FORMER QUICK AND CLEAN CLEANERS
Site # 130198

Feasibility Study
FINAL

PREPARED FOR:

380 ROCKAWAY TURNPIKE REALTY CORPORATION
36 LAWRENCE AVENUE
LAWRENCE, NEW YORK 11559

NEW YORK STATE DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

PREPARED BY:

JOHN V. SODERBERG P.E
PO BOX 265
STONY BROOK, N EW YORK

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Professional Engineer Certification

DER-10 Section 1.5(b) 2

I, John V. Soderberg, PE, certify that I am currently a NYS registered professional engineer, as defined in 6 NYCRR Part 375, and that this Remedial Design Document was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10) and that all activities were performed in full accordance with the DER-approved work plan and any DER-approved modifications.

John V. Soderberg P.E

Signature:

License number: 049975

Date: November 18, 2016

Seal: STATE OF NEW YORK JOHN V. SODERBERG 49975 LICENSED PROFESSIONAL ENGINEER

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1.0 INTRODUCTION

The following document is a Feasibility Study (FS) prepared by John V. Soderberg P.E (JVS) on behalf of 380 Rockaway Turnpike Corporation located at 380 Rockaway Turnpike, Cedarhurst, Nassau County, New York.

The FS has been developed to evaluate options for a remedial action in accordance with CERCLA [40 CFR 300.430(e)]. The FS emphasizes data analysis and is generally performed using data gathered during the Remedial Investigation (RI). The main goal of the FS is to identify the remedial program, define the nature and extent of contamination to be addressed by the alternatives developed, identify the Remedial Action Objectives (RAOs) for the site, develop remedial action alternatives and undertake an initial screening and detailed analysis of the alternatives.

1.1 Site Location and Description

The address for the subject property is 380 Rockaway Turnpike, Cedarhurst, NY. The subject property is designated as Section 39, Block 344, Lots 216 and 220 by the Nassau County Department of Assessment. The subject property is located within the Incorporated Village of Cedarhurst, Town of Hempstead, Nassau County, NY as shown in Figure-1. The lot has 123 feet of frontage on Rockaway Turnpike and is approximately 100 feet deep for a combined area of 0.318 acres (13,853 ft2). Figure-2.

The subject site is developed with a 3,984ft^2 1-story masonry building, built in 1962 for commercial (retail) use. The site was recently renovated in order to occupy a walk-in medical facility. No structural renovations were made to the buildings foundation or frame work.

The elevation of the property ranges from approximately 10 to 13 feet above National Geodetic Vertical Datum (NGVD). The topography in the vicinity of the site generally slopes from southeast to northwest. The depth to groundwater beneath the site, as determined from field measurements, is approximately 4.5 to 5.0 feet below grade surface (bgs). Groundwater flow has been determined to be northwest based on the field survey conducted and the previously conducted investigation data indicating a northwesterly groundwater flow due to the nature of the findings northwest of the Site and/or source area.

The area surrounding the Site consists of retail “strip stores” and service stations along the east side of Rockaway Turnpike with single-family residential homes located adjacent to the east. Adjacent properties to the north include a former Cumberland Farms Service Station (CFSS) and an active Shell station. Adjacent properties to the south include a Sunoco, Getty and Gulf service stations. In total the subject property is flanked north and south by four (4) active and one (1) former service station. The west side of Rockaway Turnpike is characterized by larger shopping centers with industrial buildings/warehouses, major oil storage facilities (MOSF) and the Town of Hempstead incinerator plant adjacent to the west.

1.2 Site History

The Site is the location of the former Quick and Clean Cleaners, an on-site dry-cleaning service which operated on the premises from at least 1980 to 1991. Investigations performed by the Nassau County Department of Health (NCDOH) in 1980 and 1991 found that tetrachloroethene (PCE) had been released at the Site in discharge water and/or condensate (vapors).

The Site was assigned a “P” (potential) listing on the Inactive Hazardous Waste Site Registry by the New York Department of Environmental Conservation (NYSDEC) in 2009. The NYSDEC conducted a site characterization in July-August 2001 (SCR 8/10) and upgraded the registry listing to a Class 2 site in August 2011. The environmental history of the subject lots was summarized in the SCR dated August 2010 as prepared by Environmental Assessment and Remediation (EAR) under contract to the NYSDEC. This summary consisted of a chronology of events based solely on NCDOH files. According to the SCR the NCDOH identified approximate PCE concentrations of 67,000 ppb in a sample of “industrial wastewater discharge” at the Site on 3/26/80. In 1991 NCDOH reported PCE concentrations of 1.3 million ug/kg in shallow soil (<2 ft) adjacent to a vapor discharge pipe in the rear of the building. This soil was successfully removed in 1992 by the operator under NCDOH oversight and the case was closed by NCDOH on 3/30/92. In 2009 the NYSDEC classified the site with a “P” designation for potential listing on the Inactive Hazardous Waste Site Registry.

1.3 Site Geology/Hydrogeolgy

According to boring logs included in the SCR, subsurface materials at the site consist of medium to coarse sand and gravel for the upper 10 feet followed by fine to medium sand to 18 feet below grade. A 1 to 2 ft layer of silt and clay was reported at some locations. Soils deeper than 20 feet were not characterized although silt and clay zones were suspected at 34 feet to 52 feet based on limited groundwater recharge and clogging of the groundwater sampling tools with silt and clay. The depth to groundwater was not measured at the site during the site characterization although it is reported in the drill logs at a depth of 11 feet below the surface. However, this is inconsistent with water level measurements made in monitoring wells at the adjacent property to the north that report the depth to water ranging from 3.61 to 4.89 feet. The groundwater flow direction has been determined at the site to be west northwest.

1.4 Summary of Remedial Investigation and Exposure Assessment

Chlorinated impacts tetrachloroethene (PCE) , trichloroethene (TCE), 1, 2 dichloroethene (DCE) and vinyl chloride (VC) in groundwater were identified during the site characterization phase at on-site and off-site locations. PCE contamination extended to the northwest of the site and was discovered to a depth of approximately 50' below grade surface (bgs). Multiple transformation products were also discovered off-site including TCE, 1, 2 DCE and VC. The highest levels of contamination were found off-site along the western side of Rockaway Turnpike with PCE concentrations of 20,400 ppb at 30-32' and 4,620 ppb at 50-52'. Based upon the data generated during the site characterization phase recommendations were made that included: further vertical and horizontal delineation of chlorinated contamination, vertically on-site and laterally and vertically off-site.

A Remedial Investigation (RI) was performed in order to delineate the nature and extent of contamination on-site and off-site. A series of multi-level groundwater sampling locations were selected in order to define the vertical and lateral extent of contamination and to complete the conceptual site model (CSM). On-site sampling was conducted along the eastern property boundary (GW-3, 4 and 5) at multiple depths, but no significant concentrations were detected with the highest constituent 1,2 DCE detected at 87 ppb from 30-32'. GW-2 was collected off the southwest corner of the site building in order to define the west extent of the plume and GW-1 was sampled from the surface of the water table to 70-72' bgs in ten foot increments. Previous locations (EP-15 and EP-18) that were not fully defined during the site characterization were re-evaluated in order to delineate contamination vertically. Former site characterization locations EP-15 and EP-18 were sampled to a depth of 60' bgs and contamination was successfully delineated to acceptable levels. Contamination was also delineated horizontally, to the northwest of the site, where four (4) borings were conducted with multiple sampling depths. Theses samples, collected northwest of the Chase Bank, indicated that PCE contamination was detected at 53 ppb in the 20-30' range at the GW-7 location, but deeper sampling depths were all non-detect at the deeper depths. The findings from the RI stage were successful in defining the full nature and extent of contamination emanating from the site.

1.5 Conceptual Site Model (CSM)

A CSM has been developed for the site depicting the nature and extent of groundwater contamination emanating from the site including chlorinated VOC's PCE, TCE, DCE and VC. The CSM was initially developed during site characterization phase and completed during the RI phase. During the RI phase of investigation multiple sampling locations were proposed in order to fill data gaps in the CSM developed during the site characterization and fully characterize the vertical and horizontal extent of the plume. The completed CSM shows that successful plume delineation was achieved vertically and horizontally to the east, west and north of the site. The results from the RI and the final CSM determined the need for the development of potential remedies to treat on-site and off-site groundwater contamination in order to reduce the potential for exposure to such contaminants.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section summarizes the identification and screening of technologies based on the site characterization and RI findings.

2.1 Introduction

The process used to identify and screen technologies is based on the following: site characterization data, RI data, nature and extent of contamination, potential contaminant fate and transport and the exposure assessment results. The information gathered from the above mentioned items will be used to select the most appropriate and cost effective method of treatment with regard to the overall protection of the public's health and the environment.

2.2 Remedial Action Objectives (RAOs)

Based upon contamination discovered on and off-site above regulatory standards for groundwater the following Generic Remedial Action Objectives (RAOs) will apply during the remedial phase in order to protect the environment and the interest of the public's health:

- prevent ingestion of groundwater with contaminant levels exceeding drinking water standards;
- prevent contact with, or inhalation of volatiles, from contaminated groundwater;
- restore groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable (Division of Water TOGS 1.1.1)
- remove the source of ground or surface water contamination

Based upon the potential for Soil Vapor Intrusion (SVI) due to groundwater contamination present on and off-site, the following RAOs apply for the protection of the environment and the interest of the public's health:

- mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at a site (Guidance for Evaluating Soil Vapor Intrusion - October 2006)

An Interim Remedial Measure (IRM) to address vapor intrusion in the form of a Sub-slab

Depressurization System (SSDS) in order to protect the health interest of on-site workers has been developed and approved by the Department on July 23, 2015. An IRM Construction Completion Report (CCR) was issued to the Department during February of 2016.

2.2.1 Media of Concern

The RI identified groundwater impacts on-site and off-site as the primary media of concern. Chlorinated groundwater contamination extends approximately 450' northwest of the site to depths of 12' (top of water table) to 54' bgs. Soil gas contamination resulting from the volatilization of groundwater impacts is also a media of concern as potential exposure to these vapors via soil vapor intrusion has the potential to impact nearby receptors down gradient from the site and in the vicinity of the plume.

2.2.2 Chemicals of Concern (COCs)

Investigation of sub-surface groundwater impacts documented during the RI identified the following constituents as the primary COCs.

COCs
- tetrachloroethene (PCE)
- trichloroethene (TCE)
- cis 1, 2-dichloroethene (cis DCE)
- trans 1, 2-dichloroethene (trans DCE)
- vinyl chloride (VC)

A detailed examination of these five (5) volatile organic compounds (VOCs) identified during the site characterization and RI activities determined that chlorinated VOCs emanating from the site pose the greatest human health risks due to the potential for soil vapor intrusion within neighboring structures surrounding the site. Based on these findings, inhalation exposure remains as a potential theat. Despite the fact that groundwater is not intended for potable use and discharging of groundwater to surface water is not intended or anticipated based on the geographical location of the site, the potential for these exposure pathways still exist.

2.2.3 RAOs and TOGS Standards

The main objective of the remedy is to achieve, to the extent practical, drinking water criteria

(TOGS) for on-site and off-site groundwater. The following TOGS standards for groundwater apply to the listed COCs: Tetrachloroethene (PCE) *5 ppb*, trichloroethene *5 ppb*, cis 1, 2 DCE *5 ppb*, trans 1, 2 DCE *5 ppb* and vinyl chloride (VC) *2 ppb*.

2.3 General Response Actions (GRAs)

The RAOs, in conjunction with the results of the site characterization and RI, establish the basis for identifying GRAs to remediate groundwater water on-site and off-site. The GRAs are broad categories of actions such as treatment, containment and/or combinations of the various categories. Specific categories of GRAs identified for contamination within groundwater at and down gradient of the site include the following:

- No Further Action
- Monitored Natural Attenuation (MNA)
- Institutional Controls (I.Cs)
- Engineering Controls (E.Cs)
- Ex-situ Treatment
- In-situ Treatment

The table below lists the GRAs and Identification of Potential Technologies for Groundwater Remediation at the site.

GENERAL RESPONSE ACTION/TECHNOLOGY	DESCRIPTION OF POTENTIAL TECHNOLOGY
No Further Action None	No further action taken to further reduce risk, including monitoring of groundwater and continued operation of the SSDS.
Monitored Natural Attenuation (MNA) MNA	Continued monitoring and sampling of groundwater and water quality parameters.

<u>Institutional Actions</u> Institutional Controls	Through agreement or other legal mechanisms, would restrict the use or access to groundwater on-site and off-site. Applicable water supply within the study area is currently provided via New York American Water Company (NYAWC).
<u>Engineering Actions</u> Engineering Controls	Such as soil vapor extraction (SVE) systems which provide engineering controls (i.e. vacuum recovery of vapor) mainly in conjunction with air sparging for groundwater treatment.
<u>Ex-situ Treatment</u> Air Stripping Carbon Adsorption	Air Stripping and Carbon Adsorption via groundwater pumping to treat groundwater ex-situ subsequently returning/disposing of polished water to the aquifer.

<u>In-situ Treatment</u> Air Sparging	Air Sparging is an in-situ air stripping system that incorporates the injection of air into the saturated zone below contaminated areas. Contaminants dissolved in air and sorbed to soil particles partition into the air phase. The contaminants are then transported in the gas phase to the vadose zone where they can be extracted.
Enhanced Biodegradation	A technology that involves the injection or application of microorganisms, nutrients, and oxygen or other electron acceptors into the groundwater using fixed or temporary injection wells.
In-situ Chemical Oxidation (ISCO)	In situ chemical oxidation (ISCO) involves the injection or direct mixing of reactive chemical oxidants into groundwater and soil for the primary purpose of rapid and complete contaminant destruction.

3.0 ALTERNATIVES ANALYSIS

The remedy selection evaluation is based on the criterion set fort in DER-10, section 4.2 (b-j) in order to determine the ability of each alternative or remedy to protect public health and the environment. Analysis of each alternative will include how each will eliminate, reduce or control through removal, treatment, containment, engineering/institutional controls, any existing or potential human exposures or environmental impacts identified by the RI.

The detailed analysis of alternatives presented in this chapter consists of information needed to allow for the selection of the most suitable remedy. This approach to analyzing alternatives is designed to provide sufficient information in order to compare alternatives adequately and select an appropriate remedy for the site. The following alternatives will be evaluated with regard to selecting the most practicable remedy for the site: No Further Action, Monitored Natural Attenuation (MNA), Institutional and Engineering Controls (ICs/ECs), Ex-situ Treatment and In-situ Treatment.

The anticipated volume of media to be addressed includes both on-site and off-site groundwater contamination consisting of the following COC's: tetrachloroethylene (PCE), trichloroethylene (TCE), 1,2 dichloroethylene (DCE total) and vinyl chloride (VC). Estimating from the CSM's completed as part of the RI, the total volume of PCE and TCE groundwater contamination intended to be remediated is 16,650 m^3 or 1.67 x 10^7 liters of actual contaminated liquid. TCE contamination basically alines with PCE contamination with regard to estimating the volumetric space to be remediated, although TCE concentration levels were only found as high as approximately >500 ppb where PCE levels were greater than >20,000 ppb. A majority of the PCE and TCE contamination to be addressed is located off-site along the west side of Rockaway turnpike, west-northwest.

The highest concentrations of DCE were discovered on-site with a majority of the DCE emanating from the point source area at the southeast side of the building. DCE concentrations as high as >3,500 ppb were detected on-site and VC contamination collected near the northwest corner of the property detected concentrations as high as >6,500 ppb. The estimated total volume of DCE and VC contamination to be remediated is approximately 14,270 m^3 or 1.43 x 10^7 liters of liquid contamination.

Aside from the no further action alterative discussed in section 3.1, each response action possesses the ability to eliminate, reduce or control potential human exposures and/or environmental impacts by reducing contaminant levels to meet the RAOs. The remediation of contamination to comply with RAOs would subsequently reduce the toxicity of groundwater, preventing mobilization of contaminated media in groundwater and also reduce the mobilization of soil vapor contamination. Short-term impacts to the environment and the potential for human exposures during construction of each remedy would not be an issue other than remedial measures that require ground intrusive activities (i.e., well installations). Although ground intrusive activities associated with well installations could possibly cause temporary exposure concerns, a community air monitoring plan (CAMP) would be deployed in order to monitor the potential for exposures.

3.1 No Further Action

No further action of groundwater serves as a baseline against which the performance of other remedial alternatives can be compared. At this time, given the current conditions of the groundwater on-site and off-site, no further action is not a feasible approach to a remedy. Due to the nature and extent of groundwater contamination discovered throughout the study area and the potential for exposure to nearby receptors via the vapor inhalation pathway, this remedy does not attribute to the protection of the public's health or the environment. Therefore, no further action is not a recommended alternative for remediation.

Annual Costs:.. . . . . *$0*
Capital Costs:. *$0*

3.2 Monitored Natural Attenuation (MNA)

Monitored Natural Attenuation (MNA) relies on the natural attenuation processes to achieve site specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The MNS process that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater media. These in-situ natural processes include: biodegradation, dispersion, dilution, sorption, volatilization, radioactive decay, biological stabilization, transformation or destruction of contaminants.

Although significant breakdown of PCE and daughter breakdown products has been observed at the site without any human intervention, the time and cost for MNA in the long term is not comparable given the significant levels of contamination detected in groundwater. Given the elevated levels of chlorinated contamination discovered on and off-site and the risk for human exposure to volatilization of these contaminants, MNA is not a recommended alternative for remediation. MNE annual and capital costs for up to ten (10) years are provided below.

Annual Costs:.. . . . . *$50,000*
Capital Costs:. *$230,000*

3.3 Engineering (ECs)/Institutional (ICs) Actions

Engineering Controls (ECs) include any physical barrier or method employed to actively or passively contain, stabilize, or monitor contamination, restrict the movement of contamination to ensure the long-term effectiveness of a remedial program, or eliminate potential exposure pathways to contamination. Engineering controls include, but are not limited to, pavement, caps, covers, subsurface barriers, vapor barriers, slurry walls, building ventilation systems, fences, access controls, provision of alternative water supplies via connection to an existing public water supply, adding treatment technologies to such water supplies, and installing filtration devices on private water supplies.

ICs are non-physical means of enforcing a restriction on the use of real property that limits human or environmental exposure, restricts the use of groundwater, provides notice to potential owners, operators, or members of the public, or prevents actions that would interfere with the effectiveness of a remedial program or with the effectiveness and/or integrity of site management activities at or pertaining to a site.

Currently, an active sub-slab depressurization system (SSDS) is operating to ensure the protection of the building's occupants. The EC associated with the system is a 110 volt Radonaway™ fan, GP501 series, responsible for removing harmful vapors emanating from the sub-surface soil and/or groundwater.

The SSDS has been designed with two (2) five (5') lengths of screened piping, wrapped in filter fabric and installed approximately 1' below the slab in order to remove sub-slab vapors from underneath the building's slab on grade foundation. Solid PVC riser pipe finishes the system to grade and continues to the roof where vapors are exhausted into the atmosphere. Operation, maintenance and monitoring (OM&M) of the system includes: quarterly vapor sampling (of the in-line sample ports and stack exhaust) to ensure that the system is adequately removing VOC-impacted soil vapors. During routine maintenance the following activities are performed:

- A visual inspection of the complete system (blower vent fan, piping, warning device, etc.);
- Identification and repair of leaks; and
- Inspection of the exhaust or discharge point to verify no new air intakes have been located nearby

As necessary, preventive maintenance (e.g., replacing vent fans), repairs and/or adjustments will be made to the system to ensure its continued effectiveness at mitigating exposures related to soil vapor intrusion. The need for preventive maintenance will depend upon the life expectancy and warranty for the specific part, as well as visual observations over time. The need for repairs and/or adjustments will depend upon the results of a specific activity compared to that obtained when system operations were initiated. If significant changes are made to the system or when the systems performance is unacceptable, the system may need to be redesigned and restarted. In addition to the routine OM&M activities described here, the building's owner and tenants will be given information packages that explain the systems operation, maintenance and monitoring. Therefore, at any time during the systems operation, the building's owner or tenants may check that the system is operating properly. An IC will be established in the form of an environmental easement preventing the removal of the interior concrete floor in order to maintain the operation of the EC and the associated SSD system below the floor.

The site cap/cover is an additional EC at the site in place to prevent exposure to soil vapor contamination and prevent the potential for a soil contact exposure pathway. As part of the environmental easement, an IC will be established to prevent the removal of the site cap/cover. The easement will also include provisions to maintain the concrete floor EC within the building. The following annual and capital costs to maintain the ICs and ECs for up to five (5) years are provided below.

Annual Costs. *$12,000*
Capital Costs. *$60,000*

3.4 Ex-situ Treatment (Pump and Treat)

Pump and Treat technology is a common form of groundwater remediation often associated with treatment technologies such as Air Stripping and Liquid Phase Activated Carbon Adsorption. Contaminated groundwater is pumped from the ground with the use of a submersible pump allowing extracted groundwater to be purified through a series of vessels that contain materials designed to adsorb the contaminants from the groundwater. Groundwater pump and treat technology is often best used where floating petroleum product is observed, due to its ability to alter the hydraulic gradient in the sub-surface. The pumping of groundwater forms a cone of depression at the surface of the aquifer, subsequently drawing the floating product to the recovery well.

Despite the fact that there was no observed floating petroleum observed on groundwater during the site characterization and RI, the nature of the sub-surface in the study area poses the largest issue with regard to proposing this technology as a feasible alternative. A mixture of tight sands, silts and clays resulting in low soil porosity and low permeability in the saturated zone make this a less than desirable approach for remediation of groundwater. This coupled with the fact that much of the contamination observed during the RI phase is located off-site, which raises issues with regard to the housing of ex-situ storage equipment (i.e., air strippers, carbon adsorption vessels). Pump and treat technology often takes many years to obtain clean-up goals and the costs from these efforts (long-term monitoring, maintenance of equipment, permitting, off-site storage access, disposal and discharge) can far exceed many other available technologies. Based upon all these factors, along with the chemicals of concern (DNAPL constituents making them difficult to recover at multiple depths) the Pump and Treat technology is not recommended as an alternative for remediation. The following annual and capital costs are provided for an anticipated five (5) year time frame below:

Annual Costs:. *$122,000*
Capital Costs:. *$731,000*

3.5 In-situ Treatment

In-situ treatment involves chemical or biological methods for reducing contaminant concentrations or bio-availability without first removing the contaminated media (soil or groundwater) of concern. The following in-situ treatment methods will be discussed within the following narrative: in-situ air stripping (air sparging) and Enhanced Bio-degradation.

Air Sparging

Dissolved-phase chlorinated solvents can be effectively removed via air sparging; however, rapid initial rates of contaminant removal are followed by a protracted period of lower removal rates, or a tailing effect. As the air flow rate increases, the rate of contaminant removal also increases, especially during the initial stages of air injection. Increased air injection rates will increase the density of air channel formation, resulting in a larger interfacial mass transfer area through which the dissolved contaminant can partition into the vapor phase. Air sparging can also reduce groundwater flow and subsequent downgradient contaminant migration as the increasing air saturation can reduce the relative hydraulic conductivity (K value). This technology is usually coupled with soil vapor extraction (SVE) in order to remove the soil gas generated in the vadose zone from the resulting influx of air into the contaminated aquifer.

As with the pump and treat technology, the sub-surface lithology and the dynamics of the underlying formation do not appeal to the quality performance of this in-situ method. This as well as the issue of storing large remediation sheds off-site for housing of the necessary remediation equipment (compressors, vacuum blowers, vent scrubs, exhaust vents). Long-term operational costs associated with this technology are also of concern, along with the cost to monitor and maintain the equipment for several years. Initial costs incurred to employ this technology are also an issue, as an extensive multi-level sparge well/monitoring well network would have to be installed on and off-site. Annual and capital costs are listed below for an anticipated five (5) year operational period followed by five (5) years of monitoring. Based upon the above mentioned, the air sparging technology is not recommended as an alternative for remediation.

Annual Costs. $55,000
Capital Costs. $610,000

Enhanced Biodegradation

Biodegradation is the chemical dissolution of materials by bacteria, fungi, or other biological means. This section will cover the alternative of enhanced biological degradation including: the application of microorganisms, nutrients, and/or other electron acceptors into the groundwater using fixed or temporary injection wells. This technology has the ability to reduce exposure to contamination by reducing toxicity, mobility and volume of contamination in turn protecting human health and the environment. Implementing this technology would require a vast monitoring well and injection well network similar to the alternatives discussed below. Given that fact that this remedy would require a pilot study in order to prove the effectiveness of the selected product, actual product cost, extensive monitoring for a period of five (5) years and the potential need for multiple rounds of injections, enhanced biological degradation is not recommended as an alternative for remediation. The following annual and capital costs associated with implementing this technology are listed below.

Annual Costs:. *$25,000*
Capital Costs:. *$190,000*

Analysis of the Use of In-Situ Chemical Oxidation (ISCO)

The following reference document was reviewed to provide information on the range of appropriate in-situ chemical oxidation method (ISCOs): *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater dated June 2001.* Remediation of groundwater contamination using chemical oxidation involves injecting oxidants and other amendments as required directly into the source zone and down gradient plume. The oxidant chemicals react with the contaminant, producing innocuous substances such as carbon dioxide (C02), water (H20), and inorganic chloride. However, the full spectrum of reaction intermediates and products range dramatically. Examples of potential contaminants that are amenable to treatment by ISCO include BTEX (benzene, toluene, ethylbenzene, and xylenes), tetrachloroethylene (PCE), trichloroethylene (TCE), dichloroethylenes, vinyl chloride (VC), MTBE (methyl- tert-butyl-ether), PAH (polyaromatic hydrocarbons) compounds, and many other organic contaminants. ISCO offers several advantages over conventional treatment technologies such as pump and treat. For instance, the technology does not generate large volumes of waste material that must be disposed of and/or treated. ISCO is also implemented over a much shorter time frame. Both of these advantages should result in savings on material, monitoring, and maintenance. The following ISCO technologies are commonly used; a description is provided in addition to the pros and cons for use at the site.

3.5.1 Potassium and Sodium Permanganate

Permanganate is an oxidizing agent with a unique affinity for oxidizing organic compounds containing carbon-carbon double bonds, aldehyde groups or hydroxyl groups. As an electrophile, the permanganate ion is strongly attracted to the electrons in carbon-carbon double bonds found in chlorinated alkenes, borrowing electron density from these bonds to form a bridged, unstable oxygen compound known as a hypomanganate diester. This intermediate product further reacts by a number of mechanisms including hydroxylation, hydrolysis or cleavage. Under normal subsurface pH and temperature conditions, the carbon-carbon double bond of alkenes is broken spontaneously and the unstable intermediates are converted to carbon dioxide through either hydrolysis or further oxidation by the permanganate ion. There are two forms of permanganate, KMnO and NaMnO .

Manganese dioxide (MnO) is a natural mineral already found in the soils in many parts of the country. If the precipitation of manganese dioxide in the soils is excessive, it can reduce the permeability of the soil, thus limiting injection of the aqueous oxidant. The chloride ion (Cl-) released by the oxidation reaction may be converted into chlorine gas (Cl) due to the high-redox conditions. Chlorine gas reacts immediately with groundwater and pore water to form hypochlorous acid (HOCl). This hypochlorous acid may react with methane to form trace concentrations of chloromethanes in the groundwater immediately after treatment. However, this phenomenon is typically short-lived as the subsurface conditions are converted from an anoxic state to an oxidized state.

Given that the work area at the subject property is surrounded by residential uses as well as multiple commercial properties and food preparation establishments, the possibility for the formation of chlorine gas, chloromethanes and other coloration raise potential exposure issues to nearby receptors.

An extensive injection well/monitoring well network as well as a specially designed circulation system to oxidize contaminated groundwater would be required in order to reduce contaminant concentrations. In addition to the high initial costs to design this type of system, ongoing monitoring and maintenance costs associated with maintaining the system and an anticipated five (5) years of monitoring and sampling of the groundwater, along with the potential health issues discussed above, the use of this ISCO is not recommended as a remedial alternative for the site. The annual and capital costs to implement and maintain this remedy are listed below.

Annual Costs: *$35,000*
Capital Costs:. *$230,000*

3.5.2 Hydrogen Peroxide

This process involves free radical generation and direct oxidation with hydrogen peroxide. Hydrogen peroxide, which can be delivered at depth using lance permeation or soil mixing techniques or injected water amendments, is an effective oxidizing agent. However, to achieve the desired contaminant reductions in a reasonable time, a metal catalyst is required. Iron is most commonly used and, when mixed with hydrogen peroxide, the catalyst is known as Fenton's reagent. The terms "Fenton's reagent" and "hydrogen peroxide" are used interchangeably. The process is well documented for producing hydroxyl radicals by the reaction of hydrogen peroxide and ferrous iron (Fe+2). The hydroxyl radicals (OHC) serve as very powerful, effective, and nonspecific oxidizing agents, second only to fluorine in oxidizing power. The Fenton process is relatively fast acting, taking only days or weeks. The contaminants are treated in situ, converted to innocuous and/or natural occurring compounds [e.g. H, O, CO , halide ions]. By acting/reacting upon the contaminant in place, the reagent serves to eliminate the possibility of vertical movement of the contaminant other than that resulting from the act of vertical injection itself, which is often a concern with other remediation technologies. As a side benefit, aerobic biodegradation of contaminants can benefit from the presence of O released, if large quantities of reagent need to be applied. However, the usefulness of Fenton's reagent may be limited by low soil permeability, subsurface heterogeneities, and highly alkaline soils where carbonate ions are free radical (hydroxyl) scavengers. Additionally, there is a potential for a violent exothermic hazard. The installation of an extensive injection/monitoring well network along with several years of continued monitoring and the possibility of multiple injection rounds, coupled with the proximity to residential and commercial uses as well as the possibility for a violent exothermic hazard within injection points, make the use of this ISCO undesirable. Annual and capital costs to implement and maintain this remedy are listed below.

Annual Costs:. *$35,000*
Capital Costs:. *$240,000*

3.5.3 Ozone

Ozone (O_3) is one of the strongest oxidants available for ISCO. It can be delivered via horizontal or vertical wells. Currently, it is most commonly used to remediate PAHs, BTEX, and chlorinated VOCs. Ozone can oxidize organic contaminants in two ways, either with direct oxidation by ozone or by the generation of free radical intermediates. The hydroxyl radicals are non selective oxidizers, which rapidly attack organic contaminants and break down their carbon-to-carbon bonds. Ozone can oxidize compounds such as aromatics and chlorinated alkenes. Ozone must be generated on site, and this eliminates the storage and handling problems associated with other oxidants. Typical application ratios for ozone range from 1 to 10 lb of ozone per 1 lb of contaminant. Given the proximity to residential and commercial uses, generation and handling of ozone for this application is not a desirable alternative for remediation. This is due to the fact that Ozone, at ground level is a very potent respiratory hazard and pollutant. Breathing ozone can trigger a variety of health problems including chest pain, coughing, and throat irritation. It can worsen bronchitis, emphysema, and asthma. Ozone also can reduce lung function and inflame the linings of the lungs.

The installation of an extensive injection/monitoring well network along with several years of continued monitoring and the possibility of multiple injection rounds, coupled with the proximity to residential and commercial uses as well as the possibility for respiratory hazards to nearby receptors, the use of Ozone is not recommended as a remedial alternative. Annual and capitol costs associated with implementing this remedy for a five (5) year period can be seen below.

Annual Costs:. *$40,000*
Capital Costs:. *$300,000*

3.5.4 RegneOx

RegenOx™ is a proprietary in-situ chemical oxidation process using a solid oxidant complex (sodium percarbonate/catalytic formulation) and an activator complex (a composition of ferrous salt embedded in a micro-scale catalyst gel). RegenOx™ with its catalytic system has very high activity, capable of treating a very broad range of soil and groundwater contaminants including both petroleum hydrocarbons and chlorinated solvents. Additionally, RegenOx™ has significant longevity in the subsurface allowing for both the initial contaminant degradation and the continued treatment of contaminants desorbing from the matrix. Most importantly, RegenOx, when handled appropriately, is safe and easy to apply to the contaminated subsurface without the health and safety concerns and lingering environmental issues that have become associated with other chemical oxidation technologies.

RegenOx™ can be added to excavations, soil piles using soil blending equipment and directly to groundwater via injection wells. Once in contact with contaminated media, RegenOx™ produces an effective oxidation reaction, comparable to that of Fenton's Reagent, without a violent exothermic hazard. The most aggressive approach using chemical oxidation is to maximize contact between RegenOx™ and the contaminated media. Please see Attachment-A for case studies relating to the breakdown of chlorinated solvents.

RegenOx has the ability to eliminate and/or reduce potential human exposures and impacts to the environment by degrading chlorinated contamination to safe bio-products (ethene). The elimination of groundwater contamination to applicable standards will reduce the potential for soil vapor intrusion within local businesses and residences. The remedy is expected to conform with the standards and criteria for groundwater set forth in the TOGS ambient groundwater standards document by reducing chlorinated contamination levels to within the standards discussed in section 2.2.3. Evaluating the long-term effectiveness and permanence of the remedy after the implementation of the remedy will be based upon monitoring and sampling results post remedy installation. If contamination will remain on/off-site after the selected remedy has been implemented, the remaining contamination will be assessed as to the impact it will have on human exposures. This assessment will be based upon soil vapor intrusion testing conducted on a yearly basis throughout the study area. If impacts to groundwater are to remain on/off site after completion of the remedy, an institutional control restricting the use of groundwater for potable use will be implemented. The ability of the remedy to reduce toxicity, mobility or the volume of contamination is well documented within the industry. Toxicity levels will be reduced through degradation of PCE and associated daughter breakdown products to non-toxic compounds (i.e. carbon dioxide, ethene). Stabilizing the outer edge of the plume preventing mobility of contamination will be achieved by conducting up gradient injections in order to form a degradation barrier. Reducing the toxicity levels via degradation and preventing further migration of contaminants will eventually lead to an overall reduction in contaminant mass. Short-term impacts resulting from implementing the remedy will include potential exposures to nearby receptors as a result of ground intrusive activity. Individual injection points will each require ground intrusive work, for which a community air monitoring plan (CAMP) will be deployed to monitor up-wind and down-wind conditions in order to monitor and limit exposure to nearby receptors. Technical feasibility including any difficulties associated with construction and the ability to monitor the effectiveness of the remedy will not be an issue. The aspects associated with implementing the construction portion of the remedy include: breakdown and set-up of boring equipment, CAMP set-up, and well installations. None of the aspects listed above pose any anticipated difficulties with regard to implementing the remedy. Monitoring the effectiveness via groundwater sampling from monitoring wells does not pose any additional technical difficulties. Administrative feasibility including the availability of necessary personnel, materials, access for implementation and operating approvals do not pose any foreseen difficulties in the future. The land use criterion, which includes evaluating the current and future use of the site, as it relates to the remedy, is currently categorized for commercial use. Current site use is as a emergency medical facility under the name Urgent-MD Family Urgent Care Center. The future use of the site is intended to remain the same as a medical facility with no plans for re-development. The surrounding area is currently zoned as mixed use with residential housing to the east and retail “strip stores” and service stations along the east side of Rockaway Turnpike. Adjacent properties to the north include a former Cumberland Farms Service Station (CFSS) and an active Shell station. Adjacent properties to the south include a Sunoco, Getty and Gulf service stations. In total the subject property is flanked north and south by four (4) active and one (1) former service station. The west side of Rockaway Turnpike is characterized by larger shopping centers with industrial buildings/warehouses, major oil storage facilities (MOSF) and the Town of Hempstead incinerator plant adjacent to the west. The final use determination for the site, based on the ICs and ECs remaining will be restricted-commercial. No federal or state historical or heritage sites including Native American religious sites are located nearby. No wetlands are in the vicinity of the site with the nearest major body of water located approximately one half of a mile to the north of the site. The site is located on the outskirts of a recognized flood plain as characterized by the Federal Emergency Management Agency (FEMA) with an “X zone” designation, which specifies an area that has a 0.2% chance of an annual flood. Community acceptance will be evaluated after public review of the remedy selection process as part of the final DER selection/approval of the remedy for the site. Public comments relative to these criteria will be considered by the DER after the close of the public comment period. Based on the ability for RegeOx to eliminate and/or reduce potential human exposures and impacts to the environment and given it relatively cost effectiveness, RegenOx is deemed as a suitable remedy for the site. Please see below for the anticipated annual and capital costs to launch this remedy.

Annual:. *$30,000*
Capital:. *$193,500*

4.0 RECOMMENDED REMEDY

The following section provides information on the selected remedy for the site. The selected remedial measure is expected to meet the RAOs established for the site, to the extent feasible, and also reduce the potential for human exposure to contaminated media. Also included within this section is a discussion of the site cover system, treatment remedy shutdown, vapor mitigation, EC’s and IC’s, provisions for a Site Management Plan (SMP), and an Operation, Monitoring and Maintenance Plan (OMM).

4.1 RegenOx®

In order to deliver the solution to the sub-surface, a series of on-site and off-site injections will be proposed throughout the study area. Achieving direct contact between the solution and the contaminated media will require installing a network of temporary injection points with injection intervals from the surface of the water table (10-12') to a depth of approximately 30' bgs. Off-site injections will focus more on the 20-30' zone of contamination as off-site surface water samples did not indicate the presence of shallow contamination due to vertical migration. Temporary injection points affixed with a high pressure activated injection probe will be used to deliver the solution to the sub-surface. The injection points will be bored into the subsurface using a track mounted Geoprobe to the deepest desired depth, subsequently treating each zone of contamination from the deepest to the shallowest zone. Supplemental monitoring wells will be installed to monitor the injection process and post remediation effectiveness. Monitoring wells will also be installed around the site building due to the shallow nature of the groundwater, to ensure no infiltration of groundwater/solution into the building. Additional injections will be implemented as required in order to reduce contamination to applicable standards. Please refer to Figure-2 for the locations of all proposed injection points and proposed monitoring wells.

Long-term effectiveness and permanence of the remedy will be enforced through the site management phase, which will include provisions for monitoring the conditions of the groundwater on and off-site. The current land use for the site and the surrounding area, where the remedy will be performed, is currently commercial and is not expected to change in the near future. Site management is the last phase of the remedial program, which begins with the issuance of a closure letter. The purpose of site management is to ensure the safe reuse of properties where contamination will remain in place. Issuance of the periodic review of the engineering controls will commence 18 months after issuance of the closure letter. A Periodic Review Report (PRR) will be issued to the Department with a schedule for the periodic review process to be determined by the Department. In most cases the PRR is issued on an annual basis in order to determine proper operation and maintenance of the EC and conformance with the ICs established. As the monitoring well network will act as the EC for the proposed remedy, an IC preventing the removal of this well network will be required in order to monitor groundwater conditions during the site management phase. The easement will also include a provision to prevent the use of groundwater on and off-site for potable use, should groundwater contamination remain at the site above standards during the site management phase.

Overall, RegenOx has the ability to protect the public health and environment by reducing contamination to the RAOs established for site. By reducing contaminant levels to their respective RAOs, this would in turn eliminate or reduce any potential human exposures. Due to its ready availability, relatively low cost, effectiveness, safety and use for difficult applications, the use of RegenOx™ is deemed as the selected alternative for site remediation.

4.2 Ongoing Remediation

As part of the remedial strategy, plans to maintain the site cover system including the slab on grade foundation within the site building itself, is proposed in order to maintain the effectiveness of the

SSDS. The exterior cover system currently in place at the site consists of an asphalt cap which covers approximately 90% of the property. The IC will place a restriction on the removal of the site cap including the interior concrete floor to ensure the site cap remains in place. The IC will protect the EC (GP-501 vent fan) and the associated SSD system piping located below the interior floor. Currently the EC's function is to continuously maintain a negative pressure below the building preventing the potential for soil vapor intrusion. Operation, monitoring and maintenance of the system is currently conducted on a monthly basis and includes: visual inspection of system piping and all associated components, air flow, vacuum and PID readings at various sampling ports and stack emission testing performed monthly for VOC analysis. The SSDS will not be turned off or shut down without prior approval from either the State Health Department or DEC. The SSDS will remain operational until it is no longer needed to address current or potential exposures related to soil vapor intrusion. Termination of the mitigation system will comply with the procedures discussed in the NYSDOH guidance and with NYSDEC and NYSDOH concurrence. A petition for the termination of the SSDS would be largely based upon the following:

1. Residual subsurface sources of contamination, if any, of VOCs in subsurface vapors have been remediated based upon an evaluation of appropriate post-remedial sampling results;

2. Residual contamination, if any, in sub-surface vapors is not expected to affect indoor air quality significantly based upon indoor, outdoor air and sub-slab vapor sampling results:

3. Residual contamination, if any, in sub-surface vapors is not expected to affect indoor quality significantly when the SSDS is turned off based upon indoor air, outdoor air and sub-slab vapor sampling results at representative structure; and

4. There is no "rebound" effect that requires additional mitigation efforts observed when the SSDS system is turned off for a period of time.

The property owner will be notified to make such a determination if any one of the above conditions has been satisfied. The NYSDEC and the NYSDOH will be petitioned on this matter for concurrence prior to system termination.

A Site Management Plan (SMP) will be developed in order to document that the EC for the SSDS is operational and the IC for the site remains in place, which includes maintaining the floor within the building. It is anticipated that under the SMP quarterly visits will be conducted in order to ensure the above mentioned EC and IC are undisturbed and in place.

5.0 EVALUATION OF INSTITUTIONAL/ENGINEERING CONTROLS (ICs/ECs)

The SSDS will continue to operate until it is no longer needed to address current or potential exposures related to soil vapor intrusion. Termination of the mitigation system will comply with the procedures discussed in the NYSDOH guidance and with NYSDEC and NYSDOH concurrence. A petition for the termination of the SSDS would be largely based upon the amount of residual contamination left at the site and testing to confirm no "rebounding" is observed. Until this time, the EC is intended to remain operational at the site through the site management phase. An IC in the form of an environmental easement will prevent the removal of the concrete floor EC and the site cover EC, which includes the concrete/asphalt cap throughout the property, and at the rear of the building where soil excavation was conducted in the source area.

The monitoring well network EC installed as part of the groundwater remedy will also remain in place until groundwater contamination has met the RAO's established for commercial use. An IC will be required preventing the removal of this well network until such RAO's are met. The easement will also include a provision to prevent the use of groundwater on and off-site for potable use, should groundwater contamination remain at the site above standards during the site management phase.

6.0 HEALTH AND SAFETY

The RegenOx material is relatively safe to handle; however, it is recommended that personnel avoid contact with eyes, skin and clothing. In order to ensure the safety of our workers and staff involved with the treatment procedure JVS will adhere to the Occupational Safety and Health Administration (OSHA) guidelines. During the installment procedure JVS field technicians and staff will be equipped with Level D personal protective equipment (PPE). Level D OSHA guidelines require the following PPE:

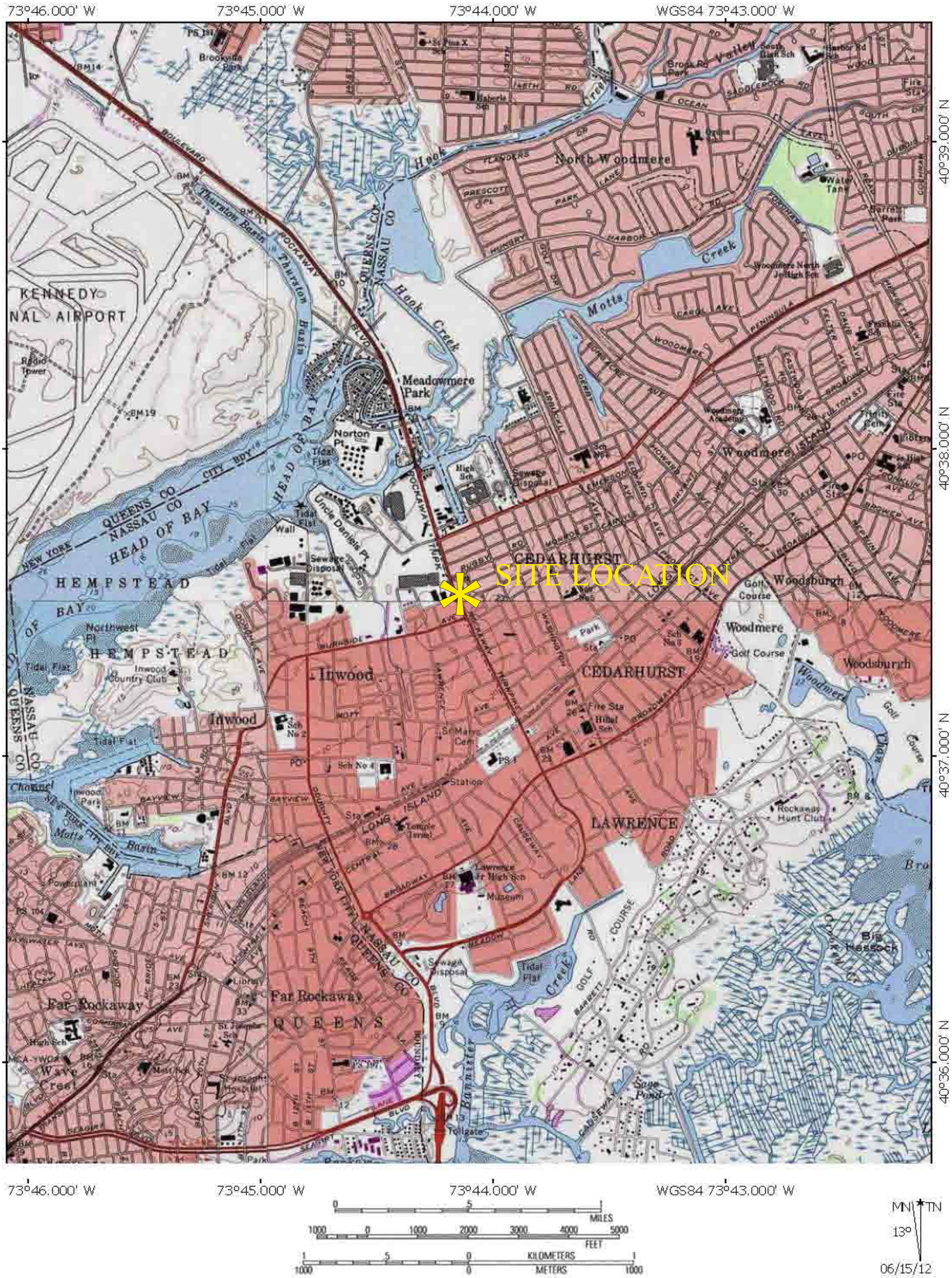
- Eye protection- wear goggles or face shield (splash prevention)
- Head- hard hat when required
- Respiratory- Use dust respirator approved by NIOSH/MSA
- Hands- Wear neoprene gloves

- Feet- Wear steel-toe boots with chemical resistant soles or neoprene covers
- Clothing- Long sleeve shirts and long pant legs. Consider using Tyvek body suit or coveralls

7.0 CONCLUSION

In conclusion, the proposed remedy is the safest and most cost effective approach to on-site and off-site remediation. It is also the most feasible form of remediation given the site characteristics and the remedies ability to reduce contaminant concentrations to acceptable levels in a timely manner. Overall, the selected remedy for the site will greatly reduce the potential for human exposure to contaminated media and prevent further off-site migration of chlorinated groundwater contamination.

FIGURES



Former Quick and Clean Cleaners 380 Rockaway Turnpike Cedarhurst, New York	Figure-1 Site Location	John V. Soderberg P.E PO Box 263 Stony Brook, New York

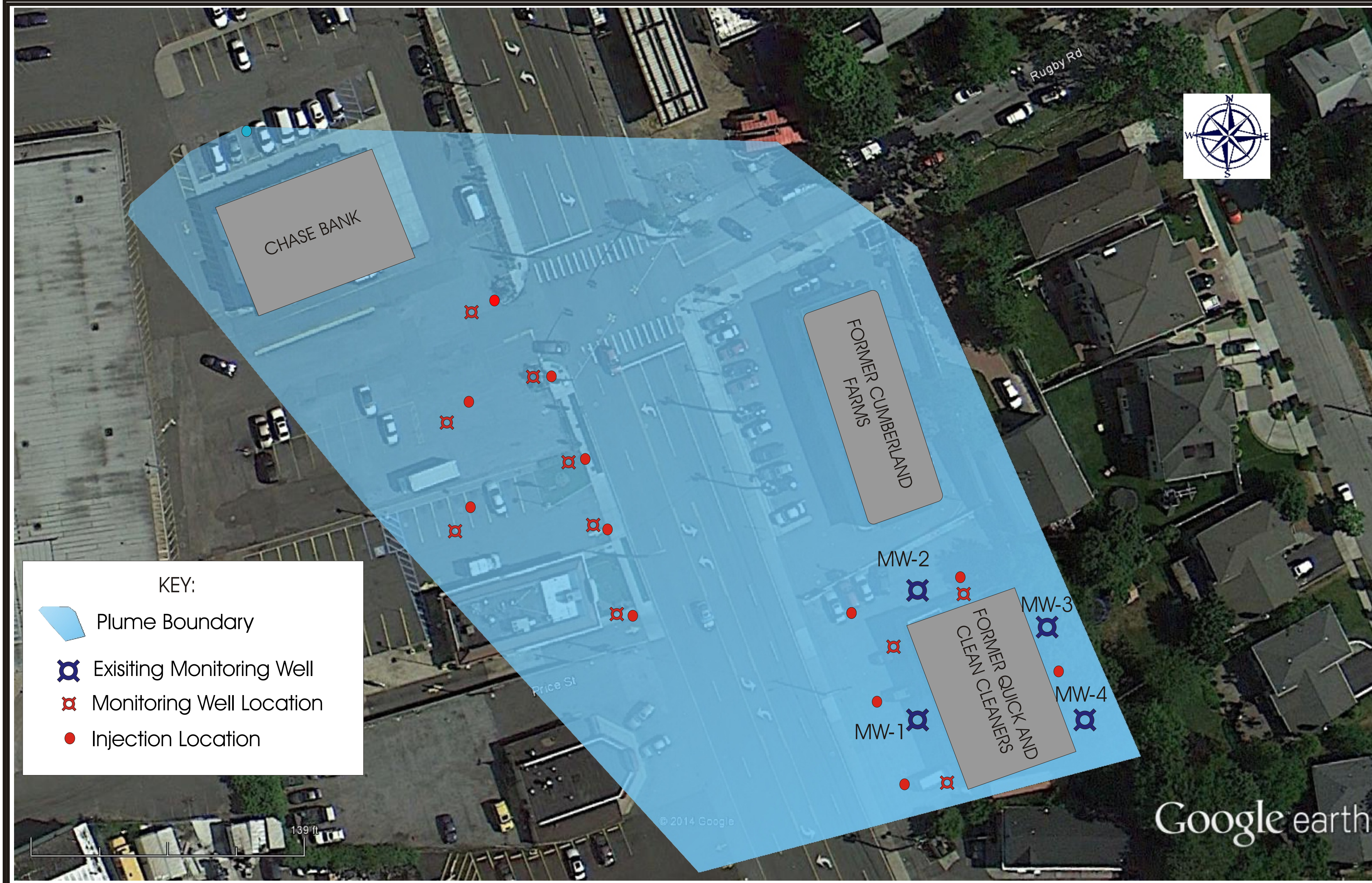


Figure- 2
Injection/
Monitoring Well
Locations

Former Quick and Clean Cleaners
380 Rockaway Turnpike
Cedarhurst, NY

John V. Soderberg P.E
PO Box 263
Stony Brook NY, 11790

Attachment-A

RegenOx Case Studies

Remediation of PHCs and VOCs at a Former Dry Cleaner Site Using RegenOx®, ORC Advanced®, and ORC® Filter Socks

Former Dry Cleaning Site Redeveloped to Serve as New Home to Non-Profit Serving Homeless in Chilliwack B.C. Area

Project Highlights

- Introduction of RegenOx® and ORC Advanced® following *in situ* treatment using PulseOx[1] resulted in the reduction in the initial concentrations of PHCs and dry cleaning chemicals in a sand and gravel aquifer, meeting site remediation goals
- Upon completion of remedial efforts, the project was awarded three British Columbia Ministry Environment instruments

Project Summary

A building occupied by a former dry cleaning business (1960s) located in Chilliwack, British Columbia was acquired by Ruth & Naomi's Mission, (www.ranmission.ca) a non-profit organization serving Chilliwack. Environmental investigations to support the redevelopment of the former dry cleaner building revealed contamination of the soil and groundwater beneath the site and the offsite alley with petroleum hydrocarbons (PHCs) and dry cleaning related chemicals. Since the remedial excavation onto the offsite alley was not considered to be practical, RegenOx, along with ORC Advanced, was utilized for the *in situ* treatment of soil and groundwater within the excavation to reduce the remaining PHC and dry cleaning chemical concentrations.

Following treatment with RegenOx, reduction in the concentrations of PHC and dry cleaning related compounds were observed in soil and groundwater samples. RegenOx was additionally injected within the alley to treat the offsite plume. As a result, all post-remediation concentrations are below the applicable commercial land use standards. Additionally, ORC socks were applied to assist natural attenuation of any residual contaminants in groundwater. The successful investigation and remedial effort received three British Columbia Ministry of Environment instruments and now safely serves as a resource center and shelter.

Concentrations

- Volatile Petroleum Hydrocarbons VPH (up to 3,400mg/kg)
- EPH_{10-19} (8,200 mg/kg)
- Ethylbenzene (33mg/kg)
- Total Xylenes (160 mg/kg)
- Perchloroethylene (7µg/g)
- Trichloroethylene (2.8 mg/kg)
- VPHw (110mg/L)
- LEPH (5.6 mg/L)
- Ethylbenzene (2.14 mg/L)
- Toluene (2.7mg/L)
- Naphthalene (410µg/L)
- Perchloroethylene (2.76 mg/L)
- Xylenes (6.78mg/L)
- Vinyl Chloride (349 µg/L)

Site Details

Site Type: Former Dry Cleaning Business

Contaminant of Concern: PHCs and VOCs

Remediation Approach: Chemical Oxidation to remediate Petroleum Hydrocarbons, Dry Cleaning compounds and degradation products

Soil Type: Sand and Gravel

Treatment Area: 600m^2 (1968 ft^2)

Technology Used:

REGEN Ox

ORC OXYGEN RELEASE COMPOUND

REGENESIS®

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Technology Description

RegenOx is a percarbonate-based *in situ* chemical oxidation technology that rapidly destroys petroleum hydrocarbons and chlorinated contaminants through powerful chemical reactions. It directly oxidizes contaminants while a catalytic component generates oxidizing free radicals to destroy the target compounds.

ORC Advanced is a proprietary formulation of food-grade, calcium oxy-hydroxide that produces a controlled release of molecular oxygen to enhance aerobic biodegredation.

ORC Filter Sock is a permeable filter sock containing calcium oxy-hydroxide based chemical which produces a controlled release of molecular oxygen (17% by weight) when hydrated.

Results

PHC and dry cleaning compounds were reduced in concentrations to groundwater standards following the application of RegenOx and ORC Advanced, facilitating the redevelopment of the former dry cleaning business to house the not-for-profit homeless shelter, Ruth and Naomi's Mission, serving the Chilliwack, B.C. community. Upon completion of investigation and remedial efforts, the project was awarded three British Columbia Ministry Environment instruments. Up to 200+ homeless are served dinner daily by this organization which provides both shelter and recovery programs to men and women, assisting them in their reintegration into the community and work place.

[1] PulseOx is a registered trademark of APT Water, Inc.

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REGENESIS®
Case Study

RegenOx® Technology Expedites Hollywood Brownfield Site Transaction

Project Highlights

- Reduction of TCE, naphthalene, and styrene levels to below risk-based closure levels via *in situ* chemical oxidation clears the way for property sale
- Flexibility of RegenOx® application allowed the remediation to be completed faster and more effectively
- Treatment of over 18,000 cubic yards of vadose soil completed within 30 days

Project Summary

A pending real estate transaction of a industrial property in Hollywood, CA was held up by contamination of the vadose zone with a mixture of chlorinated and petroleum solvents. Before the transaction could be finalized, high levels of perchloroethene (PCE), naphthalene, and styrene in the vadose zone soil had to be reduced to below risk-based closure levels. To achieve this, the engineering firm in charge of remediation selected chemical oxidation using RegenOx based on the product's proven effectiveness, low-cost, and handling safety.

<u>Direct-Push Injection</u>

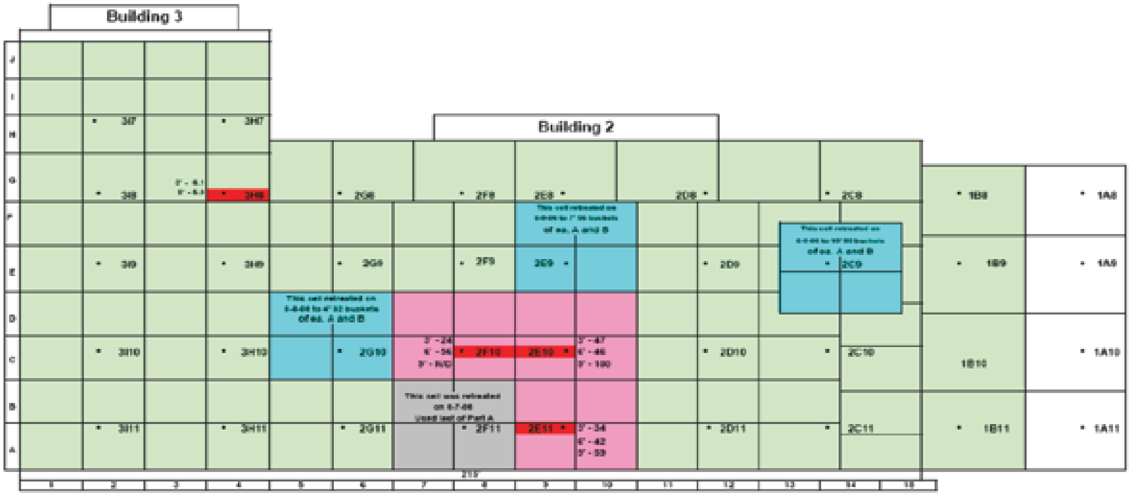
A remediation plan was developed for the contaminated site that involved two rounds of direct-push application of RegenOx separated by 4 to 6 weeks. The direct-push methodology uses specialized equipment to apply RegenOx to discrete areas of the subsurface without soil removal (i.e., *in situ*). In order to determine the effectiveness of the treatment, composite soil samples from various grid cells were taken before and after application of RegenOx. Before treatment, significant variation was seen in the contaminant concentrations, with maximum concentrations of 140 µg/kg for PCE, 1200 µg/kg for naphthalene, and 400 µg/kg for styrene. Following the first direct-push application of RegenOx, the average PCE concentration was reduced to 4 µg/kg, a decrease of 86%. Similar results were seen for the petroleum solvents and other chlorinated volatile organic compounds (cVOCs) in the composite soil samples.

<u>Soil Mixing Application</u>

Despite the contaminant reductions achieved by the first direct-push application of RegenOx, REGENESIS® Remediation Services determined that the speed and effectiveness of the remediation effort could be significantly improved by switching to soil mixing application of RegenOx. In this more aggressive approach, RegenOx was mechanically blended into the vadose soil in order to maximize the contact between the product and the contaminated soil. RegenOx was added as an eight percent solution and mixed throughout the soil using soil mixing equipment. With this treatment method, approximately twice as much soil was treated per day compared to direct-push application.

Of the 111 grids treated with RegenOx by soil mixing (Figure 1), 83 required only one treatment (green) to achieve levels below risk-based closure, 12 required two treatments (blue), and 16 required more than two treatments (pink and gray).

Figure 1. Grid Site Map with the Treatment Effectiveness Noted



Green: Met criteria after one treatment
Blue: Met criteria after two treatments
Pink/Gray: Met criteria after multiple treatments

Technology Description

RegenOx is a percarbonate-based *in situ* chemical oxidation technology that rapidly destroys petroleum hydrocarbons and chlorinated contaminants through powerful chemical reactions. It directly oxidizes contaminants while a catalytic component generates oxidizing free radicals to destroy the target compounds.

Results

The mixed chlorinated and petroleum solvent contamination of the vadose soil was effectively reduced using RegenOx in both direct-push and soil mixing applications. Soil mixing was used to complete the remediation effort rather than a second round of direct-push injections because it maximized contact between RegenOx and the contaminated soil, achieving more rapid and effective treatment.

In 74% of the treatment grids, concentrations of all the contaminants were reduced below the risk-based cleanup goal with a single application by soil mixing. Additional applications in the remaining 26% of the treatment grids also achieved the targeted levels for all the contaminants.

This remediation approach successfully treated nearly 18,000 cubic yards of soil within 30 days. Using RegenOx and flexible application methods, the site was quickly and effectively remediated, allowing for the real estate transaction to be completed.

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www.regenesis.com
1011 Calle Sombra, San Clemente CA 92673
949.366.8000