPTIONS. IT IS BASED ON OPTION#1 BUT CAN BE APPLIED TO ALL OTHER 8…

Option #1 - Design Basis - (1) Tower at 200gpm per Tower @ 50°F

Design Contaminant	Required Removal Efficiency	Calculated Removal Efficiency
PCE	99.3%	99.3%+

Packed Tower Air Stripping System

Delta recommends One (1) of our Vanguard® Model ∆S3-250DF air strippers for the subject application. The stripper is a 36” diameter Fiberglass column with 25’-0” of DeltaPAK® Structured Packing, shop installed prior to shipment. The tower shell will be fabricated from NSF Approved FRP and will include the necessary wall re-distribution rings and shell body flanges.

NOTE: All internals are pre-installed by Delta Prior to Shipment.

The other items included in Delta Cooling Towers, Inc.’s scope of supply for this project are (per tower):

- The tower will include One (1) 1.0hp TEFC 230/460/3/60 blower/motor assembly designed for 1,070cfm @ 3.5”w.c.
- The blower will be supplied with the intake filter, inlet louver, air flow

measuring station, blower inlet and outlet flexible connections, and ductwork from the blower to the tower. All ductwork material is Aluminum.

- The tower column will be provided with the flanges, nozzles, connections and manways.
- The tower will also be supplied with the required internals; FRP packing support plates, PVC mist eliminators, and PVC / Stainless Steel inlet distribution systems.
- A 3.5” Schedule 80 PVC influent pipe terminating at a flange approximately 5’-0” above the base of the stripper, and a 4” effluent flanged end FRP nozzle connection (side discharge).
- Blower Pressure Switch.
- Filter housing and packing bed differential pressure gauges
- Basic NEMA 3R Control Panel
- Design of the tower anchor bolts is by Delta Cooling Towers, Inc., the supply and installation of the bolts required are by others.
- All the necessary drawings, submittals for approval and O&M manuals.

The following items are specifically **excluded** for this proposal:

- Offloading or installation labor.
- Insulation Materials of any Type.
- Anchor Bolts.
- Controls or Instrumentation other than specifically listed above.
- Any and all taxes.

The total net price for the One (1) FRP air stripping tower is $(See Spreadsheet), FOB Philippi, W.V., Freight PP&A. Shipment can be made approximately 10 weeks after receipt of “Approved” submittals and authorization to proceed with fabrication. Please allow 2 weeks for preparation of submittals. Price is exclusive of any and all taxes.

Please feel free to contact the undersigned with any questions or comments. Thank you for your interest in Delta and its products, and for the opportunity to be of service.

Sincerely,

Joseph B. Homza, Jr.

Joseph B. Homza, Jr.
Vice President – Municipal Products Division

AECOM Budget Project
Delta Project Number B10-056
10/28/2010

Site Name	Crystal On-Site A	Crystal On-Site B	Crystal On-Site C
Flow Rate (GPM)	500	1000	5000
Temperature (°F)	50	50	50
PCE Removal Efficiency Required	98.60%	98.60%	98.60%
PCE Removal Efficiency Calculated	98.6%+	98.6%+	98.6%+
Tower Model	S4.5-230DF	S7-210DF	S10-220DF
Number of Towers	1	1	2
Diameter	54"	84"	120"
Packing Depth	23'-0"	21'-0"	22'-0"
Blower HP	2	5	10
Blower Air Flow (CFM)	2,675	5,350	13,670
Inlet Pipe Size	6"	8"	12"
Outlet Pipe Size	8"	10"	14"
NEMA 3RControl Panel Included	Yes	Yes	Yes
Pumping Included	No	No	No
Freight	PP&A	PP&A	PP&A
			(each)
BUDGET PRICE	$75,000	$100,000	$150,000

Delta Cooling Towers, Inc.

41 Pine Street · P.O. Box 315 · Rockaway, NJ 07866-0315
Phone: 973.586.2201 · Fax: 973.586.2243
Website: http://www.deltacooling.com

Delta-Pak® Structured Packing.

The PVC **Delta-Pak**® structured packing is a proprietary product, which offers unusually low air static pressure losses and provides high mass transfer efficiency.

The honeycomb-like construction allows for high air velocities for applications that demand it, and defers water loading "flooding points" well beyond typical maximum levels of random type packings.

Delta-Pak® structured packing is installed in homogeneous circular layers of nominal 12" and 6" high layers. The packing layers only weight about 2 lb/cu. ft. and can be easily handled.

Delta-Pak® structured packing can be cleaned chemically, as long as the limits of PVC corrosion and chemical resistance is respected.

If replacement of **Delta-Pak**® packing becomes necessary, the layers can be removed through the top of the air stripper column. The water distribution system can be removed to allow for packing removal. When the air stripper column is supplied as flanged sections, each packed section can be disassembled and lowered for easy access at grade level. The packing layers can be compressed in the radial direction if tight clearances are encountered, and will "spring back" to its original shape.

Do not step directly on the packing surface. Crushing of the edges of the PVC corrugations will inhibit proper air flow and water distribution, and as a result reduce performance.

If it is necessary to stand on the packing surface use a piece of plywood or similar protection to distribute weight over a greater surface. Maximum weight distribution is 80 lbs/sq. ft.

Do not stand on any packing inside a stripping tower unless it is absolutely necessary and unless proper judgment is exercised regarding the supporting capability of the packing.

Delta Cooling Towers, Inc.

41 Pine Street · P.O. Box 315 · Rockaway, NJ 07866-0315
Phone: 973.586.2201 · Fax: 973.586.2243
Website: http://www.deltacooling.com

Packing. **Delta-Pak**®, used in all standard stripper models, is a high performance structured packing constructed of Type 1 PVC material protected against UV degradation.

Applicable data below is for air - water atmospheric system:

Surface area:	90 sq. ft./cu.ft.
Void space:	Higher than 98%
Open cross-section:	Higher than 98%
Maximum air flow before flooding, at 20 gpm/sq.ft.:	750 scfm/sq.ft. or higher
Static pressure loss at 20 gpm/sq.ft. and 500 scfm/ sq.ft. air flow:	0.10 in. W.C./ft. or lower
Orientation of corrugation:	Vertical ("see - through")
Nominal corrugation size:	Approx. 3/4 in.
"Channelling" characteristics:	No channeling occurs. Packing construction prevents any radial transfer of mass, due to its spirally wound configuration. Transfer in tangential direction is negligible. No redistribution devices are required.
"Clogging" and "fouling" characteristics:	The absence of any horizontally orientated surfaces reduces accumulation of precipitates and deposition of suspended solids. Most solids including precipitates pass freely through vertical corrugations.
Standard packing layer heights:	12.6 in. and 6.3 in.

Delta Cooling Towers, Inc.

41 Pine Street · P.O. Box 315 · Rockaway, NJ 07866-0315
Phone: 973.586.2201 · Fax: 973.586.2243
Website: http://www.deltacooling.com

DELTA-PAK® STRUCTURED PACKING BENEFITS

HIGH IRON OR CALCIUM CONTENT

Concentrations of dissolved iron in ground water (in excess of 2 mg/l) has the potential to foul process equipment. High iron content water will combine with dissolved oxygen and precipitate, causing pumps, infiltration galleries, feed lines and packing media to foul.

Precipitation occurs primarily at the nozzle or inlet distribution area of an air stripper, where water mixes with the counter flowing air stream. Iron and calcium precipitate accumulates and hardens on all surfaces of packing. This precipitate will subsequently need to be removed, which is most effectively and economically removed in place. When properly cleaned, the particulate which sloughs off upper sections of random packings and may tend to "hang up" at lower levels of the packing bed. This accumulation, if not managed, can lead towards performance failure, media failure or even worse tower structural failure.

Delta-Pak® structured packing, since it does not have horizontal or angled surfaces, resists iron precipitate accumulation and therefore will operate efficiently for much longer periods between requiring chemical cleaning. In past applications **Delta-Pak**® structured packing has successfully performed four to six times longer than random packing it has replaced before having to be cleaned. The particulate which sloughs off the packing will flush straight through the media to the sump.

Delta-Pak® structured packing is recommended for applications where high iron or calcium levels are present in the process flow. Although the degree of fouling and frequency of required cleaning is site specific, it is generally recommended that
Delta-Pak® structured packing be used for iron or calcium levels above 2 mg/l.

DEAN BENNETT SUPPLY COMPANY

QUOTE

1770 East 69th Avenue Denver. CO 80229-7327
Phone (303) 286-1500 FAX: (303) 286-0001
Website: www.deanbennett.com E-mail: pumpsdbs@aol.com
Nation Wide Toll Free (800) 621-4291

Quote	0004646
Date	10/29/2010
Page	1

Bill To:

JOHN CROFT'S QUOTATIONS
PLEASE ASK FOR JOHN CROFT &
REFER TO THIS QUOTE NUMBER
WHEN PLACING YOUR ORDER.

Ship To:

AECOM/ CLAIRE HUNT
845-425-4980
WHEN PLACING YOUR ORDER.

Purchase Order No.	Customer ID	Salesperson ID	Shipping Method	Payment Terms	Req Ship Date	Master No.
AECOM/ CLAIRE HUNT	80229JOHNCRO	JOHN	TRUCK LINE	PREPAID	0/0/0000	40,187

Quantity	Item Number	Description	UOM	Unit Price	Ext. Price
1	4F85S50	85 gpm Pump End Assembly for 5 hp	Each	$1,112.00	$1,112.00
1	137456	5 hp 230 volt 3-wire Franklin Motor	Each	$1,080.00	$1,080.00
1	135269	5 hp 230 volt Delux Control Box w/ contactor	Each	$294.00	$294.00
1	20M20FBCV	2" Male x 2" Female Brass Check Valve	Each	$55.95	$55.95

FIGURED AT 30 PSI 85' DEEP STATIC 46' 100 GPM
RECOVERY. THIS IS FOR WELL # MW-2D

Subtotal	$2,541.95
Misc	$0.00
Tax	$0.00
Freight	$0.00
Trade Discount	$0.00
Total	$2,541.95

DEAN BENNETT SUPPLY COMPANY

QUOTE

1770 East 69th Avenue Denver. CO 80229-7327
Phone (303) 286-1500 FAX: (303) 286-0001
Website: www.deanbennett.com E-mail: pumpsdbs@aol.com
Nation Wide Toll Free (800) 621-4291

Quote	0004647
Date	10/29/2010
Page	1

Bill To:

JOHN CROFT'S QUOTATIONS
PLEASE ASK FOR JOHN CROFT &
REFER TO THIS QUOTE NUMBER
WHEN PLACING YOUR ORDER.

Ship To:

JOHN CROFT'S QUOTATIONS
AECOM/CLAIRE HUNT
845-425-4980
WHEN PLACING YOUR ORDER.

Purchase Order No.	Customer ID	Salesperson ID	Shipping Method	Payment Terms	Req Ship Date	Master No.
AECOM/CLAIRE HUNT	80229JOHNCRO	JOHN	TRUCK LINE	PREPAID	0/0/0000	40,188

Quantity	Item Number	Description	UOM	Unit Price	Ext. Price
1	LINE	Line 500S15HP86 PUMP END ONLY. ALL STAINLESS STEEL	Each	$2,099.00	$2,099.00
1	126555	15HP 230Volt Three Phase Motor	Each	$2,015.00	$2,015.00
1	40DICV	4" Ductile Iron Check Valve for Deep Settings	Each	$433.00	$433.00

WILL NEED MIN. 8" ID CASING. 50' DEEP STATIC 14'
500 GPM RECOVERY

Subtotal	$4,547.00
Misc	$0.00
Tax	$0.00
Freight	$0.00
Trade Discount	$0.00
Total	$4,547.00

Site Management Plans	$20,000
Periodic Review Reports	$15,000

Groundwater Sampling Event					$23,706
Items	U/M	Qty	Unit Cost	Cost	
Field Effort	hrs	56	100	$5,600	
Documentation	hrs	100	100	$10,000	
Van rental	day	3	150	$450	
Equipment rental	ls	1	$2,400	$2,400	
Analytical Costs	ls	1	$2,636	$2,636	
Travel & Incidental expenses	ls	1	$600	$600	
GW Disposal	ls	1	$2,020	$2,020	

Notes:

Low flow sampling of 6 wells

6 for voc analyses, 3 for MNA parameters

Three wells sampled per day, 2 day event

2 people, 10 hour days inc. travel

Deed Restriction					$25,000
Items	U/M	Qty	Unit Cost	Cost	
Field Effort	hrs	250	100	$25,000	

Ex Situ Installation

Extraction and Injection Well Installation					$69,342
and Connection to Storm Sewer					
Items	U/M	Qty	Unit Cost	Cost	
Pre-Design Study	hrs	200	$100	$20,000	
Mob/Demob	ls	1	$10,000	$10,000	
Utility Clearance	ls	1	$1,800	$1,800	
2 Extraction wells					
Well Drilling	ft	80	$30	$2,400	
Screen	ft	40	$30	$1,200	
Riser Pipe	ft	40	$50	$2,000	
box	ea	2	$300	$600	
Pump Installation	hrs	16	$155	$2,480	
Pumps	ea	2	$5,582	$11,164	
2 Injection wells					
Well Drilling	ft	60	$50	$3,000	
Screen	ft	40	$90	$3,600	
Riser Pipe	ft	20	$50	$1,000	
box	ea	2	$300	$600	
Standby	hrs	8	$155	$1,240	
Soil Disposal Costs					
Lab Testing	ls	1	$1,000	$1,000	
Disposal of 55 gal drums	drum	50	$73	$3,650	
QA/QC Fee	ls	1	$40	$40	
Manifest Prep Fee	ls	1	$50	$50	
Label Prep Fee	ls	1	$425	$425	
Reg. Admin Fee	ls	1	$336	$336	
Transporation	ls	1	$1,694	$1,694	
Demurrage	ls	1	$450	$450	
Tax (8.625%)	% total	$6,645	$0.08625	$573	
NJ Recycling Tax	ls	1	$40	$40	
Contractors for installation of piping/electrical					$72,160
to treatment and connection to stormwater basin					
Plumber Certified in Town	hrs	24	$200	$4,800	
Electrician Certified in Town	hrs	16	$200	$3,200	
Contractor	hrs	120	$300	$36,000	
Backhoe	day	2	$1,500	$3,000	
Mob/Demob	ls	1	$5,000	$5,000	
Materials	%	8%	$52,000	$4,160	
Road Opening Permits	ls	1	$1,000	$1,000	
SPDES permit compliance	hrs	150	$100	$15,000	
Treatment System					$100,919
Delta Cooling Towers Estimate					
System	ls	1	$75,000	$75,000	
Freight	ls	1	$10,000	$10,000	

Ex Situ Installation

Installation& Startup	hrs	72	$100	$7,200
Materials	%	2%	$75,000	$1,500
Tax	%	8.625%	$83,700	$7,219

Quote from Dean Bennett					$5,582
Items	U/M	Qty	Unit Cost	Cost	
Pump	ea	1	$2,541	$2,541	
Tax	%	8.625%	$2,541	$219	
Shipping	ls	1	$500	$500	

In Situ Installation

Pilot Study					$20,000
Items	U/M	Qty	Unit Cost	Cost	
Pilot Study	ls	1	$20,000	$20,000	
Drilling					$132,484
Items	U/M	Qty	Unit Cost	Cost	
Utility Clearance	ls	1	$1,800	$1,800	
Mob/demob	ls	1	$2,000	$2,000	
Day Rate	day	35	$3,200	$112,000	
In excess of 8hr day	day	4	$185	$740	
Pressure Washer	day	35	$155	$5,425	
Tax				$10,519	
Chemicals					$75,189
Items	U/M	Qty	Unit Cost	Cost	
Source area	points	20			
	lbs/ft	16			
	lf	25			
ChemOx	ls	8000	$2.05	$16,400	
Barrier	points	49			
	lbs/ft	16			
	lf	30			
ChemOx	ls	23520	$2.05	$48,216	
Tax				$5,573	
Shipping				$5,000	
Notes:					
Drilling Injections / day		2			