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NYSDOT REGION 9
EQUIPMENT MAINTENANCE YARD
112 BARLOW ROAD
BROOME COUNTY
NEW YORK

FINAL DRAFT

FEASIBILITY STUDY OF REMEDIATION ALTERNATIVES

PREPARED BY

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1.0 INTRODUCTION

The New York State Department of Transportation (NYSDOT) is proposing to construct a new Equipment Maintenance Facility on Barlow Road in the Town of Kirkwood, Broome County, New York (Figure 1.1). The proposed site consists of the existing 5± acre NYSDOT parcel on the north side of Barlow Road and an adjacent 2.7± acre parcel to the west, previously owned by the Gorick Construction Company (Figure 1.2).

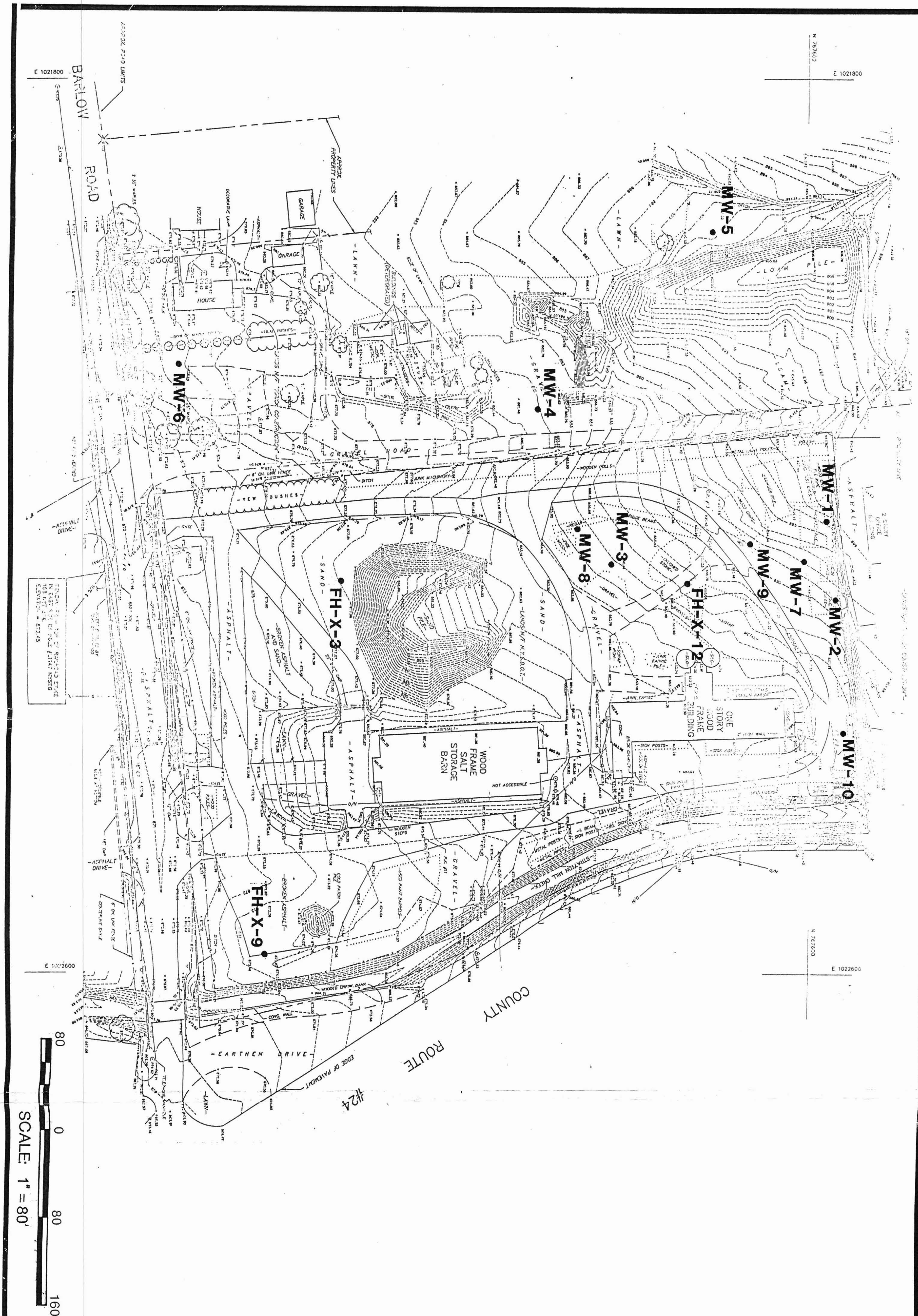
Phase I and II Hazardous Waste Assessments were performed in Fall 1993 and Winter 1994 for the two parcels referenced above. These environmental studies consisted of the installation and logging of soil borings; the installation, sampling, and analysis of groundwater monitoring wells; a soil gas survey; subsurface soil sampling; surface soil sampling; and a ground penetrating radar study. Subsequent to the results of the Phase II Hazardous Waste Assessment, a Geoprobe® study was performed, three (3) additional groundwater monitoring wells were installed, sampled, and analyzed, and hydraulic conductivity tests were conducted.

The results of the environmental studies conducted at the site indicate that trichloroethene contamination is present in the groundwater on site beneath the proposed Maintenance Facility and that the source of contamination is thought to originate from an area in the northwest corner of the NYSDOT parcel where aerial photographs revealed distressed vegetation adjacent to a small aboveground tank. Volatile petroleum hydrocarbons were also detected in the groundwater at the presumed source area but have not dispersed horizontally to the same extent as the trichloroethene. The maximum concentration of trichloroethene measured was 1,810 micrograms per liter (μg/L). The groundwater standard for trichloroethene is 5 μg/L and the Toxicity Characteristic regulatory level is 500 μg/L.

The purpose of this report is to review, evaluate, and rank interim alternative remediation methods to recover and treat the contaminated groundwater at the site. Ranking of the remediation methods are in accordance with the criteria presented in the NYSDEC Division of Hazardous Waste Remediation TAGM #HWR-90-4030, "Selection of Remedial Actions at Inactive Hazardous Waste Sites".

1.1 Background and History

The background, physical setting, and history of the site are based on a review of existing data supplemented by site reconnaissance. The study area, located on Barlow Road in the Town of Kirkwood, Broome County, consists of approximately 8 acres. The site includes the 5± acres of NYSDOT land on the north side of Barlow Road, which is a portion of the existing NYSDOT Equipment Maintenance Shop property at 112 Barlow Road, and the adjacent 2.7± acre parcel to the west previously owned by Gorick Construction Company. The property north of the NYSDOT land is also owned by the Gorick Construction Company, but only that portion of land bordering the west property line is proposed to be included for the new Equipment Maintenance Facility site.



HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE	NYSDOT Residency Site Barlow Road Kirkwood, NY	FIGURE 1.2
	DRAWN	**SAMPLING LOCATIONS**	
	NO. 6793	NYSDOT REGION 9 PIN 9650.02.301	

The NYSDOT parcel was previously used by the Binghamton State Psychiatric Facility prior to occupation by the NYSDOT. Reportedly, the NYSDOT used the property as a storage area for waste materials and a disposal area for waste toluene used to remove paint and clean equipment, in conjunction with NYSDOT equipment maintenance activities. Most notably, an area located at the northwest corner of the property was reportedly used for disposal of spent toluene. There is no knowledge of trichloroethene disposal by NYSDOT.

The NYSDOT land currently contains an approximately 16,000 square foot sand pile and a 6,750 square foot one-story wood frame building with two attached silos currently used as a sign shop. In addition to the sign shop building, the site contains an 8,700 square foot wood frame pole barn housing road salt, a waste paint/solvent and oil drum storage area, several stock piles of signs, crushed drums, metal beams, cables, reinforcing rods, and miscellaneous debris the NYSDOT has collected along highways.

Immediately upgradient (north) and adjacent to the NYSDOT site is a commercial facility occupied by the Gorick Construction Company. The facility is not served by a public sewer system. The 2.7 acre parcel owned by Gorick Construction was reportedly used for storage of construction equipment and heavy equipment vehicles. The parcel generally consists of open fields but does contain two (2) old storage buildings and a large pile of loam. Investigation of the property to the north of the NYSDOT site was not undertaken as access was denied by the owner.

Stratton Mill Creek flows in a southerly direction along the eastern property boundary of the NYSDOT site to the Susquehanna River, approximately 0.5 miles to the south. Groundwater has been encountered at the site at depths ranging from 3.6 feet to 27.7 feet. The site topography slopes downward from north to the south, at a 3 percent grade.

Broome County is located in the glaciated Appalachian Plateau. The entire county is underlain at varying depths by upper Devonian shale, siltstone, and sandstone. According to the Bedrock Geologic Map of New York, bedrock beneath the NYSDOT site consists of Devonian shale of the Sonyea Group. Bedrock was not encountered in soil borings drilled during the Phase I and II Hazardous Waste Assessments.

Pleistocene glacial deposits make up the majority of the surface soils throughout the county. According to the Soil Conservation Service of the United States Department of Agriculture, about 90 percent of the county's soils were formed in unsorted glacial till. Glacial features such as kames, kame terraces, and eskers are present throughout the valleys. Most valley deposits are interlayered and interfingered and contain varying amounts of clay, silt, sand, and gravel. The Soil Conservation Service maps the surface soils at the site as Tioga Series silt loam. Tioga soils are brown silt to sand loam sometimes with coarse sand and gravel within 30 inches of the surface. According to the Surficial Geologic Map of New York, the site is underlain by kame deposits of sand and gravel ranging in thickness from 30 to 90 feet.

Investigative soil borings at the site generally revealed two (2) unconsolidated deposits within 40 feet of the surface. The upper unit is poorly graded sand and gravel, with silt, and an approximate thickness ranging from 10 to more than 40 feet. The sand and gravel interfingers with, and overlies, a unit of interbedded fine sand and silt with little clay.

Groundwater flow is generally to the south-southwest at an average gradient of approximately 0.06 ft/ft. The water table was observed above, below, and within the silt unit beneath the site. In-situ hydraulic conductivity tests performed in wells FH-X-3, FH-X-12, MW-8, and MW-9 revealed an average hydraulic conductivity in the 10^{-4} cm/sec range.

1.2 Summary of Phase I Hazardous Waste Assessment

A Phase I Hazardous Waste Assessment of the site was performed during October and November 1993. The Phase I Assessment focused solely on the land parcel owned by the NYSDOT. This assessment consisted of a ground penetrating radar study, soil vapor survey, installation and sampling of three (3) groundwater monitoring wells (FH-X-3, FH-X-9, and FH-X-12) and subsurface soil sampling at nine (9) locations.

The Phase I Hazardous Waste Assessment revealed that a level of trichloroethene was present in the groundwater sample from monitoring well FH-X-12 at 1120 μg/L. This concentration level exceeds New York State Groundwater Standard of 5 μg/L for trichloroethene as well as the TCLP regulatory level of 500 μg/L which indicates that the groundwater would need to be classified as a hazardous waste based on the toxicity characteristic. Cis-1,2-dichloroethene was also present above State Standards in the FH-X-12 sample at 215 μg/L. Although samples from monitoring wells FH-X-3 and FH-X-9 had lower levels of trichloroethene (120 μg/L and 20.3 μg/L) and cis-1,2-dichloroethene (13.4 μg/L and 1.9 μg/L), the levels generally still exceeded New York State Standards.

Soils samples taken during the Phase I Assessment did not exhibit significant volatile organic compound (VOC) contamination. Trichloroethene was detected at well locations FH-X-3 and FH-X-9 in soil samples at 8.0 μg/Kg and 3.6 μg/Kg respectively. These levels are well below the recommended soil clean-up standard of 700 μg/Kg.

Additional information on Phase I results can be found in the NYSDOT, Phase I Hazardous Waste Assessment Report dated January 1994. The contamination levels identified during the Phase I Assessment resulted in the need for additional data to be collected during a Phase II Hazardous Waste Assessment.

1.3 Summary of Phase II Hazardous Waste Assessment

The Phase II Hazardous Waste Assessment investigated both the NYSDOT property and the 2.7 $\pm$ acre Gorick Construction Company property. The objective of this assessment was to characterize the site hydrogeology, to respond to health and safety questions from the New York State Department of Environmental Conservation (NYSDEC) and the Broome County Health Department (BCHD), to further delineate the groundwater contaminant plume, and to generate data in support of subsequent site remediation. Additional monitoring wells were installed to assess if the source of contamination was originating from off-site.

The Phase II Hazardous Waste Assessment of the site, conducted in February and March 1994, consisted of the installation and two (2) rounds of sampling of seven (7) additional groundwater monitoring wells (MW-1 through MW-7), another round of sampling of the three (3) original monitoring wells (FH-X-3, FH-X-9, and FH-X-12), a soil gas survey of the Gorick property and the proposed building footprint, and the collection of three (3) additional surface and one (1) subsurface soil sample.

The results of the Phase II Hazardous Waste Assessment were similar to those of the Phase I. A level of trichloroethene was present in the groundwater sample from monitoring well FH-X-12 at 1810 $\mu g/L$. Cis-1,2-dichloroethene was present at 188 $\mu g/L$. Samples from monitoring wells FH-X-3 and FH-X-9 contained slightly lower levels of trichloroethene (99.2 $\mu g/L$ and 7.8 $\mu g/L$, respectively) and cis-1,2-dichloroethene (4.6 $\mu g/L$ and not detected, respectively) then detected during Phase I. No VOC were detected in the new wells with the exception of monitoring well MW-2. This is an upgradient well immediately downgradient of the neighboring commercial site. The initial sampling of this well-detected tetrachloroethene at a level of 8.6 $\mu g/L$. Subsequent sampling found no VOC in this well.

Additional information on the Phase II results can be found in the NYSDOT Phase II Hazardous Waste Assessment report dated May 26, 1994.

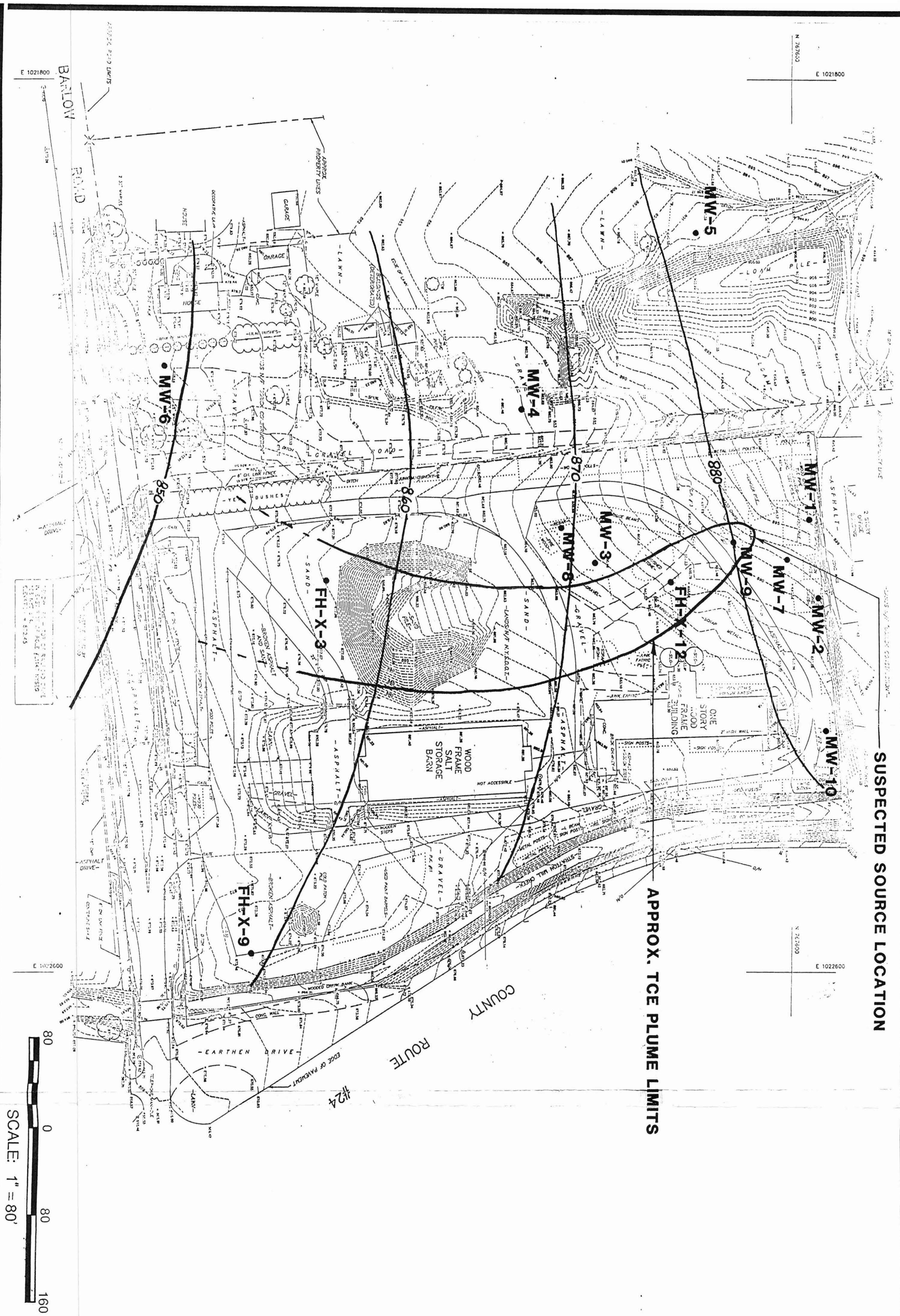
1.4 Additional Studies

Subsequent to the issuance of the Phase II report, additional tests were performed in May and June of 1994 to attempt to locate the source area of the trichloroethene and gasoline related contamination and to further delineate the extent of the groundwater contaminant plume. Two (2) Geoprobe® soil gas and groundwater samples were taken; three (3) additional groundwater monitoring wells were installed and sampled (MW-8, MW-9, and MW-10), and in-situ hydraulic conductivity tests were performed on wells MW-8, MW-9, FHX-3, and FHX-12.

The results of this additional testing found contaminants in the groundwater obtained from monitoring well MW-9. The contaminants consisted of m,p-xylene (501 $\mu g/L$); o-xylene (198 $\mu g/L$); ethylbenzene (186 $\mu g/L$); trichloroethene (39 $\mu g/L$); cis-1,2-dichloroethene (31.7 $\mu g/L$); and toluene (18.7 $\mu g/L$). The compounds detected are indicative of two source materials; gasoline and trichloroethene.

1.5 Current Understanding of Problem

Based on the data, it is believed by the NYSDOT that the source area of the trichloroethene is located near well MW-9. The petroleum-based compounds in this area and the visual evidence from aerial photos seem to indicate that the past activities which resulted in the groundwater contamination occurred at this location. It is common to see compounds with no chlorinated elements (such as the gasoline-related compounds detected at MW-9) travel relatively short distances before being degraded. Trichloroethene is much more persistent in the environment and degrades more slowly than petroleum-related compounds. Therefore, the petroleum (gasoline) related groundwater plume is confined to the immediate vicinity of MW-9 whereas the trichloroethene plume has migrated further downgradient from the source area. Figure 1.3 is a depiction of the trichloroethene plume area and groundwater contours based on sampling and average groundwater elevation data.



HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE DRAWN NO. 6793	NYSDOT Residency Site Barlow Road Kirkwood, NY **GROUNDWATER CONTOURS AND TCE PLUME** NYSDOT REGION 9 PIN 9650.02.301	**FIGURE 1.3**

2.0 DEVELOPMENT OF INTERIM REMEDIAL ALTERNATIVES

The goal of the Interim Remedial Measure shall be to remediate groundwater impacted by gasoline-related VOC and trichloroethene in the source area centered around MW-9 and FH-X-12. Removal and/or control of the source area impacted groundwater will prevent further migration of these contaminants into downgradient areas.

The primary methods currently available for remediation of dissolved VOC in groundwater are:

1. Reliance on natural attenuation of contaminants in the subsurface, with concurrent groundwater monitoring;

2. Recovery of impacted groundwater by pumping with subsequent treatment at the surface;

3. In-situ stripping of VOC from groundwater by sparging, with subsequent recovery of contaminants in the vapor phase by soil vapor extraction, and;

4 In-situ bio-degradation of the VOC through addition of nutrients, bacteria, and/or oxygen to the impacted aquifer.

Reliance on natural attenuation for site remediation generally requires that investigations be performed to assess contaminant migration rates, migration pathways, and attenuation rates in the subsurface. A site-specific model of contaminant attenuation and migration is developed, with long-term monitoring performed to verify and/or adjust the model. An assessment of impacts to potential receptors is also performed prior to choosing this alternative, in order to judge the acceptability of risks to potential receptors.

Recovery of impacted groundwater is accomplished through the use of either recovery wells or interceptor trenches equipped with pumping equipment to remove impacted groundwater to the surface for treatment or disposal. The groundwater recovery system is designed to gain hydraulic control (both vertically and horizontally) over the area targeted for remediation in order to prevent further downgradient contaminant migration in the groundwater. The design of a site specific groundwater recovery system is critical to the success of the remedial program under this option.

Once removed to the ground surface, a wide variety of methods are available to dispose and/or treat water containing dissolved phase VOC. These options range from no treatment with discharge to a permitted facility (such as the local publicly-operated treatment works), to on-site removal of contaminants from the water to levels where discharge to surface water or groundwater are permissible.

The applicability of a given treatment/disposal option is highly dependent on site-specific conditions such as influent contaminant concentrations, contaminant chemical properties, flow rates, groundwater major ion chemistry, organic/inorganic fouling potential, and treated water and/or air discharge options.

Treatment technologies utilized to remove dissolved VOC from water include adsorption onto granular activated carbon (or natural clay based or synthetic adsorbers), aeration/air stripping, oxidation by hydrogen peroxide and ultraviolet light, destruction by metallic catalyst and ultraviolet light, oxidation by ozone, and ex-situ digestion in bio-reactors.

Air sparging involves injection of air into the impacted aquifer by the use of injection wells, resulting in in-situ air stripping of VOC from the aquifer. The process normally requires concurrent soil vapor extraction to capture vapor phase VOC migrating from the saturated zone into the unsaturated zone. Additionally, it may be necessary to gain hydraulic control of the surrounding aquifer should sparging result in mounding of the water table which may induce contaminant migration from the sparged area. Recovered groundwater normally requires treatment to remove contaminants as discussed above.

In-situ bioremediation of an aquifer may be accomplished through the injection of an aqueous solution of nutrients, oxygen, and/or bacteria into the impacted groundwater to promote biological growth. Injection of these materials normally requires that hydraulic control of the aquifer be established to prevent induced contaminant or nutrient migration into unimpacted portions of the aquifer. The recovered groundwater would normally require treatment to remove contaminants as discussed above.

Contaminants are transferred to the vapor phase during treatment processes such as air stripping or recovery techniques such as soil vapor extraction. These vapors may require treatment prior to atmospheric discharge if VOC concentrations exceed regulatory limits. Techniques currently available for vapor phase VOC treatment include adsorption (onto granular activated carbon or synthetic adsorbers), thermal oxidation (incineration), catalytic oxidation, ozone/catalytic oxidation, and bio-filtration.

3.0 PRELIMINARY SCREENING

The four remediation techniques discussed in Section 2.0 are evaluated in subsequent sections of this study for possible implementation as Interim Remedial Measures at the NYSDOT Barlow Road Maintenance Facility. The use of groundwater interceptor trenches for options requiring groundwater recovery is ruled out in favor of pumping wells due to a depth to groundwater on site in excess of 17 feet. Construction costs of interceptor trenches to such depths (especially in fine grained, saturated materials) greatly exceed those of groundwater recovery wells.

The treatment technologies for aqueous phase VOC removal considered in this study are adsorption onto granular activated carbon, air stripping, and a combination of air stripping and carbon adsorption in series. Capital and maintenance costs of the other aqueous treatment technologies mentioned in Section 2.0 are not competitive with air stripping unless vapor phase treatment is necessary for air stripper vapor discharge. The oxidation and bio-treatment methods noted in Section 2.0 become cost competitive with carbon adsorption only when high influent concentrations result in excessive carbon consumption.

Vapor phase VOC treatment options are not evaluated in this report. The need for vapor phase VOC treatment from air stripping or soil vapor extraction can not be determined without the performance of site pilot tests and recovery system design to evaluate contaminant influent concentrations and flow rates. In addition, vapor phase treatment may be avoided by initially pumping groundwater or applying soil vapor extraction vacuum at low rates to keep air emissions below permissible limits. Pumping and/or vacuum rates may then be increased over time as initially high groundwater or soil vapor VOC influent levels decline to avoid the need for vapor phase treatment.

4.0 DESCRIPTION OF INTERIM REMEDIAL ALTERNATIVES

This section presents the alternative interim remediation methods investigated for addressing source area contaminated groundwater at the NYSDOT Barlow Road Equipment Maintenance Facility. This feasibility study includes a brief description of the proposed alternative, site-specific requirements of the system, preliminary construction cost estimates, estimated annual operation and maintenance costs, and the ranking of the remediation method using the NYSDEC TAGM #HWR-90-4030 guidelines.

The following remediation alternatives have been reviewed in this study:

A. No Action.

B. Groundwater Recovery by Pumping Wells, On-Site Treatment, and Sewer or Stream Disposal (Pump and Treat).

   1. Groundwater Treatment by Air Stripping.

   2. Groundwater Treatment by Carbon Adsorption.

   3. Groundwater Treatment by Air Stripping and Carbon Adsorption in Series.

C. Air Sparging and Soil Vapor Extraction.

D. Groundwater Recovery by Pumping Wells, On-Site Air Stripping, and In-Situ Bioremediation.

4.1 No Action

The no action alternative would not utilize any current technologies to clean-up or control contamination. Under the no action alternative, only environmental monitoring is continued. Groundwater remediation would be solely dependent on natural attenuation and degradation processes.

4.2 Groundwater Recovery, On-Site Groundwater Treatment, and Sewer or Stream Discharge of Treated Effluent

4.2.1 Groundwater Recovery

Prior to treatment by air stripping, carbon adsorption, air stripping with carbon adsorption, or bioremediation, the groundwater must be intercepted and pumped to the treatment system. Groundwater recovery systems are of two general types; recovery wells and interceptor trenches. The installation of trenches at the NYSDOT site is deemed impractical, due to the depth to first groundwater ranging between 17 and 27 feet below grade.

Assuming that one or more groundwater recovery wells will be utilized, it will be necessary to perform site pilot testing (an aquifer pumping test) in order to assess the number, construction, and placement of recovery wells needed to gain hydraulic control of the source area groundwater plume. The results of the aquifer test would also be utilized to establish design criteria for the groundwater treatment system such as flow rate and influent contaminant concentrations.

Groundwater recovery pump options are discussed in the following sections:

a. Air Driven Pump

The groundwater may be conveyed to the treatment system by an air powered, positive displacement, submersible pump assuming maximum well yields are less than 8 gpm. This pump system is often used for groundwater recovery due to its reliability for pumping low flows at low discharge heads. Also, it is a safe pump to use where the atmosphere has a potential to be explosive due to the presence of ignitable volatile organics.

The air-driven pump is essentially a bailer with two (2) check valves which allows approximately 0.5 gallons of water to be stored within the pump body. A compressed air charge through an air line is delivered to the pump, from an air compressor, forcing groundwater into the discharge tubing. When the air charge is removed, air is vented and the pump body refills with water.

Because the pump has only two (2) moving parts and functions solely using compressed air, it can survive dry pumping and silt that may enter the well screen. One disadvantage to air driven pumps is the need to install and operate a compressor on site.

An air-driven pump should not be confused with an airlift pump which bubbles air into water near the bottom of the water column and depends on unbalanced hydrostatic forces to lift the water. Generally air lift pumps are used in applications where only 5 to 10 feet of lift is desired.

b. High Vacuum Liquid Ring Pump

Another type of pump currently utilized in groundwater recovery is the high vacuum, liquid ring pump, where the actual riser pipe of the well functions as the outer pump casing. This system is generally capable of achieving up to 30 gpm at each well.

Liquid ring pump systems are more typically used in dense, fine grained formations, or when combined liquid and vapor phase recovery is desired. The application of a vacuum to a groundwater recovery well (known as vacuum enhanced groundwater recovery) tends to increase the flow rate into the well and therefore increase the radius of influence. Vacuum enhanced groundwater recovery coupled with soil vapor extraction may greatly speed the remediation process in formations of low permeability.

The liquid ring pump utilizes a rotor which is surrounded by water (liquid ring) to form a seal capable of obtaining much higher vacuums than rotary vane vacuum blowers. Water and gas can pass through the pump. The gas is compressed and forced radially inward toward a central port cylinder at the center of the rotor. After each revolution, the compressed gas and accompanying liquid are discharged.

Disadvantages include the requirement that a supply water tank be installed so that sufficient water is always available for the liquid ring seal. Like other surface-mounted pumps (i.e., centrifugal pumps), intake depths are limited to those attainable through suction (approximately 20 feet). Liquid ring pumps consume a large amount of energy as compared to other groundwater pumps.

c. Electric Submersible Pumps

Electric submersible pumps are most commonly used in domestic water supply wells. In recent years, they have been applied to environmental remediation systems and are now available with chemical-resistent components such as stainless steel housings and impellers and teflon seals. These pumps consist of a pump motor and pump housing which are placed downhole in a recovery well. Electric submersible pumps are available in a wide range of sizes and are capable of operating against high heads at both high and low flows. Continuous flow rate adjustment is accomplished through either a gate valve on the pump discharge line or through incorporation of a rheostat in the pump motor controller. For applications in the less than 10 gpm range, with total head less than 50 feet, a small submersible pump (0.25 to 0.5 hp motor) can meet the needs of a groundwater recovery system.

Unlike air-driven pumps, submersibles do not require a compressor and complex air control and delivery system. Compared to the liquid ring pump, electric submersibles consume much less power and do not require a sealant. The disadvantages of submersible pumps include an inability to pump free phase contaminants (not explosion-proof) and the need for a water level control system to maintain pumping levels above the pump intake at all times. The pump cannot run dry.

4.2.2 On-Site Treatment

a. Air Stripping

Air stripping is a proven cost-effective and efficient method for removing VOC from contaminated groundwater. The VOC are removed from the groundwater by transfer from the dissolved to the vapor phase. The ease with which a particular VOC may be removed from water by air stripping primarily depends on the compound's volatility and solubility. Trichloroethene, with a relatively low solubility and high volatility is readily stripped from the aqueous phase into the vapor phase as are the gasoline-related VOC present in groundwater beneath the site.

An air stripping system generally consists of constructing a packed tower, a cylindrical, or rectangular vessel partially filled with an inert packing material. The contaminated groundwater is pumped from the ground and sprayed evenly over the top of the packing material. An air blower system is installed below the packing material and concurrently blows air up through the packing material as water is filtering down through the packing material. The sizing of the air stripping equipment is based on influent contaminant concentrations and flow rates as determined during recovery system pilot testing.

The organics are transferred into the passing air. The air then carries the contaminants out of the stripper into the atmosphere. If the VOC concentrations in the air leaving the packed tower exceed New York State Guidance Values, a secondary air treatment method, such as a vapor phase carbon adsorption unit, would be required to treat the air to allowable VOC concentrations prior to the release to the atmosphere.

The most frequently encountered problem with air stripping is scaling and biological fouiing. Scaling is caused by the precipitation and buildup of inorganic materials (particularly carbonates and oxides) on the packing media. The addition of oxygen to groundwater in air strippers also promotes the growth of micro-organisms in the stripper. Scaling and biological fouling adversely impact phase transfer, pressure drop, flow rate, and mass transfer rate. These problems are generally controlled by regular system cleaning or pre-stripper influent treatment. The potential for inorganic fouling may be investigated prior to system design through major ion analyses of influent groundwater samples. Fouling control and prevention measures may then be incorporated into the recovery and treatment system designs.

b. Carbon Adsorption

Carbon adsorption is a process in which a contaminant is adsorbed from the aqueous or vapor phase to the surface of solid carbon where it accumulates for subsequent extraction or destruction. The use of granular activated carbon to purify water is a proven technology that has been in use for decades. Activated carbon is an excellent adsorbent due to its ability to remove large quantities of organic impurities and its regenerative capacity. Trichloroethene has a moderate affinity to granular activated carbon compared to other VOC and can be successfully removed from groundwater utilizing this treatment technique.

When organic chemicals in water contact activated carbon particles, the organic chemicals adsorb to the carbon decreasing the contaminants in the water. By performing adsorption in pilot tests and/or consulting adsorption isotherm charts, it is possible to obtain a relationship between the equilibrium concentration of the groundwater and the amount of organics adsorbed per unit mass of activated carbon. A general rule of thumb is to assume that it will require six to ten pounds of carbon to adsorb one pound of an organic compound.

There are several types of activated carbon adsorption processes, the most common processes being the downflow, fixed-bed adsorber. The fixed-bed adsorber consists of a single column with an inlet distribution at the top, an activated carbon bed, and an underdrain system. Contaminated water travels down through the activated carbon bed to the underdrain.

The effectiveness of adsorption depends on many factors including the molecular weight and structure, solubility, and polarity of the compound being removed as well as the pH and temperature of the aqueous phase and contact time with the adsorbing media. In groundwater treatment applications, it is often the case that granular activated carbon becomes spent through adsorption of major ions and biological fouling long before its contaminant adsorptive capacity is reached.

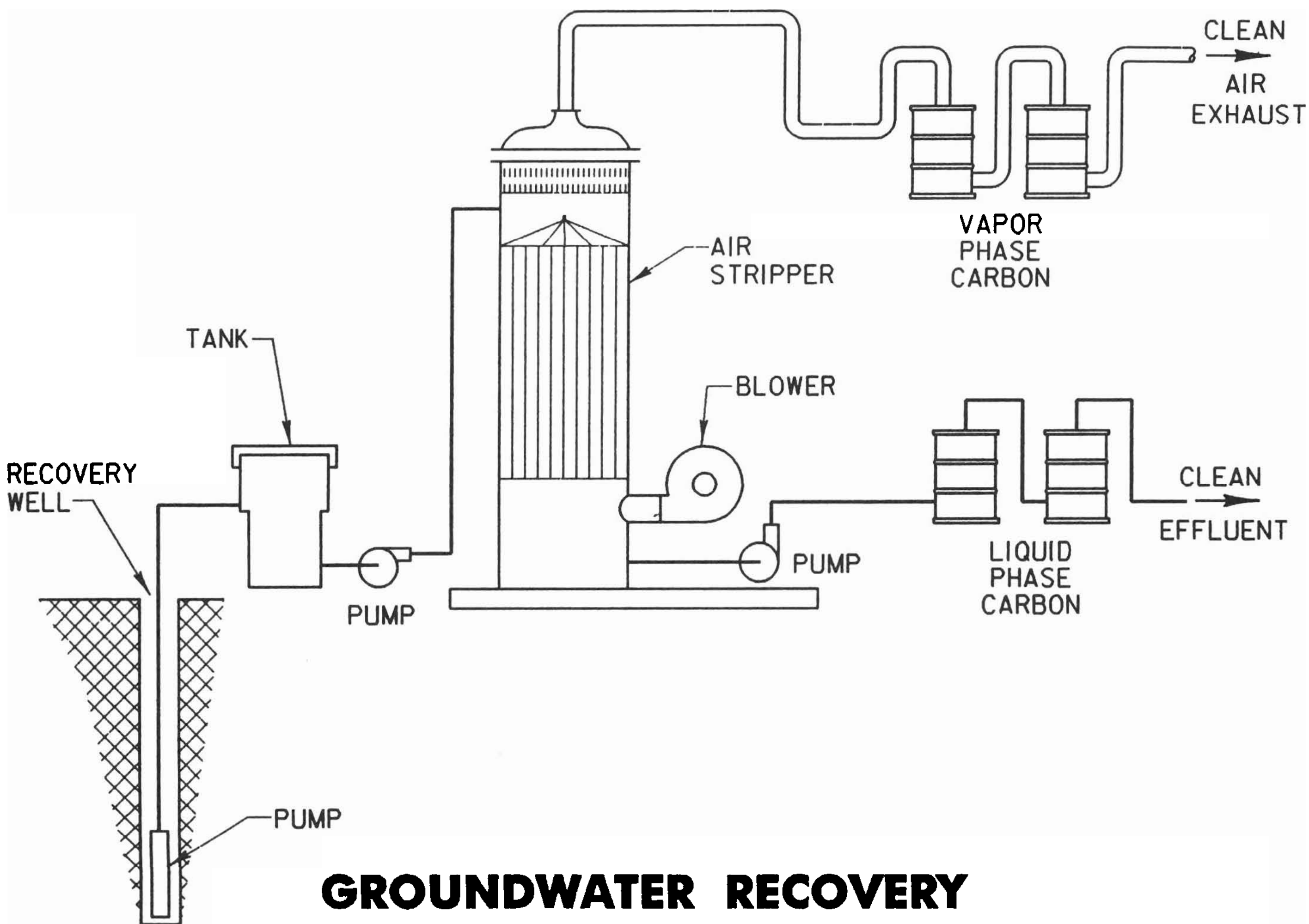
More than 90 percent of the original carbon used in the carbon adsorption process can be recovered or regenerated by chemically or thermally reversing the adsorption process. However, it is the usual case in contaminated site remediation programs to dispose of spent carbon off site and replace the carbon with new material.

c. Air Stripping and Carbon Adsorption in Series

Because treatment or proper disposal of spent carbon requires a considerable cost, the use of activated carbon is preferable where influent contaminant concentrations and flow rates are relatively low. Granular activated carbon is most effective as a secondary or polishing treatment system. Air stripping, combined with carbon adsorption in series, provides an effective treatment method optimizing the contaminant removal levels while reducing replacement and maintenance costs. The combined system is more effective in removing contaminants, remedies a wider range of contaminants, and provides a more suitable product (cleaner) for disposal. Figure 4.1 depicts a groundwater recovery and treatment system with an air stripper and carbon adsorption in series.

4.2.3 Sewer or Stream Treated Effluent Discharge

All treatment methods used in conjunction with groundwater recovery will require discharging of the treated groundwater following the treatment process. The two (2) discharge alternatives available for the NYSDOT site consist of discharge to the Binghamton - Johnson City Joint Sewage Treatment Plant or discharge to the Stratton Mill Creek. Either discharge alternative would require a permit from the receiving treatment plant or the NYSDEC. Such permits normally require that remediation system effluent samples be analyzed on a regular basis to ensure compliance with permit contaminant concentration limits.



GROUNDWATER RECOVERY AND TREATMENT SYSTEM (WITH AIR STRIPPER AND ACTIVATED CARBON)

HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE 8/1/94 DRAWN JC NO. 6793	BARLOW ROAD MAINTANENCE FACILITY **FEASIBILITY STUDY OF REMEDIAL ALTERNATIVES**	FIG. **4.1**

4.3 Air Sparging and Soil Vapor Extraction

4.3.1 Air Sparging

Air sparging is the injection of air under pressure into an aquifer via injection wells in an attempt to strip dissolved VOC from groundwater in-situ. Injected air forms bubbles that travel horizontally and vertically through the saturated zone. As in the air stripping process, volatile compounds exposed to the air bubbles volatilize into the gaseous phase and are carried by the air stream into the vadose zone where they can be captured by a vapor extraction system or vented by passive wells into the atmosphere. In the event that air sparging off gases exceed NYSDEC air quality standards, it may be necessary to collect these vapors for vapor phase treatment on site. The air sparging process also increases dissolved-oxygen content in the saturated zone which may enhance natural biodegradation.

A potential concern with the use of air sparging is that a groundwater mounding effect may occur in the air injection zone thereby inducing the migration of contaminated groundwater away from the sparging area. Air sparging systems therefore often require that hydraulic control of the plume is maintained by a groundwater recovery system. Another concern that must be considered is the potential for exhausted vapors from the air sparging process to accumulate in building basements or underground utilities. If there is a potential for this to occur, an adequate venting system or interception system would be required within, near, or under the buildings.

A combination air sparging and soil vapor extraction pilot test is performed prior to the design of air sparging systems to assess the number of sparging wells necessary to remediate the area, air injection rates and pressures needed, the extent of groundwater mounding induced by air injection, contaminant concentrations released into the vapor phase, and the ability to control these vapors through passive venting or vapor extraction.

4.3.2 Soil Vapor Extraction

As noted in Section 4.3.1, soil vapor extraction wells are often installed to depths just above the saturated zone and above the contaminate plume to collect vapors created during air sparging activities. Soil vapor extraction systems are also used alone to remediate volatile contaminants in the unsaturated zone. A soil vapor extraction pilot test is performed prior to design of the vapor extraction system in order to establish the number of vapor extraction points needed to control the site, system vacuum and flow rates, and recovered vapor concentrations.

Soil vapor extraction (SVE) is also known as vacuum extraction and soil venting and is usually used where there is significant volatile soil contamination. By using a blower to place a vacuum on the soil through a series of wells or trenches, the volatilized compounds are drawn to the surface. The ground surface is sometimes sealed to prevent short circuiting, which may result in reduction of the vapor recovery point radius of influence due to air channeling. Vacuum extraction alone is effective only in the vadose zone (unsaturated zone).

A treatment system may be required to treat the SVE off-gas to acceptable air discharge limits. Possible treatment methods for the off-gas are catalytic and/or thermal oxidation, activated carbon, or similar air pollution control mechanisms.

Soil vapor extraction, coupled with air sparging, provides the advantage of remediating unsaturated soil in the vadose zone as well as groundwater. Figure 4.2 depicts a typical air sparging and SVE system.

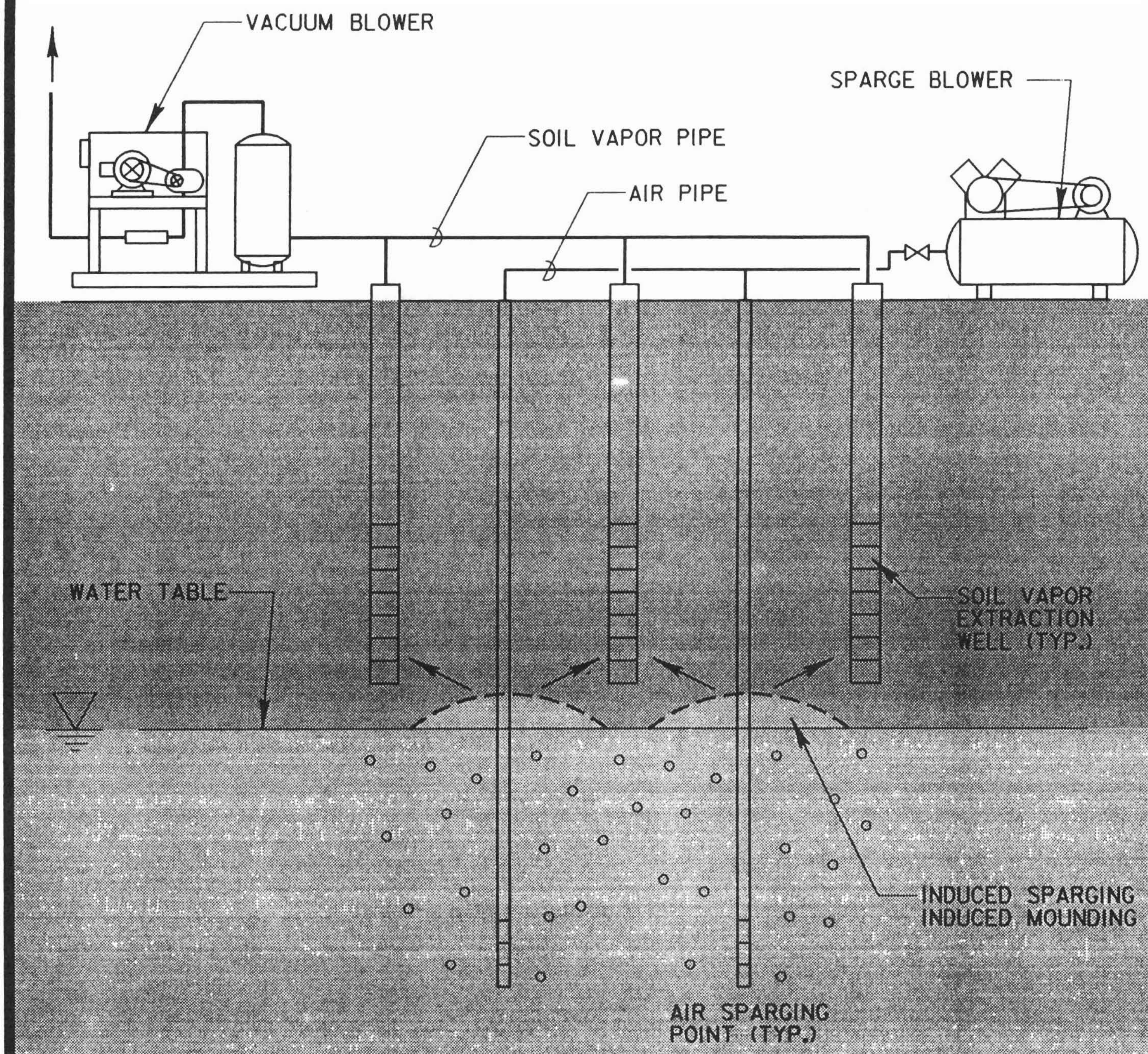
4.4 Groundwater Recovery, Air Stripping, and In-Situ Bioremediation

Bioremediation of a contaminated aquifer involves the injection of chemicals (nutrients and oxygen) into the groundwater plume to stimulate growth of indigenous bacteria and accelerate the natural rate of biodegradation of the organic contaminants. It is also possible to inject cultured bacteria capable of degrading target compounds should the site subsurface lack the appropriate bacteria genera. Bioremediation works because many organic compounds found in hazardous waste materials can be used as food by micro-organisms allowing complex molecules to be broken down into simpler, less toxic compounds. In-situ bioremediation is an effective remediation method for both groundwater contaminants and contaminated soils.

Environmental factors that affect microbial activity and that determine the rate and extent of biodegradation include:

- Appropriate levels of organic and inorganic trace elements.
- Oxygen concentration.
- Redox potential.
- pH.
- Degree of water saturation.
- Hydraulic conductivity of the soil.
- Osmotic potential.
- Temperature.
- Competition, including the presence of toxins.
- Predators.
- Type/concentration of contaminants.
- Hydrogeologic affects on microbial activity and the feasibility of in-situ treatment.

It is feasible to manipulate some of these factors to optimize subsurface environmental conditions. Nutrients and oxygen can be added to the subsurface. It may be feasible in some cases to enhance reducing conditions, thereby lowering redox potential. pH can be adjusted with the addition of dilute acids or bases. Water can be pumped into zones lacking sufficient moisture.



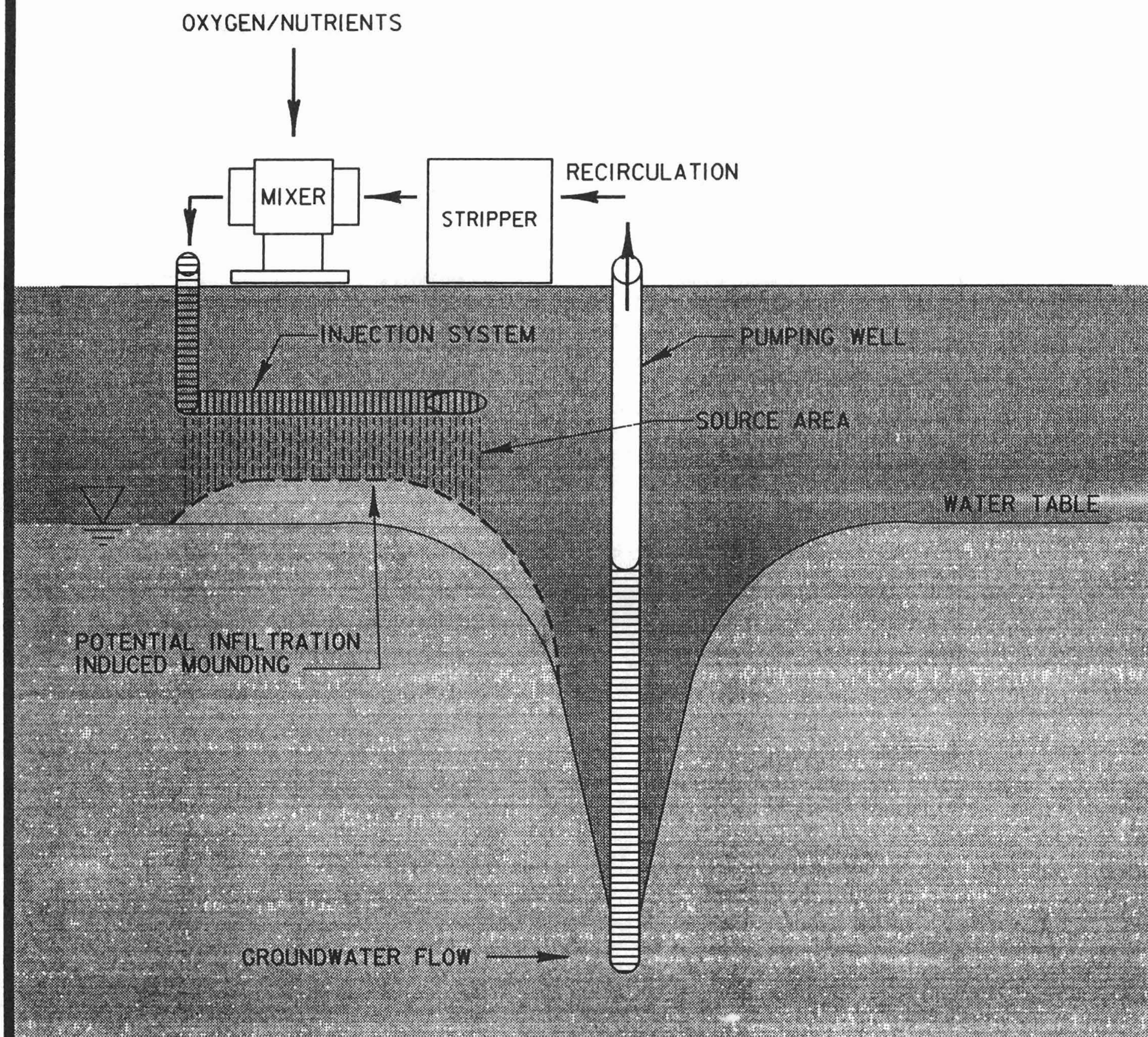
TYPICAL AIR SPARGING AND SOIL VAPOR EXTRACTION SYSTEM

HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE 9/1/94 DRAWN JC NO. 6793	BARLOW ROAD MAINTANENCE FACILITY **FEASIBILITY STUDY OF REMEDIAL ALTERNATIVES**	FIG. **4.2**

There are some factors that cannot be corrected, such as the presence of predators, competition between the microbial populations, or the salinity of groundwater. Even if substantial microbial activity is present, the wastes are biodegradable only if the hydrogeology of the site is favorable. The hydraulic conductivity must be sufficient enough so added substances, such as oxygen and nutrients, can be delivered to the impacted zone. Sandy and other highly permeable sites are far easier to treat than clayey or silty soils. Pilot tests are required to assist in determining the appropriate design parameters required for the bioremediation process including existing aquifer chemical, nutrient and oxygen conditions, subsurface hydraulic conductivity and indigenous microbes present.

One possible groundwater recovery and aerobic bioremediation alternative for this site would consist of pumping near FX-H-12 where the main contaminant, trichloroethene, (TCE) was at hazardous waste levels, treating the groundwater to remove TCE using air stripping, injecting oxygen (and possibly other nutrients or cometabolites) to the treated water by using pure oxygen or hydrogen peroxide, and reinjecting the oxygen-rich groundwater immediately upgradient from the presumed source location using an infiltration basin or wells (see Figure 4.3). Alternatively, it may be possible to use anaerobic processes to degrade trichloroethene by injecting nitrate. However, anaerobic degradation would likely result in the formation of vinyl chloride before more desirable end products are reached. Vinyl chloride is more toxic than TCE.

The injection or infiltration of treated effluent into groundwater beneath the site would require a NYSDEC SPDES permit and regular effluent monitoring. Site pilot testing would be necessary before system design to determine the radius of influence of groundwater recovery wells, treatment system influent flow rates and concentrations, and the ability of the subsurface materials to accept injected water.



TYPICAL IN-SITU BIOREMEDIATION TREATMENT SYSTEM

HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE 9/1/94 DRAWN JC NO. 6793	BARLOW ROAD MAINTANENCE FACILITY FEASIBILITY STUDY OF REMEDIAL ALTERNATIVES	FIG. 4.3

5.0 RANKING CRITERIA

The following criteria, included in the feasibility analysis and ranking of remedies, was obtained from the NYSDEC Division of Hazardous Waste Remediation TAGM #HWR-90-4030, "Selection of Remedial Actions at Inactive Hazardous Waste Sites".

1. Compliance with NYS Standards Criteria and Guidance Values (Weight = 10)

The remedial options are evaluated according to the ability of the action to ultimately achieve contaminant levels below those established by the State of New York for soil, air, surface water, and groundwater.

2. Protecting Human Health and the Environment (Weight = 20)

The evaluation of each alternative under this criterion will focus on how the remedy achieves protection over time, how risks are reduced or managed, and how the source of contamination is to be eliminated, reduced, or controlled.

3. Short-Term Impacts and Effectiveness (Weight = 10)

This criterion assesses the effects of the remedial alternative on human health and the environment during the construction and implementation phase of the remediation.

4. Long-Term Effectiveness and Permanence (Weight = 15)

Long-term effectiveness is the ability of a remedy to maintain the desired level of protection over time.

5. Reduction of Toxicity, Mobility, or Volume (Weight = 15)

Remedial alternatives are evaluated for their ability to permanently and significantly reduce the toxicity, mobility, or volume of hazardous waste at the site.

6. Implementability (Weight = 15)

Implementability is a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative.

7. Cost (Weight = 15)

Cost factors to be considered for each remedial alternative include direct capital costs and operation and maintenance costs.

6.0 ASSESSMENT OF THE ALTERNATIVES

Each alternative below is assessed for its feasibility against NYSDEC criteria. Table 6.1 details the ranking for each remedial alternative. The highest score an alternative can achieve with respect to a given criterion is the weight importance for the criterion.

6.1 No Action

1. Compliance with NYS Standards (Score: 1/10)

NYS groundwater standards for the contaminants of concern are trichloroethene (5 ppb), toluene (5 ppb), ethylbenzene (5 ppb) and xylene (5 ppb). The No Action Option relies on natural attenuation to bring groundwater contaminant concentrations to acceptable levels. An excessive amount of time would be required to accomplish compliance with groundwater standards due to the persistent character of trichloroethene in the subsurface environment.

2. Protecting Human Health and Environment (Score: 5/20)

The alternative does not create any potential for above-ground receptors to come in contact with contaminated groundwater. However, the site is within the area designated as the Endicott-Johnson City primary water supply aquifer and is 3,000 feet from the Susquehanna River, where contamination could eventually resurface.

3. Short-Term Impact and Effectiveness (Score: 4/10)

Workers would not have to work in close contact with contaminated groundwater nor will the contamination be transferred to another media where strict control and monitoring is necessary to avoid spills, air contamination, improper carbon disposal, etc.

Removal of trichloroethene, xylene, ethylbenzene, toluene, and cis-1,2-dichloroethene would depend on biochemical reactions produced by microbes already present at the site. Xylene, ethylbenzene, and toluene are regarded as biodegradable in aerobic environments, whereas, both trichloroethene and cis-1,2-dichloroethene are regarded as persistent and are expected to take longer periods to degrade. These chemicals have been shown to biodegrade but the process by which the microbes accomplish the end results (conversion to carbon dioxide, water, and additional bacteria) involves a step process in which the chlorinated hydrocarbon is transformed to another chlorinated hydrocarbon by losing chlorine molecules. The presence of cis-1,2-dichloroethene may indicate that this is occurring at the source area to some degree.

4. Long-Term Effectiveness and Permanence (Score: 10/15)

The persistence of trichloroethene in the environment reduces the effectiveness of taking no action. Trichloroethene, if left to biodegrade without intervention, may not be fully destroyed to acceptable levels after 30 years of continued monitoring.

5. **Reduction of Toxicity, Mobility, and Volume (Score: 5/15)**

Mobility would not be reduced using this alternative. The reduction of toxicity and volume of benzene, xylene, and toluene may be accomplished effectively without taking action. Significant results on the reduction of the toxicity and volume of trichloroethene is not expected within reasonable time frames.

6. **Implementability (Score: 15/15)**

Continued monitoring is easily accomplished.

7. **Cost (Score: 13/15)**

Capital costs are minimal; the administrative and analytical costs of groundwater monitoring would be spread over many years. However, long-term monitoring costs can be eliminated altogether by implementing successful remedial measures. If no action is taken, remediation may still be necessary after a prolonged monitoring period.

6.2 Groundwater Recovery, On-Site Treatment, and Sewer or Stream Discharge (Pump and Treat)

1. **Compliance with NYS Standards (Score: 7/10)**

Experience has demonstrated that pump and treat technology is effective in plume control and recovery of the bulk of the contaminant mass from impacted aquifers. Compliance with groundwater standards will ultimately depend on the effectiveness of the groundwater recovery system and not the treatment methods. However, contaminant adsorption and absorption to soil particles in the saturated zone is difficult to reverse. As impacted groundwater is removed from the aquifer, contaminants slowly desorb from impacted soil into the dissolved phase thereby recontaminating the groundwater. Due to this mechanism, it is often the case that pump and treat methods can not achieve compliance with low level (ppb) groundwater standards in a reasonable amount of time.

2. **Protecting Human Health and Environment (Scores: 13/20 stripping, 15/20 carbon, 17/20 both)**

The alternative is very effective in gaining control of plume movement. As this is an Interim Remedial Measure, the alternative does not attempt to clean up or control contamination at the downgradient fringes of the plume. Potential aboveground receptors are created by pumping and treating groundwater at the surface. The technique does not address contamination in the unsaturated zone. Stripping alone would release recovered contaminants to the atmosphere or require vapor destruction on site. Carbon alone would generate a large amount of carbon for disposal.

3. Short-Term Impact and Effectiveness (Scores: 6/10 stripping, 6/10 carbon, 6/10 both)

On-site treatment methods are readily available for effectively removing the trichloroethene and petroleum-based contaminants detected in the groundwater at the proposed NYSDOT Equipment Maintenance Facility. Effectiveness in meeting groundwater standards is dependent on the success of the recovery system and not on the treatment technology applied. Regulation and monitoring of system discharges (air and water) would minimize risks to potential receptors.

4. Long-Term Effectiveness and Permanence (Score: 10/15)

This alternative would eventually remediate the groundwater contaminants found at the source area. The system would accelerate clean-up of groundwater at the source area and depend on natural processes to remediate contamination already dispersed downgradient. Unsaturated zone impacted soil in the source area would likewise be addressed by natural attenuation and capture of contaminants migrating to groundwater by the recovery system. Natural attenuation in the unsaturated zone and downgradient groundwater can require an excessive amount of time. Once again, attainment of groundwater standards depends on the groundwater recovery system and not the treatment technology applied.

This alternative, because of migration control and high equipment reliability, is considered a permanent remedy. Air stripping, carbon adsorption, or a combined system of air stripping with carbon adsorption would all be effective treatment methods for the trichloroethene and petroleum-based contaminants. All three (3) methods would be capable of reducing the contamination level of the recovered groundwater to limits below the New York State Guidance Values or to sewer discharge limits.

Air stripping is suitable for a wide range of VOC and is capable of a 95 to 99 percent reduction of volatile contaminants. Off-gas vapors produced by the treatment process are normally released to the atmosphere (under permit) or further treated prior to atmospheric release. The removal efficiency of the air stripping tower is fixed by design and will not change over the life of the unit unless fouling of the packing material occurs. If fouled, the packing material can be cleaned or replaced.

Carbon adsorption is most effective on low solubility organics but is capable of effectively treating a wide range of organics in various concentrations including those identified at the Barlow Road site. Removal efficiencies of the carbon beds are generally very high but decrease over time as the carbon bed becomes saturated with the contaminant. Replacement or regeneration of the carbon bed will be required as the efficiencies decrease and can be costly and frequent depending on site-specific variables.

A combined air stripping and carbon adsorption system would be the most effective treatment method of the three (3) options capable of efficiently treating VOC and low solubility organics. The combined system would optimize the removal efficiency of the contaminants. Typically, the system would be designed to remove 75 percent of the VOC through air stripping. The remainder of the contaminants would be removed through the carbon adsorption process. The combination of the two (2) technologies results in optimum removal levels while reducing the potential to foul the packing material and minimizes replacing the carbon bedding material.

5. Reduction of Toxicity, Mobility, or Volume (Scores: 5/15 stripping, 8/15 carbon, 11/15 both)

Mobility is controlled very effectively using pumping wells. Pollutant mass is removed directly using physical processes and significant short-term volume reductions are likely. However, trichloroethene is considered carcinogenic and, therefore, it is regarded as toxic, even at low levels. Groundwater clean-up to parts-per-billion levels may be long and difficult using this alternative.

Trichloroethene transferred to the atmosphere by air stripping does not appear to have a significant lifetime and is likely broken down by hydroxyl radicals before it can reach the stratosphere. Spent carbon is generally disposed at a permitted landfill or thermally regenerated off site at a permitted facility. Utilization of a combination system would split the ultimate fate of the contaminant mass between stripper atmospheric discharge and carbon disposal.

6. Implementability (Scores: 5/15 stripping, 2/15 carbon, 8/15 both)

Implementation of a pump and treat system, in terms of constructability, would be favorable at the Barlow Road site. The source area as defined by current data is relatively small and located in the northwest corner of the site easily accessible for construction activities and monitoring purposes. The pump and treat system would consist of extraction wells appropriately located within the contaminated plume area and an appropriate treatment system. Site-specific design criteria for the recovery and treatment systems can be readily ascertained by site pilot testing.

In order to discharge treated groundwater to the sewer system, written authorization from the Joint Sewage Board must be obtained. The treated groundwater must be monitored to ensure that no parameters exceed the effluent limits contained in the permit. A permit fee, a unit charge per gallon discharged plus administrative fees, are charged by the Joint Sewage Board.

Discharge to the Stratton Mill Creek would require a NYSDEC State Pollutant Discharge Elimination System (SPDES) permit. The SPDES permit would impose discharge limitations, periodic monitoring, and associated fees for treated groundwater discharge to the surface waters or groundwater of the State. If air stripping is used, an air permit will also be required by the NYSDEC.

Although each treatment alternative mentioned will need to be checked periodically, the carbon only system will require the most maintenance as carbon will need to be changed and disposed when breakthrough occurs. Air stripping alone may not provide sufficient contaminant removal efficiency to meet permissible discharge limits.

7. **Cost (Scores: 5/15 both, 10/15 stripping, 8/15 carbon)**

The pump and treat alternative, when used alone, often takes a much longer time period than in-situ technologies to achieve acceptable groundwater standards. Initial capital costs and system installation costs may exceed those for air sparging but would be less than the groundwater recovery and bioremediation alternative. Administrative costs can be high due to permit reporting requirements.

Operatión and maintenance costs are high due to the need for regular (weekly) site visits to check and adjust system performance. Maintenance costs can become exceedingly high if system fouling requires regular system cleaning and parts replacement. Often it is necessary to implement alternative remedial technologies such as vapor extraction or air sparging following groundwater recovery efforts to achieve groundwater standards. Stripping alone may require more frequent system cleaning to achieve discharge standards. Carbon treatment alone will result in increased carbon disposal costs.

6.3 Air Sparging and Soil Vapor Extraction

1. **Compliance with NYS Standards (Score: 9/10)**

Air sparging is capable of removing dissolved VOC from the saturated zone to levels below New York State Groundwater Standards in a comparatively short time. Coupled with soil vapor extraction, the method removes volatile contaminants from both the saturated and unsaturated zones, thereby eliminating the source of further groundwater contamination. As with the pump and treat option, this method would rely on natural attenuation to address the plume downgradient from the source area. Air sparging has the advantage over pump and treat of speeding up removal of absorbed and adsorbed volatile contaminants as these compounds are more readily transferred to the vapor phase as opposed to the dissolved phase.

2. **Protecting Human Health and Environment (Score: 13/20)**

This alternative is effective in removing volatile pollutants from groundwater and may eliminate the potential for above-ground contact with contaminated groundwater as pumping may not be necessary. The alternative as proposed for this site targets the source area and does not attempt to clean up contamination at the downgradient fringes of the plume. Vapor control above the water table depends on a secondary soil vapor extraction system and the potential exists for vapor and/or groundwater migration away from the sparge area. Vapor accumulations may be avoided by a properly designed soil vapor extraction system. Groundwater migration (if induced) may be controlled by groundwater recovery.

Risks of uncontrolled contaminant migration are significantly reduced by basing the design on criteria established using a pilot study. Site pilot testing is deemed absolutely necessary in the design of combination air sparging/soil vapor extraction systems.

3. Short-Term Effectiveness and Impacts (Score: 9/10)

Air sparging is essentially an in-situ air stripping system and is capable within specific site conditions of removing trichloroethene and volatile petroleum-based groundwater contaminants by volatilization. Unlike the pump and treat alternative, large volumes of groundwater can be treated simultaneously and continuously, and pollutants attached to saturated soils can also be treated directly.

The distance that the air bubbles reach (radius of influence) is directly dependent on geologic conditions. Subsurface conditions at the site consist of a poorly graded sand, silt, and gravel overlying and interfingered with a clayey silt layer. The permeability of these subsurface materials is low to moderate. The low to moderate permeabilities could constrict air flow and limit the effectiveness or sparging and venting systems. Site pilot tests would be required to establish design criteria for site specific conditions.

4. Long-Term Effectiveness and Permanence (Score: 15/15)

The alternative would be effective in removing both trichloroethene and volatile petroleum compounds from both soil and groundwater medias. This alternative is considered permanent because of its proven ability to clean media contaminated with volatile compounds to environmental standards and criteria and its limited maintenance required to ensure integrity and longevity.

The method is considered to be separation and treatment as contaminants are transferred to the vapor phase, collected by the soil vapor extraction system, and either discharged directly to the atmosphere or further treated before discharge, depending on air effluent concentrations and regulatory permit conditions. The addition of oxygen to the subsurface may enhance microbial activity and promote in-situ bio-degradation of contaminants. However, this is considered a secondary process especially since trichloroethene is not considered readily biodegradable.

5. Reduction of Mobility, Toxicity, or Volume (Score: 12/15)

Toxicity and volume are expected to be significantly reduced using this alternative. However, there is some potential to increase contaminant mobility. Control of contaminant mobility may require the use of additional recovery techniques such as groundwater pump and treat.

A soil vapor extraction system would need to be installed so that the contaminated vapors created can be controlled and treated properly. Further, air vapors could accumulate in the proposed building at the site requiring a venting and or vapor barrier system under the building to protect workers from contaminant vapors.

6. **Implementability (Score: 12/15)**

Construction of an air sparging and vapor extraction system is generally less complex than installing a pump and treat system due to simplified process controls. Equipment for air sparging and soil vapor extraction includes an air blower and vacuum pump which need to be sized, based on a pilot study. The pilot study is essential in order to ensure air flow from the injection wells is being collected properly and well spacing is adequate to cover the desired area. If groundwater control is not necessary, the sparging option will require no groundwater treatment equipment or associated aqueous effluent permitting and monitoring.

7. **Cost (Score: 12/15)**

Treatment process equipment capital costs are lower than those associated with other remedial systems. Air injection and soil vapor extraction well installation costs are variable, depending on the number of points needed to cover the treatment area. Capital costs rise greatly if pilot tests show groundwater recovery and treatment are necessary to control migration from the sparge area. Also, soil vapor extraction system costs can increase if effluent vapor treatment is necessary. Assuming no groundwater or soil vapor treatment, operation and maintenance costs are lower than other remedial systems.

6.4 Groundwater Recovery, Air Stripping, and Bioremediation

1. **Compliance with NYS Standards (Score: 8/10)**

This alternative may be capable of reaching New York State Groundwater Standards for the VOC of concern at the Barlow Road site. Pump and treat technology alone may not be capable of removing contaminants from the aquifer to groundwater standards in a timely manner (see Section 6.2). The augmentation of pump and treat with in-situ bioremediation of the aquifer may be able to achieve groundwater cleanup objectives in less time than pump and treat alone.

As previously noted, trichloroethene is not readily biodegraded. The application of in-situ bioremediation to the aquifer at the Barlow Road site would require on-site and laboratory pilot studies to determine site-specific design criteria and parameters governing successful biodegradation of trichloroethene in the site subsurface environment.

2. **Protecting Human Health and Environment (Score: 18/20)**

In-situ bioremediation remediates both groundwater and soil contaminants by enhancing the natural biodegradation of the chemicals that are adsorbed onto saturated zone soils and dissolved in the groundwater. Bioremediation used alone has proven an effective remediation method for a wide range of contaminants provided that suitable environmental factors are present on site.

Combining pump and treat technologies with bioremediation allows the system to achieve control of mobility while still treating contamination that may be sorbed to soil in saturated and unsaturated zones at the source. As with the other proposed alternatives, this alternative targets the source area and is not expected to be effective in accelerating clean-up at downgradient locations.

3. Short-Term Effectiveness (Score: 7/10)

Petroleum-based contaminants are biodegradable in the presence of naturally-occurring bacteria. Chlorinated compounds such as trichloroethene have reportedly been proven difficult to biodegrade using in-situ bioremediation methods. Studies have shown that aerobic biodegradation would require a large amount of oxygen to facilitate the process and may also require a known cometubolite such as methane[1]. However, the Department of Energy, Office of Technology Development, reported a successful in-situ bioremediation demonstration of the removal of TCE from groundwater at a Savannah River test site[2].

4. Long-Term Effectiveness and Permanence (Score: 12/15)

The groundwater recovery and on-site treatment process would effectively remediate the contaminants detected at the site. Bioremediation added to the pump and treat process has the potential to enhance remediation by increasing the natural biodegradation rate of the contaminants in both the groundwater and saturated soil, potentially reducing the remediation time period. Injection of oxygenated water and possibly nutrients and microbes into the unsaturated zone may successfully remediate the source area. Once again, the application of this technique to the site would require pre-design pilot testing.

Since adsorbed/absorbed soil contamination is addressed by bioremediation, it is expected that clean-up times will decrease in comparison to pump and treat. No general statement can be made as to the remedial time period required for the bioremediation alternative. Numerous factors including compound degradability, type, and amount of bacteria in the subsurface and organic content of the soil, etc., make it difficult to predict the relative clean-up periods.

5. Reduction of Toxicity, Mobility, or Volume (Score: 13/15)

Reduction of toxicity may be slowed by the fact that trichloroethene is not readily biodegradable. Mobility is controlled effectively by using pumping wells. The volume of petroleum compounds should be reduced significantly using bioremediation and air stripping. As with the other techniques, this method is to be targeted at the source area and will rely on natural attenuation of downgradient impacted groundwater.

6. Implementability (Score: 2/15)

The construction of this alternative is more involved than the other alternatives discussed. An infiltration basin must be installed at the source area and a nutrient feeding system must be added which would be capable of providing consistent and proper mixtures.

As with the pump and treat alternatives, the NYSDOT will be generating and treating hazardous waste; the reporting and permit requirements of this action needs to be addressed. Also, the infiltration basin will likely either need an underground injection permit, SPDES Discharge to Groundwater Permit, or a variance from the NYSDEC. Because this site is over sole source aquifer, the NYSDEC may not approve of using an infiltration basin.

7. Cost (Score: 5/15)

The addition of the bioremediation process and groundwater injection will greatly increase costs for pre-design studies, design, equipment, and construction relative to the other technologies considered. Additional permitting and monitoring costs will be incurred due to the groundwater injection. Site operation and maintenance costs will be greater than the other alternatives due to the complexity of bioremediation mixing, control, and injection equipment.

6.5 Cost of Remedial Alternatives

Cost estimates for each alternative are given in this section. Tables itemizing costs for each alternative are found in Appendix A. The estimated costs for each alternative are listed below. Total costs for the remedial actions are based on remediation periods of five or ten years plus an additional monitoring period of 20 or 25 years, respectively.

	Remedial Alternative	Capital Cost	Annual O & M Cost	5-Year Present Worth[1]	10-Year Present Worth[2]	Total Project Cost[3]
1	No Action	--	--	--	--	**$228,000**
2a	Groundwater Recovery with Air Stripping	$155,000	$62,000	---	$588,000	**666,000**
2b	Groundwater Recovery with Carbon Adsorption	140,000	73,000	---	654,000	**732,000**
2c	Groundwater Recovery with Air Stripping and Carbon Adsorption	166,000	73,000	---	680,000	**758,000**
3	Air Sparging and Soil Vapor Extraction	190,000	59,000	$439,000	---	**521,000**
4	Groundwater Recovery, Stripping and Bioremediation	199,000	80,000	536,000	---	**618,000**

1. *Capital cost plus present dollars for 5 years of O & M (6 percent interest).*
2. *Capital cost plus present dollars for 10 years of O & M (6 percent interest).*
3. *Total project cost in present dollars after 30 years of monitoring.*

A 10-year period of operation is assumed for options 2a through 2c. A 5-year period of operation is assumed for options 3 and 4. Actual remediation periods may differ for each alternative. It is also assumed that each alternative will require a total of 30 years of monitoring.

TABLE 6.1

RANKING OF REMEDIAL ALTERNATIVES FOR BARLOW ROAD EQUIPMENT MAINTENANCE FACILITY

REMEDIAL ALTERNATIVE	COMPLIANCE WITH NYS STANDARDS	PROTECTING HUMAN HEALTH AND ENVIRONMENT	SHORT TERM IMPACT AND EFFECTIVENESS	LONG TERM EFFECTIVENESS AND PERMANENCE	REDUCTION OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY	COST	POINTS	RANK
No Action	1	5	4	10	5	15	13	53	5
Groundwater Recovery with Air Stripping	7	13	6	10	5	5	10	56	4
Groundwater Recovery with Carbon Adsorption	7	15	6	10	8	2	8	56	4
Groundwater Recovery with Air Stripping and Carbon Adsorption	7	17	6	10	11	8	7	66	2
Air Sparging and Soil Vapor Extraction	9	13	9	15	12	12	12	82	1
Groundwater Recovery and Bioremediation	8	18	7	12	13	2	5	65	3

7.0 CONCLUSIONS AND RECOMMENDATIONS

Table 6.1 indicates that air sparging and soil vapor extraction (Score 82) is ranked as the number one Interim Remedial Measure for remediation of the source area of the trichloroethene and gasoline-related dissolved phase VOC impacted groundwater. Groundwater recovery with treatment by air stripping and carbon adsorption is ranked second with a score of 66. Groundwater recovery with bioremediation is ranked third with a score of 65. The ranking of the second and third options is essentially equal. Additional information revealed during remedial design pilot testing and design planning for these options would establish their relative position.

The applicability of air sparging to the NYSDOT Barlow Road Maintenance Facility has yet to be proven through the performance of site pilot tests. This is also the case for any of the techniques requiring groundwater recovery. It is recommended that the next phase of the project consist of site pilot testing in order to assess the applicability of air sparging technology to site specific-conditions and to gather the necessary information to design the remedial system.

Performance of an air sparging/soil vapor extraction pilot test would require the installation of a sparging well with the screened interval set entirely below the annual low groundwater elevation for the site. Existing site monitoring wells would be assessed for possible use as observation wells or vacuum extraction points prior to test performance. The installation of additional observation points and/or a soil vapor extraction well may be necessary to perform the pilot test.

Because air sparging has the potential to induce groundwater contaminant migration, it will be necessary to install one well screened at the base of the water table aquifer (first low hydraulic conductivity layer) in order to measure changes in vertical contaminant distribution during the pilot test. Of particular concern is that free phase trichloroethene may have accumulated at the bottom of the aquifer and that air sparging could result in induced free phase product migration.

The general test procedure is to first apply a vacuum to a vapor extraction well to establish air flow rates, extracted soil vapor VOC concentrations, and induced subsurface vacuum distribution in site observation wells (radius of influence). After completion of the vapor extraction test, the soil vapor extraction vacuum is turned off, and an air sparging test is initiated by injecting air into the sparging well. Parameters measured during the air sparging test include pressure and air flow applied at the sparging point; and changes in groundwater elevation, soil vapor VOC concentrations, groundwater chemistry (dissolved oxygen, major ions, and VOC concentrations), and soil vapor pressure distribution in site observation wells.

Following the air sparging test, a combined air sparging, soil vapor extraction test is performed in order to investigate the effect of sparging on the soil vapor extraction pressure distribution and VOC vapor concentrations. The later test is necessary in order to design an integrated sparge/vent system that will contain soil vapors generated by the sparging process.

Should the results of air sparging pilot testing prove that hydraulic control is necessary to prevent induced groundwater plume migration, groundwater recovery (with air stripping and carbon adsorption) will also be needed. In this case, the NYSDOT may wish to explore a phased approach where groundwater recovery is undertaken first to reduce high VOC concentrations at the source area and gain control of plume migration. Air sparging could then be implemented at a later date after groundwater recovery has attained the maximum amount of contaminant removal possible using the technique.

8.0 REMEDIATION EFFECT ON PROPOSED FACILITIES

The installation of a recovery and treatment system during the implementation of the Interim Remedial Measure would primarily impact the northwest parking lot of the NYSDOT Barlow Road Maintenance Facility. Small equipment sheds may be required near monitoring wells MW-9 and FH-X-12. Underground piping and conduit will also be required for transmission of air and/or water and electrical power. Sheds may be situated on the fringe of the designated parking areas to reduce impact to the parking lot.

The space allotment and piping requirements required for the remediation process can be provided during the design of the selected alternative. It will be necessary for the NYSDOT and the Office of General Services (OGS) to coordinate efforts during the design and construction phases of the remedial system in order to avoid conflicts with construction of the new maintenance facility and associated utilities.

To this date, coordination efforts have resulted in the design of a passive vapor removal system to be placed under the new facility and the designation of wells to be saved or abandoned during building construction.

Figure 6.1 depicts well locations relative to the OGS site plan. Wells FH-X-3, FH-X-9, FH-X-12, MW-1, MW-2, MW-6, and MW-9 will be saved. Wells MW-3, MW-4, MW-5, MW-7, MW-8, and MW-10 will be abandoned.

HARZA NORTHEAST Architects, Engineers, and Construction Managers	DATE	NYSDOT Residency Site Barlow Road Kirkwood, NY	FIGURE 6.1
	DRAWN	**PROPOSED SITE PLAN**	
	NO. 6793	NYSDOT REGION 9 — PIN 9650.02.301	

9.0 LIMITATIONS

The services described in this report were performed consistent with generally accepted professional principles and practices, and with our agreement with our client. This report is for the use and information of our client unless otherwise noted. Reliance on this report by another must be at their risk unless of course, we are consulted on the use or limitations.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended for our client, within the purposes, locations, time frames, and project parameters indicated. We cannot be responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services without our further consultation. We can neither vouch for the accuracy of information supplied by others, nor accept consequences for unconsulted use of segregated portions of this report.

10.0 REFERENCES

1. The Boom In Situ Bioremediation, Civil Engineering "Microbes at Work", October 1995.

2. Horizontal Well Re-Circulation Demonstration, Horizontal News, Volume 1,/Number 1, Winter 1995.

APPENDIX A

SUMMARY TABLES OF INTERIM REMEDIAL OPTION COSTS

COST ESTIMATE
NO ACTION ALTERNATIVE (30 YEAR MONITORING)
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
ANALYTICAL WORK	EA	10	550	$5,500
SAMPLING - LABOR	HR	48	50	$2,400
TRAVEL/LODGING/PER DIEM				
HAZ. WASTE SURVEY VAN	MI	160	0.35	$56
PER DIEM	DAY	2	88	$176
PUMP TUBING AND MISC. SUPPLIES & SHIPPING	LS	JOB	100	$100
EQUIPMENT RENTAL				
pH METER	DAY	2	10	$20
CONDUCTIVITY METER	DAY	2	16	$32
TURBIDITY METER	DAY	2	15	$30
WATER LEVEL DETECTOR	DAY	2	9	$18
LEVEL D PPE	DAY	4	12	$48
GEOGUARD PNEUMATIC PUMP	DAY	2	63	$126
ISCO PERISTALTIC PUMP	DAY	2	15	$30
COST - ONE ROUND OF SAMPLING				$8,536
ANNUAL WELL MAINTENANCE				$650
FIRST YEAR COST - QUARTERLY SAMPLING				$34,794
PRESENT WORTH, 5 YEAR QUARTERLY SAMPLING				$146,565
PRESENT WORTH, ANNUAL SAMPLING 5 TO 30 YEARS				$81,540
TOTAL PRESENT WORTH (6% interest rate)				**$228,105**

COST ESTIMATE
ADDITIONAL MONITORING FOR ALTERNATIVES 2 THROUGH 4
NYSDOT BARLOW ROAD

AIR SPARGING AND BIOREMEDIATION ALTERNATIVES (YEARS 5 THROUGH 30)

PRESENT WORTH, ANNUAL SAMPLING 5 TO 30 YEARS (6% interest rate)	$81,540

PUMP AND TREAT ALTERNATIVE (YEARS 10 THROUGH 30)

PRESENT WORTH, ANNUAL SAMPLING 10 TO 30 YEARS (6% interest rate)	$54,671

COST ESTIMATE
GROUNDWATER RECOVERY AND TREATMENT BY CARBON ADSORPTION ONLY
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
WORK PLAN	LS	JOB		$5,000
WELL INSTALLATION (4)				
MOB/DEMOB	LS	JOB		700
6" PVC WELL	LF	120	40	4,800
SAMPLING	EA	24	20	480
MATERIALS	LS	JOB		800
HOURLY SERVICES	HR	4	135	540
			SUBTOTAL	$7,320
PUMP TEST	LS	JOB		$20,000
REMEDIATION SYSTEM DESIGN	LS	JOB		$15,000
PERMIT ASSISTANCE				
STATE	LS	JOB		2,000
LOCAL	LS	JOB		500
			SUBTOTAL	$2,500
REMEDIATION SYSTEM CONSTRUCTION				
ELECTRICIAN - Labor	LS	JOB		4,000
CONTRACTOR	LS	JOB		20,000
PIPING & ACCESSORIES	LS	JOB		1,800
ENGINEERING	LS	JOB		8,000
			SUBTOTAL	$33,800
GROUNDWATER RECOVERY EQUIPMENT				
PUMP CONTROLLER	EA	1	1,500	1,500
REMOTE SHUTOFF	EA	2	410	820
SATELLITE CONTROLLER	EA	2	215	430
STAINLESS STEEL PUMP	EA	2	350	700
COMPRESSOR	EA	1	2,100	2,100
2-WAY MANIFOLD	EA	1	135	135
			SUBTOTAL	$5,685
GROUNDWATER TREATMENT EQUIPMENT				
CARBON DRUMS	EA	8	600	$4,800
EQUIPMENT SHED (STRUCTURE)	LS			$2,000
EQUIPMENT SHED ELECTRICAL (EXPLOSION-PROOF)				
ELECTRICAL PANEL				6,000
HEATER				5,000
LIGHTING, WIRING, ACCESSORIES				8,000
			SUBTOTAL	$19,000
SYSTEM TEST AND START-UP	LS	JOB		$5,000
ANALYTICAL WORK				
WATER (VOC)	EA	6	150	900
SAMPLING - LABOR	HR	8	40	320
			SUBTOTAL	$1,220
		ESTIMATED TOTAL		$121,325
		15% CONTINGENCY		$18,199
		TOTAL COST		$140,000

COST ESTIMATE - ANNUAL OPERATION & MAINTENANCE
GROUNDWATER RECOVERY AND TREATMENT BY
CARBON ADSORPTION ONLY
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
SITE VISIT (BIMONTHLY)	EA	24	500	$12,000
PERFORMANCE EVALUATION	LS	JOB		$10,000
CARBON CHANGEOUT	EA	12	600	$7,200
CARBON DISPOSAL	EA	12	250	$3,600
UTILITY AND PARTS	LS	JOB		$9,000
ANNUAL PERMITTING	LS	JOB		$4,000
ANALYTICAL WORK				
AIR (VOC)	EA	8	250	2,000
WATER (VOC)	EA	24	150	3,600
TCLP	EA	8	200	1,600
SAMPLING - LABOR	HR	80	40	3,200
			SUBTOTAL	$10,400
ENGINEERING	LS	JOB		$7,000
		ESTIMATED TOTAL		**$63,200**
		15% CONTINGENCY		**$9,480**
		TOTAL COST		**$73,000**
		PRESENT VALUE (10 year O&M @ 6%)		$537,000

COST ESTIMATE
GROUNDWATER RECOVERY AND TREATMENT BY
AIR STRIPPING ONLY
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
WORK PLAN	LS	JOB		$5,000
WELL INSTALLATION (4)				
MOB/DEMOB	LS	JOB		700
6" PVC WELL	LF	120	40	4,800
SAMPLING	EA	24	20	480
MATERIALS	LS	JOB		800
HOURLY SERVICES	HR	4	135	540
			SUBTOTAL	$7,320
PUMP TEST	LS	JOB		$20,000
REMEDIATION SYSTEM DESIGN	LS	JOB		$15,000
PERMIT ASSISTANCE				
STATE	LS	JOB		2,000
LOCAL	LS	JOB		500
			SUBTOTAL	$2,500
REMEDIATION SYSTEM CONSTRUCTION				
ELECTRICIAN - Labor	LS	JOB		4,000
CONTRACTOR	LS	JOB		20,000
PIPING & ACCESSORIES	LS	JOB		1,800
ENGINEERING	LS	JOB		8,000
			SUBTOTAL	$33,800
GROUNDWATER RECOVERY EQUIPMENT				
PUMP CONTROLLER	EA	1	1,500	1,500
REMOTE SHUTOFF	EA	2	410	820
SATELLITE CONTROLLER	EA	2	215	430
STAINLESS STEEL PUMP	EA	2	350	700
COMPRESSOR	EA	1	2,100	2,100
2-WAY MANIFOLD	EA	1	135	135
			SUBTOTAL	$5,685
GROUNDWATER TREATMENT EQUIPMENT				
AIR STRIPPER	EA	1	12,000	12,000
BLOWER	EA	1	4,000	4,000
CARBON DRUMS	EA	2	600	1.200
			SUBTOTAL	$17,200
EQUIPMENT SHED (STRUCTURE)	LS			$2,000
EQUIPMENT SHED ELECTRICAL (EXPLOSION-PROOF)				
ELECTRICAL PANEL				6,000
HEATER				5,000
LIGHTING, WIRING, ACCESSORIES				9,000
			SUBTOTAL	$20.000
SYSTEM TEST AND START-UP	LS	JOB		$5,000
ANALYTICAL WORK				
AIR (VOC)	EA	1	250	250
WATER (VOC)	EA	6	150	900
SAMPLING - LABOR	HR	10	40	400
			SUBTOTAL	$1,550
		ESTIMATED TOTAL		**$135,055**
		15% CONTINGENCY		**$20,258**
		TOTAL COST		**$155,000**

COST ESTIMATE - ANNUAL OPERATION & MAINTENANCE
GROUNDWATER RECOVERY AND TREATMENT BY
AIR STRIPPING ONLY
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
SITE VISIT (BIMONTHLY)	EA	24	500	$12,000
PERFORMANCE EVALUATION	LS	JOB		$10,000
CARBON DISPOSAL	EA	2	250	$500
AIR STRIPPER MAINTENANCE	LS	JOB		$2,000
UTILITY AND PARTS	LS	JOB		$9,000
ANNUAL PERMITTING	LS	JOB		$4,000
ANALYTICAL WORK				
AIR (VOC)	EA	8	250	2,000
WATER (VOC)	EA	24	150	3,600
TCLP	EA	2	200	400
SAMPLING - LABOR	HR	80	40	3,200
			SUBTOTAL	$9,200
ENGINEERING	LS	JOB		$7,000
		ESTIMATED TOTAL		**$53,700**
		15% CONTINGENCY		**$8,055**
		TOTAL COST		**$62,000**
		PRESENT VALUE (10 year O&M @ 6%)		$456,000

COST ESTIMATE
GROUNDWATER RECOVERY AND TREATMENT BY
AIR STRIPPING & CARBON ADSORPTION
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
WORK PLAN	LS	JOB		$5,000
WELL INSTALLATION (4)				
MOB/DEMOB	LS	JOB		700
6" PVC WELL	LF	120	40	4800
SAMPLING	EA	24	20	480
MATERIALS	LS	JOB		800
HOURLY SERVICES	HR	4	135	540
			SUBTOTAL	$7,320
PUMP TEST	LS	JOB		$20,000
REMEDIATION SYSTEM DESIGN	LS	JOB		$20,000
PERMIT ASSISTANCE				
STATE	LS	JOB		2,000
LOCAL	LS	JOB		500
			SUBTOTAL	$2,500
REMEDIATION SYSTEM CONSTRUCTION				
ELECTRICIAN - Labor	LS	JOB		4,000
CONTRACTOR	LS	JOB		20,000
PIPING & ACCESSORIES	LS	JOB		2,000
ENGINEERING	LS	JOB		10,000
			SUBTOTAL	$36,000
GROUNDWATER RECOVERY EQUIPMENT				
PUMP CONTROLLER	EA	1	1,500	1,500
REMOTE SHUTOFF	EA	2	410	820
SATELLITE CONTROLLER	EA	2	215	430
STAINLESS STEEL PUMP	EA	2	350	700
COMPRESSOR	EA	1	2,100	2,100
2-WAY MANIFOLD	EA	1	135	135
			SUBTOTAL	$5,685
GROUNDWATER TREATMENT EQUIPMENT				
AIR STRIPPER	EA	1	12,000	12,000
BLOWER	EA	1	4,000	4,000
CARBON ADSORPTION UNIT	EA	6	600	3,600
			SUBTOTAL	$19,600
EQUIPMENT SHED (STRUCTURE)				$2,000
EQUIPMENT SHED ELECTRICAL (EXPLOSION-PROOF)				
ELECTRICAL PANEL				6,000
HEATER				5,000
LIGHTING, WIRING, ACCESSORIES				9,000
			SUBTOTAL	$20,000
SYSTEM TEST AND START-UP	LS	JOB		$5,000
ANALYTICAL WORK				
AIR (VOC)	EA	1	250	250
WATER (VOC)	EA	6	150	900
SAMPLING - LABOR	HR	10	40	400
			SUBTOTAL	$1,550
		ESTIMATED TOTAL		**$144,655**
		15% CONTINGENCY		**$21,698**
		TOTAL COST		**$166,000**

COST ESTIMATE - ANNUAL OPERATION & MAINTENANCE
GROUNDWATER RECOVERY AND TREATMENT BY
AIR STRIPPING & CARBON ADSORPTION
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
SITE VISIT (BIMONTHLY)	EA	24	500	$12,000
PERFORMANCE EVALUATION	LS	JOB		$10,000
CARBON CHANGEOUT	EA	8	600	$4,800
CARBON DISPOSAL	EA	8	250	$2,000
AIR STRIPPER MAINTENANCE	LS	JOB		$2,000
UTILITY AND PARTS	LS	JOB		$10,000
ANNUAL PERMITTING	LS	JOB		$4,000
ANALYTICAL WORK				
AIR (VOC)	EA	8	250	2,000
WATER (VOC)	EA	24	150	3,600
TCLP	EA	8	200	1,600
SAMPLING - LABOR	HR	80	40	3,200
			SUBTOTAL	$10,400
ENGINEERING	LS	JOB		$8,000
		ESTIMATED TOTAL		**$63,200**
		15% CONTINGENCY		**$9,480**
		TOTAL COST		**$73,000**
		PRESENT VALUE (10 year O&M @ 6%)		$537,000

COST ESTIMATE
AIR SPARGING AND SOIL VAPOR EXTRACTION
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
WORK PLAN	LS	JOB		$5,000
PILOT TEST				
CARBON DRUMS	EA	2	600	1,200
WELL INSTALLATION (3)	LS	JOB		5,300
EQUIPMENT RENTAL	LS	JOB		3,000
PERMITTING	LS	JOB		1,000
ANALTICAL WORK				
AIR (VOC)	EA	10	250	2,500
WATER (VOC)	EA	10	150	1,500
PIPING INSTALLATION	LS	JOB		3,000
MOB/DEMOB	LS	JOB		1,000
ENGINEERING	LS	JOB		15,000
REPORT	LS	JOB		5,000
			SUBTOTAL	$38,500
REMEDIATION SYSTEM DESIGN	LS	JOB		$25,000
PERMIT ASSISTANCE				
STATE	LS	JOB		2,000
LOCAL	LS	JOB		500
			SUBTOTAL	$2,500
REMEDIATION SYSTEM CONSTRUCTION				
WELL INSTALLATION (10)	LS	JOB		11,400
CONTRACTOR	LS	JOB		30,000
ENGINEERING	LS	JOB		10,000
			SUBTOTAL	$51,400
SYSTEM TEST & START-UP	LS	JOB		$7,500
ANALYTICAL WORK				
AIR (VOC)	EA	4	250	1,000
WATER (VOC)	EA	4	150	600
SAMPLING - LABOR	HR	10	40	400
			SUBTOTAL	$2,000
MAJOR EQUIPMENT COST				
AIR COMPRESSOR	EA	1	2,100	2,100
CARBON ADSORBERS	EA	4	600	2,400
VACUUM EXTRACTION UNIT	EA	1	6,000	6,000
			SUBTOTAL	$10,500
EQUIPMENT SHED (STRUCTURE)				$2,500
EQUIPMENT SHED ELECTRICAL (EXPLOSION-PROOF)				
ELECTRICAL PANEL				$7,000
HEATER				$5,000
LIGHTING, WIRING, ACCESSORIES				$8,000
			SUBTOTAL	$20,000
		ESTIMATED TOTAL		$164,900
		15% CONTINGENCY		$24,735
		TOTAL COST		$190,000

COST ESTIMATE - ANNUAL OPERATION & MAINTENANCE
AIR SPARGING AND SOIL VAPOR EXTRACTION
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
SITE VISIT (BIMONTHLY)	EA	24	500	$12,000
PERFORMANCE EVALUATION	LS	JOB		$10,000
CARBON CHANGEOUT	EA	4	600	$2,400
CARBON DISPOSAL	EA	4	250	$1,000
UTILITY AND PARTS	LS	JOB		$8,000
ANNUAL PERMITTING	LS	JOB		$2,000
ANALYTICAL WORK				
AIR (VOC)	EA	16	250	4,000
WATER (VOC)	EA	24	150	3,600
TCLP	EA	4	200	800
SAMPLING - LABOR	HR	80	40	3,200
			SUBTOTAL	$11,600
ENGINEERING	LS	JOB		$4,000
		ESTIMATED TOTAL		**$51,000**
		15% CONTINGENCY		**$7,650**
		TOTAL COST		**$59,000**
		PRESENT VALUE (5 year O&M @ 6%)		$249,000

COST ESTIMATE
GROUNDWATER RECOVERY AND BIORESTORATION
(INTERMEDIATE TREATMENT WITH AIR STRIPPING)
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
WORK PLAN	LS	JOB		$5,000
BIOLOGICAL AND INFILTRATION TESTING	LS	JOB		$15,000
WELL INSTALLATION (4 RW, 4 IW)				
MOB/DEMOB	LS	JOB		500
4" PVC WELL	LF	90	32	2,880
6" PVC WELL	LF	90	40	3,600
SAMPLING	EA	50	20	1,000
MATERIALS	LS	JOB		1,600
HOURLY SERVICES	HR	8	135	1,080
			SUBTOTAL	$10,660
REMEDIATION SYSTEM DESIGN	LS	JOB		$25,000
PERMIT ASSISTANCE				
STATE	LS	JOB		2,500
LOCAL	LS	JOB		500
			SUBTOTAL	$2,500
REMEDIATION SYSTEM CONSTRUCTION				
ELECTRICIAN - Labor	LS	JOB		5,000
CONTRACTOR	LS	JOB		30,000
PIPING & ACCESSORIES	LS	JOB		5,000
ENGINEERING	LS	JOB		10,000
			SUBTOTAL	$50,000
GROUNDWATER RECOVERY EQUIPMENT				
PUMP CONTROLLER	EA	1	1,500	1,500
REMOTE SHUTOFF	EA	2	410	820
SATELLITE CONTROLLER	EA	2	215	430
STAINLESS STEEL PUMP	EA	2	350	700
COMPRESSOR	EA	1	2,100	2,100
2-WAY MANIFOLD	EA	1	135	135
			SUBTOTAL	$5,685
GROUNDWATER TREATMENT EQUIPMENT				
AIR STRIPPER	EA	1	12,000	12,000
BLOWER	EA	1	4,000	4,000
TRANSFER PUMP	EA	1	500	500
CARBON UNITS	EA	2	600	1,200
			SUBTOTAL	$17,700
BIOREMEDIATION EQUIPMENT				
FEED PUMP	EA	1	4,000	4,000
TANK	EA	1	2,000	2,000
CONTROL PANEL	EA	1	5,000	3,000
FLOATS/PROBES	EA	4	800	3,200
			SUBTOTAL	$12,200
EQUIPMENT SHED (STRUCTURE)				$2,000
EQUIPMENT SHED ELECTRICAL (EXPLOSION-PROOF)				
ELECTRICAL PANEL				6,000
HEATER				5,000
LIGHTING, WIRING, ACCESSORIES				10,000
			SUBTOTAL	$21,000
SYSTEM TEST AND START-UP	LS	JOB		$5,000
ANALYTICAL WORK				
AIR (VOC)	EA	1	250	250
WATER (VOC)	EA	6	150	900
SAMPLING - LABOR	HR	10	40	400
			SUBTOTAL	$1,550
		ESTIMATED TOTAL		$173,295
		15% CONTINGENCY		$25,994
		TOTAL COST		$199,000

COST ESTIMATE - ANNUAL OPERATION & MAINTENANCE
GROUNDWATER RECOVERY AND BIORESTORATION
(INTERMEDIATE TREATMENT WITH AIR STRIPPING)
NYSDOT BARLOW ROAD

OPERATION	UNIT	QUANTITY	PRICE/UNIT	COST
SITE VISIT (WEEKLY)	EA	48	500	$24,000
PERFORMANCE EVALUATION	LS	JOB		$10,000
AIR STRIPPER MAINTENANCE	LS	JOB		$2,000
BIOREMEDIATION NUTRIENTS	LS	JOB		$2,000
UTILITY AND PARTS	LS	JOB		$10,000
ANNUAL PERMITTING	LS	JOB		$4,000
ANALYTICAL WORK				
AIR (VOC)	EA	4	250	1,000
WATER (VOC)	EA	24	150	3,600
TCLP	EA	8	200	1,600
SAMPLING - LABOR	HR	80	40	3,200
			SUBTOTAL	$9,400
ENGINEERING	LS	JOB		$8,000
		ESTIMATED TOTAL		**$69,400**
		15% CONTINGENCY		**$10,410**
		TOTAL COST		**$80,000**
		PRESENT VALUE (5 year O&M @ 6%)		$337,000