INTERIM REMEDIAL MEASURE EVALUATION REPORT

July 18, 2001

Former RonHill Dry Cleaners Site
71 Forest Avenue
Glen Cove, New York

July 18, 2001

Prepared by:

REMEDIAL ENGINEERING, P.C.
1377 Motor Parkway
Islandia, New York 11749

ROUX

TABLE OF CONTENTS

TABLE OF CONTENTS

(Continued)

TABLE

FIGURES

APPENDIX

1.0 INTRODUCTION

Roux Associates, Inc. and its associated engineering firm Remedial Engineering, P.C. has prepared an Interim Remedial Measure (IRM) Evaluation for the former RonHill Dry Cleaners facility (Site) located at 71 Forest Avenue, Glen Cove, Nassau County, New York (Figure 1). The Site has been identified by the New York State Department of Environmental Conservation (NYSDEC) as a potential source for chlorinated volatile organic compounds (VOCs) detected in groundwater in the vicinity of the Site (Registry No. 1-30-071).

This IRM Evaluation is designed to identify and evaluate applicable IRM technologies to complete the remediation of tetrachloroethene (PCE). The technologies will be evaluated based on effectiveness, implementability, and cost. Following the technology evaluation, the most feasible and cost-effective technology for use as an IRM will then be selected. This document follows a Remedial Investigation (RI) performed at the Site by Roux Associates and submitted to NYSDEC in May 2001 (Roux Associates, Inc., 2001).

1.1 Scope of Work

The scope of work associated with the IRM evaluation consists of the following tasks:

- Establish IRM objectives;
- Review of data from the RI;
- Review effectiveness of the initial IRM;
- Identification of potentially applicable IRM technologies;
- Screening of potentially applicable IRM technologies;
- Detailed evaluation of remaining IRM technologies; and
- Selection of recommended IRM technology.

1.2 IRM Objective

The primary objective of the IRM is to complete the remediation of the on-site contaminant sources to prevent the continued generation of a dissolved phase PCE plume in groundwater. An initial IRM consisting of a soil vapor extraction (SVE) system was operated at the Site from 1996 to 2000. The SVE system was designed to remove PCE from above the water table. Based on the data collected during the RI, the amount of PCE in the unsaturated zone is currently minimal. Section 3.0 presents an evaluation of the PCE removal results and the overall effectiveness of the SVE system.

Soil and groundwater results from the RI demonstrate that the majority of the PCE remaining at the Site is present below the water table. Based on descriptions in the technical literature that describe the behavior of chlorinated solvents, PCE is believed to exist as residually saturated dense non-aqueous phase liquid (DNAPL). Published literature on DNAPL mechanics and behavior (Pankow and Cherry, 1996; Cohen and Mercer, 1993; and Schwille, 1988) describe residually saturated DNAPL in porous media as interstitial droplets of immobile pure product. The IRM objective, therefore, is to utilize a technology that is capable of the removal or destruction of the residually saturated PCE from below the water table.

2.0 REVIEW OF REMEDIAL INVESTIGATION RESULTS

A review of data developed during previous investigations, including the RI, was performed to assist in the evaluation of the applicable IRM technologies. The following sections identify the geologic and groundwater parameters and characteristics of the dissolved phase and residual phase PCE product at the Site as determined during all previous investigations.

2.1 Geologic and Groundwater Parameters

Physical characteristics including geology and hydrogeology have been documented throughout previous investigations. Summaries of these characteristics are discussed in the following sections.

2.1.1 Geologic Conditions

In general, this region of Long Island is underlain by a thick-layered sequence of unconsolidated materials consisting of gravel, sand, silt, and clay. Collectively, the surface materials are known as the Upper Glacial formation, which was deposited as glacial ice melted and retreated from the area. Beneath the surficial glacial materials lies a sequence of marine sediments that includes the Magothy, Raritan, and Lloyd formations. Collectively, these formations comprise the aquifer system that Long Island residents rely on for potable water.

Based on work conducted by the U.S. Geological Survey (USGS, 1987), the Upper Glacial formation extends to a depth of approximately 160 feet below land surface (ft bls) beneath the Site. The regional depth to water at the Site is approximately 80 ft bls and the saturated zone of the Upper Glacial, therefore is approximately 80 feet thick. Based on groundwater measurements collected from the eight permanent monitoring wells at the Site on March 1, 2001, the depth to groundwater ranges from approximately 81 to 86 ft bls. The calculated groundwater elevations range from 47.56 (W-8) to 47.30 (W-3) feet above mean sea level (ft amsl).

2.1.2 Site-Specific Geologic Conditions

Based on the lithologic information recorded from the soil borings drilled at the Site, the subsurface geology consists of interbedded layers of gravel, fine to medium sand, silt and minor amounts of clay. The unsaturated zone extends to a depth of approximately 85 feet. Within this predominantly sandy zone, interbedded layers (0.5 to 1.5 feet thick) of silt with varying amounts of clay were encountered at approximately 60 to 70 ft bls. The materials within 10 feet of the water table and extending 5 feet below the water table consist mainly of fine to coarse-grained sand and gravel, and some silt. Based on the response to purging of the temporary and permanent monitoring wells installed, the materials extending at least 5 feet below the water table are productive. Based on the visual description of these materials and the recovery rates of the monitoring wells, the horizontal hydraulic conductivity is estimated to be on the order of 10 to several 100 feet per day.

2.1.3 Groundwater Flow

The hydraulic head difference between the on-site wells is only 0.26 feet indicating that there is a very slight horizontal gradient across the Site. Based on these elevations, a map of the configuration of the water table was prepared for the Site (Figure 2).

Based on the water table configuration measured on March 1, 2001, the horizontal component of groundwater flow is generally to the southwest under a very slight gradient, approximately 0.0027 feet/feet. The flow direction on the western side of the Site is generally consistent with previous groundwater flow maps prepared for the Site. However, the flow on the eastern side of the Site is more southerly compared to previous flow maps. The reason for this deviation is not clearly understood. Overall, the flow direction is consistent with a west-southwesterly regional groundwater-flow direction towards Glen Cove Creek/Hempstead Harbor. In addition, the hydraulic heads measured in monitoring well cluster W-7 and W-8 indicate that there is a slight downward gradient vertically at this cluster location.

2.2 Dissolved Phase Groundwater Contamination and Residual PCE Product

To characterize the vertical and horizontal limits of dissolved-phase PCE in groundwater at the Site and to identify the presence of residually saturated PCE product, groundwater samples were collected from both temporary wells and monitoring wells. The temporary wells were installed at the locations of four on-site borings (DB-1, DB-2, DB-3, and DB-4) as shown on Figure 3. The groundwater samples were collected by installing each temporary well with a 5-foot long well screen advanced 15-feet below the water table. Groundwater samples were collected at two depths: five and fifteen feet below the water table.

Groundwater samples collected from temporary wells installed in the four deep on-site borings (DB-1 through DB-4) reported significantly elevated concentrations of PCE in the upper fifteen feet of the saturated zone on the east side of the building. A PCE concentration of 190,000 micrograms per liter (μg/L) (DB-3) or 95 percent of the PCE solubility is a clear indication of residual DNAPL. The lateral extent of the residual DNAPL could not be determined during the RI. However, based on significantly lower PCE in groundwater samples that were collected near the northwest and southwest corner of the building, the residual PCE product does not appear to extend to the western side of the building.

PCE was detected in each of the eight permanent monitoring wells (W-1 through W-8) at levels exceeding the Standards, Criteria and Guidance Levels (SCG; 5 μg/L) for PCE ranging from 21 μg/L in W-5 (77 to 97 foot depth interval) to 100,000 μg/L in W-2 (70 to 90 foot depth interval). The distribution of dissolved PCE in the groundwater at the Site, as determined by the RI, is presented on Figure 4. The highest on-site concentration of PCE, occurring at monitoring well W-2 (100,000 μg/L), appears to indicate the residual DNAPL source area may extend to near this well location. The lowest concentration of PCE, reported from W-5 (21μg/L), is located hydraulically upgradient of the Site.

2.3 Subsurface Soil Investigation

During the RI, 34 samples were collected from 25 boring locations at depths ranging from 0 to 8 ft bls. A review of the shallow soil sample results from the RI indicates that PCE ranged from non-detect to 18,000 micrograms per kilogram (μg/kg) (SB-25A, 2-4 ft bls) and trichloroethene (TCE) ranged from non-detect to 1,400 μg/kg (SB-25A, 2-4 ft bls). Concentrations of 1,2 dichloroethene (DCE) ranged from non-detect to 1,000 μg/kg (SB-25A, 4-6 ft bls), while vinyl chloride was detected in only one sample at 25 μg/kg (SB-25A, 4-6 ft bls). PCE exceeded its corresponding SCG at three sample locations (SB-23A, SB-25A, and SB-26A), and TCE exceeded its corresponding SCG at one sample location (SB-25A). From these results, the contamination found in the shallow soil samples is generally isolated to one location (near SB-25A) in the northwest corner of the building.

Twenty soil samples were collected from four deep soil borings ranging in depths from 20 to 84 ft bls during the RI. No PCE was detected in the first three samples from DB-1. The sample directly above the water table at 84 to 86 ft bls contained 170 μg/kg of PCE. This relatively low concentration appears to be related to the influence of contaminated groundwater in the capillary zone. All four samples from DB-2 were nondetect for PCE. The upper three samples from DB-3 were below the detection limits for PCE, however, the sample from 78 to 80 ft bls contained 11,000 μg/kg of PCE. Given its depth, this sample also reflects impacts related to contaminated groundwater in the capillary zone.

Based on these results, the PCE impacted soil with concentrations exceeding the NYSDEC Recommended Soil Cleanup Objectives (RSCOs) is limited to the interval directly above the water table and shallow soil samples at the northwest corner of the building. This occurrence does not appear to be attributed to a PCE source from the unsaturated soil directly above since PCE was not detected in the shallower soils. Based on the RI data, the lack of PCE-impacted unsaturated soil is attributable to the operation of the SVE system. With the exception of the impacted shallow soil at the northwest corner of the building, since there was no evidence of PCE-impacted soil in the unsaturated zone, the IRM will focus on remediating the source area of residual PCE product (DNAPL) at or below the water table.

3.0 SOIL VAPOR EXTRACTION SYSTEM OPERATIONS

The soil vapor extraction (SVE) system previously operated at the Site was designed, installed, and operated by Tyree Brothers Environmental Services (Tyree) as an IRM to treat PCE and TCE in the unsaturated soils at the Site.

Installation of the SVE system was completed in 1996 and the system operated continuously until May 2000, with the exception of brief shutdowns for maintenance (i.e., carbon changeouts). The last suspension in operation of the SVE system was required for the collection of subsurface soil gas and soil samples for the Remedial Investigation conducted by Roux Associates.

3.1 Description of the Existing SVE System

The existing SVE system consists of four SVE wells (VW-1 through VW-4), located adjacent to each corner of the existing structure, as shown on Figure 2. The SVE wells are constructed of 4-inch diameter Schedule 40 polyvinyl chloride (PVC) screens and casings. Each of the SVE wells are installed to different depths: VW-1 is 72 ft bls, VW-2 is 67 ft bls, VW-3 is 20 ft bls, and VW-4 is 15 ft bls. The SVE wells consist of PVC screens for their entire length and are connected in series to the SVE treatment system located in the northeast corner of the Site by 4-inch diameter PVC underground piping. Each SVE wellhead is enclosed in a concrete vault and is equipped with a ball valve for individual flow control.

The SVE treatment system consists of a 3-horsepower blower, a knockout drum, and two 2,000-pound granular activated carbon adsorption units in series. The blower creates a vacuum that induces volatilization of the residual PCE and TCE into the soil vapor and causes it to flow from the vadose zone into the SVE wells. The soil vapor is passed through the carbon units, which removes PCE and TCE from the soil vapor through adsorption, prior to discharging the soil vapor into the atmosphere under a discharge permit.

Performance of the SVE system was monitored monthly by Tyree. During the monthly monitoring, the concentrations of PCE and TCE in the influent and effluent air were measured in the field using a photoionization detector (PID) and Dräeger Tubes. Air samples were also collected and sent to Environmental Testing Laboratories, Inc. (ETL) for analysis for PCE and TCE.

Groundwater samples collected from temporary wells installed in the four deep on-site borings (DB-1 through DB-4) reported significantly elevated concentrations of PCE in the upper fifteen feet of the saturated zone on the east side of the building. A PCE concentration of 190,000 micrograms per liter (µg/L) (DB-3) or 95 percent of the PCE solubility is a clear indication of residual DNAPL. The lateral extent of the residual DNAPL could not be determined during the RI. However, based on significantly lower PCE in groundwater samples that were collected near the northwest and southwest corner of the building, the residual PCE product does not extend to the western side of the building.

PCE was detected in each of the eight permanent monitoring wells (W-1 through W-8) at levels exceeding the Standards, Criteria and Guidance Levels (SCG; 5 µg/L) for PCE ranging from 21 µg/L in W-5 (77 to 97 foot depth interval) to 100,000 µg/L in W-2 (70 to 90 foot depth interval). The distribution of dissolved PCE in the groundwater at the Site, as determined by the RI, is presented on Figure 4. The highest on-site concentration of PCE, occurring at monitoring well W-2 (100,000 µg/L), appears to indicate the residual DNAPL source area may extend to near this well location. The lowest concentration of PCE, reported from W-5 (21µg/L), is located hydraulically upgradient of the Site.

2.3 Subsurface Soil Investigation

During the RI, 34 samples were collected from 25 boring locations at depths ranging from 0 to 8 ft bls. A review of the shallow soil sample results from the RI indicates that PCE ranged from non-detect to 18,000 micrograms per kilogram (µg/kg) (SB-25A, 2-4 ft bls) and trichloroethene (TCE) ranged from non-detect to 1,400 µg/kg (SB-25A, 2-4 ft bls). Concentrations of 1,2 dichloroethene (DCE) ranged from non-detect to 1,000 µg/kg (SB-25A, 4-6 ft bls), while vinyl chloride was detected in only one sample at 25 µg/kg (SB-25A, 4-6 ft bls). PCE exceeded its corresponding SCG at three sample locations (SB-23A, SB-25A, and SB-26A), and TCE exceeded its corresponding SCG at one sample location (SB-25A). From these results, the contamination found in the shallow soil samples is generally isolated to one location (near SB-25A) in the northwest corner of the building.

Twenty soil samples were collected from four deep soil borings ranging in depths from 20 to 84 ft bls during the RI. No PCE was detected in the first three samples from DB-1. The sample

3.2 Evaluation of SVE System Performance

An initial evaluation of the SVE system was performed by Roux Associates and presented in the document titled "Performance Evaluation of the Soil Vapor Extraction System" (Performance Evaluation; Roux Associates, Inc., 2000). The Performance Evaluation was based on analytical data that was provided by Tyree from samples collected during monthly monitoring from August 1996 through May 2000.

Review of the data indicates that the concentrations of PCE entering the SVE system decreased considerably since the startup of the system (TCE was not detected during the last year of continuous operation). During the first two years of operation, August 1996 through April 1998, the average concentration of PCE in the soil vapor prior to treatment was 244 parts per million by volume (ppmv). As a comparison, the average concentrations of PCE in the soil vapor during the period May 1998 through September 1999 was 144 ppmv and during the period October 1999 through May 2000 was 64 ppmv. From this comparison, the period of time required for the PCE concentration to decrease by half has progressively decreased.

The average concentration of PCE entering the system leveled off to approximately 42 ppmv during the last six months of operation with an average mass removal rate of 2.4 pounds per day. The decrease in PCE concentrations entering the treatment system correlates with an overall decrease in the total mass of PCE removed from the vadose zone over time. A plot of the amount of PCE removed as a function of time was provided in the Performance Evaluation and is presented in Appendix A.

As reported in the Performance Evaluation, the data collected on August 7, 1996 and April 19, 2000 appeared anomalous given the data prior and subsequent to those sampling dates. The data collected on August 7, 1996 represents data collected during the system startup and appears to indicate that the system had not stabilized. After a review of Tyree's monthly monitoring reports, the data collected from April 19, 2000 does not indicate an interruption of system operation. Based on the frequency of data collected, one monthly sample, the data is not representative of variability of the system throughout the month. Additionally, due to the lack of information regarding the conditions and method of which the sample was collected, the reason for the apparent anomaly cannot be determined.

Based on the results of the RI, soil vapor sample detections were slightly elevated for PCE in one location on the east side and one location on the northwest side of the building. The results of the shallow soil sampling indicated the occurrence of PCE in the three borings (SB-23A, SB-25A, and SB-26A) angled under the northwest corner of the building, which is also the location of the former earthen trench historically reported to have elevated concentrations of PCE. The three exceedances of the SCG for PCE were 4,100 µg/kg (SB-23A; 4-6 ft bls), 18,000 µg/kg (SB-25A; 2-4 ft bls) and 1,800 µg/kg (SB-26A; 6-8 ft bls). These exceedances and depths of contamination do not indicate that this area is a continuing source of residual DNAPL. The remaining 31 shallow soil samples did not detect any evidence of PCE in the shallow soil.

According to the SVE pilot test performed by Tyree (Tyree, 1995), the effective radius of influence (EROI) experienced varied at each well. A vacuum of 0.1 inches of water was used to define the EROI. An applied vacuum of 56 inches of water at VW-2 yielded an EROI of 100 feet. An applied vacuum of 48 inches of water at VW-3 yielded an EROI of 56 feet, while VW-4 yielded an EROI of 79 feet at 48 inches of water. The SVE pilot test was performed prior to the paving of the parking lot. A review of Tyree's monthly monitoring reports indicates that an average of 36 inches of water was measured at the blower inlet. Although the operating vacuum of 36 inches of water is less than the vacuum applied during the pilot testing, the parking lot was paved with asphalt after the SVE test was performed which would increase the EROI. Since only average vacuum data were provided in the monthly monitoring reports, an EROI could not be determined. However, based on the RI data the SVE system effectively addressed the impacted unsaturated soil at the Site.

Typically the NYSDEC requires that soil samples be used to demonstrate that a SVE system has effectively remediated a site. As the RI soil sampling results indicate, there is only one area with shallow soil samples with exceedances of the NYSDEC RSCOs, located in the northwest corner of the building. The air sample results show that the SVE system has reached a non-zero asymptotic level. In addition, the closest SVE well (VW-1) to the area with shallow soil exceedances is screened too deep (to 72 ft bls) to be effective at addressing this shallow soil under the building. Therefore, based on this evaluation, we recommend that the operation of the SVE system be discontinued.

4.0 REMEDIAL TECHNOLOGY SCREENING

The following sections will identify, evaluate, and screen applicable IRM technologies that could be employed at the Site to achieve the IRM objective discussed in Section 1.2. The IRM technologies identified were chosen based on their proven efficacy of remediating residually saturated PCE. The selected IRM technologies will be evaluated based on screening criteria including effectiveness, implementability, and cost.

4.1 Potentially Applicable Technologies

A range of in-situ IRM technologies with potential applicability to the remediation of residual PCE has been identified to thoroughly evaluate potential remedial alternatives. The IRM technologies to be evaluated in this section have been selected based on their capability of meeting the IRM objective. The following IRM technologies were selected for screening:

1) Air Sparging/Soil Vapor Extraction
2) Chemical Oxidation
    a) Potassium Permanganate Injection
    b) Hydrogen Peroxide Injection
    c) Ozone Injection
3) Reductive Dechlorination –Sugar/Molasses Injection

4.2 Screening Criteria

The objective of screening the technologies is to narrow the field of available technologies, eliminating those that cannot be implemented or those associated with a high cost and not a substantial increase in performance in relation to the other options. The technologies in this section have been identified through a review of relevant literature, experience with similar types of environmental conditions and engineering judgement.

The selected IRM technologies will be evaluated on the basis of:

- effectiveness;
- implementability; and
- cost.

The effectiveness criterion evaluates the extent to which the technology meets the IRM objective established for the Site.

The implementability criterion focuses on institutional aspects of the IRM technologies with factors such as institutional constraints, time schedules, and the availability of services, equipment, and trained personnel to construct and operate the system being considered as part of the evaluation.

The criterion for cost for the technology-screening phase addresses only the relative costs, including both capital and operation and maintenance costs, of the selected IRM technologies. The purpose of these relative costs is to provide a comparative analysis of the technologies exhibiting similar levels of effectiveness and implementability.

4.3 Screening of Technologies

The IRM technologies were screened based on the criteria discussed in Section 4.2. Therefore, a technology was deemed inapplicable if the technology was determined to be technically infeasible to implement at the Site, ineffective in meeting the IRM objective, or those with a high cost while not substantially effective. The preliminary screening is presented in Table 1. The following IRM technologies were selected for further evaluation:

1) Air Sparge/Soil Vapor Extraction
2) Chemical Oxidation
   a) Potassium Permanganate Injection
   b) Hydrogen Peroxide Injection

Chemical oxidation using ozone injection and reductive dechlorination using sugar/molasses were eliminated from the evaluation. Chemical oxidation using ozone injection was eliminated from the evaluation since this technology is most applicable for remediating unsaturated soil. The ozone is injected in gaseous form, which could cause agitation of the residual DNAPL as well as pose health and safety issues during injection. The reductive dechlorination using sugar/molasses injection technology was eliminated from the evaluation primarily due to the potential of producing daughter products including vinyl chloride, which is more toxic than PCE.

Additionally, this technology is more applicable for remediating groundwater with low VOC concentrations.

Air Sparge/Soil Vapor Extraction (AS/SVE) was retained for further evaluation for its proven effectiveness in remediating PCE without introducing hazardous chemicals to the subsurface. Chemical oxidation using potassium permanganate injection and hydrogen peroxide injection were retained for further evaluation for their effectiveness of remediating PCE without producing daughter products. Additionally, these technologies are employed through the injection of a liquid that chemically alters the contaminant into inert compounds or completely destroys the contaminant.

5.0 DETAILED EVALUATION OF REMAINING ACCEPTABLE TECHNOLOGIES

The IRM technologies selected following the initial screening phase have been evaluated in detail based on effectiveness, implementability, and cost and are discussed in the following sections.

5.1 Air Sparging/Soil Vapor Extraction

Air sparging and soil vapor extraction are proven remedial technologies often used in conjunction to remediate VOCs. Air sparging is an in-situ mass transfer technology that involves the injection of compressed air into the subsurface to enhance the volatilization of VOCs that are dissolved in groundwater, adsorbed to saturated soils, or trapped in soil pores (residual DNAPL) below the water table. During contact with the groundwater and the residual phase, VOCs are transferred (stripped) to the vapor phase. Soil vapor extraction then removes the VOCs by collecting VOC-laden vapors from the unsaturated zone that were generated from the volatilization caused by the air sparging.

5.1.1 System Description

The implementation of an AS/SVE system would include the installation of AS and SVE wells located in the area where the highest concentrations of PCE (residual DNAPL) were detected. The AS component of the AS/SVE treatment system would include an AS compressor or blower, pressure and temperature indicators, and interconnecting piping and valves. Incorporation of the existing Site SVE wells with the proposed IRM AS/SVE system would be unlikely due to the shallow screen lengths (to 20 ft bls) of the existing SVE wells, despite the fact that they are located in the area of the residual DNAPL. Most of the equipment from the existing SVE system, including the blower, carbon units, and knockout drum would be utilized in the IRM AS/SVE system.

5.1.1.1 Effectiveness

As previously stated, there are two primary mass transfer processes which take place during air sparging: in-situ stripping of dissolved VOCs in groundwater and volatilization of adsorbed VOCs below the water table, or trapped in soil pores (residual DNAPL). Additionally, AS promotes biodegradation of some contaminants by introducing oxygen to the saturated zone and stimulating aerobic biodegradation activity. The biodegradation aspect of utilizing AS/SVE is more suitable for non-halogenated hydrocarbons (e.g., benzene).

Based on the above mass transfer processes, the applicability of AS/SVE is dependent upon the contaminant of concern (i.e., PCE). The strippability of the VOCs is applicable to compounds with a high Henry's Law Constant, which is the rate of the partial pressure of a compound in air to the mole fraction of compound in water at equilibrium. Compounds with a high Henry's Law constant relative to other compounds (i.e., greater than 1 x 10^{-5} atmosphere-cubic meter per mole [atm-m^3/mol]) have a greater concentration in air when the air/water system is in equilibrium and therefore are more easily stripped from water. The Henry's Law constant for PCE of 8.3 x 10^{-3} atm-m^3/mol is suitable for AS/SVE. Direct volatilization of the VOCs is applicable to compounds when the aqueous solubility is less than 20,000 milligrams per liter (mg/L) and the vapor pressure is greater than 1 millimeter of mercury (mm Hg). The solubility of PCE is 150 mg/L and the vapor pressure of PCE at 190°C is 14 mm Hg, making AS/SVE suitable for treating PCE.

The limiting factor to using AS for the remediation of residual DNAPL in volatizing PCE in residual DNAPL into the dissolved phase and soil vapor is the potential of increasing the extent of the PCE-impacted soil vapor and dissolved phase contamination, and thereby promoting migration. The soil vapor would be captured by the SVE component of the system. However, increased efforts would be required to treat the dissolved phase plume while the source area is being addressed. These efforts could include the potential installation of additional AS/SVE wells outside of the source area or in the extreme case the installation of a pump and treat system. Therefore, since this technology would require addressing both the dissolved phase and residual PCE, this technology would not be effective in meeting the primary IRM objective of addressing the source area.

Although AS used in conjunction with SVE has been proven effective in remediating VOCs such as PCE, this technology has been determined to be least effective in remediating residual DNAPL.

5.1.1.2 Implementability

The implementability of AS/SVE is greatly influenced by the geology and the ability to achieve significant air distribution within the target zone. Air distribution is controlled by aquifer hydraulic conductivity and homogeneity. Sandy soils are preferable for AS/SVE because they require lower air entry pressures and enable greater air distribution, which allows for an increased radius of influence that will yield greater mass transfer efficiencies. The soil at the Site is characterized as sandy, which is suitable for effectively implementing AS/SVE.

There are Site-specific constraints that decrease the implementability of using AS/SVE. Based on the data from the RI regarding the extent of the residual PCE, the source area is located near and under the existing building. The installation of AS in the source area would generate VOC-laden vapors from the volatilization of the residual PCE. These vapors may affect the building and the indoor air quality within the building. Additionally, the installation of the AS/SVE in proximity to the building could compromise the integrity of the building foundation. The presence of the existing building and the fact that it is an active facility might inhibit the quantity of AS and SVE wells that can be installed in the source area. Additionally, the location of the residual PCE and the building may affect the method of installation of the AS/SVE wells (e.g., angle drilled wells).

The amount of time required to remediate the Site using AS/SVE is uncertain. As discussed in Section 5.1.1.1, the volatilization of the residual PCE product has the potential of increasing the extent of PCE-impacted soil vapor and dissolved phase PCE. Additionally, the implementation of AS/SVE may mobilize the residual PCE product, thus increasing the extent of source area (i.e., under the existing building). Therefore, the time to remediate the source area due to the effects of volatilization of the source area may be increased and difficult to predict.

5.1.1.3 Cost

The capital costs associated with the implementation of AS/SVE are comparatively low. Incorporating the existing SVE system with the AS/SVE system would further reduce capital costs. The capital costs would include the installation of both AS wells and additional SVE wells, as well as equipment including a blower, gauges and piping. Operation and maintenance (O&M) costs are also relatively low, consisting of routine performance monitoring, electrical costs, air and groundwater monitoring laboratory analysis, redevelopment of AS wells, and carbon changeouts.

5.2 In-Situ Chemical Oxidation

Chemical oxidation is the process of adding an oxidizing agent to chemically transform a contaminant through oxidation-reduction reactions. During the oxidation-reduction reaction, an exchange of electrons affects the oxidation state of the contaminant and as a result, double carbon bonds are broken. The double carbon bonds that characterize chlorinated ethenes are far more reactive than the single carbon bonds of chlorinated ethanes, so PCE is more susceptible to oxidation. The contaminant is either completely destroyed or converted to smaller less hazardous compounds. These compounds may also be oxidized to eventually yield carbon dioxide, water and chloride.

The chemical oxidation technology is employed by mixing the oxidant with water or a catalyst and injecting the mixture into the residual DNAPL via injection wells. The oxidant mixture is injected upgradient and within the residual DNAPL source area. The complete oxidation of the residual DNAPL is usually not achieved on the first pass. Therefore, extraction wells may be installed downgradient of the source area to allow recirculation of the oxidant or multiple treatment applications may be required.

5.2.1 Potassium Permanganate

In-situ chemical oxidation of organic contaminants can be achieved by carefully controlled injection of potassium permanganate into the subsurface. Potassium permanganate ($KMnO_4$) readily reacts with available organic compounds without the need of a catalyst and without producing daughter products that would require additional additives. The reaction by which potassium permanganate oxidizes organic contaminants involves the production of carbon dioxide, manganese dioxide (MnO_2), potassium chloride, and chlorine gas. Potassium permanganate, which has an oxidation potential (E^o) of 1.70 volts, readily oxidizes compounds that contain double carbon bonds, thus it is effective in remediating DNAPLs containing PCE. The reaction is given by the following:

$$C_2Cl_4 + 2KMnO_4 \rightarrow 2CO_2 + 2MnO_2 + 2KCl + Cl_2$$

During the reaction, carbon dioxide combines with water, thus reducing the pH, and is released as a gas within the soil matrix. Although chlorine gas (a potentially harmful gas) is produced as a result of this reaction, the chlorine will form hypochlorus acid (HOCL) and hypochlorite (OCl^-) when in contact with the water in the saturated zone. Both hypochlorus acid and hypochlorite are two strong oxidants that will be reduced by the PCE. The manganese dioxide will precipitate out and will become immobilized in the soil.

5.2.1.1 Effectiveness

Potassium permanganate has been proven effective in completely oxidizing chlorinated hydrocarbons, such as DNAPL consisting of PCE. Furthermore, the oxidizing of PCE using a sufficient quantity of potassium permanganate does not produce daughter products (i.e., TCE, DCE, and vinyl chloride) that must be treated by inducing additional reactions. Based on published literature, potassium permanganate has been tested and is effective in treating DNAPL sources in both saturated and unsaturated soils. By reacting with the PCE in place, there is little potential for the injection of the potassium permanganate to mobilize the residual PCE and/ increase the extent of the source area.

A limiting factor to the success of using potassium permanganate is mass transfer since the potassium permanganate is insoluble in DNAPL. Potassium permanganate is an effective oxidizer if a sufficient amount is available for the oxidation reaction to occur in a given area. Large quantities of potassium permanganate are required to treat DNAPL and it must be in direct contact with the contaminant for complete oxidation to occur. The oxidation reaction will also require sufficient time to go to completion. Since the contaminant is present as residual DNAPL, the reaction may require additional time to completely oxidize the PCE. It is difficult to predict the amount of time required for the oxidation reaction to effectively remediate the residual PCE. These factors could result in the need for multiple treatment applications and/or a longer treatment period to achieve the desired effect and to prevent residual untreated PCE from remaining in the saturated soil. The oxidation process tends to increase mass-transfer rates; the rate of oxidation is dependent on the rate of DNAPL dissolution and mass transfer to the aqueous phase.

An additional factor that may affect the performance of potassium permanganate injection is the effect of the resulting by-products, manganese dioxide and carbon dioxide. As discussed previously, the manganese dioxide precipitates out and will become immobilized in the soil. This coating that the manganese dioxide forms may reduce the permeability of the soil and hinder future oxidant from remediating residual contaminated areas. The carbon dioxide formed has a similar reaction. If the rate of the reaction exceeds the carrying capacity of the water, the carbon dioxide in vapor phase will form and also decrease the relative permeability in the soil. Therefore, the multiple injection of potassium permanganate must be controlled for a sufficient amount of potassium permanganate to react with the PCE. To address some of this concern, the existing SVE system may be temporarily started during the injection process to capture carbon dioxide vapors.

Potassium permanganate has the potential to oxidize metals present in the soil, thus releasing the metals from their reduced solubility precipitates. As the oxidized metals increase in solubility, the potential for mobilizing the metals increases. In this event, a hydraulic control system such as extraction wells would be required to capture any mobilized metals.

Due to the reaction rate of the potassium permanganate with PCE, the potential exists for the injected potassium permanganate to pass through the source area unreacted causing inefficient usage of the oxidant. A recirculation system may therefore be more effective than multiple injections of pure potassium permanganate. The unreacted potassium permanganate would be captured downgradient of the source area, mixed with additional potassium permanganate, and reinjected into the source area.

5.2.1.2 Implementability

The implementation of the delivery system for potassium permanganate injection is feasible at the Site. Some of the Site constraints discussed for AS/SVE also apply for potassium permanganate injection, such as the proximity of the source area to the building. The injection of potassium permanganate in liquid form completely oxidizes the PCE. The potassium permanganate would be injected through injection wells screened into the saturated zone where the residual DNAPL exists and would migrate in the direction of groundwater flow.

Additionally, based on the depth to water (approximately 80 ft bls) the injection of the potassium permanganate does not pose an impact to the building.

The injection wells would be installed upgradient and within the source area across the width of the delineated residual DNAPL. For recirculating the oxidant, extraction wells could be installed downgradient of the source area and the building. Since the source area is located partially under the building, injection wells will need to be installed very close to the building. Access to these areas might be difficult and may affect the method of installation of the injection wells (e.g., angle drilled wells).

Although in-situ chemical oxidation using potassium permanganate has been approved by the NYSDEC, there are potential concerns associated with the technology. For instance, the injection of any chemical and the recirculation of a chemical/treated water mixture must be approved by the appropriate regulatory agencies and permitting may be required. The performance of the treatment must be closely monitored. Given the difficulty in accessing the source area due to its location under the building, monitoring the performance of the thoroughness of the treatment in both soil and groundwater and verifying that the oxidation reaction has gone to completion and sufficient amounts of potassium permanganate have been delivered without leaching the PCE into the groundwater is expected to be equally difficult. Groundwater and soil quality monitoring would be required on routine basis.

5.2.1.3 Cost

Comparatively, the cost for potassium permanganate injection is higher than the other technologies being evaluated. The cost is primarily driven by the cost of the equipment to inject the oxidant. The cost of the potassium permanganate is relatively low. Additional costs are incurred by the installation of injection wells, as well as monitoring wells to monitor the performance of the potassium permanganate and bench-scale testing to determine the percentage of potassium permanganate required. Since some of the potassium permanganate is expected to pass through the source area unreacted, recirculation of the oxidant would be more cost-effective. The equipment costs associated with recirculating the potassium permanganate include extraction wells, a holding tank, pumps, piping and flow meters.

5.2.2 Hydrogen Peroxide

In-situ chemical oxidation of organic contaminants can be achieved by carefully controlled injection of hydrogen peroxide into the subsurface. Hydrogen peroxide works through two mechanisms: direct oxidation and free radical generation. Direct oxidation of PCE using hydrogen peroxide (E^o=1.76 volts) completely destroys the PCE without producing adverse daughter products. Free radical formation relies on Fenton's reagent, which was developed by H. J. H. Fenton in the 1890's and consists of hydrogen peroxide and iron salts, which is a transition-metals catalyst. Fenton's reagent is used to oxidize organic compounds by producing hydroxyl radicals ($OH^\bullet$) as follows:

$$H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^\bullet + OH^-$$

During the reaction, ferrous iron (Fe^{2+}) is converted to ferric iron (Fe^{3+}). Ferrous iron is generally soluble at a pH between 5 and 6, while ferric iron will generally precipitate out of solution at this corresponding pH range. By buffering the pH and providing adequate amounts of hydrogen peroxide, ferric iron can be converted back to the ferrous form, thus maintaining the reaction.

The hydroxyl radicals formed by Fenton's reagent are one of the most powerful oxidizers known (E^o=2.76 volts), more powerful than potassium permanganate (E^o=1.70 volts). The reactions by which organic contaminants are oxidized are complex, but essentially involve the contaminant (i.e., PCE), hydrogen peroxide, and the ferrous iron catalyst reacting to produce water and carbon dioxide, as follows:

$$RHX^{Fe2+} + H_2O_2 \Leftrightarrow H_2O + CO_2 + H^+ + X^-$$

In the above reaction, RHX represents a halogenated organic compound, where X^- is the halide (i.e., chloride). The complete destruction of the halogenated organic compound yields water, carbon dioxide, a hydrogen ion, and a halide anion. This reaction is rapid, non-selective (natural organic material in the treatment zone will also be oxidized), and generates heat and pressure in the subsurface. The use of Fenton's reagent has not been documented to cause mobilization of inorganics or chemical constituents outside the treatment area.

5.2.2.1 Effectiveness

The injection of hydrogen peroxide has been proven effective in completely oxidizing PCE without the production of daughter products (i.e.. TCE, DCE, and vinyl chloride) in both saturated and unsaturated soil. Hydrogen peroxide degrades rapidly in the subsurface and does not pose an impact to the soil or groundwater if left unreacted. Additionally, as with potassium permanganate, the hydrogen peroxide reacts with the PCE in place resulting in little potential for mobilizing the residual PCE and increasing the extent of the source area.

Chemical oxidation using Fenton's reagent has similar limiting factors to using potassium permanganate, such as injection of sufficient quantities of Fenton's reagent and time for reaction to go to completion. A sufficient amount of reagent must be injected into the residual DNAPL to ensure that the oxidant will react with the entire source area, and residual DNAPL is not left unreacted. The oxidant must be in direct contact with the residual DNAPL in order for the oxidation reaction to occur. Additionally, the reaction requires a sufficient amount of time to oxidize the PCE without leaving residual PCE in the saturated soil. While the oxidizing power of Fenton's reagent and the hydroxyl radicals that are formed increases the rate of oxidation, the oxidation reaction still requires a sufficient amount of time to go to completion. It is difficult to predict the amount of time that will be required for the Fenton's reagent to completely and effectively oxidize the residual DNAPL. Therefore, multiple treatment applications (injections) and/or longer treatment periods may be required.

5.2.2.2 Implementability

The geology of the Site is ideal for the injection of Fenton's reagent and the ability of the soil formation to accept the reagent. Once injected, the reagent will tend to follow zones of higher hydraulic conductivity, relying on diffusion to reach areas of lower hydraulic conductivity. Following treatment, concentrations of PCE in groundwater would be greatly reduced. However, a significant performance concern is that the exidation process is not complete and residual DNAPL remains untreated in the subsurface. Therefore, a small percentage of the residual DNAPL can result in a rebound in the groundwater concentrations after treatment to levels similar to those measured before treatment.

Similar to the other technologies evaluated, there are some Site-specific constraints associated with implementing Fenton's reagent injection. Injection wells would be required to be installed upgradient and within the source area, which may be located under the existing building. Additionally, based on the depth to water (approximately 80 ft bls) the injection of Fenton's reagent does not pose an impact to the integrity of the building. Due to the proximity of the source area to the building, access to the source area might be difficult and alternative methods of installation of injection wells may be necessary (e.g., angle drilled wells).

Aside from the installation of the injection wells, the Site is amenable to the implementability of the Fenton's reagent delivery system. Although the Site is active, there is minimal equipment required for this technology and should not cause interference with operations at the Site. The injection equipment, consisting of piping and pumps, would not occupy much space at the Site.

Regulatory approval (i.e., NYSDEC) would be required for the injection of the hydrogen peroxide into the subsurface. Performance monitoring would be required to monitor the performance of the hydrogen peroxide. The in-situ oxidation process generates oxygen gas and liberates PCE-laden vapors from the groundwater. Heat released by the strongly exothermic oxidation reactions raises temperatures in the aquifer and subsurface. As a result, it may be necessary to recover the oxygen gas and PCE-laden vapors during the injection process. As a precautionary action, the existing SVE system may be temporarily operated only during the injection process.

5.2.2.3 Cost

Medium capital costs are associated with this technology. These costs would include the cost of the reagent, the installation of injection and monitoring wells, a holding tank, pumps, and piping. Operation and maintenance costs associated with this technology would include routine performance monitoring, groundwater monitoring analysis, and additional injection treatments, if required, based on the monitoring data.

6.0 RECOMMENDED IRM REMEDIAL TECHNOLOGY

Based on the evaluation of IRM technologies discussed in Section 4.0 and the detailed evaluation of IRM technologies presented in Section 5.0, chemical oxidation using hydrogen peroxide is recommended for implementation at the Site. Hydrogen peroxide injection is expected to meet the IRM objective of remediating the on-Site source area to prevent the continued generation of a dissolved phase PCE plume.

This technology has been proven to remediate residual DNAPL by completely oxidizing PCE in DNAPL without the production of daughter products such as TCE, DCE, and vinyl chloride. Hydrogen peroxide reacts with the PCE in place resulting in little potential for mobilizing the residual DNAPL and increasing the horizontal and vertical extent of the source area. This technology provides a rapid and effective means of remediating PCE. This technology is technically feasible to implement and is cost-effective. The Site is amenable to the installation of the hydrogen peroxide delivery system. Additionally, vendors with experience with hydrogen peroxide injection and injection equipment are readily available to implement the installation of the system.

Respectfully submitted,

ROUX ASSOCIATES, INC.

Glen Netuschil

Glenn Netuschil, P.E.
Senior Engineer

Craig Werle

Craig Werle
Principal Hydrogeologist

7.0 REFERENCES

Cohen, R. and J. Mercer, 1993. DNAPL Site Evaluation, C.K. Smoley, 1993.

Holbrook, Timothy, et al., 1998. Innovative Site Remediation Technology, Design and Application, Vapor Extraction and Air Sparging, American Academy of Environmental Engineers, 1998.

Interstate Technology and Regulatory Cooperation Work Group, 2000. Dense Non-Aqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation Technologies, June 2000.

Jerome, K. and B. Looney, J. Wilson, 1998. Field Demonstration of In-Situ Fenton's Destruction of DNAPLs, 1998.

Nyer, Evan, et al., 1996. In Situ Treatment Technology, Lewis Publishers, 1996.

Pankow, J. and Cherry, J., 1996. Dense Chlorinated Solvents and other DNAPLs in Groundwater: History, Behavior, and Remediation, Waterloo Press, 1996.

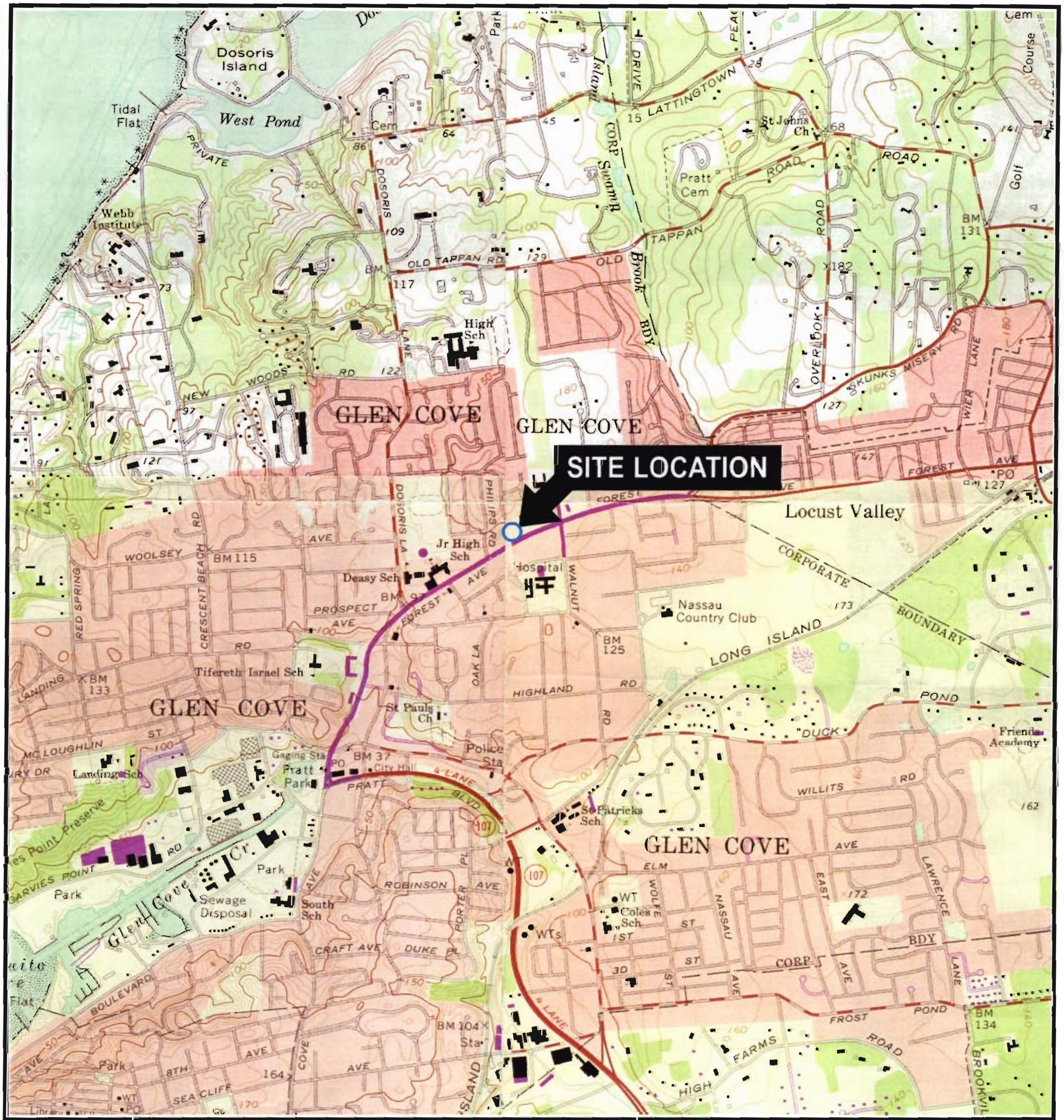
Roux Associates, Inc., 2001. Remedial Investigation Report, Former RonHill Dry Cleaners Site, 71 Forest Avenue, Glen Cove, New York (Registry No. 1-30-071), April 27, 2001.

Roux Associates, Inc., 2000. Performance Evaluation of the Soil Vapor Extraction System, Former RonHill Dry Cleaners Site, 71 Forest Avenue, Glen Cove, New York, August 24, 2000.

Schwille, Friedrich, 1988. Dense Chlorinated Solvents in Porous and Fractured Media, Model Experiments, Lewis Publishers, 1988.

Table 1. IRM Technology Screening, Former RonHill Dry Cleaners, Glen Cove, New York

IRM Technology	Results of Preliminary Screening	Explanation
Air Sparging/Soil Vapor Extraction	Retained	• In-situ technology • Very effective at remediating PCE, TCE, DCE, vinyl chloride • Does not introduce hazardous chemicals
Chemical Oxidation - Potassium Permanganate Injection	Retained	• In-situ technology • Aggressive technology • Very effective at remediating PCE, TCE, DCE, and vinyl chloride • Regulatory-approved technology
Chemical Oxidation - Hydrogen Peroxide Injection	Retained	• In-situ technology • Very effective at remediating PCE, TCE, DCE, and vinyl chloride • Regulatory-approved technology
Chemical Oxidation - Ozone Injection	Eliminated	• Causes agitation in the subsurface which could result in remobilization and spreading of DNAPL and/or increase dissolved constituent concentrations in groundwater • Health and safety issues during injection • Most applicable to unsaturated zone since ozone is applied as a gas
Reductive Dechlorination - Sugar/Molasses Injection	Eliminated	• Reductive Dechlorination of PCE can produce vinyl chloride (more toxic than PCE) • Applicable to low VOC concentrations (i.e. no DNAPL) • Need to overcome high dissolved oxygen levels



QUADRANGLES LOCATION

N

SOURCE:
USGS; 1975. Mamaroneck, Bayville,
1979. Sea Cliff and Hicksville, New York
7.5 Minute Topographic Quadrangles

0 2000'

Title:

SITE LOCATION MAP

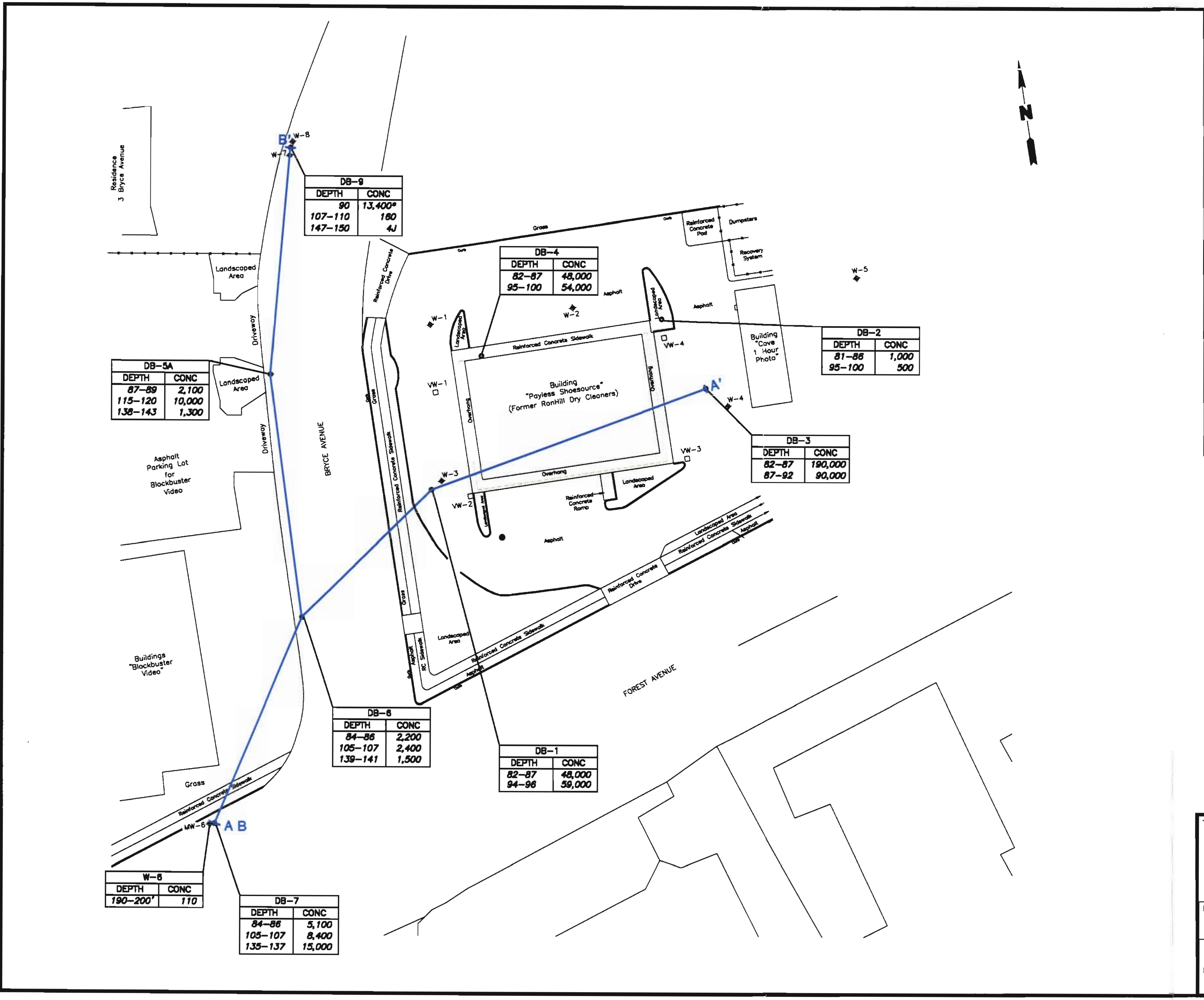
RONHILL DRY CLEANERS
GLEN COVE, NEW YORK

Prepared for:

RICHARD SILLS

ROUX ROUX ASSOCIATES, INC. Environmental Consulting & Management	Compiled by: J.P.	Date: 23MAY01	FIGURE
	Prepared by: R.K.	Scale: 1"=2000'	1
	Project Mgr.: J.P.	Office: NY	
	File No.: SIL0112401.CDR	Project No.: 74701Y	

N:\PROJECTS\SIL747Y\SIL01Y124\SIL0112401.CDR



LEGEND

W-4 ⌖ LOCATION AND DESIGNATION OF MONITORING WELL

DB-1 ● LOCATION AND DESIGNATION OF TEMPORARY MONITORING WELL

VW-1 ☐ LOCATION AND DESIGNATION OF SVE WELL

LOCATION OF EXISTING

DB-1	
DEPTH	CONC
87-95	45,000
94-96	59,000

CONCENTRATION OF TETRACHLOROETHYLENE DETECTED IN GROUNDWATER MEASURED IN MICROGRAMS PER LITER (ug/L)

DEPTH BELOW GROUND SURFACE (MEASURED IN FEET) THAT SAMPLE WAS COLLECTED

A⊢⊣A' CROSS-SECTIONAL LINE

J ESTIMATED VALUE

* BL ANALYTICAL ONSITE MOBILE LABORATORY ANALYSIS

40' 0 40'

Title:

PCE IN GROUNDWATER SAMPLES FROM TEMPORARY WELLS

RONHILL DRY CLEANERS
GLEN COVE, NEW YORK

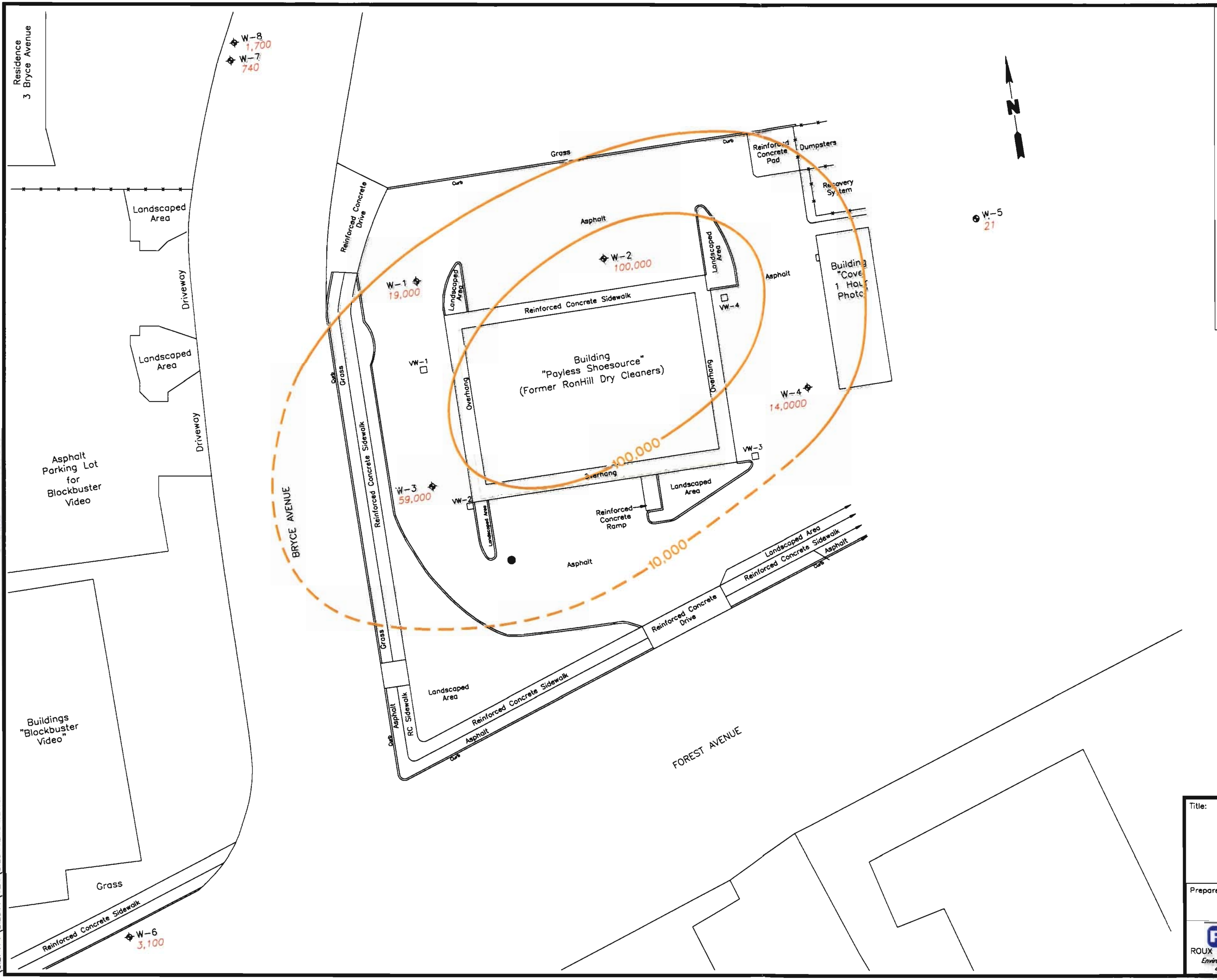
Prepared For:

RICHARD SILLS

ROUX ASSOCIATES, INC.
Environmental Consulting & Management

Compiled by: T.D.	Date: 29MAY01	FIGURE
Prepared by: R.K.	Scale: AS SHOWN	3
Project Mgr: R.J.M.	Office: NY	
File No: SIL0112403	Project: 74701Y	

\SIL747Y\SIL01Y\124\SIL0112404.DWG



LEGEND

VW-1 ☐	SVE WELL
W-4 ⊕	LOCATION AND DESIGNATION OF MONITORING WELL
14,0000	CONCENTRATION OF PCE IN GROUNDWATER IN MICROGRAMS PER LITER (ug/L)
D	DILUTION RUN RESULTS
—10,000	APPROXIMATE LOCATION OF PCE ISOCONCENTRATION LINE AT THE WATER TABLE (IN ug/L)
●	CATCH BASIN

Title:

PCE IN GROUNDWATER SAMPLES FROM MONITORING WELLS

RONHILL DRY CLEANERS
GLEN COVE, NEW YORK

Prepared For:

RICHARD SILLS

ROUX
ROUX ASSOCIATES, INC.
Environmental Consulting & Management

Compiled by: J.P.	Date: 29MAY01	FIGURE
Prepared by: R.K.	Scale: AS SHOWN	4
Project Mgr: J.P.	Office: NY	
File No: SIL0112404	Project: 74701Y	

APPENDIX A

Figure 1
Removal Rate of PCE from Soil
Via SVE Versus Time

Figure 1 - Removal Rate of PCE From Soil Via SVE Versus Time
Former RonHill Dry Cleaner Site
71 Forest Avenue
Glen Cove, New York