report. 3140B4. 2003-01-15.

FS_Report.

FEASIBILITY STUDY REPORT

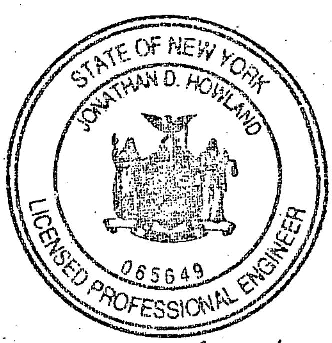
Apple Valley Shopping Center
Site No. 3-14-084
Work Assignment No. D003821-14.1

Prepared for:

Superfund Standby Program
New York State Department of Environmental Conservation
625 Broadway
Albany, New York 12233

Prepared by:

Earth Tech Environment & Infrastructure, Inc.
40 British American Boulevard
Latham, New York 12110



J. D. Howland 1/15/03

January 2003

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

This Feasibility Study (FS) for the Apple Valley Shopping Center (AVSC) site, site number 3-14-084, was prepared for the New York State Department of Environmental Conservation (NYSDEC) under work assignment D003821-14 of the NYS Superfund Standby Contract between NYSDEC and Earth Tech. The FS was prepared conjunction with the Remedial Investigation (RI) that was conducted by Earth Tech at the AVSC.

1.1 Purpose and Organization of Report

The purpose of the document is to identify and analyze remedial alternatives that: are protective of human health and the environment; attain, to the maximum extent practicable, federal and State standards, criteria and guidelines (SCGs); and, are cost effective. Accordingly, the AVSC FS is based on the objectives, methodologies, and evaluation criteria as generally set forth in the following federal and State regulations and guidelines:

- the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and the Superfund Reauthorization Act of 1986 (SARA);
- the National Oil and Hazardous Substances Contingency Plan (NCP);
- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, October 1988);
- New York Rules for Inactive Hazardous Waste Disposal Sites, 6 NYCRR Part 375 (May 1992);
- CERCLA Compliance with Other Laws Manual, 1988, OSWER Directive No. 9234.1-01 and -02;
- NYSDEC Technical and Administrative Guidance Memorandum (TAGM) #HWR-89-4025 "Guidelines for RI/FS's";
- NYSDEC TAGM #HWR-90-4030 "Selection of Remedial Actions at Inactive Hazardous Waste Sites"; and,
- NYSDEC TAGM #HWR-89-4022 "Records of Decision for Remediation of Class 2 Inactive Hazardous Waste Disposal Sites".

The remainder of Section 1.0 contains background information about the Site and surrounding area, and a brief summary of the scope of the RI and pertinent findings including the physical systems and the nature and extent of contamination. Section 2.0 identifies the remedial action objectives, general response actions and remedial technologies, and presents the screening of the remedial technologies to identify those that would be effective for the wastes and media at the site. In Section 3.0, the technologies are grouped into remedial alternatives, which are then screened to eliminate those that are not suitable. In Section 4.0, a detailed analysis of the retained alternatives is presented, and the recommended remedial alternative is identified and described.

1.2 Background Information

1.2.1 Description of the Apple Valley Property Site

The Apple Valley Shopping Center Site is located in the Town of LaGrange, New York, about seven miles east of the City of Poughkeepsie (See Figure 1, Site Location Map). The site consists of the Apple Valley Shopping Center, located at the southwest corner of the junction of State Route 55 and Titusville Road. The shopping center was constructed in 1967 - 1968, and contains a number of businesses including the former Apple Valley Dry Cleaners (AVDC - currently Absolute Pizza), the Norgetown Laundromat (currently Apple Valley Laundromat), and a Food Town supermarket.

In 1988, prompted by a homeowner's complaint, the Dutchess County Department of Health (DCDOH) collected and analyzed samples of groundwater from several residential supply wells located in the Woodbridge Estates subdivision. The samples were found to contain tetrachloroethene (PCE) and its breakdown products including trichloroethene (TCE) and isomers of dichloroethene (DCE). The DCDOH also sampled the shopping center's supply wells, well AV-1 (abandoned due to poor yield) and its replacement, well AV-2. Much higher concentrations of the same chlorinated compounds were detected, with greater than 5,000 parts per billion (ppb) of PCE in well AV-1. A point-of-entry (POE) granular activated carbon (GAC) filter system was installed to treat the shopping center's well water. A POE treatment system is designed to treat one individual potable water supply well, as opposed to a system that treats water from multiple wells or surface water sources. In 1989, a third supply well was installed in a presumed upgradient location on the shopping center property.

In 1990, the DCDOH conducted more extensive sampling of the supply wells in the subdivision or south of AVSC, and found that a number of wells were contaminated with chlorinated compounds at levels above the NYS standards for public drinking water supplies. Affected residents were supplied with bottled water for drinking and cooking purposes.

In 1992, POE GAC filters were installed on the wells of eight residences in the subdivision. An air stripper system was installed to pre-treat the well water supplied to two residences (at lots 7 and 11 in Locust Crest Court), which also had GAC filters. A second air stripper was installed on shopping center well AV-2. The well was pumped continuously in an effort to control the migration of contaminated groundwater from the shopping center property. The treated well water from AV-2 was distributed for use by shopping center tenants, and excess water was discharged to the adjacent wetland. Responsibility for operation and maintenance of the GAC filters and the air strippers was assumed by the owner of the shopping center, James Klein.

Several potential sources of the chlorinated compounds have been proposed. The former AVDC facility operated as a commercial dry cleaning facility since 1968. PCE was stored at the AVDC facility until 1995. The former Norgetown Laundromat contained a coin operated dry cleaning machine and stored dry cleaning fluid in a 55-gallon drum located in an unpaved closet. Morwhite, Inc. of Albany, New York supplied PCE to both facilities. Food Town maintained a trash compactor for disposal of its waste. It has been alleged by others that leachate from the compactor contained PCE and other chlorinated compounds. A number of investigations have been undertaken by the shopping center owner, the Norgetown Laundromat, the Food Town and others in an effort to determine the source of the contamination. These studies include several soil and soil gas sampling efforts, and limited on-site groundwater sampling.

1.2.2 Previous Investigations

The historical environmental sampling events, analytical data, and other pertinent information completed prior to the RI are discussed in a Data Gap Investigation report dated February 2000, prepared by Earth Tech for the NYSDEC. In addition, Section 4.1 of the RI Report provides a brief summary of the scope of historical sampling for on-site and off-site locations.

1.3 Summary of Remedial Investigation

The field investigation activities of the Remedial Investigation (RI) were initiated in June 2001 and completed in December of 2001. The purpose of the RI was to evaluate potential source areas, assess the nature and extent of groundwater contamination identified in local water supply wells, characterize the Site, and gather the data necessary to support the evaluation of remedial alternatives for the Apple Valley FS. The investigation included: a review of available technical data generated during previous investigations; preparation of an accurate base map of the site from aerial photographs and ground surveys; evaluation of hydrologic and other environmental conditions; determination of the extent of the groundwater impacts; and sampling and analysis of on-site and off-site surface water, groundwater, sediments, soils, and indoor air. The scope of the investigation is detailed in the RI Report (Earth Tech, September 2002). This section briefly describes the pertinent findings of the RI.

1.3.1 Physical Setting

Bedrock: The rock underlying the site is a folded and fractured slate. Fractures in the bedrock are associated with bedding planes (the original horizontal interfaces between distinct sedimentary rock layers) and faults, joints, and veining.

Overburden: The unconsolidated geologic materials on the site consist of fill and glacial till. The glacial till consists of poorly sorted material ranging from boulders to silt, but rich in sand deposited beneath glacier ice. Fill consists of excavated and graded glacial till and other granular materials imported from offsite sources. The thickness of the overburden deposits ranges from zero to approximately 22 feet.

Bedrock Hydrogeology: Groundwater in the uppermost bedrock occurs in the interstices of the highly weathered slate that comprises this zone. During monitoring well drilling, the auger was generally able to penetrate approximately three to five feet of highly-weathered bedrock below the point of split-spoon refusal. The upper-most, sapprolitic bedrock probably forms a hydrologic continuum with the overlying glacial materials. Groundwater becomes increasingly confined to well-defined fracture planes as the bedrock becomes more competent with depth. In the deeper more competent bedrock, primary groundwater flow paths are dominated by a complex fault-fracture system with secondary flow paths associated with folded bedding planes, joints, and veining. A detailed description of water bearing features is summarized in the RI.

Groundwater Flow: All water level measurements were taken while well AV-2 was actively pumping, and reflect its influence on the surrounding aquifer. Measurements also reflect the influence of the actively pumping residential supply wells located in the Woodbridge Estates subdivision immediately south of the site. The groundwater contours indicate that groundwater in the bedrock aquifer under the central portion of the site flows in a southwesterly and then westerly direction toward pumping well AV-2. Horizontal gradients increase sharply with proximity to AV-2. The limited data suggest that the capture zone of AV-2 may include the potential source areas in the vicinity of the former Apple Valley Dry Cleaners and the former Norgetown Laundromat.

As noted in the Data Gap Study, on March 25, 1993 TRC measured static water levels in re-drilled well AV-1, AV-2, and in four of the Woodbridge Estates subdivision residential wells. As indicated by the potentiometric surface contour map prepared by TRC, the direction of groundwater flow from the area of the former AVDC facility was west and southwest, toward the Woodbridge Estates subdivision, with a component of flow toward the northwest. The potentiometric surface and the apparent groundwater flow directions were probably influenced by pumping of the domestic supply wells and supply well AV-3 located to the east. These wells were reportedly active and pumping during the monitoring.

It is not possible to predict flow directions with certainty in the hypothetical scenario in which the pumping of the AV-2 well and the numerous residential wells is suspended. Topographic contours suggest that the general direction of groundwater flow would be southwesterly toward an unnamed tributary of Wappinger Creek. However, the presence of high-angle faults oriented in an east-east direction could cause a component of groundwater flow to be diverted to the east or west of the site. Such conditions may be responsible for the presence of PCE at an estimated concentration of five ppb detected in well AV-3 (east of the Food Town) during packer testing.

Site Surface Water: There are no standing or pooled bodies of surface water on the site. There is a storm water drainage ditch (natural bottom) located north of the site. This drainage ditch flows east to west along the north side of NY State Route 55. The drainage ditch originates from two up gradient surface water drainage channels that converge northeast of the site. The drainage ditch collects surface water runoff from these drainage features, storm water runoff via sheet flow from NY State Rout 55, and storm water runoff from up gradient and side gradient developed and undeveloped areas.

The northern drainage ditch flows through a concrete culvert under Route 55. This concrete culvert discharges to another natural bottom drainage ditch that borders the western edge of the site. The drainage ditch along the western boundary of the site collects storm water runoff via sheet flow from paved and unpaved areas surrounding the shopping center in addition to storm water runoff discharged from catch basins located in the paved parking area in the shopping center. The western drainage ditch discharges to a wetland located off the west, southwest boundary of the site. This wetland has been identified as a NYSDEC Regulated Wetland from the New York State Wetland Inventory Map for Dutchess County and also identified as a Federally Regulated Wetland from the National Wetland Inventory Map for the Pleasant Valley Quadrangle.

A second drainage ditch extends westward from the air stripper for well AV-2. That ditch conveys treated water discharged by the air stripper to the aforementioned wetland. Treated water was also discharged to the wetland from the residential well air stripper until operation of the system was discontinued in July 2001.

The wetland discharges to an unnamed tributary of Wappinger Creek that flows in a southerly direction for approximately one mile south and then northwesterly for approximately two miles to its confluence with Wappinger Creek. Wappinger Creek flows to the south for approximately eight miles where it discharges to the Hudson River.

1.3.2 Nature of Contamination

The nature and extent of the contamination and its relationship to environmental quality standards were used as the basis for the Feasibility Study. In the process of evaluating potential chemical hazards at the AVSC Site, the environmental samples collected during the RI, and in previous investigations, were grouped into five media:

1) Subsurface soil;
2) Surface soil;
3) Groundwater;
4) Indoor air; and
5) Surface water and sediments.

Subsurface Soil: Ten subsurface soil samples were collected during October and November 2001 as part of the RI from eight direct-push technology (DPT) soil borings and from two hand auger locations on the AVSC Site. All subsurface soil samples were submitted for laboratory analysis of full target compount list for volatile organic compounds (TCL VOCs) by ASP 95-1 and semi-volatile organic compounds (SVOCs) by ASP 95-2.

The following analytes were identified as the compounds of concern for subsurface soil.

- cis-1,2-Dichloroethene (cis-DCE)
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)

Surface Soil: No surface soil samples were collected during the RI. Previous investigations indicated that detectable concentrations of PCE and TCE were present in the surface soil samples collected from the dirt floor of the Norgetown Laundromat storage closet (now covered with concrete) and in surface soil samples collected from paved and unpaved areas throughout the AVSC Site. In addition, cis-1,2-DCE and trans-1,2,-DCE were each detected in one surface soil sample collected during the previous investigations. The detected concentrations of these chlorinated volatile organic compounds (VOCs) in surface soil samples were all well below the NYSDEC's recommended soil cleanup objective (RSCO). Surface soil is not considered a media of concern at the site.

Groundwater: On January 28 and 29, 2002 Earth Tech collected groundwater samples from five on-site monitoring wells (MW-01, MW-02, MW-03, MW-4A, and MW-4B), one off-site open hole bedrock well (MW-05), and one overburden piezometer (P-05). The groundwater samples were analyzed for TCL VOCs by ASP 95-1 and SVOCs by ASP 95-2. It should be noted that the sample from MW-01 was not analyzed for SVOCs since the sample bottle broke in transit to the laboratory.

These analytical results indicated the presence of detectable levels of three (3) VOCs (cis-1,2-dichloroethene, PCE and TCE) in groundwater samples collected from on-site monitoring wells MW-02, MW-4A and MW-4B. The detected concentrations of these VOCs were all above the NYS standards (i.e., 10 NYCRR, Part 5, Subpart 5-1) established for public drinking water supplies. No VOCs were detected in on-site monitoring well MW-03 or piezometer P-05. Off-site open borehole MW-05 presented a PCE concentration at the NYS standard of 5 ppb. It should be noted that acetone was detected in the Equipment Blank MW-02 and Equipment Blank MW-4A however, the presence of acetone is believed to be the result of contaminated deionized water used to clean the Grundfos pump used to purge and sample the wells.

Only one SVOC analyte was detected in groundwater samples collected during the RI. Bis(2-ethylhexyl)phthalate was detected at estimated concentrations below the laboratory method detection limits in MW-03, MW-4A, MW-4B and MW-05. Although it was not detected in the quality control samples, this compound is not associated with any site activities, is a common laboratory contaminant, and may have been present in the polyethylene tubing used to collect the groundwater sample. As such, the presence of this SVOC may not be site-related. Further, bis(2-ethylhexyl)phthalate was detected at concentrations below the NYS standards (i.e., 10 NYCRR, Part 5, Subpart 5-1) established for public drinking water supplies.

The off-site groundwater quality data, obtained through the sampling of tap water or treatment system influents during historical investigations have indicated exceedances of NYS standards (i.e., 10 NYCRR, Part 5, Subpart 5-1) established for public drinking water supplies for PCE, TCE, DCE and vinyl chloride in the off-site private wells. It should be noted that low levels of chloroform, and no other VOCs, were noted in the tap water from three residences west of the AVSC Site. Chloroform is a common by-product of chlorinating water, and in the absence of any other chlorinated compounds it is unlikely that its presence is related to the AVSC Site. Methylene chloride, a common laboratory contaminant, was detected in one private well on one occasion, and in the absence of other chlorinated compounds is not considered to be site-related. The tap water from Joe's Sunoco Station (sampled in January 1989 and June 1990), located northwest of the AVSC Site, contained benzene, toluene, ethylbenzene and xylenes (collectively referred to as BTEX) and methyl tertiary-butyl ether (MTBE). However, BTEX and MTBE are constituents of gasoline and are not considered related to the AVSC Site. Historical analytical data for groundwater samples collected from the on-site bedrock wells indicated the presence of PCE, TCE, cis- and trans-1,2-DCE, and vinyl chloride at concentrations above the NYS standard, and may indicate the presence of dense non-aqueous phase liquid (DNAPL).

Based on the above considerations, the following analytes were selected as contaminants of concern for evaluating site groundwater in this FS:

- cis-1,2-Dichloroethene
- trans-1,2-Dichloroethene
- Tetrachloroethene
- Trichloroethene
- Vinyl Chloride

Indoor Air: The New York State Department of Health (NYSDOH) collected air samples at 7 locations within 4 of the tenant occupied areas of the AVSC. These indoor air quality samples were collected in June 2002, using passive diffusion sampling devices and analyzed for specifically for PCE. The analytical results indicated that PCE was present in the air in 3 of the 4 tested areas. These results suggest that soil gas from a subsurface source of PCE is adversely impacting the indoor air-quality in the occupied on-site buildings.

All detected concentrations of PCE were less than the NYSDOH guideline of 100 micrograms per cubic meter of air (100 $\mu g/m^3$) for PCE in air. However, indoor air concentrations can be highly variable due to a number of factors influencing the migration of soil gas into buildings and the accumulation of these gasses within the indoor-air. The NYSDOH sampling event was performed during warm weather when the back door was open and the cooking hoods were in operation at the Absolute Pizza establishment. Additional indoor air sampling is planned to evaluate potential impacts to indoor air quality during the colder months of the year.

The NYSDOH did not sample the indoor air for detectable levels of PCE breakdown products (TCE, cis-1,2-dichloroethene, trans-1,2-dichlorothene and vinyl chloride), therefore, their presence or absence in indoor air cannot be evaluated (a potential data gap) at this time.

Based on these considerations, the following analytes were selected as contaminants of concern for evaluating indoor air in this FS:

- cis-1,2-Dichloroethene
- trans-1,2-Dichloroethene
- Tetrachloroethene
- Trichloroethene
- Vinyl Chloride

Surface Water and Sediment: As part of the Remedial Investigation activities, three (3) surface water and sediment samples were collected during November 2001 from three (3) locations selected along the two surface water drainage courses on or adjacent to the AVSC property. These included an upstream sample location (SW-01/SED-1) and two downstream sample location (SW-02/SED-2 and SW-03/SED-3) obtained to evaluate potential impacts to the wetland area located to the south and west of the AVSC Site due to discharge from the AVSC air stripper or discharge of contaminated groundwater. All surface water and sediment samples were submitted for laboratory analysis of VOCs via ASP 95-1 and SVOCs via ASP 95-2.

The validated results of the laboratory analysis of the stream surface water samples indicated the presence of two (2) VOCs including carbon disulfide in downstream surface water sample SW-03 and MTBE in upstream location SW-01. These VOCs are unlikely to be site-related since they were not considered contaminants of concern for site soil and groundwater and are not components of dry cleaning solvents. In addition, MTBE was only detected in the upstream location and the detected concentration of carbon disulfide was well below the NYS standard. No SVOCs were detected in surface water samples collected during the RI.

The validated results of the laboratory analysis of the sediment samples collected during the RI did not indicate the presence of detectable concentrations of VOCs, with the exception of a single detection of acetone (at an estimated concentration below the laboratory detection limit) in SED-3. Although acetone is a common laboratory contaminant, it was not detected in any laboratory quality control samples. However, since this result is an isolated occurrence and acetone was not considered a contaminant of concern for soils, groundwater or surface water, acetone is not considered a contaminant of concern for the site. A total of sixteen (16) polyaromatic hydrocarbons (PAHs) were detected in downstream sediment sample locations. No human health-based sediment standards or guidance values have been developed by federal or state regulatory agencies. However, PAHs are not known to have been present in any of the dry cleaning solvents used at the AVSC Site. Due to the detection of several of these PAHs in the upstream sediment sample location, the presence of the detected PAHs may be due to an upstream source. PAHs are commonly found in sediments of urban areas due to highway and parking lot runoff, and from sources such as motor vehicle lubricants, exhaust particulates, and asphalt paving.

Based on the above considerations, no VOC or SVOC parameters were selected as site-related contaminants of concern for evaluating surface water and sediments in this FS.

1.3.3 Contaminant Fate and Transport

Apple Valley Dry Cleaners: It has been alleged by others that dry cleaning fluid was released on one or more occasions in the vicinity of the former Apple Valley Dry Cleaners (AVDC), through one or more potential mechanisms including leakage of fluid storage vessels or piping, and spillage of fluid during bulk deliveries. The results of the RI indicate that residues of spilled dry cleaning fluid are present in the soil, bedrock and groundwater in the vicinity of the former AVDC.

Former Norgetown Laundromat: The results of the RI indicate that residues of spilled dry cleaning fluid are also present in the soil, bedrock and groundwater in the vicinity of the former Norgetown Laundromat. PCE was detected in the soil beneath and adjacent to the laundromat at 7-19 ppb (borings SB-3, SB-5). TCE was detected at an estimated concentration of 3 ppb. During packer testing of well MW-2, PCE concentrations ranging from 1,104-4,399 ppb (0.25% - 2% of solubility) were detected in three discrete depth intervals, indicating the potential presence of DNAPL in this area.

The data suggest two alternative sources of the solvent residues near the laundromat:

1. Dry cleaning fluid was released from coin-operated dry cleaning equipment or storage drums that were present on the laundromat premises. Earlier soil analyses indicate that at least a small volume of chlorinated solvent was spilled on the dirt floor of the storage closet where a drum of dry cleaning fluid was stored. As reported in the Data Gap Study, shallow soil samples collected in 1991 from the dirt floor of the closet contained PCE at 230-780 ppb and TCE at 120 ppb. Similarly elevated ratios of TCE/PCE were not found in the vicinity of the former AVDC.

2. Dry cleaning fluid was released in the vicinity of the AVDC and migrated as DNAPL to the area of the laundromat. It is possible that the contamination identified in the areas of the laundromat and the former dry cleaner are attributable to releases near the dry cleaner and are part of a continuum of contamination spanning both areas. The presence of residual PCE contamination in soil north of the former dry cleaner (SB-1) indicates that a release near the rear of the store could have spread 100 feet or more to the north and west. Solvent could have migrated to the area of the laundromat (and beyond) along the surface of the westward dipping bedrock.

The ratios of TCE/PCE and DCE/PCE in one zone (66'-81') of MW-2 were elevated relative to other areas of the site. This may be due to relatively advanced chemical decomposition due to localized conditions favoring biodegradation, or a release of solvent in the laundromat that was enriched in TCE and DCE.

The dry cleaning fluid and its related constituents can migrate as DNAPL, in the aqueous phase in groundwater, and in the gas phase in soil gas.

DNAPL: At the time the dry cleaning solvent releases occurred, the solvent migrated as DNAPL into the overburden and the underlying, saturated bedrock. The DNAPL was mobile as long as its mass was concentrated enough to overcome the interfacial surface tension resisting its movement. In addition to sinking, the DNAPL would have initially spread laterally over any water-saturated soils and the bedrock surface, especially in a down-dip direction. In the area where the release(s) occurred, the bedrock surface appears to dip to the northwest toward a former stream channel that traversed the site before the shopping center was constructed.

The DNAPL probably penetrated the bedrock, migrating through water-saturated fractures that intersected the bedrock surface. The depth reached by the DNAPL was determined by the DNAPL mass and by the apertures of the rock fractures. Elevated concentrations of chlorinated solvents in deeper groundwater indicate that DNAPL may have migrated to depths of 90 feet. Eventually the DNAPL mass became diffused to the point that it could no longer overcome resisting forces and ceased migration. Future increases in groundwater removal through remedial pumping could de-water DNAPL-filled fractures and remobilize the DNAPL.

Groundwater: Currently, aqueous phase transport appears to be limited to the unconfined bedrock aquifer. No VOCs were detected in the groundwater sample from overburden well P-5, the only overburden monitoring well that contained sufficient water for sampling during the January 2002 groundwater sampling event.

All groundwater data were obtained under conditions that reflect the artificial influence of pumping wells, including the continuously operating recovery well (AV-2) and the numerous residential supply wells located immediately south of the site. Prior to operation of well AV-2 as a recovery well, chlorinated VOCs migrated from the site to residential supply wells located as far as 560 feet south of the site. The extent to which this southward transport was (and is) magnified or redirected by the combined influence of the residential pumping has not been determined.

Under the influence of pumping, chlorinated VOCs are currently transported from the source area(s) to the AV-2 groundwater recovery well and air stripper, where they are removed from the water and discharged to ambient air. No information about loadings to the air has been provided. Based on packer testing results, the majority of contaminated water appears to be entering well AV-2 through two transmissive features, at approximately 35-37 ft. and 92-94 ft. below ground surface. Packer testing indicated that contaminated groundwater may also enter well AV-2 through a fractured zone at 178.0-190.5 ft below ground surface, although the testing was inconclusive with regard to the water-bearing capacity of this zone.

The operation of the AV-2 pumping well does not appear to have captured all chlorinated VOC contamination in the bedrock aquifer south of the site. PCE was reported at an estimated concentration of 5 ppb in the groundwater sample collected in January 2002 from monitoring well MW-5. A sample of influent for the residential well air stripper analyzed by field gas chromatograph (GC) during packer testing activities (July, 2002) contained a total of 8.9 ppb of PCE and TCE. The influent was produced from the residential supply wells, located north of the cul-de-sac on Locust Crest Court (lots 7 and 11). It is not possible to determine if the reason contaminants are present at these offsite locations is because an active groundwater flow path from the source area is beyond the influence of the AV-2 pumping well or because contaminants that previously migrated from the site have not been completely retrieved.

Bedrock groundwater flow is governed by the orientation of fractures in the rock. Fracture trace analysis indicates the presence of one primary set of fractures trending along northeast-southwest lines and passing through the site and the subdivision to the south. The analysis also indicates the presence of other fracture sets passing through the site and areas to the east and west. The elimination of artificial groundwater gradients to the south, for example, by shutting down AV-2 or by placing the residential subdivision on municipal water, would create the potential for VOCs to migrate to areas not currently impacted. The presence of fractures extending to areas east and west of the site creates a potential for groundwater flow to these areas. During the RI, trace levels of chlorinated VOCs were detected east of the source area in well AV-3 and, historically, north of the source area in well AV-4.

Surface Water: A comparison of groundwater and surface water elevations indicates that, under current conditions, vertical groundwater gradients are not sufficient to carry contaminants upward into the wetland in the limited area near the southwest corner of the site. Groundwater elevations in the two monitoring wells closest to the wetland (bedrock well MW-2 and overburden piezometer P-5) are lower than the surface water elevation measured at the staff gauge. Two considerations indicate that this condition may be localized and not apply to the entire wetland: First, the zone of influence of the pumping well is limited, as indicated by groundwater elevations in more distant wells (MW-1, MW-4a, and MW-4b) that are higher than the measured surface water elevation. Secondly, the elevation of the surface water measured at the staff gauge may reflect a localized anomaly caused by the continual discharge of treated water from the AV-2 air stripper into the stream channel that empties into the wetland in this area. Surface water elevations elsewhere in the wetland may be lower.

Soil Gas: The presence of chlorinated VOCs in soil gas was documented during investigations conducted for the site owner in 1991 and 1993. PCE, TCE and related daughter products were identified in the vicinity of the AVDC and, at lesser concentrations, in the vicinity of the Norgetown

Laundromat. The chlorinated VOC vapors desorb from contaminated soil and bedrock, and/or partition into the soil gas from contaminated groundwater.

Indoor air sampling and analysis conducted by the NYSDOH during the summer of 2002 detected PCE in the indoor air of three stores located in the vicinity of the former AVDC: Absolute Pizza (70 $\mu g/m^3$ and 24 $\mu g/m^3$), Gartland Liquor (50 $\mu g/m^3$), and Carvel (5 $\mu g/m^3$). Contaminated soil gas may migrate into these facilities by diffusion and advection through porous or cracked concrete floor slabs, floor drains, imperfectly sealed expansion joints and roof drain/utility soffits. These pathways may be enhanced through negative indoor pressures created by a ventilation hood or by the "chimney effect" in winter caused by the lower density of heated indoor air.

Environmental Fate of PCE: The principal contaminant associated with the site is PCE and, to a significantly lesser extent, its potential degradation products TCE, cis and trans 1,2-DCE, and vinyl chloride. The physical and chemical properties of PCE and its reaction in the environment are presented below and discussed in the following text.

Molecular Weight	165.83
Boiling Point	121 °C
Density	1.62 g/cm^3
Solubility at 25°C	150 -200 mg/L (ppm)
Log K_{OC} (Sorption Partition Coefficient)	2.38-2.56
Log K_{OW} (Octanol/Water Partition Coeff.)	2.60-2.88
Henry's Law Const. at 20° C	1175-1998 $Pa \cdot m^3$ /mol
Bioconcentration Factor	1.49-2.40

The relatively high solubility and low partition coefficient values (Kow and Koc) for PCE indicate that it will be mobile in soil and bedrock and will exhibit a tendency to leach to groundwater. The low Koc indicates that adsorption to sediments will generally not be significant. However, in sediments with high organic carbon concentrations, PCE can adsorb to sediments. The high density indicates that pure PCE will behave as a dense non-aqueous phase liquid (DNAPL) in the subsurface environment. The low bioconcentration factor indicates that PCE does not bioaccumulate.

The Henry's Law Constant indicates that PCE will readily volatilize from surface water to the atmosphere. The primary aquatic removal process will be evaporation, with the half-life dependent on the surface water turbulence.

Abiotic (hydrolysis and oxidation) and biotic (microbial) degradation of PCE have been documented in the literature. The abiotic degradation process is relatively slow, with a reported half life of 8.8 months. Aqueous aerobic biodegradation half-lives in groundwater of 8,640-17,280 hours (approximately 1-2 years) have been reported. Research has indicated that biotic degradation products of PCE include TCE; 1,2-dichloroethene (primarily the cis isomer) and vinyl chloride. However, in order for biotic degradation to occur, field conditions must be conducive to bacterial life, and bacterial populations capable of degrading chlorinated compounds (such as methanogens and sulfate reducing bacteria) must be present at the site.

Groundwater analytical data from the RI indicate that degradation of PCE may be occurring in the area of the former Norgetown Laundromat. Comparison of parent (PCE or TCE) to daughter (TCE or DCE) ratios reveals two populations, one parent enriched and one daughter enriched.

There are many variables potentially controlling the different parent/daughter ratios found at the site. Some of these factors are:

1. Variable migration rates (vertically and/or horizontally) and therefore differing residence times in environments conducive to degradation;
2. Variable bacteriological environments with respect to biodegradation; and
3. Variable initial mixes of parent and daughter(s) in the spilled product.

1.4 Summary of Qualitative Human Health Exposure Assessment

A Qualitative Human Health Exposure Assessment (QHHEA)was prepared as part of the RI process at the Apple Valley Shopping Center (AVSC) site. The purpose of this QHHEA was to identify chemicals in environmental media at the Site that may pose a hazard to human health, characterize the exposure setting (including the physical environment and potentially exposed human populations), and identify human exposure pathways of potential concern at the AVSC Site. This evaluation considered data obtained by others during previous investigations as well as the data collected as part of the RI/FS process, and characterized site conditions to determine whether the AVSC Site poses an existing or potential hazard to the exposed or potentially exposed populations. It was based on an evaluation of identified contamination, the presence of potential human receptors, and potential pathways for exposure of contaminants to the potential human receptors.

This QHHEA was limited to the identified environmental conditions found at the AVSC Site. No quantitative estimates of potential human health risks were presented. Rather, potential health hazards were based upon the detected concentrations, contaminant fate and transport processes, and potential human exposure pathways/routes.

The scope of work for included:

- An evaluation of historical, chemical, hydrologic, hydrogeologic, demographic, and other information;

- Identification of chemicals in environmental media which are likely to contribute significantly to potential human health risks;

- Contaminant fate and transport processes;

- Identification and characterization of completed exposure pathways by the evaluation of impacted environmental media, current and surrounding land use, human exposure (contact) points, and chemical intake routes; and

- A qualitative evaluation of potential health hazards.

The conclusions and recommendations were based on a careful evaluation of this information in order to determine the potential human exposures and subsequent hazards to human health posed by the AVSC Site. Exposure pathways were identified for groundwater, subsurface soil/bedrock, and indoor air.

Potential or current exposure pathways to contaminated groundwater include ingestion or direct contact by future workers at the former Paulings Savings Bank; future on-site residents, workers, visitors, or nearby residents; and future construction or utility workers.

Potential or current exposure pathways to contaminated subsurface soil or bedrock include incidental ingestion or dermal contact by future on-site residents, workers or visitors; and future construction or utility workers.

Potential or current exposure pathways to contaminated indoor air include migration of VOCs from groundwater into indoor air of the on-site building and inhalation by future nearby residents, current and future site workers or visitors, and future on-site residents.

1.5 Identification of SCGs

Remedial actions at the Apple Valley Shopping Center (AVSC) site must, at a minimum, achieve overall protection of human health and the environment and comply with New York State Standards, Criteria, and Guidelines (SCGs) as defined by NYSDEC Technical and Administrative Guidance Memorandum (TAGM) #4030. In New York State, a remedial program is governed by the Environmental Conservation Law (ECL) and the regulations in 6 NYCRR Part 375. These regulations which are analogous to the Federal National Contingency Plan (40 CFR 300) which requires that the selection of remedial actions meet applicable or relevant and appropriate requirements (ARARs) of state and federal environmental laws and regulations.

SCGs are defined in 6 NYCRR Part 375 as follows: "A site's program must be designed so as to conform to standards and criteria that are generally applicable, consistently applied, and officially promulgated, that are either directly applicable, or that are not directly applicable but are relevant and appropriate, unless good cause exists why conformity should be dispensed with. Such good cause exists if any of the following are present:

a) The proposed action is only part of a complete program that will conform to such standard or criterion [of guidance] upon completion; or

b) Conformity to such standard or criterion will result in greater risk to the public health or to the environment than alternatives; or

c) Conformity to such standard or criterion is technically impracticable from an engineering perspective; or

d) The program will attain a level of performance that is equivalent to that required by the standard or criterion through the use of another method or approach."

SCGs are used to assist in determining the appropriate extent of site cleanup, to scope and formulate remedial action alternatives, and to govern the implementation of a selected response action. Laws and regulations identified as SCGs are either applicable or, alternatively, relevant and appropriate. In accordance with TAGM #4030, an alternative which does not meet the SCGs should not be considered unless a waiver to the SCG(s) is appropriate or justifiable.

This section of the FS identifies potential SCGs for the AVSC site. These SCGs are identified as chemical-specific, location-specific, or action-specific. SCGs are used to create a framework for determining health- and risk-based limits for remedial action and developing remedial action alternatives, as outlined in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988).

Initially, potential SCGs are compiled. After review of the potential SCGs, media-specific preliminary remediation goals are defined. Remedial action objectives are then developed which specify the contaminants of concern (COCs), exposure routes and receptors, and acceptable contaminant levels for each exposure route (preliminary remediation goals). Ultimately, it is necessary to demonstrate that the final remedy addresses all pathways and COCs, not just those that trigger the need for remedial action.

The remedial action alternatives evaluated as part of this Feasibility Study must attain New York State environmental standards and federal environmental laws and regulations, standards, goals, guidelines or other criteria applicable to specific site concerns resulting from the groundwater and soil contamination. In determining chemical-specific, location-specific, and action-specific SCGs for treatment of the contaminated groundwater and soil, the state, local, and federal regulatory requirements listed below were considered.

1.5.1 Potentially Applicable Guidelines, Regulations, and Other Criteria

Potential SCGs are broken down into three groups:

1. Location-specific SCGs;
2. Chemical-specific SCGs; and
3. Action-specific SCGs;

Each of these groups of SCGs is described below. In addition, other criteria to be considered (TBC), which are not enforceable standards but may be technically or otherwise appropriate for consideration in the development of remedial alternatives, are described below.

1.5.2 Location-Specific SCGs

These are restrictions based on the conduct of activities in specific locations. Examples of natural site features include wetlands, scenic rivers, and floodplains. Examples of man-made features include historic districts and archaeological sites. Remedial action alternatives may be restricted or precluded depending on the location or characteristics of the site and the requirements that apply to it. Potential location-specific SCGs and their applicability to the AVSC site and remedial alternatives are identified and detailed in Table 1-1.

1.5.3 Chemical-Specific SCGs

These are health- or risk-based numerical values or methodologies that establish concentration or discharge limits, or a basis for calculating such limits, for particular contaminants. Examples of chemical-specific SCGs are drinking water MCLs, ambient air quality standards, or ambient water quality criteria for PCBs. If more than one such requirement applies to a contaminant, compliance with the more stringent applicable SCG is required. Potentially applicable guidelines and regulations include those promulgated by the State of New York and those of the U.S. Government. Potential chemical-specific SCGs and their applicability to the AVSC site and remedial alternatives are identified and detailed in Table 1-2.

1.5.4 Action-Specific SCGs

Action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous substances, pollutants, or contaminants, and are primarily used to assess the feasibility of remedial technologies and alternatives. Action-specific SCGs are applicable to particular remedial actions, technologies, or process options. As such, these do not define site cleanup levels or remedial action objectives, but affect the implementation of specific types of remediation. For example, although ambient air has not been identified in the RI as a contaminated medium of concern, air quality SCGs are listed below, since some potential remedial actions may result in air emissions of toxic or hazardous substances. As such, these SCGs are not considered in the development of the remedial action objectives; these action-specific SCGs are considered in the screening and evaluation of remedial alternatives in subsequent chapters of this report.

Certain action-specific SCGs include permit requirements; however, under the NYSDEC Inactive Hazardous Waste Disposal Site Remedial Program, state and local permits and other administrative requirements are not required for remedial actions conducted entirely on sites being remediated pursuant to an Order on Consent with New York State. Exemptions from permit requirements include approval of or consultation with administrative bodies, documentation, reporting, record-keeping and enforcement. However, the substantive requirements of other SCGs, such as health-based, technology-based, or site-specific requirements still must be satisfied. Potential action-specific SCGs and their applicability to the AVSC site and remedial alternatives are identified and detailed in Table 1-3.

1.5.5 Other Criteria to be Considered (TBC)

TBC criteria are not enforceable standards but may be technically or otherwise appropriate to consider in developing site- or media-specific remedial action objectives or cleanup goals. Federal secondary drinking water standards are considered as TBC criteria in the development of remedial alternatives. Federal secondary drinking water standards are based on aesthetic considerations rather than human-health considerations. As such, many of the secondary criteria relate to qualities of finished (treated) potable water (e.g., taste, color, turbidity) and are not applicable to groundwater or water sources.

Criteria established by publicly-owned treatment works (POTWs), such as pretreatment requirements or other acceptance criteria, for discharge of wastewater into public sewer systems are also considered TBCs.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 Introduction

This section identifies the remedial action objectives, general response actions, and remedial technologies for the AVSC Site. Remedial technologies are identified that are potentially capable, either individually or in combination with other technologies, of meeting the remedial action objectives. Each remedial technology is evaluated, and appropriate technologies are retained for use in developing remedial action alternatives for the Site.

2.2 Remedial Action Objectives

The remedial action objectives (RAOs) provide for protection of human health and the environment. They have been selected to minimize the potential for human exposure to or environmental damage from the presence or migration of volatile organic compounds (VOCs) and/or any other contaminants of concern associated with the improper on-site disposal/spillage of chlorinated compounds.

The site-specific RAOs are as follows:

- Rapidly and significantly reduce or eliminate the potential human health risks associated with the consumption of impacted groundwater.
- Rapidly and significantly reduce or eliminate the potential human health risks associated with the inhalation of VOCs associated with the volatilization of contaminants from the groundwater and/or residually impacted soils.
- Rapidly and significantly reduce or eliminate the potential human health risks associated with direct contact with impacted groundwater and/or residually impacted soils.
- Protect the aquifer beneath the Site by eliminating, to the extent feasible, any residual free product in the aquifer and reducing the dissolved contaminant concentrations in the groundwater to concentrations below New York State Ambient Water Quality Standards to the extent feasible.
- Protect the local ecology and environment by eliminating, to the extent feasible, or preventing the discharge of impacted groundwater to surface water receptors.

For the purpose of evaluating the effectiveness of each remedial action alternative with respect to at achieving the RAOs, it is assumed that success will be measured by:

1. Reducing residual contaminant concentrations in the groundwater to concentrations less than or equal to the New York State Ambient Water Quality Standards in TOGS v.1.1.1. The current maximum contaminant limit (MCL) for each compound of concern is 5 μg/l (0.31g/l for vinyl chloride); and,

2. Reducing residual contaminants of concern in the air within on-site buildings to ambient background concentrations.

2.3 General Response Actions

General response actions are actions that may satisfy the remedial action objectives. They may individually or in combination include in-situ treatment, containment, withdrawal and treatment, or monitoring of impacted media. The general response actions selected for the groundwater at the Apple Valley Site are identified below:

- No Action,
- Monitored Natural Attenuation,
- Institutional Controls,
- Engineering Controls,
- In-situ Treatment,
- (Ex-Situ) Removal, Treatment, and/or Disposal of impacted media.

A description of each general response action is included in Table 2-1.

2.4 Identification and Screening of Remedial Technologies

NYSDEC guidance documents recommend initially screening alternative remedial technologies using the criteria of effectiveness and implementability. In this section, a broad range of remedial technologies is identified and screened to eliminate from further consideration those technologies and processes that may be of limited effectiveness, or may not be able to be rapidly and practically implemented at the Site. The purpose of this screening is to better focus the FS on only those technologies with high potential of being effective and that can be readily implemented within a reasonable time frame.

Potentially applicable remedial technologies are identified for the Site to satisfy the general response actions specified in Section 2.3. The general response actions and remedial technologies are identified on Table 2-2. These remedial technologies are evaluated based on site-specific information and are screened initially for technical applicability. Technologies are considered applicable if, individually or in combination, they would achieve the remedial action objective. Innovative technologies are not retained for further analysis unless they are proven and are readily available. Table 2-3 provides the results of the initial screening of the remedial technologies, including the technical justification for eliminating technologies from further consideration.

Those technologies retained after the initial screening are further evaluated/screened based on effectiveness and implementability. The anticipated effectiveness of a technology refers to the ability of that technology to contribute to a remedial program that is protective of human health and the environment, and capable of meeting the stated remedial action objectives. In assessing the effectiveness of each technology, the demonstrated successful performance of each technology is considered. Implementability is the feasibility and the ease with which the technology can be applied at the Site. Implementability takes technical and administrative factors into consideration, such as:

- Are the hazardous substances present at the Site compatible with the technology?
- Is there sufficient room at the Site to install and/or operate the technology?
- Will access difficulties prevent delivery of certain treatment equipment?
- Is the use of the technology compatible with surrounding land uses?
- Will application of the technology unacceptably interfere with other ongoing uses of the Site?
- What permitting and other regulatory requirements apply to use of the technology?
- Does the technology require resources of a type or in a quantity that is not readily available at the Site?
- Are there experienced contractors that can provide, install, and operate the technology?

During this secondary phase of the screening process, the relative costs of the alternative technologies are also considered. Table 2-4 presents the results of the second level of screening.

2.5 Summary of Remedial Technologies

2.5.1 Remedial Technologies Retained for Further Consideration

The remedial technologies retained for further consideration following the secondary phase of the screening process (detailed on Table 2-4) are listed below. A general description of each of these technologies/processes is included in Table 2-4. These technologies are further evaluated and described in Sections 3 and 4.

- No action
- Institutional Controls
- In-Situ Enhanced Bioremediation
- In-Situ Chemical Oxidation
- Bedrock Fracturing
- Soil Vapor Extraction (including sub-slab vapor extraction)
- Hydraulic Containment
- Interceptor Trench (Blast Fracturing)
- Monitored Natural Attenuation
- Directional Wells
- Dual-Phase Extraction
- Groundwater Pumping/Pump and Treat
- Advanced Oxidation Processes
- Air Stripping
- Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption
- Thermal Catalytic Oxidation
- GAC/Vapor Phase Carbon Adsorption

2.5.2 Remedial Technologies Not Retained for Further Consideration

Certain technologies were not retained for further consideration. Although these technologies may be applicable to VOC-contaminated soils and waste, they were eliminated for reasons which include: a) lack of effectiveness in the long term, b) longer implementation time, c) not applicable to specific Site conditions, or d) lack of effectiveness relative to other viable technologies. The remedial technologies not retained for further consideration following the secondary phase of the screening process (detailed on Table 2-4) are:

Engineering Controls:

Physical Containment: Use of natural and/or synthetic cover materials and/or vertical barriers (grout curtains) could be used as means of reducing direct exposure but would not result in the reduction or elimination of the contaminants. Lateral containment in a fractured bedrock system would be difficult to impossible to implement with any degree of certainty. Vertical containment could not be achieved. Alterations in the flow regime caused by the barriers could result in unpredictable negative impacts.

Alternate Water Supply: Development of an alternate water supply for the impacted residential supply wells could be used to eliminate direct exposure to impacted groundwater. The engineering, design and construction costs associated with a new municipal water supply system would be significantly higher compared to the already proven point-of-entry treatment systems used to treat drinking water at affected residences. This option by itself would not protect indoor air-quality in the Site buildings, restore the aquifer, or protect the ecology. Its effectiveness would be dependant on impacted residents opting to switch from their well to the public water supply. This technology is eliminated from further consideration because point-of-entry treatment systems provide a comparatively cost effective and proven method of protecting residential water quality.

Treatment Technologies/Processesss:

Flushing: Groundwater is circulated through the area of impact by a process of cyclic withdrawl-treatment-reinjection to mobilize the contamination and increase the rate of dissolution. Surfactants may be added to accelerate the process of dissolution. While Site data suggest that pumping from AV-2 is hydraulically capturing groundwater impacted by residual contaminants in the source area, the flow pathways in the fractured bedrock are not well defined. Flushing would likely occur along preferential pathways and may not be effective at impacting pockets or dead-end fractures. Flushing alone could take an extended time period to dissolve residual free product in the flow paths. Flushing is not retained as injection of oxidants is considered a preferred technology since duration times would be shorter and creating a circulation system would not be essential.

Thermal Treatment (Enhanced Vapor Extraction): Direct thermal treatment is not practical in a subaqueous environment. The addition of heat to the subsurface in the form of steam, hot gasses, direct current, etc. can increase the rate of dissolution and volatilization of NAPL and/or dissolved components increasing their mobility and ease of withdrawal. The effect is limited by the thermodynamics of water and the characteristics of the aquifer, and tends to be highly localized to the immediate vicinity of the injection point(s) requiring an excessive number of injection points in a fractured bedrock system to be useful.

<u>Air Sparging:</u> Air is injected into the aquifer and disperses vertically and laterally, essentially creating an in-ground air stripper that strips contaminants from the groundwater by volatilization. There are limited application studies available for evaluation relative to bedrock aquifers.

<u>Bioslurping</u>: This is a process of enhanced aerobic biodegradation and free product recovery. It is not effective for halogenated compounds or DNAPL.

<u>In-Well Air Stripping</u>: This is a similar process to air-sparging. Air is injected into a well between two screen intervals set at the base and near the top of the well. The rising air bubbles in the well strip the contaminants from the water and raises the water level so that water flows out the top screen and is replaced from below. As with sparging, the process is not effective with DNAPL or halogenated compounds nor proven in bedrock aquifers.

<u>Separation:</u> Contaminants are concentrated through separation techniques (freezing, crystallization, electroplating, etc). This technology is primarily used for industrial wastewater (large permanent facilities). No portable field application has been demonstrated or is readily commercially available.

<u>Biofiltration</u>: This process employs vapor phase treatment with biologically active soil bed. It is primarily an aerobic process that is not effective with halogenated compounds.

<u>Quarrying:</u> Conventional surficial mining technologies may be used to remove contaminated bedrock, and expose pools and pockets of DNAPL for easy removal. In addition to being very expensive in comparison to the existing system, quarrying is not practical in a developed area or below the water table without extensive hydraulic controls. Would require the total removal of all surface structures and infrastructure.

<u>High Energy Destruction:</u> High-energy destruction uses very high voltage electricity to destroy contaminants. This is a pilot-scale technology being developed by the US DOE that is not currently available for field applications. Usage requires access to substantial electrical power resources.

<u>Membrane Separation:</u> A high pressure membrane separation system has been designed by DOE to treat feedstreams that contain dilute concentrations of VOCs. The organic vapor/air separation technology involves the preferential transport of organic vapors through a nonporous gas separation membrane (a diffusion process analogous to pumping saline water through a reverse osmosis membrane). Technology being applied in full-scale demonstration project but not yet readily commercially available.

<u>Scrubbers:</u> Scrubber units are designed for removal of Hazardous Air Pollutants (per CAA section 112) and generally reserved for fixed permanent installations with very high system air volume fluxes. Not readily portable for field applications.

<u>Deep Well Injection:</u> Deep-well injecting uses closed subsurface geological structures (such as salt domes) as a storage receptacle for hazardous liquids. Process generally used for acutely toxic free-product/hazardous liquids. Availability of deep structure on or near site is significant factor in application. Technology is not applicable to the AVSC site.

<u>Off-site Disposal:</u> Impacted media would be transported off-site for disposal at a facility permitted to handle the waste. A common removal/treatment/disposal option generally reserved for emergency removal actions, spill response actions, and/or low volumes of contaminated media due to costs. Cost of disposal of groundwater ranges from \$0.70-\$1.10 per gallon compared to on-site treatment costs of \$1.75-\$8.00 per 1000 gallons (not including design and construction of system). Current system costs are approximately \$0.002 per gallon.

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

3.1 Introduction

This section presents a preliminary description of remedial action alternatives that have been developed for the AVSC Site. Alternatives were developed by combining one or more of the applicable remedial technologies that passed the preliminary screening. Table 3-1 summarizes the Remedial Action Alternatives to be retained for detailed evaluation.

3.2 Development of Representative Technologies

General response actions are broad categories of remediation that may be applicable to a specific Site. Certain general response actions (i.e., hydraulic containment, groundwater treatment, or vapor treatment) have a number of possible technologies that could be employed depending on Site-specific conditions. Rather than evaluating each permutation of applicable technologies available to a specific alternative, one representative technology was selected for each alterative to represent the range of technologies that could be used. For example, vapor phase treatment can be accomplished by advanced oxidation, thermal catalytic destruction, or granular activated carbon (GAC) adsorption. Therefore, for the evaluation of each alternative with a vapor phase treatment component it was assumed that GAC adsorption would be utilized. The specific technology to be used for the final selected remedy would be determined based on the results of an engineering design study performed prior to implementation of the selected remedy.

3.2.1 Bedrock Fracturing

Fracturing is an enhancement technology designed to increase the efficiency of pumping or in-situ technologies in bedrock conditions. The fracturing laterally extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction. In the fractured bedrock environment, the extent and interconnectivity of the existing fractures will dictate the formations "bulk" permeability or hydraulic conductivity. Fracturing not only expands and dilates primary fractures, but also interconnects secondary fracture networks. Fracturing has been demonstrated to increase bulk permeability in the fractured zone by 0.5 to 2 orders of magnitude up to 60 feet from the propagation point based on rock type, depth, and fracture method. Considerable laboratory and field studies have been conducted to examine the permanence of fractures. Bedrock fracturing is commonly performed by one of the following three methods:

- Hydraulic Fracturing;
- Pneumatic Fracturing; and
- Blast Enhanced Fracturing.

The effectiveness of fracturing can be evaluated by means of a pilot study designed to compare fractured and non-fractured permeability.

Hydraulic Fracturing: Hydrofracturing is a technology in which pressurized water is injected to increase the permeability of rock. The fracturing process begins with the injection of water into a sealed borehole until the pressure of the water exceeds the overburden pressure and a fracture is created or an existing fracture is enlarged. A slurry composed of a coarse-grained sand and guar gum gel or a similar substitute is then injected into the fracture as the fracture expands away from the well. After pumping, the sand grains hold the fracture open while an enzyme additive breaks down the viscous fluid. The thinned fluid is pumped from the fracture, forming a permeable subsurface channel suitable for delivery or recovery of a vapor or liquid. The hydraulic fracturing process can be used to promote more uniform delivery of chemical oxidants or biological reagent or to accelerate the extraction of mobilized contaminants. Typical fracture propagation for the bedrock at the Site is expected to be 50-60 feet beyond the injection point.

Hydraulic fracturing is commercially available from several companies. The cost of hydraulic fracturing is small compared to the benefits of enhanced remediation and the reduced number of wells needed to complete a successful remediation.

Factors limiting the applicability and effectiveness of the process include; the potential to open new pathways leading to the unwanted spread of contaminants (e.g., dense non-aqueous phase liquids [DNAPLs]), pockets of low permeability that may still remain after using this technology and the inability to control the final location or size of the fractures. While hydraulic fracturing produces larger apertures and can be performed at greater depths than pneumatic fracturing, the addition of water in hydraulic fracturing may create a larger volume of contaminated media possibly requiring further remediation. Since hydraulic containment of groundwater emanating from the source has already been demonstrated at the Site, the concern related to the spread of contaminants is mitigated. Therefore, hydraulic fracturing may be considered as a viable option at the Site.

Pneumatic Fracturing: Pneumatic fracturing is a process whereby a gas is injected into the subsurface at pressures exceeding the strength of the bedrock and at flow volumes exceeding the natural permeability of the bedrock. Typical pneumatic fracturing events require a gas injection rate as high as several thousand cubic feet per minute (cfm), at pressures typically less than 100 psig. This causes failure of the medium resulting in the propagation of a fracture network radiating outward from the injection point. Fracture propagation distances of 30-60 feet are common in rock formations.

Examination of a pressure - time history curve provides evidence that the cohesive bonds within the geologic matrix are broken and the creation of a fracture network occurs within the subsurface. Prior to pneumatic fracturing, vacuum is applied in two designated wells to determine the airflow rate under a pre-fracture condition.

For maximum control, the fracturing is carried out in narrow depth intervals using a proprietary lance or HQ Injector equipped with rubber packers which are expanded by pressurization with air to isolate each interval of the well bore from those above and below it. This tends to concentrate the effect of the pressure pulse and may also help minimizing the formation or propagation of vertical fractures by providing resistance above and below. The spacing of the fracture boreholes is based on the radius of influence and the rock type. According to the vendor, fracture propagation in the bedrock at the Site is expected to be 50 to 60 ft from the borehole.

It is expected that the fracture distribution in a formation will not be homogeneous, since certain geologic conditions will possess preferential fracture propagation directions. Fractures will typically propagate along existing planes of weaknesses such as bedding planes, existing fractures, joints, and faults.

There is a potential for air to become trapped within the newly created fractures displacing groundwater. However, discussions with the vendors indicate that this is not a significant problem as this method creates a dense fracture network emanating from each injection point. By overlapping the injection points, the uniformity of the fracture density increases, reducing the potential for trapped air to remain in the formation.

It is noted that highest contaminant concentrations usually occur within and adjacent to existing structural discontinuities in the formation (e.g. joints, cracks, bedding planes). Since pneumatic fracturing dilates and interconnects existing discontinuities, direct access is provided to majority of the contaminant mass. The high potential for even small fractures may be explained by the "cubic law", which states that flow rate in planar fractures is proportional to the cube of the aperture. Since the diffusive distance is shortened by pneumatic fracturing, chemical or biological reagents will be delivered more readily and withdrawal technologies would be more effective.

Pneumatic fracturing equipment includes a compressor, pressure regulator, and receiver tank with in line flow meter and pressure gauge, air is injected at 72.5-290 psi for <30 seconds using a proprietary nozzle. There are no additives injected into the newly created fractures in the bedrock. Pneumatic fracturing has been patented by the New Jersey Institute of Technology (NJIT). The NJIT has licensed pneumatic fracturing to Accutech Remedial Services, Inc (ARS).

The use of an inert (i.e., N_2) gas as an injection fluid in pneumatic fracturing leads to some significant and advantageous differences compared with hydraulic or blast fracturing. Specifically:

- Pneumatic fracturing does not introduce liquids into the formation which may tend to remobilize contaminants in the vadose zone;
- Pneumatic fracturing provides beneficial aeration and/or sparging during pneumatic injection; and,
- Pneumatic fracturing causes less permanent ground deformation, which may be of concern when fracturing is performed in proximity to structures and/or utilities.

Therefore, pneumatic fracturing may be the preferable enhancement technology for application at the AVSC site in the source areas that are near and/or beneath the on-Site buildings. Pre-design geotechnical evaluations should be performed to evaluate the specific conditions at the AVSC site.

Blast Enhanced Fracturing: Blast-enhanced fracturing is a process used at Sites with contaminated bedrock formations. The increased well yields, hydraulic conductivity values, and capture zones occur as a result of the highly fractured area created by detonation of explosives in boreholes. Compared to other fracturing methods, blast fracturing has the greatest potential positive impact, with respect to increasing the bulk permeability but the smallest potential radius of effect, generally 5-10 meters from the shot-holes.

A blasted bedrock zone or trench is created by detonating trenching-type explosives in a timed sequence within closely spaced subsurface shot-holes. Blasting effectively increases groundwater recovery rates and capture zone dimensions by creating a zone of new fractures and by connecting pre-existing fractures. The high flow rate associated with pumping from a blasted bedrock zone creates a broad region of drawdown and groundwater capture.

Blasting results in the creation of a highly fractured area localized around each shot-hole, and completion of the blasting pattern should result in the creation of a continuous intensely fractured zone. There may be a risk of damage to building and structures. A design study would be needed to evaluate the potential risks and benefits of this technology.

Summary: Pneumatic and hydraulic fracturing methods are similar in cost and effectiveness and either could be implemented at the AVSC Site. These methods would likely create the widest area of influence and would not have the potential structural risks associated with blast fracturing. For cost estimating purposes, pneumatic fracturing is selected as the representative fracture enhancement technology. The most appropriate fracturing method would be determined during design.

3.2.2 Hydraulic Containment

Hydraulic containment is the interception or reversal of a migrating aqueous phase groundwater contaminant plume through the pumping of groundwater. The pumping produces a physical or potentiometric depression in the water table that induces a gradient to the withdrawal point(s). The size of the depression, zone of influence, and effectiveness of capture are functions of aquifer specific parameters and the pumping rate. Individual groundwater extraction wells or interceptor trenches in combination with wells may be used for hydraulic containment. Because hydraulic containment generally involves the removal of impacted groundwater it also provides a reduction in mobility and volume of contaminants through the removal of the contaminated groundwater from the subsurface. Hydraulic containment usually requires ex-situ treatment of the water prior to discharge.

Groundwater extraction wells are generally installed with a drilling rig. The extraction wells can be open across the full length of the borehole or constructed with well screens and filter packs installed to intercept the entire saturated thickness of the contaminated water-bearing zone or to target discreet intervals. Hydraulic containment can be achieved at the AVSC Site by pumping from

- One or more vertical bedrock wells (possibly fracture enhanced),
- One or more directionally drilled horizontal bedrock wells (possibly fracture enhanced), or
- Construction of a blasted trench.

Vertical bedrock wells: Currently, groundwater pumping at well AV-2 appears to be capturing contaminated groundwater at the Site. AV-2 is an open bedrock well that is likely producing water from a series of fractures and bedding planes. Based on the results of RI packer testing, the concentrations of contamination from the various fractures are likely to differ. Installation of one or more new pumping wells with discrete pumping zones targeted at intervals with higher contamination may be effective in improving the pumping efficiency while still hydraulically containing contaminated groundwater. Packer testing would be performed to identify contaminated zones prior to well screen construction. Selection of well locations would be based on fracture trace analysis but the risk of drilling into a competent, minimally fractured area is always present.

Fracture enhancement, such as hydraulic fracturing could be considered to increase the hydraulic conductivity of the bedrock in such an event.

Horizontal bedrock wells: Angled or horizontal drilling is a proven method for installing wells in soil or bedrock. Construction of horizontal wells requires specialty drilling equipment and experienced operators. Often the well head must be a significant distance away from the desired location of the well to achieve required depths since angle drilling precedes horizontal drilling. The advantage of horizontal drilling is that multiple vertical fractures (tending to be the primary groundwater flow conduits) can be intercepted to increase pumping yields in contaminated zones and focus pumping at desired depths. Installation costs are typically higher than conventional vertical wells.

Blasted trench: The method described above for blast fracturing would be used to create a downgradient trench designed to capture contaminated groundwater. Groundwater would be pumped at rate sufficient to reverse hydraulic gradients. While this technique is likely to be highly effective, blasting would need to be performed by an experienced contractor. The trench could be constructed a distance from Site buildings or structures, but the potential for structural impacts would need to be evaluated. Costs associated with blast fracturing would be significantly higher than conventional vertical wells.

Summary: Since Site data suggest that pumping at AV-2 and at residential wells at lots 7 and 11 Locust Crest Court (vertical wells) were successfully controlling contaminated groundwater flow, and this technology is more cost effective than horizontal bedrock wells or blast fracturing, use of the existing well, or enhancing the pumping system through installation of additional vertical wells is the selected representative technology for hydraulic containment. Pumping at the residential wells was discontinued in July 2001. No data are available to indicate how much the groundwater pumping associated with the residential wells (lots 7 and 11 Locust Crest Court) air stripper may have contributed to the reduction of groundwater contaminant levels in the downgradient residential wells. New monitoring data are needed to evaluate the effect of the recent discontinuation of continual pumping at these residential wells on the overall hydraulic containment of groundwater contaminants at the Site.

3.2.3 Source Area In-Situ Chemical Treatment

An in-situ treatment response action provides reduction or elimination of toxicity, mobility, or volume of contaminants without extracting the contaminated groundwater from the subsurface. During the treatment process, the contaminants may be altered to a less toxic form, isolated, or completely destroyed. In-situ treatment can be accomplished through biological or physical/chemical means. The in-situ treatment options considered for this Site consist of technologies that destroy organic contaminants by the direct injection of chemical oxidizing agents such as potassium or sodium permanganate and Fenton's Reagent.

The fractured bedrock at the AVSC Site poses some uncertainties for successful implementation of these in-situ technologies. The lack of fracture inter-connectivity is the major limiting factor affecting the success of in-situ technologies at the AVSC Site. The nature of fluid flow and contaminant transport in a fractured bedrock aquifer is more complicated than in a porous media (soils) and harder to predict. Dispersion of chemical reagents in the impacted source area may be difficult due to the very low transmissivity and potential lack of connectivity of the flow paths. To overcome these difficulties enhanced fracturing is recommended to increase the migration and dispersion of the injected chemical reagents. Therefore, fracture enhancement is considered as a prerequisite for in-situ treatment. However, due to fracturing, the migration rate of organic contaminants of concern (COCs) may increase. A treatability study and a pilot scale field test are required to determine the effectiveness of the oxidizing agents, the quantities of reagents required, and the optimal number and spacing of the injection points.

Potassium or Sodium Permanganate: This in-situ technology option involves injection of either a potassium or sodium permanganate solution into the subsurface. The permanganate solution reacts with and oxidizes the organic contaminants. Oxidation using potassium or sodium permanganate is effective in treating organic contaminants (i.e. alkenes, polyaromatic hydrocarbons (PAHs), phenols, pesticides and organic acids), including the majority of the Site COCs without the need for vapor control measures. However, this chemical agent is not as cost effective as other reagents or technologies for destroying chlorinated alkanes (1, 2-Dichloroethane) and aromatic hydrocarbons (BTEX). The following equation illustrates the oxidation of tricloroethene (TCE) using potassium permanganate (USDOE, 1999):

$$2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 2Cl^- + HCl$$

Factors which must be considered when implementing this technology include depth of contaminants and Site-specific geology. The optimum pH range is 7 to 8, but it is effective over a wide pH (Yin et. Al., 1999). System effectiveness is dependent on how well the permanganate can be dispersed and contacted with the contamination. Given the low permeability of the bedrock aquifer, fracture enhancement by pneumatic or controlled blasting is necessary at the Site. Sodium permanganate has demonstrated higher solubility in aqueous solutions than its potassium counterpart. This in turn allows for liquid chemical feed delivery (USEPA, 1998) or injection of increased concentrations (Amarante, 2000). For costing purposes, sodium permanganate is the selected option for this alternative. Potassium permanganate may still be applicable and can be considered during final remedy implementation.

Oxidation using sodium or potassium permanganate would be applied to on-Site groundwater for this alternative. Off-Site contamination, organic contamination remaining in the groundwater after oxidation treatment would be allowed to naturally attenuate. Groundwater monitoring would be performed to monitor changes in contaminant concentrations and distribution.

Institutional controls would be required to prevent exposure to contaminated groundwater. Minor administrative difficulties are anticipated for implementation of this technology because addition of reagents such as potassium or sodium permanganate to the subsurface could require an EPA Underground Injection Control (UIC) permit, and permits from the NYSDEC.

Potassium and sodium permanganate have both been used for full-scale remediation of volatile organic compound (VOC) contamination at various Sites as documented by the USEPA and the DOE. Both TCE and cis-DCE have been successfully removed in full-scale, field demonstrations

(USEPA, 1998). The cost to remediate a Site using in-situ oxidation with potassium or sodium permanganate falls between $75 and $100 per 100 gallons of groundwater treated.

Fenton's Reagent: This in-situ treatment technology involves injection of Fenton's Reagent into the subsurface. Chemical oxidation of organic contaminants is achieved by injection of hydrogen peroxide and a catalyst formulation into the affected media under carefully controlled conditions. This in-situ oxidation system is capable of complete, non-selective oxidation of organic compounds in groundwater, including the majority of the Site COCs. The basic reaction in the in-situ oxidation process is simplified below:

Hydrogen Peroxide + Organic Contaminant → Carbon Dioxide + Water

During the oxidation of chlorinated hydrocarbons HCl is formed in addition to carbon dioxide and water. For example the oxidation reaction for TCE is as follows:

$$3H_2O_2 + C_2HCl_3 \rightarrow 2CO_2 + 2H_2O + 3HCl$$

During the reaction sequence, the organic compounds are successively converted to shorter chain mono- and dicarboxylic (fatty) acids. These compounds are further degraded into carbon dioxide and water by subsequent reactions. Fenton's reagent-based in-situ oxidation occurs more readily in slightly acidic conditions, and some vendors of the technology add a weak acid along with the reagents to lower the pH and improve treatment efficiency. Reagents can be injected into the aquifer under pressure or by diffusion. Because the Fenton's reagent treatment is exothermic, application of this technology may result in generation of significant heat.

The Geo-Cleanse Process, developed by Geo-Care, Inc., requires installation of a patented injector system into the subsurface prior to treatment. The injectors each contain a mixing head which can mix reagents as well as stimulate circulation of groundwater. The injectors are designed to withstand the elevated temperatures and pressures resulting from the Fenton's reagent treatment. At the start of the injection process, air and a catalyst solution are injected to open the injector to the subsurface formation and to adjust the groundwater pH to between 4 and 6. Once an acceptable flow rate is established and the appropriate pH has been attained, hydrogen peroxide and more catalyst solution are added simultaneously under pressure (typically ranging from 15 to 60 psi). The hydrogen peroxide and catalyst solution is added until groundwater sampling indicates that the contaminant levels have dropped below cleanup levels.

The actual oxidation is driven by formation of a free hydroxyl radical via Fenton's reaction chemistry. The preferred Fenton's Reaction is:

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

The hydroxyl free radical (OH.) is an extremely powerful oxidizer of organic compounds. Residual hydrogen peroxide, due to its unstable characteristics, rapidly decomposes to water and oxygen in the subsurface environment. Soluble iron amendments added to the aquifer during the in-situ process in trace quantities may precipitate out during conversion to ferric iron. The ferrous iron that exists in the aquifer is also converted to ferric iron due to reaction with the reagent. In fracture enhanced bedrock the permeability may be reduced due to precipitation of iron. However, the Fenton's reagent is injected into the aquifer under acidic conditions at which the oxidation reaction is most effective. Significant quantities of iron precipitation due to formation of ferric iron is not expected during the injection of reagent at the lower pH ranges required for effective oxidation. It should also be noted that during the oxidation of organic contaminants acidic conditions prevail since the acids are generated as a result of these reactions. Most of the iron is expected to precipitate at a later stage after the reagent injection is stopped, and the pH of the groundwater gradually increases following the oxidation reactions. The kinetics of iron precipitation as opposed to the rate of oxidation reactions, and the effect of iron precipitation on the effectiveness of remediation should be investigated during the pilot study.

Factors that must be considered when implementing this technology include depth of contaminants and Site-specific geology. System effectiveness is dependent on how well the Fenton's reagent can be dispersed and contacted with the contaminants. Given the low permeability bedrock aquifer, fracture enhancement may be necessary at the Site.

Fenton's reagent would be applied to on-Site groundwater for this alternative. Off-Site contamination remaining in the groundwater after Fenton's reagent treatment would be allowed to naturally attenuate. Groundwater monitoring and modeling would be performed to monitor changes in contaminant concentrations and distribution on Site and off Site over time.

Institutional controls would be implemented to prevent exposure to contaminated groundwater. Minor administrative difficulties are anticipated for implementation of this technology because addition of reagents such as Fenton to the subsurface could require an EPA Underground Injection Control (UIC) permit, and permits from the NYSDEC.

The cost of this technology varies depending on the system size and contaminant concentrations. Typically, pilot-scale (approximately $100,000) treatability testing is required prior to full-scale treatment. The cost of the reagents is on the order of $15,000 to $20,000 per injection per well, and as such, represents the bulk of the treatment cost.

Summary: Potassium and/or sodium permanganate are likely to be effective on the Site contaminants, and these oxidants don't create heat or the potential for iron precipitation, as associated with Fenton's reagent. Consequently, the injection of potassium or sodium permanganate is the assumed representative technology for in-situ chemical treatment at the Site. The cost estimates for direct chemical oxidation assume that permanganate is reagent to be used.

3.2.4 Source Area Collection/Extraction

A source area collection/extraction-based response action provides reduction in mobility and volume of contaminants through the removal of the contaminated groundwater from the subsurface with the use of source area groundwater extraction wells or interceptor trenches. Groundwater extraction wells are generally installed with a drill rig. Well screens and filter packs are generally installed to intercept the saturated thickness of the contaminated water bearing zone. Extraction wells can be installed to provide a hydraulic barrier for control of migration of contaminated groundwater, or at specific locations for source area remediation. The collection/ extraction response action is typically combined with ex-situ treatment of the extracted groundwater. The source area collection-extraction option considered for the AVSC Site is Dual Phase Extraction. Dual Phase Extraction involves removal of contaminant-laden groundwater and vapor from a dual-phase well system from the aquifer under high vacuum (generally up to 28 inches of mercury). Dual-phase extraction involves above ground treatment of extracted groundwater and vapors from the subsurface using other technologies prior to discharge/disposal

3.2.5 Ex-Situ Groundwater Treatment

An ex-situ treatment response action provides reduction in toxicity, mobility, or volume of contaminants following extraction of contaminated groundwater from the subsurface. Ex-situ treatment can be accomplished through biological or physical/chemical means and can be conducted on-Site or off-Site. The extracted groundwater and vapor are treated at the surface prior to discharge.

The ex-situ groundwater treatment options considered for AVSC Site is air stripping (the technology used for the existing on-Site treatment system). GAC or ultraviolet (UV) oxidation would be considered for groundwater treatment during design if ex-situ treatment becomes part of the selected remedy.

3.2.6 Ex-Situ Vapor Treatment

Vapor phase treatment can be accomplished by advanced oxidation, thermal catalytic destruction, or GAC adsorption. GAC is the selected representative technology for vapors. If concentrations in the vapor are high, advanced oxidation or thermal catalytic destruction may be a more cost effective technology and this determination would be made based on pre-design studies.

3.3 Development of Alternatives

3.3.1 Alternative 1: No Action

The National Contingency Plan (NCP - 40 CFR Part 300.430[e][6]) requires that a No Action response action be considered in the detailed analysis of alternatives to provide a baseline from which other alternatives can be evaluated. Under the No Action alternative, it is assumed that the current groundwater removal and treatment system and the point-of-entry treatment systems at downgradient residential supply wells would be discontinued. No actions would be taken to reduce the potential impacts associated with Site contaminants.

3.3.2 Alternative 2: Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) is essentially the same as No Action with the addition of long term water quality monitoring. The volume and toxicity of contaminants are reduced over time by naturally occurring processes in soil and groundwater. The natural attenuation processes that may reduce contaminant concentrations in groundwater include advective and radial dispersion, volatilization, adsorption, biodegradation, and chemical reactions with other subsurface constituents. Extensive Site modeling and monitoring are performed as part of the MNA alternative to demonstrate that contaminants do not represent significant risk and that degradation is occurring.

MNA can be implemented in combination with other remedial actions at the Site or as a stand-alone alternative. When implemented with other remedial actions, MNA can be selected for downgradient areas after source treatment or for areas with low levels of contamination.

MNA would be implemented with institutional controls such as restrictions on groundwater use without treatment through deed restrictions or prohibition of new well construction. The effectiveness of deed restrictions is dependent on proper enforcement. Deed restrictions, however, would not reduce the migration and the associated environmental impact of the contaminant plume. Implementation may be accomplished with existing resources. Deed restrictions may be difficult to enforce over the long term and may limit future land use options.

3.3.3 Alternative 3: Hydraulic Containment using Current Pump and Treatment System

- Hydraulically contain plume with current pump and treat system
- Vent air from under buildings with sub-slab vapor extraction
- Continue operating point-of-entry (POE) treatment systems for downgradient receptors as necessary
- Install property-boundary monitoring wells downgradient of AV-2 to monitor effectiveness of hydraulic containment system
- Long-term monitoring

The current operational remedial system was installed on the Site as an interim remedial measure (IRM). The major components of the existing system include hydraulic containment by groundwater pumping, treatment of removed groundwater with an air stripper system prior to discharge, and individual GAC-based POE treatment systems at ten impacted downgradient residential supply wells. An additional air stripper system was added to pre-treat water at lots 7 and 11 on Locust Crest Court (who also had GAC-based POE systems).

Residential wells with POE treatment systems were sampled by the USEPA and levels were observed to decrease over time indicating that pumping from AV-2 and the residential wells at lots 7 and 11 had reversed the pattern of off-site migration of groundwater contaminants. At eight of the impacted residential wells, the water quality was improved to such a level that the USEPA deemed that the POE systems were no longer needed. The pumping and treatment system at lots 7 and 11 were discontinued in the last year but the two POE systems at these residences are still actively treating potable water.

Alternative 3 assumes that the existing groundwater pumping and treatment systems would continue to hydraulically contain the contaminated groundwater at the Site. Further investigation would be needed evaluate whether hydraulic containment is being maintained without the pumping from the residential wells.. Hydraulic containment would be utilized to reduce the migration of contamination from the source area toward potential downgradient receptors. The POE systems would be discontinued if the residential wells were to achieve drinking water standards.

Vapor extraction would be implemented to mitigate impacted indoor air quality. This would be implemented through the use of a sub-slab vapor extraction system.

3.3.4 Alternative 4: Enhanced Hydraulic Containment with Sub-Slab Vapor Extraction

- Enhance hydraulic containment by pumping from additional discreet interval bedrock wells (possibly fracture enhanced)
- Treat removed groundwater using existing or modified treatment system
- Vent air from under buildings with sub-slab vapor extraction
- Continue operating POE treatment systems for downgradient receptors as necessary
- Install property-boundary monitoring wells downgradient of AV-2 to monitor effectiveness of hydraulic containment system
- Long-term monitoring

Under Alternative 4, the current system would be reevaluated with respect to effectiveness and enhancements added to improve overall operational efficiency. Enhancements may include installation of one or more additional discreet interval pumping wells to improve containment. The additional well would be constructed to target specific zones of contamination identified during the installation process, rather than as a continuous open borehole. Fracture enhancement could be used to improve the yield of contaminant bearing fractures. A vapor extraction system consisting of a sub-slab vapor extraction system would be installed to protect indoor air quality.

3.3.5 Alternative 5: In-situ Oxidation of Source Area Contaminants, Hydraulic Containment and Sub-Slab Vapor Extraction

- Install source-area chemical injection wells enhanced through bedrock fracturing
- Continue pumping from current pumping well or enhanced pumping system
- Treat removed groundwater using existing or modified system
- Vent air from under buildings with sub-slab vapor extraction
- Install property-boundary monitoring wells downgradient of AV-2 to monitor effectiveness of hydraulic containment system
- Install deep monitoring wells outside injection area at depths below fracture enhancement zone to monitor potential downward migration due to fracturing
- Continue operating POE treatment systems for downgradient receptors as necessary
- Long-term monitoring

Alternative 5 assumes that, the operation and maintenance of the current system would continue without alteration of the existing operational parameters. Direct oxidation (in-situ treatment) by injection would be used in the identified source areas to reduce non-aqueous phase liquid (NAPL) and dissolved contaminants, to the extent feasible. Pneumatic or hydraulic fracturing would be used in the injection wells to enhance the permeability of the aquifer and improve the penetration of the chemical oxidants. For evaluation purposes, it is assumed that permanganate would be used as the chemical agent. A vapor extraction system consisting of an under-slab vapor extraction system would be installed to protect indoor air quality.

3.3.6 Alternative 6: Dual-Phase Extraction in Source Area and Hydraulic Containment

- Install source-area dual-phase extraction wells, enhanced through pneumatic or hydraulic bedrock fracturing
- Continue pumping from current pumping well as necessary
- Vent air from under buildings with sub-slab vapor extraction
- Treat removed groundwater using existing or modified system
- Treat removed vapor as necessary
- Install property-boundary monitoring wells downgradient of AV-2 to monitor effectiveness of containment system
- Install deep monitoring wells outside fracture enhancement area at depths below fracture enhancement zone to monitor potential downward migration due to fracturing
- Continue operating POE treatment systems for downgradient receptors as necessary
- Long-term monitoring

Under Alternative 6, groundwater and vapor would be removed from one or more recovery wells located within the contaminant source area and treated ex-situ prior to discharge. The liquid-phase treatment system would consist of an air stripper tower to remove contaminants from the groundwater prior to discharge. A vapor phase treatment system consisting of a thermal catalytic oxidizer would be used to treat the air from the stripper air prior to discharge. An integrated soil vapor extraction system or sub-slab vapor extraction system would be used to protect indoor air quality. Pneumatic or hydraulic fracturing would be used to enhance the removal capacity of the well(s) and increase mobility of any DNAPL. Periodic groundwater monitoring in the source area and at strategic downgradient points would be routinely conducted to demonstrate the effectiveness of the system.

3.4 Screening of Alternatives

Alternatives 1 through 4, which range from no action to addition of conventional pumping wells are readily implementable and viable for carrying through to a detailed evaluation. Additionally, Alternative 5 incorporates a relatively well-demonstrated technology that is suitable for the specific conditions at the AVSC Site. As the conceptual design for the Dual Phase Extraction (DPE) component of Alternative 6 was developed for the detailed analysis, several significant disadvantages were identified that justified eliminating this alternative from further consideration. The following is a description of the limitations of DPE at the AVSC Site.

It was estimated that a minimum of 24 fracture-enhanced DPE wells would be required in the source areas to effectively influence the impacted area. To effectively remove DNAPL from the bedrock formation, where it is likely trapped in small fractures, groundwater would need to be drawn down a minimum of 90 feet over an area of 19,200 ft^2. A preliminary assessment was performed of the pumping rates associated the DPE alternative and it was determined that to dewater the area to be influenced by the DPE wells would require an estimated pumping rate between 250 and 350 gpm (see worksheets in Appendix A). This pumping rate does not include any upward vertical component of groundwater flow created by the depressed water table. The pumping rate is based on the determined aquifer transmissivity from a pumping test at AV-2, conducted prior to the RI.

A pumping rate of this magnitude would require a significantly larger groundwater treatment system and a substantial blower system to extract vapors. Additionally, a vapor phase treatment system would be required to treat the vapor phase prior to discharge. Because the existing system does not have sufficient flow-through capacity, it would need to be significantly upgraded or totally replaced at substantial capital costs. Long-term operation and maintenance costs would also be proportionally higher than the current system.

High pumping rates would likely impact the production at local public water supply wells such as the well used by a nearby bank and residential wells. Without more extensive pumping tests, it is difficult to predict the affect of pumping on nearby wells, but if impacts were identified, reduced pumping would render the DPE technology ineffective (since removal of DNAPL occurs predominantly in the desaturated zone rather than through removal of groundwater).

Based on these Site-related limitations, Alternative 6 was not retained for detailed analysis. Alternatives 1 through 5 were retained and are discussed in detail in Section 4.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section describes the detailed analysis of the alternatives retained after the preliminary screening of alternatives. Section 4.1 identifies and describes the evaluation criteria. Section 4.2 presents the detailed analysis of the remedial alternatives. The remedial alternatives are described, and then systematically assessed, on an individual basis, relative to the evaluation criteria. In Section 4.3 the alternatives are compared on the basis of these evaluation criteria.

4.1 Evaluation Criteria

NYSDEC TAGM 4030 on selection of remedial actions (NYSDEC, 1989; revised, 1990) presents seven criteria to be used for evaluating remedial alternatives that have passed the preliminary screening process. These criteria are as follows:

- Compliance with New York State Standards, Criteria and Guidelines (SCGs);
- Overall protection of human health and the environment;
- Short-term effectiveness;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility or volume through treatment;
- Implementability; and
- Costs (capital, annual operation and maintenance, present worth).

The National Contingency Plan (NCP) establishes two tiers to the above seven criteria. The first two are threshold factors and the next five are primary balancing factors. Additionally, community acceptance would be considered as a modifying consideration. These tiers are reflected in the detailed analysis. Descriptions of the seven criteria are provided below.

4.1.1 Compliance with New York State SCGs

This evaluation criterion is used to assess compliance with promulgated chemical-specific, action-specific, and location-specific Standards, Criteria and Guidance (SCGs). SCGs for the AVSC Site are discussed in Section 1.4. Proposed remedial action alternatives are analyzed to assess whether they achieve the SCGs under Federal and State environmental laws, public health laws, and State facility siting laws, or whether they may be subject to one of the six waivers allowed under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). As a threshold factor, an alternative must be compliant with the SCGs (or receive a waiver) to be considered further.

4.1.2 Overall Protection of Human Health and the Environment

This evaluation criterion is designed to determine whether a proposed remedial alternative is adequate with respect to protection of human health and the environment. The evaluation focuses on how each proposed alternative achieves protection over time; how Site risks are eliminated, reduced, or controlled; and whether any unacceptable short-term impacts would result from implementation of the alternative. The overall protection of human health and the environment evaluation draws on the assessments for long-term effectiveness and permanence, short-term effectiveness, and compliance with SCGs. As a threshold factor, an alternative must be compliant with overall protection of human health and the environment to be considered further.

4.1.3 Short-Term Effectiveness

This evaluation criterion is used to assess short-term potential impacts associated with the construction and implementation phase of remediation. Alternatives are evaluated with regard to their effects on human health and the environment. These considerations include:

- Protection of the community during implementation of the proposed remedial action (i.e., dust, inhalation of volatile gases, odors, noise);

- Protection of workers during implementation;

- Environmental impacts that may result from the implementation of the remedial alternative and the reliability of mitigative measures to prevent or reduce these impacts; and

- Time until remedial response objectives are met, including the estimated time required to achieve protection.

4.1.4 Long-Term Effectiveness and Permanence

This criterion addresses the long-term effectiveness and permanence of the remedial alternative with respect to the quantity of residual chemicals remaining at the Site after response goals have been met. The principal focus of this analysis is the adequacy and reliability of controls necessary to manage any untreated media and treatment residuals. Characteristics of the residual chemicals such as volume, toxicity, mobility, degree to which they remain hazardous, and tendency to bioaccumulate must also be examined. Specifically, these considerations are:

- Magnitude of residual risk;
- Adequacy of controls; and
- Reliability of controls.

4.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion is used to assess the degree to which the remedial alternative utilizes recycling and/or treatment technologies that permanently decrease toxicity, mobility, or volume of the chemicals as their primary element. It also assesses the effectiveness of the treatment in addressing the predominant health and environmental threats presented by the Site. The specific factors considered under this evaluation criterion include:

- Treatment process the remedy would employ and the materials it would treat;

- Amount of contaminants that would be treated or destroyed;

- Degree of expected reduction in toxicity, mobility, or volume (expressed as a percentage of reduction or order of magnitude);

- Degree to which the treatment would be irreversible;

- Type and quantity of treatment residuals that would remain following treatment accounting for persistence, toxicity, mobility and the tendency to bioaccumulate; and

- Whether the alternative would satisfy the statutory preference for treatment as a primary element.

4.1.6 Implementability

This criterion assesses the technical and administrative feasibility of implementing a remedial alternative and the availability of various services and materials that would be required during its implementation. Factors considered include the following.

- Technical feasibility: includes the difficulties and unknowns relating to construction and operation of a technology, the reliability of the technology (including problems resulting in schedule delays), the ease of performing additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility: involves coordinating with governmental agencies to obtain necessary permits or approvals.

- Availability of services and materials: includes sufficiency of off-Site treatment, storage and disposal capacity; access to necessary equipment, specialists and additional resources; potential for obtaining competitive bids especially for new and innovative technologies; and availability of state-of-the-art technologies.

4.1.7 Costs

This criterion assesses the costs associated with a remedial action. It can be divided into capital costs, annual operation and maintenance (O&M) costs, and net present worth costs. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs.

Direct capital costs include:

- Construction and equipment costs: includes all materials, labor, equipment required to install/perform a remedial action.

- Land and site-development costs: includes land purchase and associated expenses, site preparation of existing property.

- Building and service costs: includes all process and non-process buildings, utility connections, and purchased services.

- Disposal costs: includes all transporting and disposing of materials.

Indirect capital costs include:

- Engineering expenses: administration, design, construction, supervision, drafting, and treatability testing.

- Legal fees and license or permit costs: administrative and technical costs expended to obtain licenses and permits for installation and operation.

- Start up: costs incurred during initiation of remedial action.

- Contingency allowances: costs resulting from unpredicted circumstances (i.e., encountering unanticipated volumes of contaminants, odor control, adverse weather, strikes, etc.).

Annual O&M costs are post-construction costs expended to maintain and ensure the effectiveness of a remedial action. The following are annual O&M costs evaluated:

- Labor costs: wages, salaries, training, overhead, and fringe benefits for operational labor.

- Maintenance materials and maintenance labor costs: labor and parts, etc. necessary for routine maintenance of facilities and equipment.

- Auxiliary materials and utilities: chemicals and electricity needed for treatment plant operations, water and sewer services.

- Disposal of residue: disposal or treatment and disposal of residues such as sediments from treatment processes.

- Purchased services: sampling costs, laboratory fees, and professional fees as necessary.

- Administrative costs: costs associated with the administration of O&M that have not already been accounted for elsewhere.

- Insurance, taxes, and licensing costs: liability and sudden accidental insurance, real estate taxes on purchased land or rights-of-way, licensing fees for certain technologies, permit renewal and reporting costs.

- Replacement costs: maintenance of equipment or structures that wear out over time.

- Cost of periodic Site reviews if a remedial action leaves residual contamination.

Net present worth consists of capital and O&M costs calculated over the lifetime of the remedial action and expressed in present day value. For the purposes of this FS, a discount rate of 5% was assumed when calculating the net present worth of an alternative. The lifetime of the remedial action is considered to be a maximum of 30 years for costing purposes.

Any remedial action that leaves hazardous waste at a site may affect future land use, resulting in a loss of business activities, residential development, and taxes. This unquantified cost is not included in the cost evaluations for the alternatives that would leave hazardous wastes on site.

4.1.8 Community Acceptance

Community acceptance is a modifying consideration and can only be evaluated in the FS to a limited extent at this time. Typically, these considerations are not taken into account until after the public comment period on the proposed plan and RI/FS report. Comments received from the public are assessed to determine aspects of each remedy that are supported or opposed. However, since a public comment period for the FS has not yet been held, the evaluation presented in the FS at this time is very general. Public comments would be considered prior to issuance of the Record of Decision.

4.2 Remedial Alternatives Analysis

This detailed analysis evaluates the remedial alternatives developed in Section 3.0 relative to the seven evaluation criteria and the modifying factor of community acceptance. It focuses upon the relative performance of each alternative. The remedial alternatives that are evaluated in the detailed analysis are as follows:

- Alternative 1: No Action
- Alternative 2: Monitored Natural Attenuation
- Alternative 3: Hydraulic Containment using Current Pump and Treatment System with Sub-Slab Vapor Extraction
- Alternative 4: Enhanced Hydraulic Containment with Sub-Slab Vapor Extraction
- Alternative 5: In-situ Oxidation of Source Area Contaminants, Hydraulic Containment and Sub-Slab Vapor Extraction

4.2.1 Alternative 1 - No Action

4.2.1.1 Description

Evaluation of the No Action Alternative (Alternative 1) is required under the National Contingency Plan (NCP) to establish a comparative baseline for evaluating the cost and effectiveness of the remedial action alternatives. Under this alternative the existing containment/remedial system would be discontinued and no additional actions taken to remove or treat contaminated media or otherwise restrict use or access to these resources. No long-term monitoring of groundwater would be performed.

4.2.1.2 Assessment

Compliance with SCGs

Under this alternative, chemical specific SCGs would not be attainable in the foreseeable future. Contaminated groundwater would remain available for consumption and migration. Contaminated soil, if any, would remain for potential contact upon excavation and soil gas would continue to affect indoor air quality. No disposal or treatment requirements would apply since groundwater and soil would not be actively managed.

Location specific and action specific SCGs are not applicable with this alternative.

Overall Protection of Human Health and the Environment

This alternative provides no means of controlling direct exposure to or migration of contaminated groundwater and soil. Therefore, it would not reduce potential risks to human health or the environment.

Short-Term Effectiveness

Community, worker and environmental protection: Since no action would be taken to mitigate the groundwater and soil under this alternative, implementation would not pose any short-term risks to workers, the community, or the environment as a result of construction activities.

Long-Term Effectiveness and Permanence

Residual risk: The long-term risk of exposure for this alternative is not reduced since the potential for migration of contaminated groundwater and soil gas would not be controlled. Nearby residential wells that are currently protected by the hydraulic containment of on-Site contaminants resulting for pumping at AV-1 would be at risk of becoming contaminated thereby increasing the potential for human consumption of contaminated groundwater. This risk is high since some of the residential wells were previously impacted prior to initiating on-Site pumping. The potential for exposure to contaminated soil vapors in on-Site buildings would not be mitigated under the no action alternative.

Adequacy of controls: Long-term human health or ecological risks due to exposure to affected groundwater and soil would not be reduced.

Reliability of controls: No controls would be implemented for this alternative.

Reduction of Toxicity, Mobility, and Volume Through Treatment

The No Action Alternative would not reduce the toxicity, mobility or volume of the contaminants in the groundwater or soil. Mobility of the contamination would be increased by discontinuation of the current hydraulic containment system. Since treatment is not part of this alternative, irreversibility does not apply.

Implementability

No construction or operation would be required to implement the No Action Alternative. No treatment would be performed, and therefore, no permits or approvals are necessary. The No Action Alternative does not complicate or prevent any future remedial actions from being implemented at the Site.

Cost

There are no capital or long-term costs associated with this alternative.

Community Acceptance

This alternative is unlikely to achieve community acceptance because potable groundwater and soil gas containing VOCs would continue to pose unacceptable potential risks to human health and the environment.

4.2.2 Alternative 2 - Monitored Natural Attenuation

4.2.2.1 Description

Monitored Natural Attenuation (MNA) involves long-term quarterly groundwater quality monitoring. One annual sampling event is assumed. Samples would be collected annually from eight on-Site wells (AV-1, AV-2, MW-1, MW-2, MW-3, MW-4a, MW-4b and MW-5), two off-Site residential wells, and four additional monitoring wells installed along the property boundary between the source areas and downgradient receptors. The volume and toxicity of contaminants are reduced over time by naturally occurring processes in soil and groundwater. The natural attenuation processes that may reduce contaminant concentrations in groundwater include advective and radial dispersion, dilution, volatilization, adsorption, biodegradation, and chemical reactions with other subsurface constituents. The effectiveness and applicability of MNA is generally a complex function of residence time of contaminants and proximity of downgradient receptors.

Extensive site modeling and monitoring would be necessary as part of the MNA alternative to evaluate plume migration and degradation rates, determine primary site-specific degradation mechanics, develop isoconcentration projections over time and distance, determine compliance limits, and demonstrate that the contaminants do not represent a significant risk (or potential future risk) to downgradient receptors.

Institutional controls such as prohibition of new well construction and deed restrictions would be implemented with this alternative.

4.2.2.2 Assessment

Compliance with SCGs

This alternative would not achieve chemical-specific SCGs such as the New York State Water Quality Regulations, ECL Article 15, Title 3 and ECL Article 17, title 3 and 8, and 6 NYCRR Parts 700-706. Federal guidelines such as the National Drinking Water Standards, Safe Drinking Water Act, and 40 CFR Parts 141 through 143 would not be achieved. Additionally, the impacted residential supply wells located immediately downgradient of the Site boundaries indicate that the residence time and distance to these receptors is insufficient for MNA to effectively degrade contaminants to below the chemical-specific SCGs prior to impacting these receptors.

The potential exists for soil contamination and indoor air quality at the AVSC Site to not meet the chemical specific SCGs. Limited historical soil sampling and indoor air quality sampling have not detected concentrations of contaminants in excess of state guidelines under current conditions. No active remedial efforts for these media are in progress.

Location specific SCGs are not applicable with this alternative.

The USEPA has published Guidelines concerning the use of MNA as a site remedy for Superfund, Resource Conservation and Recovery Act (RCRA) corrective action, and underground storage tank (UST) sites (Office of Solid Waste and Emergency Response [OSWER] Directive 9004.2). The action specific guidance indicates the MNA is not an effective mechanism for use with chlorinated solvents due to the persistence of these compounds under natural aquifer conditions (aerobic environment). Additionally, MNA is generally not applicable in complex hydrological environments containing strong preferential flow pathways, such as in fault-fracture controlled bedrock, and/or for sites in relatively close proximity to sensitive downgradient receptors. USEPA guidance for the evaluation of the efficacy of MNA at a specific site assumes that source area controls and/or removal actions have been completed and that no uncontained/uncontrolled dense non-aqueous phase liquid (DNAPL) remains on-site.

Overall Protection of Human Health and the Environment

This alternative provides no protection of human health and the environment. Sensitive downgradient receptors are well within the contaminant plume and would be negatively impacted almost immediately if the existing containment system was discontinued. It would take decades for the concentrations of contamination in the groundwater to degrade to protective levels. In addition, demonstration of the long-term effectiveness and permanence would require an indefinite monitoring program that may be costly.

Short-Term Effectiveness

Community, worker and environmental protection: This alternative would require no active disturbance of contaminated groundwater and soil. Therefore, short-term risks are low compared to alternatives that would require removal of groundwater and soil. Workers who perform the groundwater sampling at the site would wear appropriate personnel protective equipment to avoid health risks due to exposure to contaminants and physical hazards. In addition, equipment used during sampling activities would be decontaminated prior to leaving the site as necessary to prevent off-site transport of contaminants. Potential for impact to the community, workers or the environment would be minimal. Discontinuance of the current hydraulic containment system would result in increasing concentrations of contaminants of concern in downgradient residential supply wells with increasing exposure risk.

Long-Term Effectiveness and Permanence

Residual risk: Discontinuation of the current hydraulic containment system would result in an increasing risk to downgradient receptors of exposure and ingestion. The long-term risk to the ecology for this alternative is difficult to predict but it is considered probable that impacted groundwater would discharge to downgradient surface waters before natural degradation processes reduced contaminant concentrations to ambient water quality standards.

MNA would not achieve any of the remedial action objectives in the short-term nor would it achieve the state and/or federal groundwater standards for decades. Natural attenuation depends on many factors (i.e. type of contaminant, contaminant degradation, hydrogeologic conditions, geochemistry, and environmental variability) that individually or in combination affect the concentrations of contamination. The long-term effectiveness of natural attenuation is absolute in that it would ultimately result in the complete degradation of the contaminants. But, unless very favorable conditions are present and remain present over time, this alternative is unlikely to be effective with respect to reducing residual risks to acceptable levels within a reasonable time frame (assumed 30 years).

It is anticipated that contaminant concentrations would decrease over time under favorable conditions. However, it is unknown if these favorable conditions would remain static or if concentrations would actually be reduced. Because this alternative does not involve removal or treatment of the contaminated groundwater, the volume of contaminants in the groundwater, and the risks associated with the groundwater contamination would decrease very slowly. Migration of the contaminants would continue, potentially impacting currently non-impacted receptors

Adequacy and reliability of controls: This alternative would not require controls, but long-term human health or ecological risks due to exposure to affected groundwater and soil would not be reduced.

Reduction of Toxicity, Mobility, and Volume Through Treatment

This alternative does not utilize any treatment technologies, consequently no reduction in contaminant mobility would be achieved. In fact, discontinuation of the existing hydraulic containment system would result in increased mobility of the migrating dissolved contaminant plume.

There would be no reduction in the toxicity or volume of the contaminants initially, however, over time it is predicted that toxicity and volume of contaminants would be reduced.

Implementability

Administrative: This alternative would not achieve New York State Water Quality Regulations, ECL Article 15, Title 3 and ECL Article 17, title 3 and 8, and 6 NYCRR Parts 700-706. In addition, federal guidelines such as the National Drinking Water Standards, Safe Drinking Water Act, and 40 CFR Parts 141 through 143 would also not be achieved. Given the volume of contaminants remaining at the Site, any reduction in risk associated with natural attenuation is expected to be minimal. Therefore, while the implementability of this alternative is high, the adequacy of this alternative in addressing the risk at the Site is low. This alternative would only be considered implementable if no other reasonable alternative is identified.

Technical: Periodic sampling and analysis of groundwater would be required to monitor the contaminants and evaluate the efficacy of the process. All technologies required for this alternative are proven, reliable, and readily commercially available.

Cost

Capital costs associated with this alternative are estimated at $127,000. Annual O&M and monitoring costs are estimated at $35,300 with an additional $35,300 every fifth year for reevaluation and reporting. The net present worth of this alternative is estimated at $723,000. A cost summary is included in Table 4-1 and backup for these costs are included in Appendix B.

Community Acceptance

EPA guidance documents and case histories indicate a very strong community resistance to MNA due primarily to the misperception of MNA as a "do-nothing" strategy. Additionally, this alternative would require institutional controls, the use of potable groundwater within the (expanding) plume of contamination up to the limits of compliance. Therefore, this alternative would most likely not achieve community acceptance without an intensive public education effort and substantial (very costly) scientific support. This could result in a considerable increase in the estimated cost of implementation of this alternative.

4.2.3 Alternative 3 - Hydraulic Containment using Current Pump and Treatment System with Sub-Slab Vapor extraction

4.2.3.1 Description

The remedial system that is currently in operation on the Site is part an interim remedial measure (IRM) that included:

- a hydraulic containment system (pumping system at AV-2 with an air stripper treatment system) that went into operation in 1991,
- granular activated carbon (GAC)-based point-of-entry (POE) treatment systems installed at impacted residential wells, and
- an additional air stripper treatment system for groundwater pumped from residential wells at lots 7 and 11 on Locust Crest Court to supplement the POE systems at these locations.

Certain remedial components that were installed as part of the IRM have since been discontinued. Over time, as groundwater chemistry reduced to below drinking water standards, all of GAC-based POE systems have been discontinued except the two at lots 7 and 11 Locust Crest Court. Also, in July 2001, the air stripper system at lots 7 and 11 was discontinued.

The major components of the existing system include hydraulic containment by groundwater pumping at AV-2 and treatment of removed groundwater with an air stripper system prior to discharge. The two POE systems being operated at lots 7 and 10 and Site groundwater monitoring wells are periodically monitored.

Alternative 3 assumes that the existing hydraulic containment and groundwater treatment systems would continue to be operated and maintained, and sub-slab vapor extraction systems would be installed in portions of the Site buildings near the source areas to improve indoor air quality. Figure 1-2 shows the location of the current pumping well (AV-2) and treatment system.

Hydraulic containment by pumping AV-2 would be used to reduce/prevent the migration of contamination from the source area(s) toward potential downgradient receptors. The effect of discontinuing pumping at the lots 7 and 11 air stripper on the hydraulic system is not known. Monitoring at the previously impacted downgradient residential wells would be need to continue to ensure that pumping at AV-2 alone sufficiently contains the Site groundwater contaminants. The POE systems would be discontinued if the residential wells were to achieve drinking water standards or reestablished if new impacts were detected.

Additional monitoring wells would be installed along the property boundary between the source areas and downgradient receptors to improve the current hydrogeologic model of the Site, to help predict the migration pathway of the contaminant plume, and monitor the effectiveness of the current hydraulic containment system. For estimating purposes, it is assumed that 4 additional wells would be installed (deep open hole wells). The number, locations, and depths of the additional wells would be determined during design.

Venting of the air beneath the floor slabs of the two on-site buildings would be implemented to reduce risks associated with current impacts to indoor air quality. No information is currently available on the construction of the floor slab but it is assumed that there is sufficient gravel under the slab to allow venting of sub-slab vapors. The sub-slab vapor extraction system would consist of a series of vents drilled through the floor-slab or from outside the building, manifolded to an electric blower and vented to the outside air. The blower would be used to create a vacuum, depressurizing the sub-slab materials (assuming they are sufficiently permeable) relative to the indoor air pressure to prevent migration of soil gasses into the buildings. Off-gas vents located outside the building would be used to discharge the air drawn out from beneath the slab.

For estimating purposes, it is assumed that one vent would be installed for each 1,200 square feet of floor area to be vented. Each vent would be fitted with an appropriately sized vacuum/blower unit capable of producing a sustained vacuum beneath the slab. It may also be necessary to reseal the floors and/or foundations to prevent leakage or loss of vacuum. It is assumed that a 100-watt high flow/low vacuum blower would be sufficient for each vent. An assumed area of approximately 80 x 80 ft^2 would be depressurized in each building requiring a total of five vent systems per building.

4.2.3.2 Assessment

Compliance with SCGs

This alternative would not result in the rapid reduction/elimination of the contaminants of concern relative to the groundwater. The chemical-specific SCGs are not likely to be achieved within a short time period (probably more than 30 years). The overall mass of contaminants in the aquifer would not be reduced significantly. Consequently, the alternative would fail to achieve the groundwater protection remedial action objectives. Based on current data, the existing system is capable of protecting most downgradient receptors from impacted groundwater. Analysis of the influent of the POE system in the residence located at lot 11 during the RI revealed PCE at 3 ppb (ug/L).

Implementing a sub-slab vapor extraction system as part of this alternative should achieve the chemical-specific SCGs relative to the indoor air quality. Based on the concentrations removed by the sub-slab system, the system may require additional air/vapor treatment prior to discharge.

Discharge of impacted soil gas requires compliance with action specific SCGs such as Air Pollution Control Regulations, ECL Article 19, title 3, and 6 NYCRR Parts 200, et al. These guidelines establish strict prohibition on the emission of air contaminants that jeopardize human, plant or animal life, is ruinous to property, or causes a level of discomfort. Emissions from an air contaminant source in excess of standards is prohibited except in accordance with a permit or registration certificate issued under Part 201.

- National Pollution Discharge Elimination System, 40 CFR 403
- National Pollution Discharge Elimination System General and Categorical Pre-treatment Standards, 40 CFR 403
- National Primary and Secondary Ambient Air Quality Standards, 40 CFR 50.
- Standard of Performance for New Stationary Sources, 40 CFR 60.
- National Emission Standards for Hazardous Air Pollutants, 40 CFR 61.
- Standards Applicable to Owners and Operators of Treatment, Storage, and Disposal Facilities, 40 CFR 264-267.

Location-specific SCGs are not applicable with this alternative.

Overall Protection of Human Health and the Environment

This alternative would provide some protection of human health and the environment. The current pump and treat system appears to be significantly reducing or preventing the groundwater plume from migrating off the AVSC Site and has resulted in a reduction in the concentrations of contaminants in downgradient water supply wells to below Ambient Water Quality Standards. In addition, the continued operation of POE treatment systems for downgradient receptors would treat any break through contamination. Due to the current lack of data necessary to evaluate all of the plume migration pathways it cannot be determined if all potential downgradient receptors are protected.

The sub-slab vapor extraction system would be expected to reduce the levels of contamination within the effected buildings on Site. This would achieve the RAO for indoor air quality and be protective of human health and the environment.

Short-Term Effectiveness

Community, worker and environmental protection: This alternative would require minor active removal and/or handling of contaminated groundwater in addition to that already being performed, particularly during well installations and development. Minor disturbance of the subsurface would occur during placement the sub-slab vapor extraction system, potentially exposing workers to soil gasscs.

Minor potential risks to the community and environment would result from the handling and transportation of monitoring well development water and additional site traffic. These additional hazards are considered minimal and would be controlled and/or mitigated by the Site-specific health and safety procedures during the construction operations and during routine O&M. These short-term risks are considered low compared to other alternatives that would require removal, handling,and/or in-situ treatment of groundwater or soil. Potential for impact to the community, workers or the environment would be minimal or negligible.

Long-Term Effectiveness and Permanence

Residual risk: The long-term risk of exposure for this alternative is considered low because the continued pumping and treating of groundwater would prevent most or all of the contamination from migrating off Site. The AVSC is currently receiving potable water from a public water supply and is not using the contaminated aquifer. The continued operation of downgradient POE systems would treat break through contamination in groundwater and prevent direct contact by receptors. The risk to potential future receptors due to migration of or direct contact with contaminated groundwater is mitigated effectively. A sub-slab vapor extraction system would reduce contamination levels in the soil and eliminating the risk to future receptors.

Adequacy of controls: Hydraulic containment and sub-slab vapor extraction, in all probability, would achieve its performance requirement of preventing direct contact to future potential receptors. Implementation of and compliance with land use restrictions and long-term maintenance obligations would aid in preserving treatment systems (permanence) and limiting exposure. Long-term monitoring and maintenance activities, including monthly inspection and repairs (as necessary) of the treatment systems and quarterly groundwater monitoring would be used to evaluate the system integrity and efficacy.

Reliability of controls: With proper construction and long-term maintenance, the groundwater treatment systems would provide a highly reliable isolation barrier to potential future receptors. It is anticipated that with proper maintenance, the containment system would provide protection to downgradient receptors indefinitely. It should be noted that the contaminant source area may continue to cause exceedances of groundwater standards beyond the 30 years duration used for estimating present worth costs.

Reduction of Toxicity, Mobility, and Volume Through Treatment

A reduction in contaminant mobility (primarily groundwater flow) would be achieved by continuing to pump and treat groundwater with the current system. However, due to the high concentrations of contamination in the groundwater in the source areas it is unlikely that this alternative would achieve a sufficient reduction in the toxicity or volume of the contaminants to achieve the remedial action objectives within a predictable time period (likely more than 30 years).

The sub-slab vapor extraction system would achieve a reduction in contaminant mobility (primarily soil gas) and reduce contaminant toxicity relative to impacts to the indoor air quality. The removal of volatile soil gasses may also result in a reduction in total contaminant mass beneath the slab by inducing volatilization.

Implementability

Administrative: Due to the high levels of groundwater contamination, this alternative would not quickly achieve New York State Water Quality Regulations (ECL Article 15, Title 3 and ECL Article 17, title 3 and 8, and 6 NYCRR Parts 700-706) or some of the remedial action objectives identified for the AVSC Site. In addition, federal guidelines such as the National Drinking Water Standards, Safe Drinking Water Act, and 40 CFR Parts 141 through 143 would not be achieved for several years or decades. Therefore, while the implementability of this alternative is high, the adequacy of this alternative in addressing the chemical-specific SCGs and the remedial objectives of the Site is low.

Technical: The technologies used for this alternative are proven, reliable, and readily available. They have been implemented at many other sites with variable success ranging from attainment of all SCGs and objectives to total failure. Based on the performance of the existing system, it is considered likely that these technologies would be effective and easily implementable.

Cost

The estimated present worth cost to implement Alternative 3 would be $1,377,000. This includes $282,000 in capital costs and the present worth of the costs of inspection, operations, maintenance, monitoring, and reporting at $71,000 per year for 30 years, although these activities could extend beyond that time frame under this alternative. A summary of the estimated costs for Alternative 3 is provided on Table 4-1 with backup provided in Appendix B.

Community Acceptance

This alternative is likely to achieve community acceptance. Although contaminant concentrations would not be reduced immediately, the plume would be effectively contained and therefore the potential for human health and environmental exposure would be significantly reduced. The levels of contamination migrating via soil gas into indoor air, would be reduced and rapidly protect human health.

4.2.4 Alternative 4 - Enhanced Hydraulic Containment with Sub-Slab Vapor Extraction

4.2.4.1 Description

Alternative 4 is essentially the same as Alternative 3 with the installation of additional discreet-interval pumping wells to improve overall system efficiency and increase the effective capture zone of the existing hydraulic containment system. For estimating purposes, it is assumed that 2 additional wells would be installed. The approximate locations of these two additional capture wells are depicted on Figure 4-1. The proposed locations for the two additional discreet-interval wells are outside and downgradient of the source area. Depending on the degree of fracturing encountered in the new wells, pneumatic or hydraulic fracturing may be necessary in the identified water bearing zones to improve the recovery of highly impacted groundwater. For the purposes of this FS analysis, pneumatic fracturing is assumed to be performed at each of the two new pumping wells.

Locating the new pumping wells in the source area was considered, but bedrock fracturing in areas that may contain DNAPL could potentially remobilize the DNAPL to areas where groundwater is not currently being captured. The groundwater pumping associated with this alternative would do little to remove the DNAPL. The more cautious and essentially as effective approach is to select locations outside the source area.

Under Alternative 4 additional borings would be installed west and south of the source areas and evaluated to identify significant water-bearing zones with high contaminant concentrations. Discreet-interval pumping wells would then be constructed in these zones.

Groundwater would be pumped from these wells and piped to the existing treatment facility. The treatment system could be modified if the capacity was not sufficient.

4.2.4.2 Assessment

Compliance with SCGs

This alternative would not result in the rapid reduction/elimination of the contaminants of concern but would be more effective than the current system. The chemical-specific SCGs are not likely to be achieved within a short time period (probably more than 30 years). The overall mass of contaminants in the aquifer would be somewhat reduced over time and may eventually achieve the objective of aquifer protection. The enhancement wells would improve the overall system effectiveness with respect to protecting downgradient receptors.

Compliance with SCGs, relative to the sub-slab vapor extraction system would be the same as that described for Alternative 3.

Location specific SCGs are not applicable with this alternative.

Overall Protection of Human Health and the Environment

This alternative would provide some protection of human health and the environment. The sub-slab vapor extraction system should significantly reduce or eliminate the accumulation of soil gasses within the impacted on-site buildings. Data indicate that the current pump and treat system is preventing most of the groundwater plume from migrating off the AVSC Site. The enhancement wells would improve the overall protection of these receptors and marginally (as compared to Alternative 5) accelerate the remediation of the aquifer by increasing the rate of contaminant removal from the aquifer.

Short-Term Effectiveness

Community, worker and environmental protection: This alternative would require some additional active removal and handling of contaminated groundwater during well installation and development and during the pumping and treatment period. Minor disturbance of the subsurface would occur during placement of the sub-slab vapor extraction system. Minor potential risks to the community and environment would result from the handling and transportation of well development water and additional site traffic. These additional hazards are considered minimal and would be controlled and/or mitigated by the Site-specific health and safety procedures during the construction operations and during routine O&M. These short-term risks are considered low compared to other alternatives that would require removal, handling, and/or in-situ treatment of groundwater or soil. Potential for impact to the community, workers or the environment would be minimal or negligible.

Long-Term Effectiveness and Permanence

Residual risk: Some reduction in the residual risk would be achieved due to the accelerated rate of aquifer remediation caused by pumping higher concentrations of contaminants from the impacted zones. Additionally, the improved containment/capture zones would be more protective of downgradient receptors.

Adequacy of controls: Site data indicate that the current system is effective at preventing most of the off-site migration of contaminants to identified downgradient receptors. Enhancement of the existing system would likely result in an improvement in the overall adequacy of these controls.

Reliability of controls: With proper construction and long-term maintenance, enhanced hydraulic containment would provide a reliable isolation barrier to potential future receptors. It is anticipated that with proper maintenance, the containment system would provide protection to downgradient receptors indefinitely. It should be noted that the contaminant source area may continue to cause exceedances of groundwater standards beyond the 30 years duration used for estimating present worth costs.

Reduction of Toxicity, Mobility, and Volume Through Treatment

A reduction in contaminant mobility (primarily groundwater flow) would be achieved by continuing to pump groundwater with the current treatment system. However, due to the high levels of contamination in the groundwater in some areas, this alternative would not achieve a significant reduction in the toxicity or volume of the contaminants within a predictable time period (likely more than 30 years). The sub-slab vapor extraction system would achieve a reduction in contaminant mobility (primarily soil gas) and reduce contaminant toxicity and mobility.

The sub-slab vapor extraction system would achieve a reduction in contaminant mobility (primarily soil gas) and reduce contaminant toxicity relative to impacts to the indoor air quality. The removal of volatile soil gasses may also result in a reduction in total contaminant mass beneath the slab by inducing volatilization.

Implementability

Administrative: Due to the high levels of groundwater contamination, this alternative would not immediately achieve New York State Water Quality Regulations (ECL Article 15, Title 3 and ECL Article 17, title 3 and 8, and 6 NYCRR Parts 700-706) or some of the remedial objectives identified for the AVSC Site. In addition, federal guidelines such as the National Drinking Water Standards, Safe Drinking Water Act, and 40 CFR Parts 141 through 143 would not be achieved for several years or decades. Therefore, while the implementability of this alternative is high, the adequacy of this alternative in addressing the chemical-specific SCGs and remedial objectives for this Site is low.

Technical: The technologies to be used in implementing this alternative are proven, reliable and readily available. They have been effectively implemented at this and other sites with success.

Cost

The estimated present worth cost to implement Alternative 4 is $1,532,000. This cost includes $371,000 in capital costs and the present worth of inspection, operations, maintenance, monitoring, and reporting at $75,000 per year for 30 years although these activities could extend beyond that time frame under this alternative. A summary of the estimated costs for Alternative 4 is provided on Table 4-1 with backup provided in Appendix B.

Community Acceptance

This alternative is likely to achieve community acceptance. Although contamination levels would not be immediately reduced, the contamination plume would be contained. Therefore, the potential risk to human health and the environment from exposure would be significantly reduced. Concentrations of soil gasses affecting the indoor air quality would be reduced resulting in immediate protection of human health and the environment from exposure to contaminated air.

4.2.5 Alternative 5: In-Situ Oxidation in Source Area(s) with Hydraulic Containment and Sub-Slab Vapor Extraction

4.2.5.1 Description

Alternative 5 is the same as Alternative 3 with the addition of direct chemical oxidation of contamination in the source area(s) by injection of chemical oxidants. Direct oxidation (in-situ treatment) by injection would be used in the identified source areas to reduce DNAPL, to the extent feasible and significantly reduce the dissolved concentrations of contaminants. Hydraulic fracturing would be used in the injection wells to enhance the permeability of the aquifer and improve the penetration of the chemical oxidants. Three additional groundwater monitoring wells would be installed below the identified zone of contamination to evaluate potential vertical migration of DNAPL that might be mobilized by the processes used for this alternative. The hydraulic containment system and sub-slab vapor extraction system described in Alternative 3 would also be included in this alternative.

Bedrock fracture enhancement: Bedrock fracture enhancement using pneumatic and/or hydraulic fracturing would be performed in each of the oxidizing agent injection wells to enhance the effective dispersion of the oxidant. It is assumed that a minimum of 15 fractured locations would enhance the bedrock fracture density over the approximately 240 ft by 80 ft source area. The injection points would be approximately 100 feet below grade (80 feet of bedrock). For estimating purposes, it is assumed that pneumatic fracturing would be used.

Based on recommended spacings described in USEPA technology evaluation reports, 15 fracturing points would be installed in 2 offset parallel rows of 8 points and 7 points each as depicted in Figure 4-2. A spacing of approximately 30-feet between the fracturing points would be used in each row with an approximate 40-foot spacing and 15 foot offset between the rows. The pneumatic/hydraulic fracturing process may generally be described as the injection of air/water (possibly containing sand or glass beads to hold fractures open) into the subsurface at a pressure that exceeds the confining strength of the rock, and at flow volumes exceeding the natural permeability of the formation. This causes failure of the rock and creates a fracture network radiating outward from the injection point. Fracture propagation radial distances have been observed to extend up to 60 ft in rock formations. The thick overburden at the Site helps to reduce surface energy losses and should promote higher fracture density. A pilot test would be necessary to determine the optimal location and spacing of the fractured injection wells. For calculation and estimating purposes an effective radius of 20 feet has been assumed.

Bedrock fracturing may mobilize DNAPLs currently trapped in the bedrock fractures and vertical migration pathways may be inadvertently opened. In order to evaluate the potential impact of fracture enhancement on vertical migration of contaminants, additional monitoring wells would be installed in three locations immediately outside the source areas as depicted in Figure 4-2. These wells would monitor depths of approximately 150 feet below grade, which is below the fracture-enhanced zone.

In-Situ Oxidation Treatment: In-situ direct chemical oxidation of DNAPL and dissolved constituents would be used to remove the organic COCs in the on-Site source area. Prior to the design phase of the project, bench-scale treatability testing would be conducted to determine optimum concentrations of reagents necessary for effective treatment. Prior to full-scale implementation, a pilot-scale treatability test (pilot test) would be conducted to determine effective radii of influence of injection wells, quantities of reagents, and verification of efficacy of treatment process. Therefore, the details of the in-situ oxidation treatment program described below are preliminary only and are subject to change, based on pilot testing results.

Based on the stoichiometric analysis included in USEPA technology evaluation reports, a quantity of sodium permanganate equal to five times the estimated mass of contaminants is recommended to effect the remediation of the contaminants of concern. For the purposes of determining the quantities of reagents and evaluating the cost of this alternative it was assumed that DNAPL is present in 1% of the total available fracture/pore space (total pore space is estimated at 1% of the total rock volume) in the source areas from a depth of 50 to 90 feet below grade. A total of 15 injection points with an effective radius of influence of 20 ft generally cover the estimated source area. Using the 20 foot radius, the 40 foot depth interval and the 1% pore space occupied by DNAPL, a DNAPL quantity of 36 gallons per injection point or a total of approximately 540 gallons was assumed to be present. 36 gallons of DNAPL is equivalent to 470 pounds of solvent (using a specific gravity of 1.62). The mass of reagent required to oxidize this mass is approximately 2,300 lbs (470 x 5) per injection point. Therefore, the total quantity of permanganate is estimated at 34,500 pounds (15 x 2,300).

For full-scale treatment, each of the 15 bedrock fracture points would be converted to injection points. Permanganate would be injected in 3 phases with approximately 1,150 lbs of reagent injected at each point during the initial injection, and 575 lbs of reagent injected at each point during each of the subsequent phases. Injection would be performed using pumps via small diameter injection wells. A conceptual design with the locations of reagent injection points is shown on Figure 4-2. Injection well locations would be determined during final design and would take into account Site features such as underground utilities. The quantities of reagent to be used per injection point for the initial injection would be determined based on the results of the bench-top treatability study and the results of pre-injection sampling. Subsequent injection quantities and locations would be determined based on the results of the post-injection 7-day and 30-day sampling events

A total treatment time of approximately four to six months, including the bench-top treatability study, pilot test, injection point installation, and reagent application (including the waiting period between injection events), is assumed. Treatment verification monitoring would include collection of groundwater samples from wells within and downgradient of the treatment areas; samples would be analyzed for VOCs. It is assumed that three samples would be collected and analyzed from each monitoring well; one pre-injection sample, and two post-injection samples collected 7 days and 30 days after the first application is complete. Results from the monitoring program would determine whether or not additional rounds of reagent application are required to meet the treatment objectives.

Continue Current System: The current hydraulic containment pumping and treatment system would continue to be operated and maintained to protect downgradient receptors until monitoring indicates that contaminant concentrations have been significantly reduced. It is anticipated that the system would need to be operated for a minimum of two years after completion of the injection program to remove residual impacts in the groundwater that had escaped the source area prior to treatment and establish conclusive proof of the effectiveness of the process. After that the system would be deactivated and ultimately decommissioned. For estimating purposes, five years of continued operations were assumed.

Long-Term Groundwater Monitoring: As in Alternative 3 and 4, property-boundary monitoring wells would be installed between the source area and downgradient receptors to monitor potential changes in the migration pathway of the contaminant plume migration as a result of bedrock fracture enhancement and to evaluate the extent of hydraulic containment. Monitoring would continue quarterly during the oxidation program and then annually until ambient water quality standards are achieved. The POE systems would be discontinued when drinking water standards were met or reconnected if new impacts are detected.

Limitation of Assumptions: The assumptions that could impact the overall effectiveness, implementability and cost of the in-situ oxidation portion of Alternative 5 are:

- DNAPL, if present, is located within the defined source area and is limited to approximately 550 gallons,
- installation of 15 pneumatically or hydraulically fractured injection points will hydraulically connect all fractures containing DNAPL,
- injected fluid will carry permanganate to all DNAPL globules in the bedrock, and
- the pump and treat well can be turned off after 5 years.

Site groundwater data and historic use of the Site indicate that DNAPL is present in the proposed source area. There is insufficient data to clearly define the nature of extent of residual DNAPL in these source areas. More investigation points would be needed to confirm the presence of DNAPL and the extent of it. Due to the nature of fractured bedrock, no system of investigation points could define all potential fracture pathways.

Case studies have shown that bedrock well fracturing is an effective means of increasing the hydraulic conductivity of bedrock. Other cases studies have shown that in-situ oxidation is effective in granular media. It is assumed that fracturing would create as system of flow paths that will allow groundwater to flow through a large system of small fractures rather than preferentially through a few primary (large) fractures. The fracture density and geometry of the hydraulically fractured system and where and how oxidation chemicals would flow is difficult to predict or define. Fluid (assumed to be water) containing permanganate would not behave the same as a DNAPL (i.e., would not sink with gravity) and therefore may not go to all fractures (i.e., dead-ends) containing DNAPLs.

In summary, if DNAPL were located outside the defined source area, the proposed configuration of injection points may not effectively deliver oxidation chemicals it. If the fractured media is not homogeneous enough to allow the oxidation fluids to reach all fractures containing DNAPL, than DNAPL could remain as a continuous source of contamination to groundwater. If a source of groundwater contamination remained, the current pump and treat system would need to be operated for longer than the estimated 5 years.

The following assessment assumes that the in-situ oxidation would effectively remove the source area DNAPL as a continuing source of groundwater contamination within two years.

4.2.5.2 Assessment

Compliance with SCGs

It is anticipated that this alternative would achieve the chemical-specific SCGs in a relatively short period of time (compared to Alternative 4). The rapid reduction/elimination of DNAPL the source area would effectively discontinue the dissolution and migration of dissolved components to downgradient receptors, significantly reduce or eliminate dissolved compounds in the area effected by the process, and significantly decrease the time required for plume attenuation factors to restore the aquifer to ambient water quality standards. Therefore it is anticipated that New York State Water Quality Regulations (ECL Article 15, Title 3 and ECL Article 17, title 3 and 8, and 6 NYCRR Parts 700-706) and the remedial objectives for the AVSC Site would be achieved. In addition, federal guidelines such as the National Drinking Water Standards, Safe Drinking Water Act, and 40 CFR Parts 141 through 143 would also be achieved.

Overall Protection of Human Health and the Environment

This alternative would provide substantial protection of human health and the environment. The use of in-situ oxidation chemicals (i.e., permanganate solution) provides treatment of groundwater and DNAPL specifically in the source area to significantly decrease contamination levels. The current pump and treat system would continue to contain the contamination plume and also treat groundwater as long as it remains necessary. Continued operation of the POE systems would protect downgradient receptors. A sub-slab vapor extraction system would immediately reduce the levels of contamination within the effected buildings protecting human health and the environment.

Short-Term Effectiveness

Community, worker and environmental protection: This alternative would not require direct contact or handling of contaminated groundwater other than that associated with continued operation of the the current pump and treat system. Bedrock drill cuttings and minor disturbance of the subsurface soil would occur resulting in direct contact. The levels of contamination in bedrock cuttings and soil are minimal therefore short-term risks are low. Site workers would wear appropriate personal protective equipment (PPE) to minimize exposure to contamination and as protection from physical hazards.

The primary risk to workers occurs during handling of the in-situ oxidation chemicals such as the permanganate solution. The permanganate solution is a strong oxidizer and is incompatible with certain combustibles. Precautions must be taken to avoid spills and to keep the materials away from potentially sparking equipment. Site workers would wear appropriate PPE to minimize exposure to contamination and as protection from physical hazards.

During oxidation treatments, there is a possibility that emissions of VOCs or elevated temperatures or pressures may be generated. These parameters would be monitored. There is the possibility that injected reagent may ooze out of the ground. The treatment operations would be adjusted as necessary to adequately control these effects.

Long-Term Effectiveness and Permanence

Residual risk: The long-term risk of exposure for this alternative is considered low because the continued pumping and treating of groundwater would prevent contamination from migrating off Site. The AVSC is currently receiving potable water from a public water supply and not utilizing the contaminated aquifer. The continued operation of downgradient POE systems would treat break through contamination in groundwater and prevent direct contact with receptors. The risk to potential future receptors due to migration of or direct contact with contaminated groundwater is mitigated effectively. A sub-slab vapor extraction system would reduce contamination levels in the indoor air therefore eliminating the risk to future receptors. The long-term effectiveness of this alternative would be assessed through routine groundwater and indoor air monitoring.

Adequacy of controls: Hydraulic containment and sub-slab vapor extraction, in all probability, would achieve its performance requirement of preventing direct contact to future potential receptors. Implementation of and compliance with land use restrictions and long-term maintenance obligations would aid in preserving treatment systems (permanence) and limiting exposure. Long-term maintenance activities, including monthly inspection of the treatment systems, and repairs as necessary, would ensure system integrity.

Reliability of controls: With proper construction and long-term maintenance, the groundwater and soil treatment systems would provide a highly reliable isolation barrier to potential future receptors. It is anticipated that with proper maintenance, the treatment systems should last indefinitely.

Reduction of Toxicity, Mobility, and Volume Through Treatment

A reduction in contaminant mobility (DNAPL movement and groundwater flow) would be achieved by this alternative. The current pumping system would contain groundwater and prevent contamination from migrating off Site. This alternative would also provide in-situ treatment of groundwater and DNAPL in bedrock specifically in the source area to significantly reduce levels of organic contamination. As a result, this alternative would achieve a reduction in the volume and toxicity of organic contaminants. However, due to an increase in oxidation potential of groundwater, the solubilities of inorganics or metals would change during these oxidation processes. Groundwater would become more acidic resulting in resuspension of metals in groundwater at higher concentrations and increased turbidity. This alternative cannot reduce the toxicity of the inorganics but would utilize controls to reduce the potential for human exposure thereby reducing risks.

The sub-slab vapor extraction system would immediately achieve a reduction in contaminant mobility (primarily soil gas) in addition to reducing contaminant volume and toxicity affecting indoor air quality.

Implementability

Administrative: Institutional controls, which sometimes are difficult to administer and enforce would be required to prevent exposure to contaminated groundwater. Minor administrative difficulties are anticipated for implementation of in-situ oxidation because addition of reagents such as potassium or sodium permanganate to the subsurface could require an USEPA Underground Injection Control (UIC) permit, and permits from the NYSDEC.

Technical: The in-situ oxidation technologies to be used during this alternative have been implemented at other sites with success. Hydraulic containment has been successfully demonstrated at this Site.

Cost

The estimated present worth cost to implement Alternative 5 is $1,643,000. This includes capital costs of $1,116,000 and the net present worth of annual groundwater monitoring for 20 years and operations and maintenance of the groundwater pumping system and sub-slab vapor extraction systems for five years. A summary of the estimated costs is included in Table 5-1. Back-up calculations for these estimates are included in Appendix B.

Community Acceptance

This alternative is likely to achieve community acceptance. Levels of contamination in groundwater and soil would be immediately reduced and the contamination would be contained protecting downgradient receptors. Therefore the potential for human health and environmental exposure would be significantly decreased.

4.3 Comparison of Alternatives

This analysis provides a comparative assessment of the remedial alternatives to evaluate their relative performance for each of the seven specific evaluation criteria. The results of the individual analyses (Section 4.2) are used in this evaluation to determine which alternative best satisfies the evaluation criteria. The purpose is to identify the advantages and disadvantages of each alternative relative to one another so that the key tradeoffs that must be balanced can be identified.

The comparative analysis focuses mainly on those aspects of the alternatives that are unique for each. This summary can be used to quickly compare the alternatives and facilitate selection of an appropriate remedy for the AVSC Site.

4.3.1 Compliance with SCGs

All of the alternatives would ultimately achieve the SCGs with respect to the reduction of contaminants to New York State Ambient Water Quality Standards. Alternatives 1 and 2: MNA, would result in the degradation/attenuation of the contaminants and the dissolved plume but only after decades of negatively impacting downgradient receptors. The current system and enhancements to the current system, as proposed in Alternatives 3 and 4, would result in an almost immediate achievement of the applicable SCGs relative to indoor air quality, but neither alternative would result in a reduction of contaminant concentrations to below ambient water quality standards within the projected lifetime of the alternative.

Only Alternative 5 has a potential of achieving all of the SCGs within a reasonable period of time (less than 30 years).

4.3.2 Overall Protection of Human Health and the Environment

Alternative 1: No Action, and Alternative 2: MNA, are the least protective of human health and the environment. They do not prevent exposure to contaminated media or reduce potential risks to human heath and the environment. Alternatives 3 and 4 are more protective in that they would rapidly and significantly reduce indoor-air concentrations of contaminants and provide protection to downgradient receptors during their lifetime. Alternative 5 is the most protective of human health and the environment in that it offers all of the benefits of Alternative 3 and 4 with the addition of the rapid reduction/elimination of sequestered source area NAPL and/or dissolved phase compounds. Eliminating some or all of the source significantly reduces the potential of exposure from both volatilized gasses and from ingestion or usage of impacted groundwater.

4.3.3 Short-Term Effectiveness

No short-term impacts to human health or the environment would result from Alternative 1 since no construction, treatment, removal or transport of impacted media would take place and only minor impacts would be associated with Alternative 2 from exposure during monitoring. Potential short-term impacts progressively increase for Alternatives 3, 4, and 5. The installation phase of each alternative generates potential risks to workers and the community from the construction activities and exposure to impacted groundwater from accidental releases during removal and transportation. Some, but not all of this potential risk can be reduced or eliminated by Site health and safety and operational procedures.

The highest potential short-term risk is associated with Alternative 5 due to the handling, usage, and injection of direct oxidation chemicals. In addition to direct exposure to these chemicals (during transport, temporary storage, and/or usage) there is the potential for exposure to volatilized off-gasses and dissolved compounds generated by their usage.

4.3.4 Long-Term Effectiveness and Permanence

Alternative 1 and Alternative 2 would have residual long-term risks because exposure to impacted media would not be reduced. Impacts to affected media would continue with the potential for degradation of additional downgradient receptors. Neither alternative is considered reliable or adequate.

In order of increasing effectiveness and permanence Alternatives 3, 4, and 5 offer long-term protection. With proper maintenance, the sub-slab vapor extraction systems would protect indoor air-quality indefinitely. The potential migration of contaminants to sensitive downgradient receptors would be controlled/prevented by hydraulic containment, which is a reliable technology when properly maintained. Alternatives 3 or 4 would require operation and maintenance for an indefinite period (likely well beyond 30 years).

Alternative 5 is reliable, adequate, and offers the maximum potential reduction in residual risks in that the in-situ destruction of DNAPL and dissolved compounds would significantly reduce or eliminate the continued release of dissolved compounds into the groundwater and remove the potential for impacts for downgradient receptors. Alternative 5 is considered to be the most effective and permanent of the remedial action alternatives.

4.3.5 Reduction of Toxicity, Mobility and Volume Through Treatment

Alternatives 1 and 2 offer no reduction in toxicity, mobility, or volume of the contaminants except through natural processes. Under both of these alternatives, the discontinuance of the existing hydraulic containment system would allow for the expanded downgradient migration of the contaminant plume and increasing potential impacts to downgradient receptors.

Under Alternatives 3 and 4 there would be some reduction in mobility of contaminants with respect to groundwater. The removal and treatment of impacted groundwater hydraulic contains Site contaminants but since these contaminants are transferred to air in the air stripper, toxicity (other than through dilution) and volume are not reduced. Over time, the removal of dissolved contaminants would reduce the total mass of contaminants in the subsurface and restrict mobility with respect to plume migration. The enhancements of the containment system in Alternative 4 are an improvement over the current system and are designed to increase the current system's ability to reduce toxicity, mobility, and volume of the contaminants. In this respect, Alternative 4 is considered superior to Alternative 3.

Alternative 5 is preferable to Alternative 3 or 4 with respect to the reduction of toxicity and volume and equal to Alternative 4 with respect to the reduction of mobility. The significant reduction or elimination of source area DNAPL and high concentrations of dissolved components by direct oxidation would result in comparatively rapid reduction of toxicity and volume.

4.3.6 Implementability

Alternative 1 is readily implementable technically since no construction or Site activities are part of this alternative, however this alternative could not be implemented administratively since it would not be acceptable to the overseeing regulatory agencies. The remaining alternatives could be implemented using readily available materials, equipment, and construction practices. Alternative 5 may be associated with a minimal disruption of AVSC businesses associated with installation of injection wells.

4.3.7 Cost

A summary of the estimated cost to implement each of the remedial action alternatives is included as Table 4-1. Supplemental cost information; backup tables, calculations, and assumptions, are included in Appendix B. The cost of implementation of the remedial action alternatives (excluding the no action alternative) ranges from approximately $723,000 to $1,643,000 dollars.

As detailed in the backup material, many of the estimated costs are based on assumptions that may or may not be valid due to undetermined site-specific conditions and/or are based on limited data. For each alternative, it was assumed that the alternative would operate for a period of 30 years or less with a discount rate of 5%. It is likely that Alternatives 1 through 4 would in-fact be required for considerably longer than the 30 years used for determining present-worth values and consequently the true cost of implementation of these alternatives could be significantly higher. Additionally, these costs do not include the potential costs of any liabilities associated with potential risks to human health or the environment, which under some of the alternatives could be considerable.

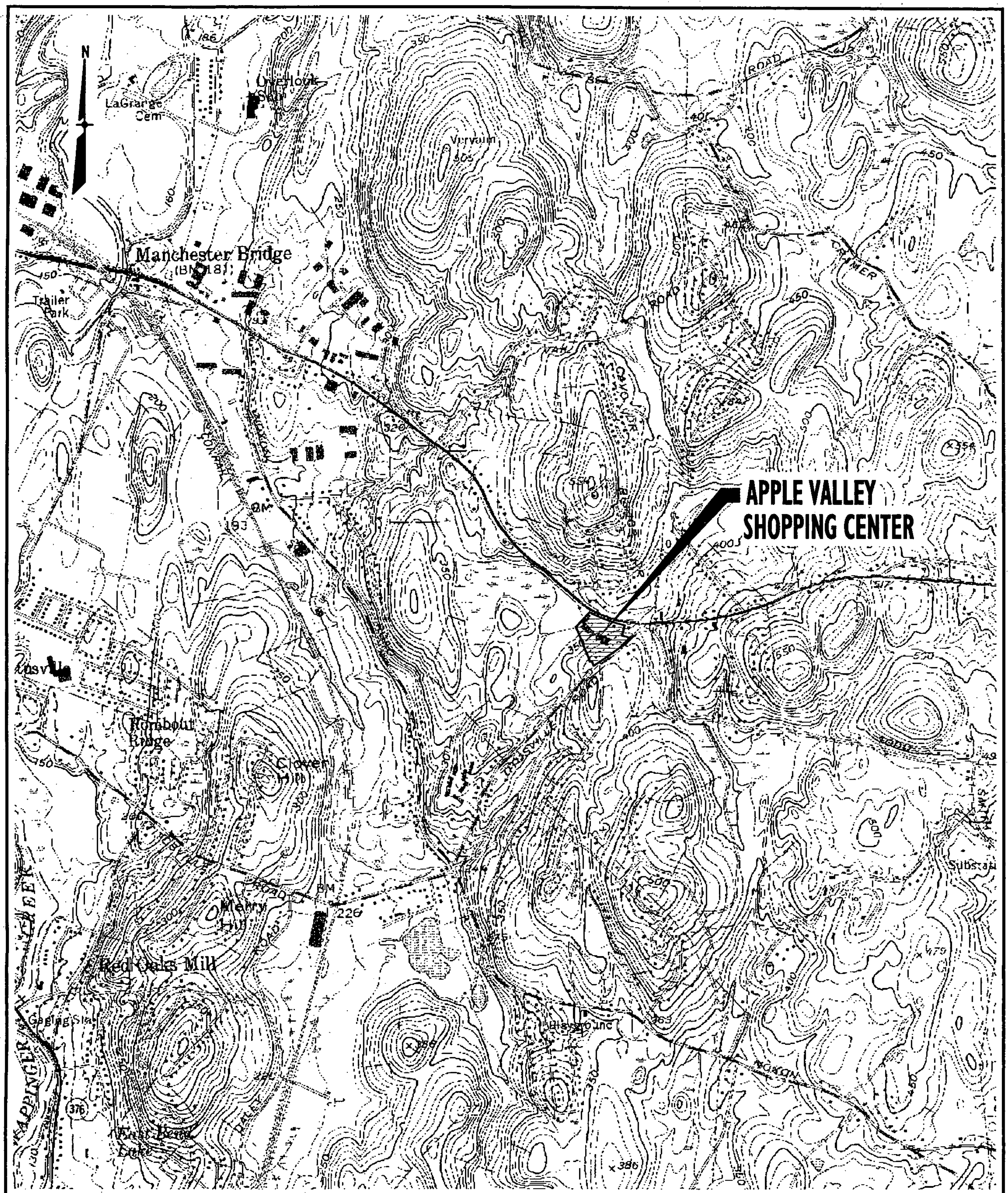
4.3.8 Community Acceptance

Alternatives 1 and 2 are unlikely to achieve community acceptance. No action or the perception of no action (MNA) would not safeguard the residences or environmental resources downgradient from the Site nor be protective of on-Site workers. Consequently, these alternatives would likely be deemed unacceptable.

Alternatives 4 and 5 are likely to achieve acceptance with Alternative 4 being more likely to be readily accepted. Both Alternatives involve considerable construction activities during initial implementation with potential disruptions to the normalcy of local activities and daily living. Of these two alternatives, Alternative 5 is likely to be the most resisted. The use of direct oxidants may require considerable efforts to educate the public concerning the relative safety of their use and the direct injection program requires a somewhat extended period of on-Site activities and potential disruptions of AVSC business for up to six months.

The continued operation of the existing system with the inclusion of the sub-slab vapor extraction system (Alternative 3) is likely to be the most readily accepted remedy. The alternative would require minimal disruptive Site construction activities and the system appears to be functioning as intended. The somewhat lengthy duration (in excess of 30 years) required for this alternative may cause some concern in the residential community.

FIGURES



EARTH TECH
A tyco INTERNATIONAL LTD. COMPANY

0' 1000' 2000'
SCALE

DATE: JANUARY 2000 PROJECT NO: 37014

APPLE VALLEY SHOPPING CENTER

NYSDEC SITE NO: 3 - 14 - 084

Town of LaGrange
Dutchess County, New York

FIGURE 1

Site Location Plan

PLOT DATE: 02/01/2000 FILE NAME: FIG_01.DWG IMAGE: FIG-01.TIF

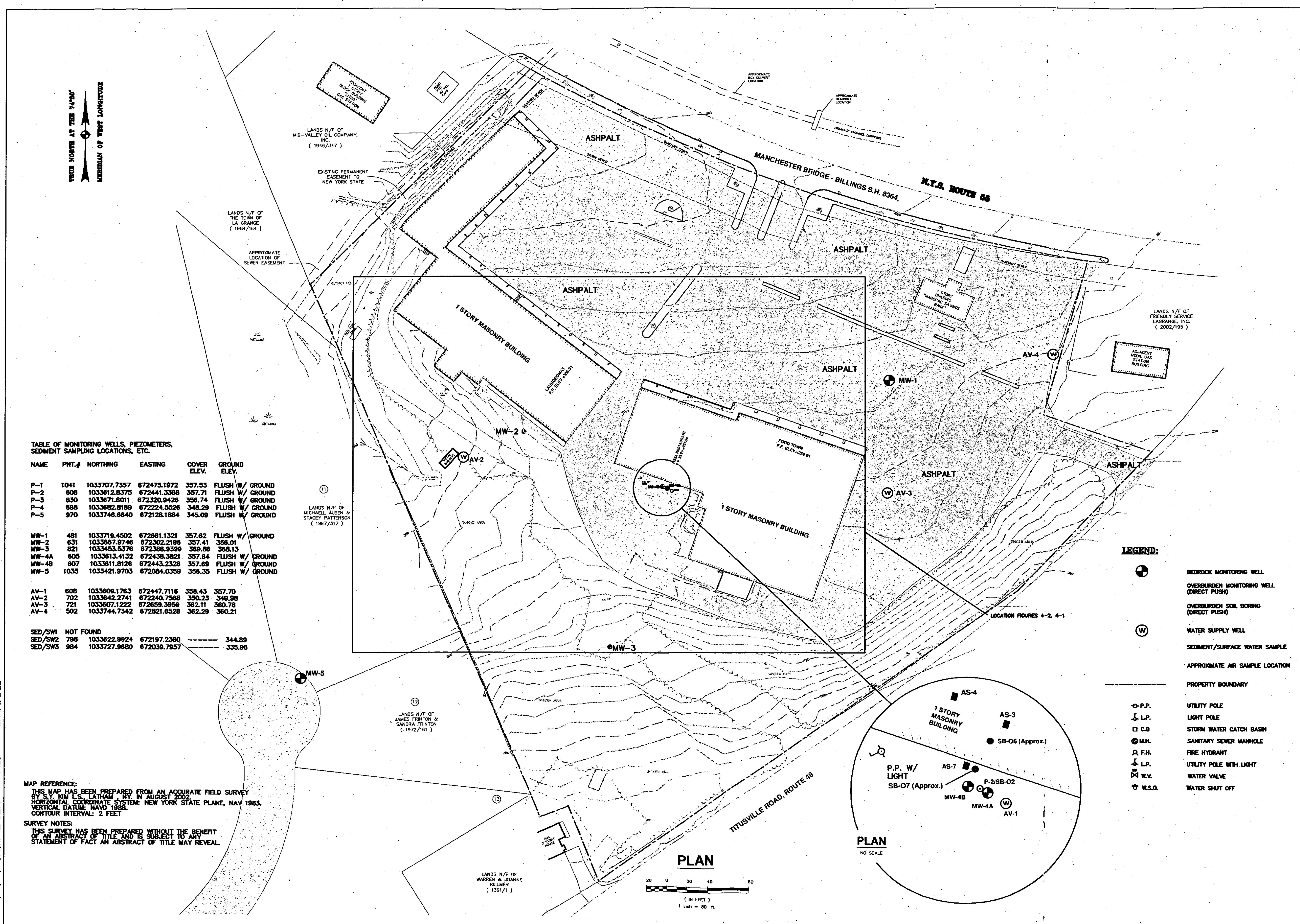


TABLE OF MONITORING WELLS, PIEZOMETERS, SEDIMENT SAMPLING LOCATIONS, ETC.

NAME	PNT.#	NORTHING	EASTING	COVER ELEV.	GROUND ELEV.
P-1	1041	1033707.7357	672475.1972	357.53	FLUSH W/ GROUND
P-2	606	1033612.8375	672441.3368	357.71	FLUSH W/ GROUND
P-3	630	1033671.6011	672320.9426	356.74	FLUSH W/ GROUND
P-4	698	1033682.8189	672224.5526	348.29	FLUSH W/ GROUND
P-5	970	1033746.6640	672128.1884	345.09	FLUSH W/ GROUND
MW-1	481	1033719.4502	672661.1321	357.62	FLUSH W/ GROUND
MW-2	631	1033667.9746	672302.2196	357.41	356.01
MW-3	821	1033453.5376	672386.9399	369.86	368.13
MW-4A	605	1033613.4132	672438.3821	357.64	FLUSH W/ GROUND
MW-4B	607	1033611.8126	672443.2328	357.69	FLUSH W/ GROUND
MW-5	1035	1033421.9703	672084.0359	356.35	FLUSH W/ GROUND
AV-1	608	1033609.1763	672447.7116	358.43	357.70
AV-2	702	1033642.2741	672240.7568	350.23	349.98
AV-3	721	1033607.1222	672659.3959	362.11	360.78
AV-4	502	1033744.7342	672821.6528	362.29	360.21
SED/SW1	NOT FOUND				
SED/SW2	798	1033622.9924	672197.2360	-------	344.89
SED/SW3	984	1033727.9680	672039.7957	-------	335.96

MAP REFERENCE:
THIS MAP HAS BEEN PREPARED FROM AN ACCURATE FIELD SURVEY BY S.Y. KIM L.S. LATHAM , NY. IN AUGUST 2002.
HORIZONTAL COORDINATE SYSTEM: NEW YORK STATE PLANE, NAV 1983.
VERTICAL DATUM: NAVD 1988.
CONTOUR INTERVAL: 2 FEET

SURVEY NOTES:
THIS SURVEY HAS BEEN PREPARED WITHOUT THE BENEFIT OF AN ABSTRACT OF TITLE AND IS SUBJECT TO ANY STATEMENT OF FACT AN ABSTRACT OF TITLE MAY REVEAL.

LEGEND:
- BEDROCK MONITORING WELL
- OVERBURDEN MONITORING WELL (DIRECT PUSH)
- OVERBURDEN SOIL BORING (DIRECT PUSH)
- WATER SUPPLY WELL
- SEDIMENT/SURFACE WATER SAMPLE
- APPROXIMATE AIR SAMPLE LOCATION
- PROPERTY BOUNDARY
- P.P. UTILITY POLE
- L.P. LIGHT POLE
- C.B. STORM WATER CATCH BASIN
- M.H. SANITARY SEWER MANHOLE
- F.H. FIRE HYDRANT
- L.P. UTILITY POLE WITH LIGHT
- W.V. WATER VALVE
- W.S.O. WATER SHUT OFF

EARTH TECH
A tyco INTERNATIONAL LTD. COMPANY
40 BRITISH AMERICAN BLVD. LATHAM, NEW YORK

DRN	KAM	9/2002
DES	MK	9/2002
CHK	FW	9/2002
APP	–	–

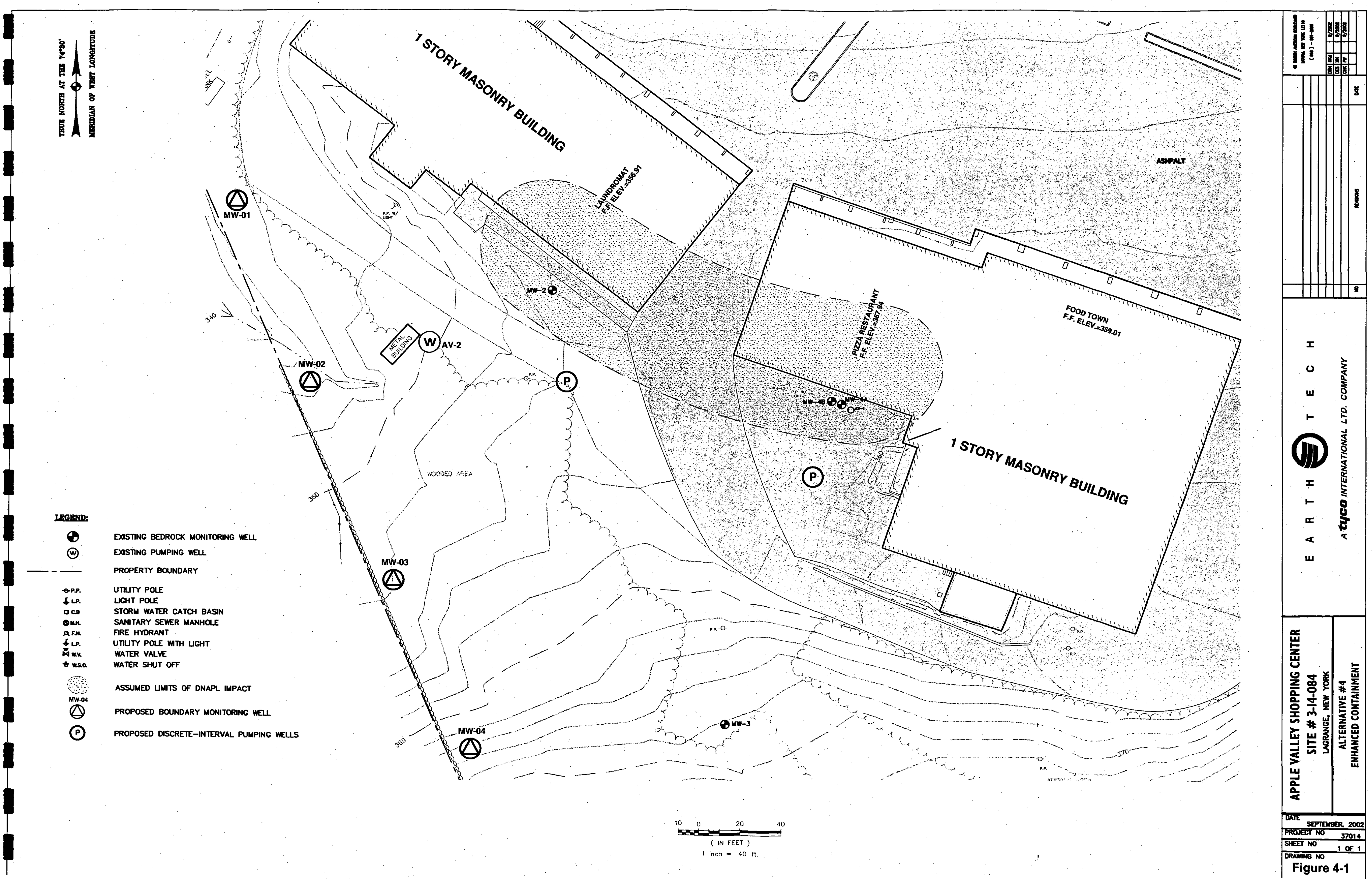
Copyright © Earth Tech A tyco INTERNATIONAL LTD. COMPANY

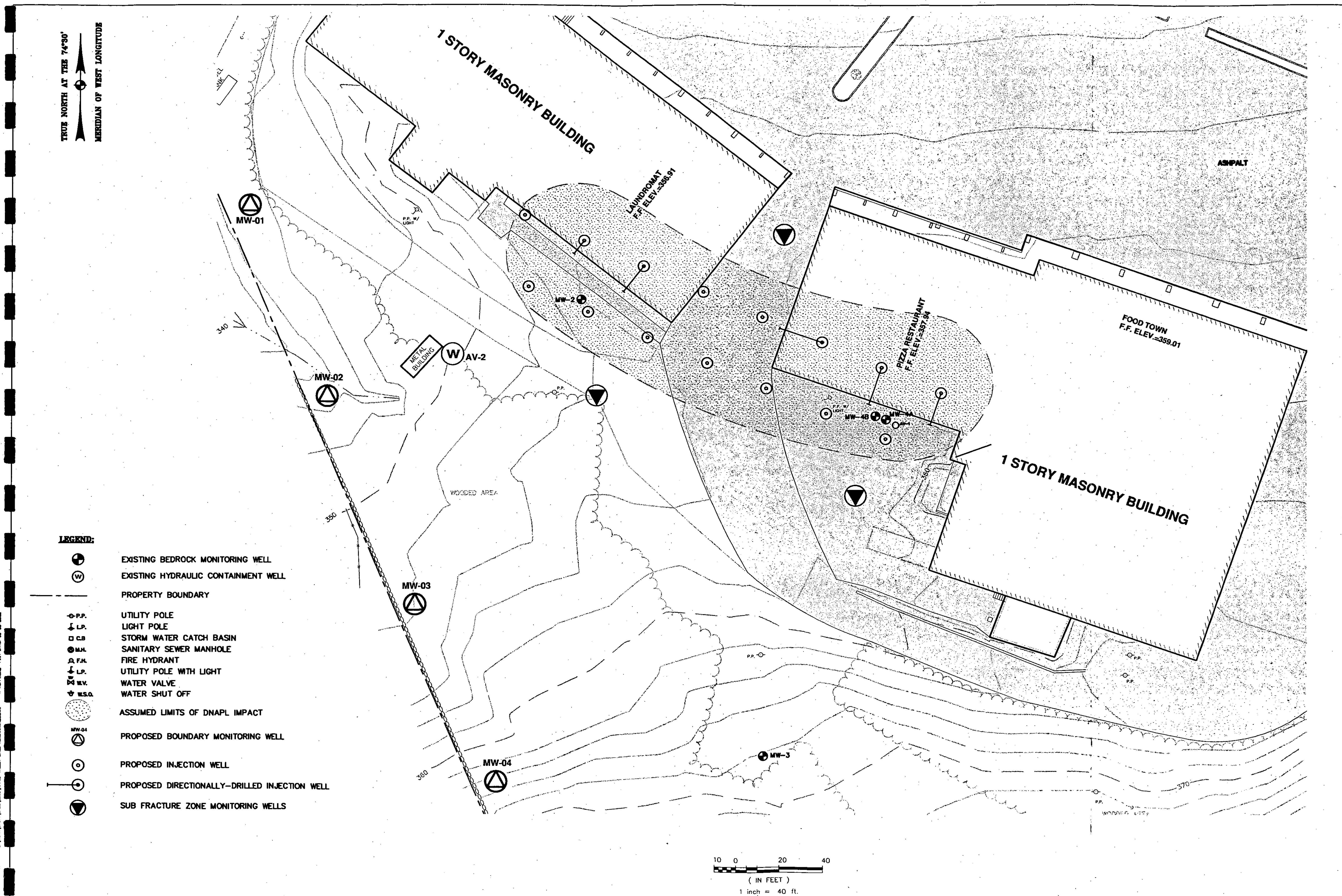
NO | REVISIONS | DRN | CHK | DATE

APPLE VALLEY SHOPPING CENTER
SITE # 3-14-084
LAGRANGE, NEW YORK

SITE LAYOUT

DATE	SEPTEMBER, 2002
PROJECT NO	37014
FILENAME	37014
SHEET NO	1 of 1
DRAWING NO	Figure 1-2


TRUE NORTH AT THE 74°30' MERIDIAN OF WEST LONGITUDE
1 STORY MASONRY BUILDING
LAUNDROMAT
F.F. ELEV.=356.91
ASHPALT
PIZZA RESTAURANT
F.F. ELEV.=357.94
FOOD TOWN
F.F. ELEV.=359.01
1 STORY MASONRY BUILDING
MW-01
MW-02
MW-03
MW-04
MW-2
MW-3
MW-4B
MW-4A
AV-2
METAL BUILDING
WOODED AREA
P.P. W/ LIGHT
P.P.
340
350
360
370
LEGEND:
EXISTING BEDROCK MONITORING WELL
EXISTING PUMPING WELL
PROPERTY BOUNDARY
P.P. UTILITY POLE
L.P. LIGHT POLE
C.B STORM WATER CATCH BASIN
M.H. SANITARY SEWER MANHOLE
F.H. FIRE HYDRANT
L.P. UTILITY POLE WITH LIGHT
W.V. WATER VALVE
W.S.O. WATER SHUT OFF
ASSUMED LIMITS OF DNAPL IMPACT
MW-04
PROPOSED BOUNDARY MONITORING WELL
PROPOSED DISCRETE-INTERVAL PUMPING WELLS
10 0 20 40
(IN FEET)
1 inch = 40 ft.
EARTH TECH
A tyco INTERNATIONAL LTD. COMPANY
APPLE VALLEY SHOPPING CENTER
SITE # 3-14-084
LAGRANGE, NEW YORK
ALTERNATIVE #4
ENHANCED CONTAINMENT
DATE SEPTEMBER, 2002
PROJECT NO 37014
SHEET NO 1 OF 1
DRAWING NO
Figure 4-1



APPLE VALLEY SHOPPING CENTER
SITE # 3-14-084
LAGRANGE, NEW YORK

ALTERNATIVE #5
IN-SITU OXIDATION INJECTION WELL LAYOUT

DATE	SEPTEMBER, 2002
PROJECT NO	37014
SHEET NO	1 OF 1
DRAWING NO	Figure 4-2

TABLES

Table 1-1
Location-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
STATE:		
- Use and Protection of Waters - ECL Article 15, Title 5 and ECL Article 17, Title 3 - 6 NYCRR Part 608	Establishes permit requirements to change, modify, or disturb any protected stream, its bed or banks, or remove from its bed or banks sand or gravel or any other material; or to excavate from or place fill in any of the navigable waters of the state or in any marsh, estuary or wetland that are adjacent to and contiguous at any point to any of the navigable waters of the state and that are inundated at mean high water level or tide. Also establishes requirement that any application for a federal license or permit to conduct any activity which may result in a discharge into navigable water must obtain a State Water Quality Certification under Section 401 of the Federal Water Pollution Control Act, 33 USC § 1341.	Not applicable. The AVSC site is not located on or near a protected stream or a navigable water body.
- Endangered and Threatened Species of Fish and Wildlife; Species of Special Concern - ECL Article 11, Title 5 - 6 NYCRR Part 182	Establishes prohibition for the taking or possession of any NYS endangered or threatened species, except in accordance with permit issued under this Part. "Taking" may include destruction or degrading of critical habitat of any such species.	Potentially applicable. Since no Fish and Wildlife Impact Assessment was considered necessary at the site, the presence of endangered or threatened species is unknown. A wetlands area is present near the site. If a remedy includes disruption of the wetland in association with construction of a treatment system or temporary storage pad, a this regulation would apply if endangered or threatened species were identified during pre-design studies.
- Freshwater Wetlands - ECL Article 24, Title 7 - 6 NYCRR Parts 662-665	Establishes prohibition on alteration or disturbance of freshwater wetlands and adjacent areas except in accordance with permit issued under this Part. Establishes procedural requirements and standards for issuance of freshwater wetlands permit.	Potentially applicable, if remedial activities include construction in nearby wetland areas.
- Siting of Industrial Hazardous Waste Facilities - ECL Article 27, Title 11 - 6 NYCRR Part 361	Establishes siting criteria for new industrial hazardous waste treatment, storage and disposal facilities.	Potentially applicable, if remedial activities were to include construction of a new industrial hazardous waste treatment, storage and/or disposal facility.
- Standards for Hazardous Waste Treatment, Storage and Disposal Facilities - ECL Article 27, Title 9 - 6 NYCRR Subpart 373-2	Establishes additional siting standards and minimum site characteristics for new hazardous waste treatment, storage and disposal facilities. Establishes construction requirements for new hazardous waste facilities located in a 100-year floodplain.	Potentially applicable, if remedial activities were to include construction of a new hazardous waste treatment, storage and/or disposal facility.

Table 1-1
Location-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
FEDERAL:		
- Endangered Species Act - 16 U.S.C §§ 1531-1544 - 40 CFR Part 17, Subpart I - 40 CFR Part 402	Establishes requirement that federal agencies must confirm that any action authorized, funded or carried out by them is not likely to jeopardize the continued existence of any endangered or threatened species, or result in the destruction or adverse modification of a critical habitat of such species, unless the agency has been granted an appropriate exemption by the Endangered Species Committee.	Potentially applicable. Since no Fish and Wildlife Impact Assessment was considered necessary at the site, the presence of endangered or threatened species is unknown. A wetlands area is present near the site. If a remedy includes disruption of the wetland in association with construction of a treatment system or temporary storage pad, a this regulation would apply if endangered or threatened species were identified during pre-design studies.
- National Historic Preservation Act - 16 U.S.C § 470 et seq. - 36 CFR Part 800	Establishes requirements that proposed site activities must take into account potential effects on properties (i.e., historic and archaeological resources) listed or eligible for listing in the National Registry of Historic Places. Any Federal agency undertaking a project which may have a potential effect on any such property must provide the Advisory Council on Historic Preservation a reasonable opportunity to comment on the proposed project.	Potentially applicable. A Stage 1A cultural resource survey may be necessary to determine the existence of any sites listed or eligible for listing on the National Registry that potentially could be impacted by the remedial activities.
- Statement of Procedures on Floodplain Management and Wetlands Protection - Executive Order 11988 (Floodplain Management) and Executive Order 11990 (Protection of Wetlands) - 40 CFR Part 6, Appendix A	Establishes EPA policy and guidance for implementing Executive Orders 11988 and 11990.Executive Order 11988 required federal agencies to evaluate potential effects of actions they may take in a floodplain to avoid, to the extent possible, adverse effects associated with development within a floodplain. The agencies must avoid adverse impacts or minimize them if no practical alternative exists. Executive Order 11990 requires federal agencies conducting certain activities, to avoid, to the extent possible, the adverse impacts associated with destruction or loss of wetlands if practicable alternatives exist. The agencies must avoid adverse impacts or minimize them if no practicable alternative exists.	Potentially applicable. Remedial activities at the AVSC site are not planned to occur in a floodplain or federal-jurisdiction wetland but there is a wetland in close proximity and immediately downgradient that could be impacted by remedial activities. The potential effects of the selected alternative on these wetlands would need to be evaluated during the engineering design phase of remediation and appropriate controls emplaced to avoid or mitigate these impacts.
- Farmland Protection Policy Act of 1981 - 7 U.S.C. § 4201 - 7 CFR Part 658	Regulates the extent to which federal programs contribute to the unnecessary and irreversible conversion of farmland to non-agricultural uses.	Not applicable. Remedial activities are not planned to encompass irreversible conversion of farmland to non-agricultural uses.

Table 1-2
Chemical-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
STATE:		
- Division of Water Technical and Operational Guidance Series (TOGS 1.1.1)Water Quality Regulations - ECL Article 15, Title 3 and ECL Article 17, Titles 3 and 8 - 6 NYCRR Parts 700 – 706	Establishes water body classifications and ambient water quality standards for surface waters and groundwaters of NYS. Provides ambient water quality standards for approximately 200 listed contaminants.	Applicable. Ambient groundwater standards are applicable for the Apple Valley Shopping Center (AVSC) site.
- Technical and Administrative Guidance Memorandum (TAGM) #4046	Established recommended soil cleanup objectives to restore soils at inactive hazardous waste sites to predisposal conditions, to the extent feasible and authorized by law.	Not applicable. Soil is not a media that is being considered for remediation at the AVSC site.
- Tetrachloroethene (PERC) in Indoor and Outdoor Air (October 1997).	Establishes the NYS Department of Health (NYSDOH) guideline of 100 micrograms per cubic meter for indoor air.	Applicable. PERC has been detected in air samples collected in AVSC site buildings. Indoor air quality guideline would apply in evaluating detected levels and establishing cleanup goals.
FEDERAL:		
- Toxic Pollutant Effluent Standards - Clean Water Act [Federal Water Pollution Control Act, as amended], 33 U.S.C §§ 1251-1387 - 40 CFR Part 129	Establishes toxic pollutants and toxic pollutant effluent standards for water discharges to navigable waters	Not Applicable. There are no identified navigable waters directly associated with the AVSC site.
- National Drinking Water Standards - Safe Drinking Water Act, 42 U.S.C. §§ 300f – 300j-26 - 40 CFR Parts 141 through 143	Establishes primary and secondary standards for public water supply systems.	Applicable. Groundwater in the immediate vicinity of the AVSC site and downgradient is utilized as a potable source of water.

Table 1-3
Action-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
STATE:		
- Hazardous Waste Management Regulations - ECL Article 27, Title 3, 7 , 9 and 13 - ECL Article 3, Title 3 - 6 NYCRR Parts 370 through 376	Establishes definition of hazardous wastes. Establishes standards and requirements for generators and transporters of hazardous waste. Establishes standards, permit requirements and construction and operating requirements for hazardous waste storage, treatment and disposal facilities. Establishes standards for the development and implementation of remedial programs for inactive hazardous waste disposal sites.	Applicable. Generator and transporter standards would apply to the remedial activities. In the event that a new hazardous waste storage, treatment and/or disposal facility is encompassed by the remedial activities, the appropriate construction, permitting and operating standards of Parts 370 through 376 would apply.
- Standards for Waste Transportation - ECL Article 27, Title 3 - 6 NYCRR Part 364	Establishes standards for collection, transport and delivery of regulated wastes, including NYS-defined solid hazardous wastes.	Applicable. Remedial activities could include collection, transport and delivery of NYS-defined hazardous wastes and may include collection, transport and delivery of non-hazardous solid wastes.
- Solid Waste Management Facilities - ECL Article 27, Title 7 - 6 NYCRR Part 360	Establishes standards and requirements for construction, permitting and operation of solid waste management facilities.	Potentially applicable, in the event that construction of a new solid waste management facility is encompassed for disposal of solid (i.e., non-hazardous) wastes generated by the remedial activities.
- Air Pollution Control Regulations - ECL Article 19, Title 3 - 6 NYCRR Parts 200, et al	Establishes strict prohibition on emission of air contaminants that jeopardize human, plant or animal life, or is ruinous to property, or causes a level of discomfort. Establishes prohibition for emission of an air contaminant source except in accordance with a permit or registration certificate issued under Part 201.	Applicable in the event that remedial activities encompass a regulated air emission source. In this event the remedial activities (as they pertain to an air emission source) must be designed and conducted consistent with the Part 201 requirements and typical NYSDEC permit conditions.
- New York State Pollutant Discharge Elimination System (SPDES) Requirements - ECL Article 17, Title 5 - 6 NYCRR Parts 750 through 758	Establishes prohibitions and standards for discharge of pollutants to storm water runoff, surface waters and ground waters. Establishes prohibition of discharge of pollutants to waters of the State except in accordance with a permit issued under Part 752	Applicable. SPDES standards and requirements typical NYSDEC Part 752 permit conditions may be used, in part, to design process water treatment system and to authorize discharge of process water treatment system effluent.
- Fish and Wildlife Law – Water Pollution Prohibition - ECL Article 11, Title 5 - Citation N/A	Establishes that no deleterious or poisonous substances shall be thrown or allowed to run into any public or private waters in quantities injurious to fish life, protected wildlife or waterfowl inhabiting those waters, or injurious to the propagation of fish, protected wildlife or waterfowl therein.	Applicable. General "performance" standard that would apply to the overall remedial activities

Table 1-3
Action-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
STATE:		
- Contravention of Water Quality Standards - ECL Article 17, Title 5 - Citation N/A	Establishes as an unlawful act for any person, directly or indirectly, to throw, drain, run or otherwise discharge into waters of the State organic or inorganic matter that shall cause or contribute to a condition in contravention of the applicable ambient water quality standards established at 6 NYCRR § 701.1.	Applicable. General "performance" standard that would apply to the overall remedial activities.
FEDERAL:		
- Hazardous Materials Transportation - 49 U.S.C. §§ 5101-5127 - 49 CFR Part 171	Establishes Federal Department of Transportation standards for transport of hazardous materials, including standards for packaging, labeling, manifesting and transporting hazardous materials.	Applicable. Hazardous materials includes hazardous wastes. Remedial activities encompassing transport of hazardous waste must comply with the Part 171 standards.
- National Contingency Plan. - 40 CFR 300	The purpose of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) is to provide the organizational structure and procedures for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants.	Applicable. Contaminants at the site are required to be managed under the National Contingency Plan.
- OSHA Worker Protection. - 29 CFR 1904, 1910, 1926	1904 Recording and Reporting Occupational Injuries and Illnesses 1910 General Industry Selected Topics 1926 Construction Industry Standards	Applicable for any remedial activities that included on-site construction.
- National Pollution Discharge Elimination System (NPDES). - 40 CFR 122, 125	Subpart 122 - The NPDES program requires permits for the discharge of pollutants from any point source into waters of the United States. Subpart 125 establishes criteria and standards for the imposition of technology-based treatment requirements in permits under section 301(b) of the Act, including the application of EPA promulgated effluent limitations and case-by-case determinations of effluent limitations under section 402(a)(1) of the Act.	Applicable for remedial activities that include water treatment systems that discharge water directly to drainage ditches or streams.

Table 1-3
Action-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
FEDERAL:		
- National Pollution Discharge Elimination System General and Categorical Pre-treatment Standards - 40 CFR 403	Establishes responsibilities of Federal, State, and local government, industry and the public to implement National Pretreatment Standards to control pollutants which pass through or interfere with treatment processes in Publicly Owned Treatment Works (POTWs) or which may contaminate sewage sludge.	Applicable for remedial activities that include water treatment systems that discharge water directly to a local POTW.
– Underground Injection Control (UIC) Program – – 40 CFR 144, 146	Subpart 144 establish minimum requirements for UIC programs. To the extent set forth in part 145, each State must meet these requirements in order to obtain primary enforcement authority for the UIC program in that State. Subpart 146 sets forth technical criteria and standards for the UIC Program	Applicable for remedial activities that involve injection of oxidants to remediate PERC in bedrock.
– Federal Water Quality Criteria (FWQC) Summary. – CERCLA Section 121[d][2][B]	The FWQC include guidance values issued by the USEPA Office of Science and Technology, Health and Ecological Criteria Division, 1994. However, these guidance values should be considered if more stringent than the promulgated values, "where relevant and appropriate under the circumstances of the release or threatened release"	Applicable for remedial activities that include discharges to surface water.
– National Primary and Secondary Ambient Air Quality Standards – 40 CFR 50	Defines levels of air quality which the EPA Administrator judges are necessary, with an adequate margin of safety, to protect the public health.	Applicable for remedial activities that include discharge of potentially contaminated air.
– Standards of Performance for New Stationary Sources – 40 CFR 60	Provides standards and emission guidelines for a wide list of stationary sources.	Applicable for remedial activities that include discharge of potentially contaminated air.
– National Emission Standards for Hazardous Air Pollutants – 40 CFR 61	Identifies those substances, including PCE and its daughter products that, pursuant to section 112 of the Clean Air Act, have been designated as hazardous air pollutants (HAPs).	Applies to the owner or operator of any stationary source for which a standard is prescribed under this part and includes remedial actions.
– Identification and Listing of Hazardous Waste – 40 CFR 261	Identifies those solid wastes which are subject to regulation as hazardous wastes under parts 262 through 265, 268, and parts 270, 271, and 124 of this chapter and which are subject to the notification requirements of section 3010 of RCRA.	Applicable for remedial activities where potentially hazardous materials are removed from the ground and actively managed.
FEDERAL:		
– Standards Applicable to	Specifies that generators who treat,	Applicable for remedial activities

Table 1-3
Action-Specific Standards and Criteria
Apple Valley Shopping Center Site

Program/Authority/Citation	Synopsis	Project Application
Generators of Hazardous Waste – 40 CFR 262	store, or dispose of hazardous waste on-site must only comply with the following sections of this part with respect to that waste: Section 262.11 for determining whether or not he has a hazardous waste, § 262.12 for obtaining an EPA identification number, § 262.34 for accumulation of hazardous waste, and § 262.40 (c) and (d) for recordkeeping.	where potentially hazardous materials are removed from the ground and actively managed (i.e., treated, stored or disposed).
– Standards Applicable to Transporters of Hazardous Waste – 40 CFR 263	Establishes standards which apply to persons transporting hazardous waste within the United States if the transportation requires a manifest under 40 CFR part 262.	Applicable for remedial activities where potentially hazardous materials are removed from the ground and transported off site for treatment or disposal.
– Standards Applicable to Owners and Operators of Treatment, Storage, and Disposal Facilities – 40 CFR 264-267	Establishes minimum national standards which define the acceptable management of hazardous waste	Applicable for remedial activities where potentially hazardous materials are removed from the ground and actively managed (i.e., treated, stored or disposed).
– Land Disposal Restrictions – 40 CFR 268	Identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be land disposed.	Applicable for remedial activities where potentially hazardous materials are removed from the ground and transported off site for disposal.
– Hazardous Materials Transportation Regulations – 49 CFR 107, 171-177	Provides DOT regulations for transport of hazardous materials.	Applicable for remedial activities where potentially hazardous materials are removed from the ground and transported off site for treatment or disposal.

TABLE 2-1
Remedial Action Objectives and General Response Actions
Apple Valley Shopping Center Site #3-14-084

REMEDIAL ACTION OBJECTIVES	
1	Rapidly and significantly reduce or eliminate the potential human health risks associated with the consumption of impacted groundwater.
2	Rapidly and significantly reduce or eliminate the potential human health risks associated with the inhalation of VOCs associated with the volatilization of contaminants from the groundwater and/or residually impacted soils.
3	Rapidly and significantly reduce or eliminate the potential human health risks associated with direct contact with impacted groundwater and/or residually impacted soils.
4	Protect the aquifer beneath the Site by eliminating, to the extent feasible, any residual NAPL in the aquifer and reducing the dissolved contaminant concentrations in the groundwater to concentrations below New York State Ambient Water Quality Standards to the extent feasible.
5	Protect the local ecology and environment by eliminating, to the extent feasible, any residual NAPL in the aquifer and reducing the dissolved contaminant concentrations in the groundwater to concentrations below the New York State Ambient Water Quality Standards to the extent feasible.

TABLE 2-1
Remedial Action Objectives and General Response Actions
Apple Valley Shopping Center Site #3-14-084

GENERAL RESPONSE ACTIONS	
Monitored Natural Attenuation	Monitored Natural Attenuation involves the continued sampling and analysis of groundwater and indoor air quality. Contamination is allowed to degrade by natural physical and biological processes. Monitoring is performed to verify reduction of concentrations to acceptable levels at the limits of the area of concern.
Institutional Controls	Institutional controls involves land use restrictions, groundwater withdrawal restrictions, and various other ordinances to protect human health by preventing contact with contamination. No technologies are involved, and therefore this general action will not be evaluated in the technology screening process but will be retained and included as a potential remedial alternative either alone and/or in conjunction with other alternatives.
Engineering Controls	Engineering controls involve use of various technologies designed to prevent exposure to contamination generally without removal or treatment of the contaminants. It may include development of alternate water supply sources, hydraulic containment with extraction wells or grout barriers, point-of-entry systems, air cleaners, etc. Some engineering controls (such as hydraulic containment) may require that treatment technologies be employed.
In-situ Treatment	Various in-situ treatment technologies exist for the reduction and/or elimination of contamination from soils and/or groundwater without removing the impacted media. Most of these technologies involve the injection of chemical or biological reactive agents designed reduce residual concentrations by interacting directly and /or indirectly with the contaminants of concern.
Removal, treatment, and/or disposal of impacted media.	Direct removal of contaminated media may be accomplished through the application of various proven technologies. Treatment and disposal technologies will consider both on-site and off-site options.

Table 2-2
Remedial Technologies and General Process Options
Apple Valley Shopping Center Site # 3-14-084

General Response Actions	Remedial (and Associated) Technologies	General Process Options
Monitored Natural Attenuation	Monitoring	Environmental Media (groundwater, soil gas, sampling)
		Land Use (indoor air quality sampling)
Institutional Controls	Access Restrictions	Land Use/Deed Restrictions
		Resource Usage Restrictions
Engineering Controls	Containment	Capping
		Grout Barriers
		Hydraulic Containment
	Alternative Resource Development	Municipal water supply
In-situ Treatment	Biological	Bioventing
		Enhanced Bioremediation
		Phytoremediation
	Physical	Electrokinetic Separation
		Fracturing
		Flushing
		Thermal Treatment
	Chemical	Chemical Oxidation
		Solidification/Stabilization
Removal, treatment, and/or disposal of impacted media.	Removal	Vapor Extraction
		Air Sparging
		Directional Wells
		Blasted inteceptor trench(es)
		Quarrying
		Dual Phase Extraction
		Hydrofracturing Enhancements
		In-Well Air Stripping
		Passive/Reactive Treatment Walls
	Ex-Situ Treatment (assumes pumping) of Groundwater	Advanced Oxidation Processes
		Air Stripping
		Granulated Activated Carbon
		Groundwater Pump&Treat
		Ion Exchange
		Separation
		Sprinkler Irrigation
	Ex-Situ Treatment (of gaseous phase)	High Energy Destruction
		Membrane Separation
		Oxidation
		Scrubbers
		Vapor Phase Carbon Adsorption
	Dispsoal (of groundwater)	Direct (permitted) Surface Discharge
		Deep Well Injection
		Off-site dispsoal

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
No Action	Non-technology Based	**Not Applicable**	No Action assumes that no remedial activities will be conducted. Evaluation is required under the NPL to establish the baseline for screening remedial alternatives.	No Action conditions will be evaluated. This assumes discontinuation of the current IRM activities.	Y
Monitored Natural Attenuation	Monitoring	**Environmental Sampling**	Routine sampling for contaminants of concern, breakdown products, and water quality parameters to monitor natural attenuation of plume.	Used in conjunction with other response actions and technologies or as sole remedy under appropriate site-specific conditions.	Y
		Land Use (tenant occupied areas)	Routine sampling of indoor air quality.	Used in conjunction with other response actions and technologies or a sole remedy under appropriate site-specific conditions.	Y
Institutional Controls	Access Restrictions	**Land Use/Deed Restrictions**	Municipal Land usage and/or deed restrictions used to limit on-site activities and future property development.	Used in conjunction with other response actions and technologies or a sole remedy under appropriate site-specific conditions.	Y
		Resource Usage Restrictions	Municipal restrictions imposed on future groundwater usage.	Used in conjunction with other response actions and technologies or a sole remedy under appropriate site-specific conditions.	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Engineering Controls	Containment	**Capping**	Impermeable barrier layer installed at (or near) surface to prevent escape of volatilized contaminants.	Generally used to prevent direct contact with impacted media and dissolution of contaminants through infiltration of precipitation. May be useful in conjunction with a soil gas collection system.	Y
		Grout Barriers	Fractures and fissures in aquifer sealed with injected grouting materials.	May be useful at partially isolating source areas or diverting groundwater away from downgradient supply wells. Horizontal flow barriers are a relatively common technology but vertical barriers to prevent downward movement would be difficult to emplace with acceptable degree of certainty.	Y
		Hydraulic Containment	Groundwater withdrawn from a series of withdraw points with overlapping piezometric cones of depression to prevent escape of contaminants from area of concern.	May require treatment and discharge/disposal of groundwater.	Y
	Alternative Resource Development	**Construct Municipal Water Supply System**	Impacted private supply wells replaced by municipal supply system.	Extension of municipal water supply systems to include impacted downgradient residential areas currently under consideration by local water district. High potential long-term solution used in conjunction with other technologies and/or response actions.	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
In-situ Treatment	Biological Processes	**Bioventing**	Bioventing stimulates the natural in situ biodegradation of any aerobically degradable compounds in soil by providing oxygen to existing soil microorganisms.	Primarily a soil-based technology, results from tests under bedrock aquifer conditions are poor or inconclusive.	N
		Enhanced Bioremediation	Enhanced bioremediation is a process in which indigenous or inoculated micro-organisms (e.g., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or ground water, converting them to innocuous end products.	Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials. Nutrient and substrate injection is a proven technology for dehalogenating chlorinated hydrocarbons.	Y
		Phyto-remediation	Use of plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation, phyto-extraction (also called phyto-accumulation), phyto-degradation, and phyto-stabilization.	Primarily used for binding heavy metals in near surface environment. Limited application with volatile compounds and gasses in soils, no application to deep bedrock contamination.	N
	Chemical Processes	**Chemical Oxidation**	Direct injection of oxidation agents chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, chlorine dioxide, and permanganate.	Very useful for rapid elimination of NAPL. Fracturing may be used to improve dispersion of oxidants.	Y
		Solidification /Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Primarily a soil-based technology.	N
		Passive/Reactive Treatment Walls	A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others.	Generally used in shallow overburden aquifer conditions. Untested in bedrock. May be used separately or in conjunction with other general responses an/or technologies.	N

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
In-situ Treatment (cont)	Physical Processes	**Electrokinetic Separation**	The Electrokinetic Remediation (ER) process removes metals and organic contaminants from low permeability soil, mud, sludge, and marine dredging. ER uses electrochemical and electrokinetic processes to desorb, and then remove, metals and polar organics. This in situ soil processing technology is primarily a separation and removal technique for extracting contaminants from soils.	Primarily used for soils. No application to bedrock groundwater contamination.	N
		Fracturing	Injection of pressurized water or air through wells used to expand existing fractures and joints in bedrock. Cracks may be filled with a porous media to maintain pumping efficiency by holding the expanded fissures open and to serve as a substrate for bioremediation.	Used to alter site-specific conditions to affect other technological remedial solutions.	Y
		Flushing	Flushing is the extraction of contaminants with water or other suitable aqueous solutions. Flushing is accomplished by passing the extraction fluid through the aquifer with an injection or infiltration and recollection process. Cosolvents are generally used to enhance the solubility of sequestered residual free products. Technology is typically applied to soils but may also be used in bedrock. Flushing requires substantial in-place control technologies to prevent escape of flushing solution. Extraction fluids must be recovered from the underlying aquifer and, when possible, they are recycled.	Requires other processes such as containment and/or treatment.	Y
		Thermal Treatment	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants.	Vaporized components removed by vacuum extraction and then treated. Hot water or steam-based techniques include Steam Injection and Vacuum Extraction (SIVE), In Situ Steam-Enhanced Extraction (ISEE), and Steam-Enhanced Recovery Process (SERP).	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Removal of impacted media	Removal Processes	**Groundwater Pumping/ Pump&Treat**	Groundwater is removed from aquifer and treated prior to reinjection or discharge.	Currently in-use at site. Pumping and treating water from pumping well AV-2.	Y
		Vapor Extraction	Soil vapor extraction (SVE) is an in situ unsaturated (vadose) zone soil remediation technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semivolatile contaminants from the soil. The gas leaving the soil may be treated to recover or destroy the contaminants.	Proven technology for removal of soil gas. May also be used in conjunction with other technologies (hot-air, steam injection, etc) to strip volatiles from groundwater.	Y
		Air Sparging	Air is injected into saturated matrices to remove contaminants through volatilization.	Requires gas extraction collection system.	N
		In-Well Air Stripping	Air injected into a double screened well, lifts water and forces it out the upper screen. Simultaneously, additional water is drawn in the lower screen. VOCs in the contaminated groundwater are transferred from the dissolved phase to the vapor phase by air bubbles. Generated vapors are drawn off and treated by a vapor extraction system.	Hydrogeology is not suitable for the circulation needed for in-well air stripping to be effective.	N
		Dual Phase Extraction	Dual-phase extraction (DPE) uses a high vacuum system to remove various combinations of contaminated ground water, separate-phase petroleum product, and hydrocarbon vapor from the subsurface.	Extracted liquids and/or vapors are treated and collected for disposal, or re-injected to the subsurface (where permissible under applicable state laws). DPE is also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping.	Y
		Quarrying	Excavation of overburden and quarrying of impacted bedrock to remove impacted zone(s) and facilitate DNAPL and impacted groundwater recovery.	Not applicable to developed lands.	N

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Removal of impacted media (cont)	Removal Enhancement Processes	**Directional Wells**	Drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling.	Directional drilling may be used to enhance other in-situ or in-well technologies such as groundwater pumping, bioventing, SVE, soil flushing, and in-well air stripping.	Y
		Blasted Interceptor Trench(es)	High explosives positioned and detonated to create a zone of highly fractured rock.	Similar to fracturing or hydrofracturing but more massive. Ideally it creates blasted lineations that intercept all existing groundwater flow pathways. May be used to divert flow, in conjunction with groundwater recovery system, or emplacemnt of grout barriers for containment. May also be used to create collection sumps beneath zones of free product to facilitate collection and removal.	Y
		Hydrofracturing Enhancements	Addition of surfactants, cosolvents, reagents, and/or other chemical or physical (heat, pressure, etc) mechanisms during the fracturing process to enhance recovery of groundwater and/or contaminants .	Enhancing agents added to pressurized injection waters during fracturing process to improve the results, dissolve calcified deposits, and/or increase mobility and/or solubility of NAPL.	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Treatment of impacted media.	Ex-Situ Treatment (assnmes pumping) of Groundwater	**Adsorption /Absorbtion**	Groundwater is passed through a filtering system composed of an adsorptive material that removes dissolved phase contaminants from the water. The most common adsorbent is granulated activated carbon (GAC) . Other natural and synthetic adsorbents include: activated alumina, forage sponge, lignin adsorption, sorption clays, and synthetic resins.	Common component of groundwater pump&treat remedial system.	Y
		Advanced Oxidation Processes	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect, or escape.	Currently in-use in IRM POE systems. Usage generally confined to low flow (less than 50gpm) solutions.	Y
		Air Stripping	Volatile organics are partitioned from extracted ground water by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.	Common component of groundwater pump&treat remedial system.	Y
		Granulated Activated Carbon(GAC)/Liquid Phase Carbon Adsorption	Ground water is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.	Common component of groundwater pump&treat remedial system.	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Treatment of impacted media	Ex-Situ Treatment (assumes pumping) of Groundwater	**Ion Exchange**	Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for re-use.	Case studies indicate technology is not successful with dissolved or gaseous halogenated hydrocarbons.	**N**
		Separation	Separation processes seek to detach contaminants from their medium (i.e., ground water and/or binding material that contain them). Ex situ separation of waste stream can be performed by many processes: (1) distillation, (2) filtration/ultrafiltration/microfiltration, (3) freeze crystallization, (4) membrane pervaporation and (5) reverse osmosis.	The ex situ separation process is used mainly as a pretreatment or post-treatment process to remove contaminants from waste water. The target contaminant groups for ex situ separation processes are VOCs, SVOCs, pesticides, and suspended particles. Solvents may be recovered for reuse.	**Y**
		Sprinkler Irrigation	Sprinkler irrigation is a relatively simple treatment technology used to volatilize VOCs from contaminated wastewater. The process involves the pressurized distribution of VOC-laden water through a standard sprinkler irrigation system. Sprinkler irrigation transfers VOCs from the dissolved aqueous phase to the vapor phase, whereby the VOCs are released directly to the atmosphere.	Relatively new technology. Insufficient case history to establish applicability or cost basis for evaluation. Requires large tracts of areable land to be effective. May aslo be considered a disposal technology.	**N**

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Treatment of impacted media (cont)	Ex-Situ Treatment (of gaseous phase)	**Biofiltration**	Vapor-phase organic contaminants are pumped through a soil bed and sorb to the soil surface where they are degraded by microorganisms in the soil.	Proven technology but with limited application to halogenated compounds.	Y
		High Energy Destruction	The high energy destruction process uses high-voltage electricity to destroy VOCs at room temperature.	Experimental technology, not portable to field at this time.	N
		Membrane Separation	A high pressure membrane separation system has been designed by DOE to treat feedstreams that contain dilute concentrations of VOCs. The organic vapor/air separation technology involves the preferential transport of organic vapors through a nonporous gas separation membrane (a diffusion process analogous to pumping saline water through a reverse osmosis membrane).	Experimental technology, not portable to field at this time.	N
		Oxidation	Organic contaminants are destroyed in a high temperature 1,000°C (1,832 °F) combustor. Trace organics in contaminated air streams are destroyed at lower temperatures, 450 °C (842 °F), than conventional combustion by passing the mixture through a catalyst.	Organic contaminants are destroyed in a high temperature 1,000°C (1,832 °F) combustor. Trace organics in contaminated air streams are destroyed at lower temperatures, 450 °C (842 °F), than conventional combustion by passing the mixture through a catalyst.	Y
		Scrubbers	Scrubber is an air washer with refinement device which is used for cleaning gases from soluble or particulates.	General a fixed emplacement technology used on an industrial scale. Limited field applications, energing technology for temporary site uses.	N
		Vapor Phase Carbon Adsorption	Vapor-phase organic contaminants are pumped through a series of GAC tanks where VOCs are sorbed to the carbon.	Common component of groundwater pump&treat remedial system and or vapor phase treatment systems	Y

Table 2-3
Preliminary Remedial Technologies Screening
Apple Valley Shopping Center Site #3-14-084

General Response Actions	Remedial (and Associated) Technologies	Process Options	Description	Screening Comments	Retain
Disposal	Disposal (of groundwater)	**Direct Discharge**	Treated groundwater is discharged directly to the ground, sewer system, or surface water body. Discharge receptors and affect permit requirements.	Common component of groundwater pump&treat remedial system and or vapor phase treatment systems	**Y**
		Deep Well Injection	Treated (and potentially untreated) groundwater/liquid waste is injected into deep confined strata.	Concentrated hazardous liquids injected into deep (>1000 ft) litholgic structures (such as salt domes).	**N**
		Off-site disposal	Treated and/or untreated water transported off-site to permitted disposal facility .	Commonly used for small quantities of removed groundwater. Not cost effective or practical for use with pumping systems withdrawing substantial quntities of water for long durations.	**N**
		Shallow Reinjection	Treated groundwater reinjected into aquifer, usually upgradient of affected area to create cyclic loop, and/or a hydraulic barrier.	Commonly used in shallow water table and soil aguifers with confining semi-impermeable basal unit. May significantly alter hydrologic regime.	**Y**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
SOIL AND BEDROCK TREATMENT TECHNOLOGIES			
In-Situ Biological Treatment	**Enhanced Bioremediation**	Enhanced bioremediation is a process in which indigenous or inoculated micro-organisms (e.g., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or ground water, converting them to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	**Effectiveness:** Requires indigenous biological population and/or inoculation to be effective. Primarily a soils and/or groundwater based application that is not directly applicable to bedrock (although it can be used to treat groundwater in a bedrock aquifer). **Implementability:** Not applicable to bedrock. **Comments:** Not applicable to direct treatment of the bedrock, may be used for treating groundwater and will be evaluated as an in-situ treatment technology for remediating groundwater. **ELIMINATED**
In-Situ Physical/Chemical Treatment	**Chemical Oxidation**	Direct injection of Oxidation agents chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, permanganate, hypochlorites, chlorine, and chlorine dioxide.	**Effectiveness:** Direct oxidation can achieve rapid destruction of contaminants of concern with reported rates of 90%+ destruction within minutes of injection. Very effective for destroying residual NAPL. **Implementability:** Relatively simple technology to use and easy to implement. May require additional site characterization to facilitate drilling of additional injection points. Remedial effect limited to areas of direct contact between injected fluids and COCs. Penetration of aquifer by injected oxidants may be increased with aquifer enhancement technologies. Fracturing may be required to ensure complete destruction of DNAPL. **Comments:** May produce unwanted side effects and/or by-products including excessive heat, damage to aquifer fracture system, and formation of other toxic chemicals. Direct oxidation of NAPL can produce a violent reaction. Most effective method of rapidly reducing contaminant levels and destroying residual NAPL. **RETAINED**
	Fracturing	Fracturing is an enhancement technology designed to increase the efficiency of other in situ technologies in difficult soil and/or bedrock conditions. The fracturing extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction. When fracturing has been completed, the formation is then subjected to removal technologies such as vapor extraction (in soils), or groundwater extraction (soil and bedrock). Technologies commonly used in fracturing include pneumatic fracturing (PF), hydraulic fracturing, blast-enhanced fracturing, and Lasagna™ process.	**Effectiveness:** The function of fracturing is to increase overall permeability by enlarging water bearing zones and intercepting fractures by creating a zone of shattered rock. Numerous studies indicate that fracturing can increase permeability of bedrock from 0.5 to 2 orders of magnitude within 5 to 20 meters of the fracturing point. Effectiveness of pneumatic/hydraulic fracturing is a function of the overall competency of the bedrock with high competency generally yielding greater effectiveness. Fissile rock type composed of shales, siltstones, and sapprolites resist fracturing as pneumatic pressure dissipates more readily and finer grained materials may reseal opened channels when pressure is removed. Blast fracturing is significantly more effective and somewhat indifferent to rock type. The LasagnaTM Process is limited to soils and consequently eliminated from further evaluation. **Implementability:** Technology is relatively simple and easy to employ. Blast fracturing creates a potential physical hazard that may be unacceptable in an inhabited area. **Comments:** Review of numerous case studies of pneumatic and hydraulic fracturing indicate that technology ranges from marginal to highly effective. Case studies of blast fracturing indicate technology is very effective. Fracturing is an enhancement technology intended to improve the connectivity of flow paths within the aquifer and enhance withdrawal and/or injection technologies. Pneumatic, hydraulic, and blast fracturing are applicable in bedrock. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
In-Situ Physical/Chemical Treatment	**Flushing**	In situ flushing is the extraction of contaminants with water or other suitable aqueous solutions. Flushing is accomplished by passing the extraction fluid through the aquifer with an injection or infiltration and recollection process. Cosolvents are generally used to enhance the solubility of sequestered residual NAPLs. Technology is typically applied to soils but may also be used in bedrock. Flushing requires substantial in-place control technologies to prevent escape of flushing solution. Extraction fluids must be recovered from the underlying aquifer and, when possible, they are recycled.	**Effectiveness:** Application of flushing technology has not been effectively demonstrated in a bedrock aquifer. Technology generally relies on natural (semi) confining layers to obstruct vertical migration of mobilized materials (NAPL) and form the "floor" of the flushing zone. Confining layers may not be available in a fractured bedrock system. Hydraulic control technology needed to prevent lateral migration necessary to contain impact zone and create the closed loop system. **Implementability:** Difficult to design and implement with high degree of confidence. Requires a comprehensive understanding of bedrock aquifer dynamics. **Comments:** May result in downward migration of mobilized NAPL. Hydraulic regime and interconnectivity of bedrock fracture system must be very well understood to ensure extraction and reinjection into connected fracture systems that communicate through the contamination zone. Technology could be enhanced by use of blast fracturing technologies. **ELIMINATED**
	Vapor Extraction [Including sub-slab depressurization]	Vacuum is applied to extraction wells to create a pressure gradient that induces gas-phase volatiles to be removed from soil (or bedrock) through extraction wells. This technology also is known as in-situ soil venting, in situ volatilization, enhanced volatilization, or soil vacuum extraction. Generally, wells are placed in the overburden for the length of the unsaturated soil column, alternately a sub-slab depressurization system may be used to protect buildings.	**Effectiveness:** Soil vapor extraction (SVE) is a widely proven and effective technology for removing volatile gases from soils above the water table. Flow rates and extraction grid density are functions of the soil type and extent of contamination. Removal of the soil gas would result in additional volatilization (Henry's Law) of NAPL from the groundwater. **Implementability:** Relatively simple technology to implement. Additional site characterization and pilot area study needed to determine the flow rates and grid density. Technology would rapidly reduce soil gases in areas of SVE impact and control air quality within the on-site buildings. **Comments:** Useful technology for controlling soil gas concentrations. Must be used in conjunction with other technologies to effectively achieve RAOs. Extracted gases may require treatment prior to discharge. Primary function of SVE would be to protect indoor air quality which could also be accomplished with a sub-slab depressurization system installed beneath the concrete slab on-grade floors of the current buildings. **RETAINED**
	Thermal Treatment (Thermally Enhanced Soil Vapor Extraction)	Heat added to contaminant zone to increase volatilization rate and improve efficiency of SVE system.	**Effectiveness:** Limited effectiveness and/or efficiency in saturated zone. Thermodynamics restrict application. Rapid conductance of heat through water column dissipates heat too rapidly severely restricting the area of effect below the water table. **Implementability:** NA **Comments:** Generally limited to vadose zone in soils **ELIMINATED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
GROUNDWATER AND AIR TREATMENT TECHNOLOGIES			
Engineering Controls/Containment	**Physical Barriers (Grout Injection)**	Impermeable material injected into fracture system to create physical barrier to groundwater flow.	**Effectiveness:** Limited effectiveness in fractured bedrock systems. Generally requires a confining layer to act as the "floor" of the containment system. Used primarily to isolate source areas from the groundwater flow paths to retard, channnelize, or eliminate migration.
			Implementability: Difficult to ensure complete barrier placement. Area of effect limited by permeability of formation. Enhancement with blast fracturing has proven more effective.
			Comments: Permanently alters hydrologic regime. May have unpredictable consequences. **ELIMINATED**
	Hydraulic Containment	Withdrawal of groundwater to create overlapping cones of depression that prevent the downgradient migration of contaminants.	**Effectiveness:** Use of hydraulic gradients and or physical barriers to prevent lateral migration of dissolved plume has had a wide range of success and is generally effective. Current system is partially protecting downgradient residential supply wells by application of this principle. Effectiveness may be enhanced by addition of aquifer enhancement techniques and/or discreet interval withdrawal techniques.
			Implementability: Current system uses containment through withdrawal of groundwater and has demonstrated ability to contain the migration of the plume. Proven effective and reliable technology readily commercially available and can be engineered for a wide range of applications.
			Comments: May not result in complete containment. Vertical component of flow and downward migration of DNAPL may increase by changes in flow patterns. **RETAINED**
	Interceptor Trench (Blast Fracturing)	Blast fracturing used to create subsurface zone of high permeability generally perpendicular to axis of plume migration. Pumping from the trench is used to create a line sink between the source area(s) and the sensitive downgradient receptors.	**Effectiveness:** Very effective at enhancing permeability in the blasted zone.
			Implementability: Specialized form of fracturing requiring high degree of competency and experience. May have limited commercial availability.
			Comments: Specialized form of hydraulic containment that uses blast fracturing to create an artificial zone of high permeability. May result in creation of new and unpredictable pathways. Not generally recommended for use in populated areas. **ELIMINATED**
	Alternative Water Supply	Design, engineer, and construct of a municipal water supply system to provide potable water to existing downgradient residences and future potential receptors.	**Effectiveness:** Does NOT alter or effect the nature or extent of contamination or otherwise protect potential receptors. Would require institutional controls to protect future groundwater users.
			Implementability: Extensive engineering, design, construction and legal components required including takings for right of ways. Long -term maintenance issues, potential jurisdictional obstacles, cost intensive, and does not prevent exposure to impacted groundwater or indoor-air.
			Comments: Very expensive "immediate" solution that could take many years to implement and would not meet the SCGs or RAOs. **ELIMINATED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
In Situ Biological Treatment	**Enhanced Bioremediation**	Enhanced bioremediation is a process in which indigenous or inoculated micro-organisms (e.g., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or ground water, converting them to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	**Effectiveness:** The contaminants of concern consist primarily of halogenated hydrocarbons, which degrade most rapidly under anaerobic environmental conditions. The use of induced reductive dehalogenation through the injection of hydrogen releasing compounds has been demonstrated to be an effective method of eliminating a dissolved chlorinated solvent contaminant plume. Numerous case studies report reductions of dissolved concentrations of PCE, TCE, and TCA in excess of 1000 ppm to below EPA MCLs in less than five years by application of Hydrogen Releasing Compounds. End product of breakdown cycle yields compounds that degrade aerobically (vinyl chloride).
			Implementability: Relatively simple technology, easy to implement. May require drilling of additional injection points and aquifer enhancements to improve dispersion of materials. Food grade additives used for substrate are environmental benign.
			Comments: Aquifer and groundwater chemistry parameters determine quantities of additives needed and time required to complete remediation. Process may require a very long time (in excess of ten-thirty years) to achieve goals. Does not directly impact free phase product, if present, but may cause dissolution of additional NAPL by equilibrium imbalance caused by increased consumption of dissolved components. Daughter products of dehalogenation of PCE include TCE, DCE, and Vinyl Chloride all of which are more environmentally persistent and more toxic than PCE. Recommended source are removal/elimination to be effective or multiple reinjections over an extended time period. **ELIMINATED**
	Monitored Natural Attenuation	MNA involves the long term monitoring of groundwater plume while allowing for natural biological degradation and dispersive attenuation to reduce concentrations to permissible levels at downgradient points of compliance. COCs and attenuation parameters are monitored on a routine basis. No direct remedial action is performed. Natural attenuation is not a "technology" per se.	**Effectiveness:** Effectiveness contingent on proximity of downgradient receptors, site-specific conditions, and natural decay rates of COCs. Not appropriate for use on sites with imminent risks or existing complete exposure pathways. USEPA Guidance indicates low success rate of MNA with Halogenated compounds.
			Implementability: Consideration of this option usually requires modeling and evaluation of contaminant degradation rates and pathways and predicting contaminant concentration at down gradient receptor points, especially when plume is still expanding/migrating. The primary objective of site modeling is to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long term monitoring must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.
			Comments: MNA is not likely to be an effective primary remedial action with respect to the RAOs due to the threat to immediate downgradient drinking water supplies and the nature of the contaminants. However, it is retained and will be evaluated. It may be used in combination with other technologies as the final stage in a remedial action sequence. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
In Situ Physical/Chemical Treatment	**Air Sparging**	Air sparging is an in situ technology in which air is injected through a contaminated aquifer. Injected air traverses horizontally and vertically creating an underground stripper that removes contaminants by volatilization. This injected air helps to flush (bubble) the contaminants up into the unsaturated zone where a vapor extraction system is usually implemented in conjunction with air sparging to remove the generated vapor phase contamination.	**Effectiveness:** Available data suggests average effectiveness (relative to other treatment technologies) of air sparging with respect to Halogenated compounds. Technology is most effective in highly permeable soils and highly fractured bedrock (or fracture enhanced bedrock). Generally used in conjunction with a vapor recovery system. Injection pressures, depths, and grid spacing functions of aquifer parameters and physical properties of COCs. **Implementability:** Tested and proven technology, readily available, and easy to implement. Additional site characterization needed to determine location and spacing of injection grid. May require SVE system to collect and treat generated vapors. **Comments:** Long term technology not conducive to rapid reduction of contamination. Process does not function efficiently in presence of free phase product. Injection of oxygen reduces reductive environment and may retard natural biological degradation causing diffusive plume to extend downgradient unless hydraulic controls are implemented. Primarily a soil based technology with limited pilot scale testing in bedrock. **ELIMINATED**
	Bioslurping	Bioslurping combines the two remedial approaches of bioventing and vacuum-enhanced NAPL recovery. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils. Vacuum-enhanced NAPL recovery extracts LNAPLs from the capillary fringe and the water table.	**Effectiveness:** Very effective technology but inappropriate for site-specific conditions. Bioslurping is designed to enhance biodegradation of residual contaminants in the soils while enhancing NAPL removal. The soil component is not applicable. Vacuum enhanced NAPL removal is discussed under dual-phase extraction removal technology. **Implementability:** Not applicable to DNAPL in bedrock **Comments:** No demonstrations of applicability of technology to DNAPL in a bedrock aquifer. **ELIMINATED**
	Chemical Oxidation	Direct injection of Oxidation agents chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, permanganate, hypochlorites, chlorine, and chlorine dioxide. Complete Oxidation of chlorinated solvents has been demonstrated in full scale remedial studies.	**Effectiveness:** Variable depending on aquifer parameters, and COCs but generally highly effective in area impacted by injection. Most commonly used oxidants for halogenated compounds include Ozone, Peroxide, and Permanganate. Both ozone and peroxide require a relatively tight injection grid as these compounds degrade rapidly. Permanganate is more stable and can diffuse further into the aquifer from injection points. **Implementability:** Relatively simple technology to use and easy to implement. May require additional site characterization to facilitate drilling of additional injection points. Remedial effect limited to areas of direct contact between injected fluids and COCs. Penetration of aquifer by injected oxidants may be increased with aquifer enhancement technologies. **Comments:** Very effective at rapidly destroying dissolved and free phase VOCs. Proven technology but somewhat controversial. Daughter products of reactions difficult to predict, excessive heat has reportedly generated steam geysers and /or caused ground heaving. Process can seriously alter groundwater chemistry and result in salt precipitates in flow paths that permanently alter hydrological regime. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
In Situ Physical/Chemical Treatment	**Directional Wells**	Drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling. Directional drilling may be used to enhance other in-situ or in-well technologies such as ground water pumping, bioventing, SVE, soil flushing, and in-well air stripping.	**Effectiveness:** Very effective at positioning wells in difficult to reach (obstructed) locations such as beneath buildings. **Implementability:** Angle drilling requires specially designed rigs and is generally significantly more expensive than conventional vertical drilling but technology is well proven and readily available. Additional site characterization needed to maximize potential benefits of directional drilling. **Comments:** Angel drilling technology is generally used for situations that require well placement beneath obstructions, where access restrictions prevent vertical wells, building obstructions, or complex site geology (such as drilling parallel to the underside of a dipping aquitard without penetrating the layer). **RETAINED**
	Dual Phase Extraction	A high vacuum system is applied to simultaneously remove various combinations of contaminated ground water, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. Dual-phase extraction (DPE), also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping, is a technology that uses a high vacuum system to remove various combinations of contaminated ground water, separate-phase product, and vapor from the subsurface. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the subsurface (where permissible under applicable state laws).	**Effectiveness:** Successful demonstration of technology reported at numerous sites for removing dissolved phase components of LNAPL and DNAPL and free-phase LNAPL from soils and bedrock aquifers. Case studies of DNAPL remediation with dual-phase extraction have reported a range of results from total failure to highly successful. All the highly successful cases involved the use of aquifer enhanced fracturing technology and high extraction point grid densities. In these cases, dual-phase extraction resulted in significantly decreased time needed to complete site remediation. Will remove contaminant mass up to asymptotic limit - residual mass may approach 30%-50% **Implementability:** Technology is readily available although somewhat more costly to install than conventional pumping systems and SVE systems (which it combines into one system). Factors that may limit the applicability and effectiveness of the process include: site geology and contaminant characteristics/distribution, combination with complementary technologies (e.g., pump-and-treat) may be required to recover ground water from high yielding aquifer, and dual phase extraction requires both water treatment and vapor treatment. Generally requires fracturing technology be applied for DNAPL removal. **Comments:** Although identified as an in-situ process, it is in fact a removal based technology. Extraction (and treatment) of contaminated groundwater is integral part of process. Drawdown of water table (removal of impacted groundwater) is necessary to expose product layers and allow vacuum to remove vapors from exposed fractures. Impacted groundwater would need to be treated prior to discharge (or reinjection). **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
In Situ Physical/Chemical Treatment	**Thermal Treatment**	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated (vadose) zone where they are removed by vacuum extraction and then treated.	**Effectiveness:** Pilot scale technology, insufficient case studies to demonstrate effectiveness with DNAPL in bedrock. Case studies indicate effectiveness is limited to immediate vicinity of injection wells and therefore may require densely packed injection grid. **Implementability:** Hot water or steam flushing/stripping is a pilot-scale technology intended to volatilize contaminants and/or enhance dissolution and mobilize NAPL. Vapor phase collection, in situ biological treatment, enhanced reduction, and/or groundwater removal may follow the displacement and is continued until ground water contaminants concentrations satisfy statutory requirements. Not readily commercially available. **Comments:** Experimental Technology. Insufficient case studies available to fully evaluate technology. **ELIMINATED**
	Hydrofracturing Enhancements	Hydrofracture (see reference above) process is enhanced by the injection of porous material (sand, silica beads, etc) into the fractures to physically support the fractures, preventing them from sealing after pressure is removed. Additionally, acidic solutions can be used to dissolved calcium/lime deposits within the fractures to improve permeability.	**Effectiveness:** Proven technology for industrial (oil) drilling, limited applications in environmental remedial activities. Full scale demonstrations of the process have had mixed success with over-consolidated sediments and pilot scale success with bedrock applications.. **Implementability:** Emerging technology for bedrock (remedial) applications and not yet readily commercially available. **Comments:** Insufficient applications/case studies of usage comparable to existing site-conditions. **ELIMINATED**
	In-Well Air Stripping	Air is injected into lower screen of double screened well causing water levels to rise and flow out the upper screen. Air bubbling up through the water column strips volatiles from the water which is then extracted and treated as needed.	**Effectiveness**: Limited by depth of water table, does not work well in shallow or thin aquifers. Limited number of pilot studies available and none pertaining to bedrock aquifers. Technology is NOT recommended for areas containing NAPL. **Implementability:** Not readily commercially available technology for application to bedrock. **Comments:** Insufficient applications/case studies of usage comparable to existing site-conditions. **ELIMINATED**
Ex Situ Physical/Chemical Treatment	**Ground Water Pumping/Pump and Treat**	Groundwater is removed from the aquifer with one or more groundwater recovery wells and may be processed through a treatment plant prior to discharge or reinjection or transported to a treatment facility. Pumping may be used to remove impacted groundwater and/or free-phase product, create hydraulic barriers to contaminant migration, or a combination of these effects.	**Effectiveness:** Varies based on nature and extent of contaminants, site-specific hyrdogeological conditions, and presence of free-phase products. Free-phase DNAPL has proven to be very difficult to remove from the subsurface by pumping without enhanced recovery techniques. **Implementability:** Drawdown pumping is a commercially available technology that can be easily implemented with conventional pumps in wells or trenches. Quality of site characterization essential in determining the optimal locations and pumping rates of recovery wells. **Comments:** Primary component of most groundwater remediation projects. Current operating IRM system using groundwater pumping to create hydraulic barrier protecting downgradient residential supply wells. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
Ex Situ Physical/Chemical Treatment (assuming pumping)	**Advanced Oxidation Processes**	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect, or escape.	**Effectiveness:** The UV/oxidation is an innovative ground water treatment technology that has been used in full-scale ground water treatment application for more than 10 years. Currently, UV/oxidation processes are in operation in more than 15 full-scale remedial applications. A majority of these applications are for ground water contaminated with petroleum products or with a variety of industrial solvent-related organics such as TCE, DCE, TCA, and vinyl chloride. Current "Point-of-Entry" treatment systems using UV and/or GAC to effectively eliminate contamination that bypasses hydraulic controls.
			Implementability: A wide range of sizes of UV/oxidation systems are commercially available. Single-lamp benchtop reactors that can be operated in batch or continuous modes are available for the performance of treatability studies. Pilot and full-scale systems are available to handle higher throughput (e.g., 3,800 to 3,800,000 liters or 1,000 to 1,000,000 gallons per day).
			Comments: Energy costs may be excessive (compared to other technologies). Generally used for emergency treatment systems until full scale remedial solutions can be installed. **RETAINED**
	Air Stripping	Volatile organics are partitioned from extracted ground water by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration	**Effectiveness:** Removal efficiencies around 99% are typical for towers that have 4.6 to 6 meters (15 to 20 feet) of conventional packing and are removing compounds amenable to stripping. Removal efficiencies can be improved by adding a second air stripper in series with the first, heating the contaminated water, or changing the configuration of packing material. Thermal units for treating air stripper emissions can be used as a source of heat. The performance of aeration tanks can be improved by adding chambers or trays, or by increasing the air supply, depending on the design of the tank.
			Implementability: Technology is readily available Factors that may limit the applicability and effectiveness of the process include: The potential exists for inorganic (e.g., iron greater than 5 ppm, hardness greater than 800 ppm) or biological fouling of the equipment, requiring pretreatment or periodic column cleaning. Effective only for contaminated water with VOC or semivolatile concentrations with a dimensionless Henry's constant greater than 0.01. Consideration should be given to the type and amount of packing used in the tower. Process energy costs are high. Compounds with low volatility at ambient temperature may require preheating of the ground water. Off-gases may require treatment based on mass emission rate.
			Comments: Current system includes air stripper. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
Ex Situ Physical/Chemical Treatment (assuming pumping)	**Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption**	Ground water is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required	**Effectiveness:** Primary target contaminant groups for GAC treatment do NOT include halogenated compounds. Limited success with GAC and chlorinated solvents in groundwater as a primary treatment technology. Frequently used in conjunction with air stripper technology as a post-stripper secondary treatment prior to discharge to "polish" the effluent. **Implementability:** Readily available commercial technology. Useful in areas of low concentrations of dissolved phase contamination but increasingly less cost effective with increasing concentrations. **Comments:** Technology is not applicable to site as primary treatment technology but is retained for consideration in combination with other technologies **RETAINED**
	Separation	Separation techniques concentrate contaminated waste water through physical and chemical means.	**Effectiveness:** Primarily used for pre-treatment or post treatment of industrial waste water but has been successfully demonstrated at the pilot-scale level for groundwater remediation projects. Destruction efficiencies of 99% achieved in pilot-tests at costs comparable to air stripping and GAC applications. **Implementability:** Pilot scale technology for field applications. Not readily commercially available. Primarily used for fixed (permanent) facilities applications. **Comments:** Insufficient applications/case studies of usage comparable to existing site-conditions. **ELIMINATED**
Air Emissions/Off-Gas Treatment	**Oxidation**	Organic contaminants are destroyed in a high temperature 1,000°C (1,832 °F) combustor. Trace organics in contaminated air streams are destroyed at lower temperatures, 450 °C (842 °F), than conventional combustion by passing the mixture through a catalyst.	**Effectiveness:** Thermal Oxidizers are highly effective at destroying VOCs in the vapor stream but are significantly less effective with halogenated hydrocarbons. Halogenated VOCs generally require catalysts to promote thermal destruction. Catalytic thermal oxidizers have proven very effective with halogenated VOCs but may require significant maintenance to remain effective. **Implementability:** The target contaminant groups for oxidation are nonhalogenated VOCs and SVOCs, and fuel hydrocarbons. Both precious metal and base metal catalysts have been developed that are reportedly capable of effectively destroying halogenated (including chlorinated) hydrocarbons. Specific chlorinated hydrocarbons that have been treated include TCE, TCA, methylene chloride, and 1,1-DCA. Halogenated compounds can poison/deactivate the catalyst requiring replacement. Destruction of halogenated compounds requires special catalysts, special materials or construction, and the addition of a flue gas scrubber to reduce acid gas emissions. **Comments:** May be more cost effective for treating high contaminant concentrations, high flow volumes, or both in vapor phase. **RETAINED**
	High Energy Destruction	The high energy destruction process uses high-voltage electricity to destroy VOCs at room temperature.	**Effectiveness:** Very effective at destroying halogenated VOCs from vapor-phase. Portable units have demonstrated a significant lack of required maintenance over extended periods of operation (over a year). **Implementability:** Emerging commercially available technology. **Comments:** This technique is specifically useful for destroying organics and chlorinated solvents such as TCE, PCE, carbon tetrachloride, chloroform, diesel fuel, and gasoline. Both gas and liquid phase contaminants are treatable. The technology is best suited for treatment of gaseous streams with small concentrations of VOCs especially chlorinated compounds. Typically used as a vapor-phase polishing action prior to air discharge. **RETAINED**

Table 2-4
Detailed Remedial Technology Screening
Apple Valley Shopping Center Site # 3-14-084

TECHNOLOGY		DESCRIPTION	PRELIMINARY EVALUATION
Air Emissions/Off-Gas Treatment	**Biofiltration**	Vapor-phase organic contaminants are pumped through a soil bed and sorbs to the soil surface where they are degraded by microorganisms in the soil.	**Effectiveness:** Biofiltration is a low-cost and highly effective air pollution control (APC) technology in which vapor-phase organic contaminants are passed through a bed of porous media and sorb to the media surface where they are degraded by microorganisms in the media. Specific strains of bacteria may be introduced into the filter and optimal conditions provided to preferentially degrade specific compounds. The biofilter provides several advantages over conventional activated carbon adsorbers. First, bio-regeneration keeps the maximum adsorption capacity available constantly; thus, the mass transfer zone remains stationary and relatively short. The filter does not require regeneration, and the required bed length is greatly reduced. These features reduce capital and operating expenses. Additionally, the contaminants are destroyed not just separated, as with granulated activated carbon (GAC) technologies.
			Implementability: The following factors may limit the applicability and effectiveness of the process: The rate of influent air flow is constrained by the size of the biofilter. Fugitive fungi may be a problem. Low temperatures may slow or stop removal unless the biofilter is climate-controlled. Compounds that are recalcitrant to biodegradation will not be converted to harmless products. Moisture levels, pH, temperature, and other filter conditions may have to be monitored to maintain high removal efficiencies. Filter flooding and plugging as a result of excessive biomass accumulation may require periodic mechanical cleaning of the filter. Technology is less effective with Halogenated VOCs.
			Comments: Insufficient case/studies of use of this technology with halogenated compounds in a bedrock aquifer. **ELIMINATED**
	Vapor Phase Carbon Adsorption	Off-gases are pumped through a series of canisters or columns containing activated carbon to which organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.	**Effectiveness:** Proven reliable and effective technology for handling vapor-phase contaminants prior to emission.
			Implementability: Readily available commercial technology commonly used to treat vapor phase prior to emission from air-strippers and SVE systems. Not recommended for high concentrations of contaminants. Factors that may limit the effectiveness of this process include: (1) Spent carbon transport may require hazardous waste handling; (2) Spent carbon must be disposed of and the adsorbed; (3) Contaminants must be destroyed, often by thermal treatment; (4) Relative humidity greater than 50% can reduce carbon capacity; (5) Elevated temperatures from SVE pumps (greater than 38° C or 100° F) inhibit adsorption capacity; (6) Biological growth on carbon or high particulate loadings can reduce flow through the bed.
			Comments: **RETAINED**

TABLE 3-1
SUMMARY OF REMEDIAL ALTERNATIVES
Apple Valley Shopping Center

Alternative	Major Elements of Alternative
1	No Action
2	Monitored Natural Attenuation • Long-term monitoring • Institutional controls
3	Hydraulic Containment using Current System with Sub-Slab Vapor Extraction • Hydraulically contain plume with current pump and treat system • Vent air from under buildings with sub-slab soil vapor extraction • Continue operating POE treatment systems for downgradient receptors as necessary • Long-term monitoring
4	Enhanced Hydraulic Containment with Sub-Slab Vapor Extraction • Enhance hydraulic containment by pumping from additional discreet interval bedrock pumping wells (possibly fracture enhanced) • Treat removed groundwater using existing or modified treatment system • Vent air from under buildings with sub-slab soil vapor extraction • Continue operating POE treatment systems for downgradient receptors as necessary • Long-term monitoring
5	In-situ Oxidation of Source Area Contaminants, Hydraulic Containment and Sub-Slab Vapor Extraction • Install source-area chemical injection wells enhanced through bedrock fracturing • Continue pumping from current pumping well (or enhanced pumping system) • Treat removed groundwater using existing or modified system • Vent air from under buildings with sub-slab soil vapor extraction • Install sentry wells downgradient to monitor for potential mobilization of contaminants due to fracturing • Continue operating POE treatment systems for downgradient receptors as necessary • Long-term monitoring
6	Dual-Phase Extraction in Source Area and Hydraulic Containment and Sub-Slab Vapor Extraction as Necessary • Install source-area dual-phase extraction wells, enhanced through pneumatic or hydraulic bedrock fracturing • Continue pumping from current pumping well as necessary • Treat removed groundwater using existing or modified system • Treat removed vapor as necessary • Vent air from under buildings with sub-slab soil vapor extraction if dual phase extraction is not sufficient • Install sentry wells downgradient to monitor for potential mobilization of contaminants due to fracturing • Continue operating POE treatment systems for downgradient receptors as necessary • Long-term monitoring

Table 4-1
Remedial Action Alternatives-Cost Estimate Summary
Apple Valley Shopping Center-Feability Study

Item	Item Description	Alt 1	Alt2	Alt 3	Alt 4	Alt 5
CAPITAL COSTS						
Subcontractor Costs						
MWI	Monitoring Well Installations	-	$51,460	$51,460	$93,370	$97,454
BFE	Bedrock Fracture Enhancement	-	-	-	$12,715	$35,215
PT	Pilot Tests/Treatability Studies	-	-	-	-	$65,332
ISDO	In-Situ Direct Oxidation	-	-	-	-	$331,600
DR	Deed Restrictions	-	$30,300	$30,300	$30,300	$30,300
SSDS	Sub-Slab Depressurization Systems (Installation)	-	-	$14,833	$14,833	$14,833
GWM	Groundwater Monitoring First Year (Quarterly)	-	-	$85,200	$88,000	$144,000
	Subtotal Subcontractor Costs	-	$81,760	$181,793	$239,218	$718,734
	General Contractor (15%)	-	$12,264	$27,269	$35,883	$107,810
	Subtotal Construction Costs (Sub/Gen. Contr.)	-	$94,024	$209,062	$275,101	$826,544
	Design Engineering (15% Construction Costs)	-	$14,104	$31,359	$41,265	$123,982
	Contingency (20% Construction Costs)	-	$18,805	$41,812	$55,020	$165,309
	TOTAL CAPITAL COSTS	$0	$126,932	$282,234	$371,386	$1,115,834
ANNUAL O&M COSTS (Long term)						
AGWM	Annual Ground Water Monitoring (20-30 Yr)	-	$32,400	$21,300	$22,000	$24,950
SYSOPS	Hydraulic Containment System O&M (20-30 yr)	-	-	$48,000	$51,600	-
SSDS	Sub-Slab Depreesuriaztion System O&M (20-30yr)	-	-	$1,888	$1,888	-
	Total Annual O&M Costs	$0	$32,400	$71,188	$75,488	$24,950
OTHER COSTS (periodic reveiws and short-term sysops)						
5YRR	Five Year Reviews	-	$35,300	-	-	-
SYSOPS	Hydraulic Containment System O&M	-	-	-	-	$48,000
SSDS	Sub-slab Depressurization System O&M	-	-	-	-	$1,888
	Total Other Costs	$0	$35,300	$0	$0	$49,888
PRESENT WORTH OF COSTS						
	Total Capital Costs	$0	$126,932	$282,234	$371,386	$1,115,834
	Total Annual Costs	$0	$498,067	$1,094,340	$1,160,442	$310,932
	Total Other Costs	$0	$98,206	$0	$0	$215,991
	TOTAL PRESENT WORTH	$0	$723,205	$1,376,574	$1,531,828	$1,642,757
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE	**$0**	**$723,000**	**$1,377,000**	**$1,532,000**	**$1,643,000**

Table 4-A1
Alternative 1: No Action - Cost Estimate Summary
Apple Valley Shopping Center Site - Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
	NONE				-
	Total Capital Cost				**$0**
ANNUAL O&M COSTS					
	Total Annual O&M Costs				**$0**
PRESENT WORTH OF COSTS					
	Total Capital Cost				$0
	Annual O&M Costs (30-year duration)				$0
	TOTAL PRESENT WORTH				**$0**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$0**

Table 4-A2
Alternative 2: Monitored Natural Attenuation - Cost Estimate Summary
Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (Total cost of 4 wells)*	1	$ 51,460	LS	$ 51,460
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
	Subtotal Subcontractor Costs				$ 81,760
	General Contractor (15% subcontractor)				$ 12,264
	Subtotal Construction Costs				$ 94,024
	Groundwater Modeling & Design Engineering (15% construction)				$ 14,104
	Contingency (20%)				$ 18,805
	TOTAL CAPITAL COSTS				$ 126,932
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (14 Wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	year	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	year	$ 2,400
GW4	Sample Analysis and Data Validation (14 VOCs/MNAs)	1	$ 14,500	year	$ 14,500
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 8,400	year	$ 8,400
	Total Annual O&M Costs				**$ 32,400**
OTHER COSTS					
5YR	**Five Year Review**	1	$ 35,300	LS	$ 35,300
	Total Other Costs				**$35,300**
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 126,932
	Annual O&M Costs (30 year duration)				$ 498,067
	Five Year Review Costs (30 year duration)				$ 98,206
	Total Present Worth				**$ 723,205**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 723,000**

Table 4-A3
Alternative 3: Hydraulic Containment with Current System - Cost Estimate Summary
Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (Total cost of 4 wells)*	1	$ 51,460	LS	$ 51,460
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*Groundwater Monitoring First Year(quarterly)*	4	$ 21,300	quarter	$ 85,200
	Subtotal Subcontractor Costs				**$ 181,793**
	General Contractor (15% subcontractor)				$ 27,269
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				**$ 209,062**
	Design Engineering (15% construction)				$ 31,359
	Contingency (20%)				$ 41,812
	TOTAL CAPITAL COSTS				**$ 282,234**
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (14 Wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	year	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	year	$ 2,400
GW4	Sample Analysis and Data Validation (14 VOCs)	1	$ 7,600	year	$ 7,600
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	year	$ 4,200
SysOp	***System Operations and Maintenance***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (Annual Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 900	month	$ 10,800
SSDS	***Sub-Slab Depressurization System***				
SSDS4	SSDS O&M Costs	12	$ 107	month	$ 1,288
SSDS5	Air quality sampling	1	$ 600	year	$ 600
	Total Annual O&M Costs (Long-term monitoring)				**$ 71,188**
PRESENT WORTH OF COSTS					
	Total Capital Costs				$ 282,234
	Annual O&M Costs (Long term monitoring for 30 years)				$ 1,094,340
	TOTAL PRESENT WORTH				**$ 1,376,574**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,377,000**

Table 4-A4
Alternative 4: Enhanced Hydraulic Containment with Current System - Cost Estimate Summary
Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring/Pumping Well Installations (6 new wells)*	1	$ 93,370	LS	$ 93,370
BFE	*Bedrock Fracture Enhancement (2 wells)*	1	$ 12,715	LS	$ 12,715
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*Groundwater Monitoring FirstYear(quarterly)*	4	$ 22,000	LS	$ 88,000
	Subtotal Subcontractor Costs				**$ 239,218**
	General Contractor (15% subcontractor)				$ 35,883
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				**$ 275,101**
	Design Engineering (15% construction)				$ 41,265
	Contingency (20%)				$ 55,020
	TOTAL CAPITAL COSTS				**$ 371,386**
ANNUAL O&M COSTS					
MWI	***Annual Groundwater Monitoring (16 wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	quarter	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	quarter	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	quarter	$ 2,400
GW4	Sample Analysis and Data Validation (16 VOCs)	1	$ 8,300	quarter	$ 8,300
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	LS	$ 4,200
SysOp	***Treatment System O&M***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (System Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 1,200	month	$ 14,400
SSDS	***Sub-Slab Depressurization System***				
SSDS4	Depressurization System O&M	12	$ 107	month	$ 1,288
SSDS5	Air quality monitoring	1	$ 600	year	$ 600
	Total Annual O&M Costs (Long-term monitoring)				**$ 75,488**
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 371,386
	Annual O&M Costs (Long term monitoring for 30 years)				$ 1,160,442
	TOTAL PRESENT WORTH				**$ 1,531,828**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,532,000**

Table 4-A5
Alternative 5: In-Situ Oxidation - Cost Estimate Summary
Apple Valley Shopping Center-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (7 monitoring wells)*	1	$ 97,454	LS	$ 97,454
BFE	*Bedrock Fracture Enhancement (15 wells)*	1	$ 35,215	LS	$ 35,215
PT	*Pilot Test*	1	$ 65,332	LS	$ 65,332
ISDO	*In-Situ Direct Oxidation*	1	$ 331,600	LS	$ 331,600
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*GW Monitoring First Year (quarterly - VOCs/Metals/MNAs)*	4	$ 36,000	quarter	$ 144,000
	Subtotal Subcontractor Costs				**$ 718,734**
	General Contractor (15% subcontractor)				$ 107,810
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				$ 826,544
	Design Engineering (15% Construction)				$ 123,982
	Contingency (20%)				$ 165,309
	TOTAL CAPITAL COSTS				**$ 1,115,834**
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (17 wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 7,200	year	$ 7,200
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 3,200	year	$ 3,200
GW4	Sample Analysis and Data Validation (17 VOCs)	1	$ 8,650	year	$ 8,650
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	year	$ 4,200

Table 4-A5
Alternative 5: In-Situ Oxidation - Cost Estimate Summary
Apple Valley Shopping Center-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
	Total Annual O&M Costs				$ 24,950
OTHER COSTS (O&M on PT and SSDS for 5 years)					
SysOp	***Pumping and Treatment System O&M***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (System Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 900	month	$ 10,800
SSDS	***Sub-Slab Depressurization System***				
SSDS4	Sysops & O&M Costs	12	$ 107	month	$ 1,288
SSDS5	Air quality sampling	1	$ 600	year	$ 600
	Total Other Costs				$ 49,888
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 1,115,834
	Annual GW Monitoring Costs (20 year duration)				$ 310,932
	Annual Containment and SSDS O&M Costs (assumed 5 years)				$ 215,991
	TOTAL PRESENT WORTH				**$ 1,642,757**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,643,000**

APPENDIX A

Apple Valley Shopping Center Site- Feasibility study

Source area dewatering inflow calculations Method 2

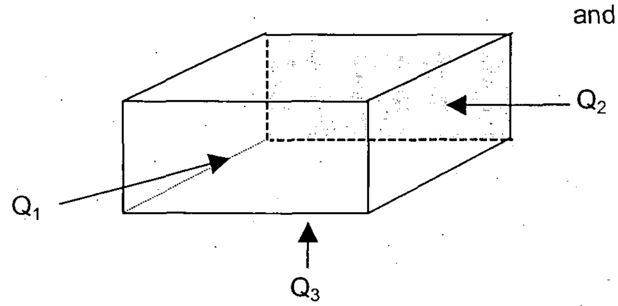
Given T =	300 ft²/day from pumping test analysis	for ~300 ft of aquifer
for b =	300 ft	
K =	1 ft/day	

Assume Dewatering over an area 240 x 80 ft², to depth of 100 ft below grade
and, wt@20ft dbg

b =	80	ft
T =	Kb =	80 ft²/day

Total flow into "the box" equals

$2 * Q_1 + 2 * Q_2 + Q_3 = 2 (Q1+Q2)$ where Q_1 = lateral flux through one long side (240 ft)
and Q_2 = lateral flux through one short side (80 ft)
and Q_3 = upward flux through floor (240x80 ft²)



Q_1 =	240*80 =	19200	ft³/day =	142618
Q_2 =	80*80 =	6400	ft³/day =	47539
Q_3 =	assumed to be zero			

Q_{total} =	380313.6	gpd =	**264 gpm**

Calculations based on assumption of a hydraulic gradient of 1 ft/ft with no upwelling.
Actual flow volume necessary to dewater source area would be considerably higher.

APPENDIX B

Table 2-A
Alternative 2: Monitored Natural Attenuation - Cost Estimate Summary
Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (Total cost of 4 wells)*	1	$ 51,460	LS	$ 51,460
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
	Subtotal Subcontractor Costs				$ 81,760
	General Contractor (15% subcontractor)				$ 12,264
	Subtotal Construction Costs				$ 94,024
	Groundwater Modeling & Design Engineering (15% construction)				$ 14,104
	Contingency (20%)				$ 18,805
	TOTAL CAPITAL COSTS				**$ 126,932**
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (14 Wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	year	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	year	$ 2,400
GW4	Sample Analysis and Data Validation (13 VOCs/MNAs)	1	$ 14,500	year	$ 14,500
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 8,400	year	$ 8,400
	Total Annual O&M Costs				**$ 32,400**
OTHER COSTS					
5YR	Five Year Review	1	$ 35,300	LS	$ 35,300
	Total Other Costs				**$35,300**
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 126,932
	Annual O&M Costs (30 year duration)				$ 498,067
	Five Year Review Costs (30 year duration)				$ 98,206
	Total Present Worth				**$ 723,205**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 723,000**

AGWM Annual Groundwater Monitoring (14 Wells)

Assume annual monitoring on long-term basis
Assume 14 monitoring wells to sample (4 new wells and 10 existing wells)
Existing 10 monitoring wells are assumed to be AV-1, AV-2, MW-1, MW-2, MW-3, MW-4a, MW-4b, MW-5 and two residential wells

No. GW1 Organization of Sampling Event (e.g., Staffing, Lab Procurement, Obtaining Equipment)

Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

=	$	40	per hour x	4	hours x	3 multiplier +
	$	30	per hour x	8	hours x	3 multiplier +
	$	20	per hour x	8	hours x	3 multiplier
=	$	1,680	per sampling event			
Assume:	**$**	**1,700**	**per sampling event**			

No. GW2 Sampling Labor

Assume 2 persons for 3 - 10 hour days @ $30 per hour
Assume 5 wells per day including purging and sampling
Two Sampling personnel and one Sample Management Organizer/Field Team Leader
Assume salary multiplier of 3

= 2 persons x 10 hours/day x 3 days x $ 30 / hour 3 multiplier
= $ **5,400 per sampling event**

No. GW3 Sampling Equipment

Assume sample shipping cost of $200 per day
Assume sampling equipment (e.g., bailers and pumps) @ $100 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $100 per day

Shipping	$	200	per day x	3 days =	$	600
Sampling Equipment	$	100	per day x	3 days =	$	300
Monitoring Equipment	$	100	per day x	3 days =	$	300
PPE	$	40	$20 per set/2 set /day x	3 days =	$	120
Vehicle Rental	$	70	per day x	3 days =	$	210
Per Diem	$	100	per person day/	6 man days=	$	600
Misc	$	100	per day x	3 days =	$	300
=	$	**2,430**	**per sampling event**			
Assume:	**$**	**2,400**	**per sampling event**			

No. GW4 Sampling Analysis and Validation

Assume groundwater samples will be collected from 13 monitoring wells; analyzed for VOCs and natural attenuation parameters

Total No. of Samples:	14 samples	
(at 20 per SDG)	1 field duplicate	1 per SDG
	2 MS	1per SDG per analysis suite
	2 MSD	1per SDG per analysis suite
	1 Field Blank	1 per SDG
	3 Trip Blanks	1 per day
	23 Total Samples Per Sampling Event	

Assume	$	150	per sample for VOC analysis by ASP-CLP with full Class B deliverables
	$	300	per sample for natural attenuation parameter analysis
	$	450	Total sample cost

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 46 hours x 3 multiplier + $ 4,140

Analysis Cost: 23 samples x $ 450
= $ 10,350 per sampling event

Total Analysis & Validation: $ 14,490
Assume: $ 14,500

No. GW5 Data Review & Reporting (Annual Monitoring Report)

Assume 2 senior engineers/chemists at $35 per hour for 80 hours per sampling event
Assume salary multiplier of 3

= 2 person x $ 35 per hour x 40 hours x 3 multiplier
= $ **8,400**

MWI Monitoring Well Installation (Total cost of 4 wells)

Assume the installation of 4 new bedorck monitoring wells along western site boundary

Bedrock assumed at 20 feet below grade
Water Table assumed at 20 feet below grade
All the wells are assumed to be 120 feet below grade - Approximately 100 below top of bedrock
Wells assumed to be open boreholes from rock socket to depth

Driller Procurement and Statement of Work Preparation

$	30	per hour x	40	hours x	3	multiplier =	$ 3,600

MWI1 Monitoring Well Installation

Assumes an average depth of 120 ft Total number of wells = 4

	12-inch borehole drilling (HSA to top of Bedrock)	20	ft	x	$	26	per LF	$	520
	8-inch borehole drilling (Air rotary, hammer, or cable)	100	ft	x	$	17	per LF	$	1,700
	8-inch carbon steel casing (from +3ft from grade to -5 ft into ı	28	ft	x	$	30	per LF	$	840
Assume	4-inch SS casing (top of screen to grade)	0	ft	x	$	30	per LF	$	-
open	Well completion materials	0	ft	x	$	8	per LF	$	-
borings	4-inch SS 10 slot screen	0	ft	x	$	55	per LF	$	-
	5' Steel protective casing	1	LS	x	$	225	each	$	225
	Well development (10 well volumes per well)	4	hr	x	$	160	per hr	$	640
	Decon of equipment (200 gallons - 4 drums per well)	1	hr	x	$	180	per hr	$	180
	Drum (decon & cuttings, includes drum, filling, and staging)	10	each	x	$	100	drum	$	1,000
							Total for One Well	$	**5,105**

Misc Items

Drum disposal (decon fluids)	40	each	x	$	120	each	$	4,800
Purge water disposal	10,400	gal	x	$	0.35	per gal	$	3,640
Driller oversight (@0.5 wells per day average rate)	8	day	x	$	1,000.00	per day	$	8,000
Driller mobilization	1	LS	x	$	2,000	each	$	2,000
Baker tank rental	1	tank	x	$	8,000	each	$	8,000
Contingency	1	LS	x	$	1,000	each	$	1,000
Total misc.							$	27,440

Total Cost	$	3,600	+	4	wells x	$	5,105 +	$	27,440	$ **51,460**

	Purge Volume calcs			Cuttings Volume calcs		
pi*r² (r=4")	0.348		ft²	0.348		
h (=dow-dwt)	100		ft	120		
#wells	4			4		
#well volumes	10			167.2		ft³
	1393.47	0.00	ft³		167.2	ft³
conversion factor	7.48	7.48	gal/ft³		6	yds³
	10423.17	0.00	gal		0.280970626	yd/drum
		10423.17	gal		22	drums

DR **Deed Restrictions**

Filing of the necessary paperwork to place deed restrictions
involves properties affected by the plume

Assume 1 persons for 1 month.
Assume salary rate of $60/hour.
Assume salary multiplier of 3.

=	1 person x	$	60 /hour x	40 hours/week x	4.2 weeks/month x	1 month x	3 multiplier
		= $	30,240				
	Assume:	$	**30,300**				

5YR Five Year Review

Assume 5-year reviews will be conducted every 5 years

Work includes: 5-year review of groundwater monitoring data and modeling
Preparation of report

Assume 2 persons for 1 month
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

= 2 persons x $ 35 /hour x 40 hours/week x 4.2 weeks/month x 1 month x 3 multiplier

= $ 35,280

Assume: $ 35,300

PWC PRESENT WORTH CALCULATIONS

Assume discount rate is 5%: **0.05**

No. 0 **Total Annual O&M Costs**

This is a recurring cost every year for 30 years
This is a problem of finding P given A, i, n, or (P/A,i,n)
P = Present Worth
A= Annual amount
i = interest rate
Assume 5%

$$P = A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

n =	30
i =	0.05
The multiplier is =	15.372

No. 0 **Total 5-year review costs**

This cost occurs every 5 years.

need to calculate the effective interest rate i_e

Given i = 5% (nominal interest rate)	0.05	
m= # of compounding periods = 5 years	5	
$i_e = (1+i)^m - 1$	0.276 =	28% / 5 years

$$P = A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

in this case there are 6 - 5yr periods

n = 6	6
i =	0.276
The multiplier is =	2.782

Table A-3
Alternative 3: Hydraulic Containment with Current System - Cost Estimate Summary
Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (Total cost of 4 wells)*	1	$ 51,460	LS	$ 51,460
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*Groundwater Monitoring First Year(quarterly)*	4	$ 21,300	quarter	$ 85,200
	Subtotal Subcontractor Costs				**$ 181,793**
	General Contractor (15% subcontractor)				$ 27,269
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				**$ 209,062**
	Design Engineering (15% construction)				$ 31,359
	Contingency (20%)				$ 41,812
	TOTAL CAPITAL COSTS				**$ 282,234**
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (14 Wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	year	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	year	$ 2,400
GW4	Sample Analysis and Data Validation (13 VOCs)	1	$ 7,600	year	$ 7,600
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	year	$ 4,200
SysOp	***System Operations and Maintenance***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (Annual Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 900	month	$ 10,800
SSDS	***Sub-Slab Depressurization System***				
SSDS4	SSDS O&M Costs	12	$ 107	month	$ 1,288
SSDS5	Air quality sampling	1	$ 600	year	$ 600
	Total Annual O&M Costs (Long-term monitoring)				**$ 71,188**
PRESENT WORTH OF COSTS					
	Total Capital Costs				$ 282,234
	Annual O&M Costs (Long term monitoring for 30 years)				$ 1,094,340
	TOTAL PRESENT WORTH				**$ 1,376,574**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,377,000**

MWI Monitoring Well Installation (Total cost of 4 wells)

Assume the installation of 4 new bedrock monitoring wells along western site boundary
Bedrock assumed at 20 feet below grade
Water Table assumed at 20 feet below grade
All the deep wells are assumed to be 120 feet below grade - Approximately 100 below top of bedrock

Driller Procurement and Statement of Work Preparation

$ 30	per hour x	40 hours x	3 multiplier =	$	**3,600**

Monitoring Well Installation
Assumes an average depth of 120 ft — Total number of wells = 4

	12-inch borehole drilling (HSA to top of Bedrock)	20	ft	x	$	26	per LF	$	520
	8-inch borehole drilling (Air rotary, hammer, or cable)	100	ft	x	$	17	per LF	$	1,700
	8-inch carbon steel casing (from +3ft to grade to 5 ft into	28	ft	x	$	30	per LF	$	840
assume	4-inch SS casing (top of screen to grade)	0	ft	x	$	30	per LF	$	-
open	Well completion materials	0	ft	x	$	8	per LF	$	-
borings	4-inch SS 10 slot screen	0	ft	x	$	55	per LF	$	-
	5' Steel protective casing	1	LS	x	$	225	each	$	225
	Well development (10 well volumes per well)	4	hr	x	$	160	per hr	$	640
	Decon of equipment (200 gallons - 4 drums per well)	1	hr	x	$	180	per hr	$	180
	Drum (decon & cuttings, includes drum, filling, and stagi	10	each	x	$	100	drum	$	1,000
							Total for One Well	$	**5,105**

Misc Items

	Drum disposal (decon fluids)	40	each	x	$	120	each	$	4,800
	Purge water disposal	10,400	gal	x	$	0.35	per gal	$	3,640
*	Driller oversight (@0.5 wells per day average rate)	8	day	x	$	1,000.00	per day	$	8,000
	Driller mobilization	1	LS	x	$	2,000	each	$	2,000
	Baker tank rental	1	tank	x	$	8,000	each	$	8,000
	Contingency	1	LS	x	$	1,000	each	$	1,000
	Total misc.							$	**27,440**

Total Cost	$ 3,600 +	4 wells x	$ 5,105 +	$ 27,440	$	**51,460**

* Oversight by Geologist/Scientist at $30 per hour for 10 hours per day at 3x multiplier with $100 per diem

Supporting Volume Calculations

	Purge Volume calcs			Cuttings Volume calcs		
pi*r² (r=4")	0.348		ft²	0.348		
h (=dow-dwt)	100		ft	120		
#wells	4			4		
#well volumes	10			167.2		ft³
	1393.47	0.00	ft³		167.2	ft³
conversion factor	7.48	7.48	gal/ft³	=	6	yds³
	10423.17	0.00	gal	@	0.2809706	yd/drum
	SUM	10423.17	gal	=	22	drums

AGWM Annual Groundwater Monitoring (14 Wells)

Assume annual monitoring on long-term basis
Assume 14 monitoring wells to sample (4 new wells and 10 existing wells)
Existing 10 monitoring wells are assumed to be AV-1, AV-2, MW-1, MW-2, MW-3, MW-4a, MW-4b, MW-5 and two residential wells

No. GW1 Organization of Sampling Event (e.g., Staffing, Lab Procurement, Obtaining Equipment)

Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

=	$	40	per hour x	4	hours x	3 multiplier +
	$	30	per hour x	8	hours x	3 multiplier +
	$	20	per hour x	8	hours x	3 multiplier
=	$	1,680	per sampling event			
Assume:	**$**	**1,700**	**per sampling event**			

No. GW2 Sampling Labor

Assume 2 persons for 3 - 10 hour days @ $30 per hour
Assume 5 wells per day including purging and sampling
Two Sampling personnel and one Sample Management Organizer/Field Team Leader
Assume salary multiplier of 3

=	2	persons x	10 hours/day ›	3	days x	$ 30 / hour	3 multiplier
=	$	**5,400**	**per sampling event**				

No. GW3 Sampling Equipment

Assume sample shipping cost of $200 per day
Assume sampling equipment (e.g., bailers and pumps) @ $100 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $100 per day

Shipping	$	200	per day x	3 days =	$	600
Sampling Equipment	$	100	per day x	3 days =	$	300
Monitoring Equipment	$	100	per day x	3 days =	$	300
PPE	$	40	$20 per set/2 set /day x	3 days =	$	120
Vehicle Rental	$	70	per day x	3 days =	$	210
Per Diem	$	100	per man-day/	6 man-days=	$	600
Misc	$	100	per day x	3 days =	$	300
=	$	**2,430**	**per sampling event**			
Assume:	**$**	**2,400**	**per sampling event**			

No. GW4 Sampling Analysis and Validation

Assume groundwater samples will be collected from 13 monitoring wells; analyzed for VOCs

Total No. of Samples:	14 samples	
(at 20 per SDG)	1 field duplicate	1 per SDG
	2 MS	1per SDG per analysis suite
	2 MSD	1per SDG per analysis suite
	1 Field Blank	1 per SDG
	3 Trip Blanks	1 per day
	23 Total Samples Per Sampling Event	

Assume	$	150	per sample for VOC analysis by ASP-CLP with full Class B deliverables
	$	-	per sample for natural attenuation parameter analysis
	$	150	Total sample cost

Assume samples validated @ 2 hrs per sample

$	30	per hour x	46	hours x	3 multiplier +	$ 4,140

Analysis Cost:	23	samples x	$	150
=	$	3,450	per sampling event	

Total Analysis & Validatioı	$	7,590
Assume:	**$**	**7,600**

No. GW5 Data Review & Reporting (Annual Monitoring)

Assume 2 senior engineers/chemists at $35 per hour for 40 hours per sampling event
Assume salary multiplier of 3

=	2	person x	$ 35	per hour x	20	hours x	3 multiplier
=	$	**4,200**					

SysOp System Operations and Maintenance

Assumes 1 visit per month to collect influent and effluent samples, system operations parameters and provide maintenance as needed. System continues to operate at 20gpm.

S01 Organization of Monthly Event (e.g., Staffing, Lab Procurement, Obtaining Equipment)
Assume 1 Project Manager @ $40 per hour for 1 hours
Assume 1 Engineer @ $30 per hour for 2 hours
Assume 1 Technician @ $20 per hour for 4 hours
Assume salary multiplier of 3

=	$	40	per hour x	1	hours x	3	multiplier	=	120
	$	30	per hour x	2	hours x	3	multiplier	=	180
	$	20	per hour x	4	hours x	3	multiplier	=	240
=	$	540	per sampling event						
Assume:	**$**	**500**	**per sampling event**						

S02 O&M Labor
Assume 1 persons for 1 - 10 hour day@ $20 per hour
Assume salary multiplier of 3

1 persons x 10 hours/day › 1 days x $ 20 / hour x 3 multiplier
= $ **600 per sampling event**

S03 Sampling Equipment
Assume sample shipping cost of $100 per day
Assume sampling equipment (e.g., bags, pumps) @ $50 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $25 per day

Shipping	$	100	per day x	1	days =	$	100
Sampling Equipment	$	25	per day x	1	days =	$	25
Monitoring Equipment	$	50	per day x	1	days =	$	50
PPE	$	20	$20 per set/2	1	days =	$	20
Vehicle Rental	$	70	per day x	1	days =	$	70
Per Diem	$	100	per person dɛ	1	man days=	$	100
Misc	$	25	per day x	1	days =	$	25

= $ **390 per sampling event**
Assume: $ 400 per sampling event

S04 Sampling Analysis and Validation (3 VOCs)
Assume 3 samples will be collected; analyzed for VOCs
Total No. of Samples: 3 Total Samples Per Sampling Event

Assume $ 150 per sample for VOC analysis by ASP-CLP with full Class B deliverables
$ 150 Total sample cost

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 6 hours x 3 multiplier + $ 540

Analysis C 3 samples x $ 150
= $ 450 per sampling event

Total Analysis & Validatio $ 990
Assume: $ 1,000

S05 Data Review & Reporting (Annual Monitoring)
Assume 1 senior engineers/chemists at $35 per hour for 40 hours per annual review
Assume 1 junior engineers/scientist at $25 per hour for 40 hours per annual review
Assume salary multiplier of 3

1	person x	$	35	per hour x	40	hours x	3 multiplier	$	4,200
1	person x	$	25	per hour x	40	hours x	3 multiplier	$	3,000

= $ **7,200**

S06 Other costs (electrical, replacement parts)
Electrical Usage fee 400 mo
Relplacement items 500 mo
= **$900**

Total System Operations Costs

SSDS **Sub-Slab Depressurization System** Installation and Operations

Assume retrofitting of existing structures with sub-slab depressurization system
Assume 1 well point and 1 100 watt blower per 1280 sq ft of building
Assume venting to outside with no treatment

SSDS1 **Sub-Slab Depress. Sys. Design and Installation**

Assume 1 Project Manager @ $40 per hour for 8 hours
Assume 1 Engineer @ $30 per hour for 24 hours
Assume 1 Technician @ $20 per hour for 8 hours per well point installing one vent per day
Licensed electrician at $100 per well point for blower hookups
Assume salary multiplier of 3
Labor

=	8 hrs x	$40 $/hr x	3 multiplier	=		$960
=	24 hrs x	$30 $/hr x	3 multiplier			$723
=	8 hrs x	$20 $/hr x	3 multiplier	x wellpoint	10 =	$4,800
=		$100 per well		xwells	10 =	$1,000
					Total Labor	$7,483

SSDS2 **Sub-Slab Depress. Sys. Materials**

Core drill	$100 day	10 days	$1,000
Blower unit	$200 point	10 points	$2,000
Plumbing fixtures	$50 point	10 points	$500
Roof vents and mounting	$120 point	10 points	$1,200
Slab sealant	$25 point	10 points	$250
		Total Equipment Cost	$4,950

SSDS3 **Building Air Quality Testing First Year (quarterly)**

2 sample x	$300 x	4 quarters	=	$2,400
			Total Installation cost	**$14,833**

SSDS4 **SSDS O&M Costs**

Electricity

10	blowers x	100	watts@	=	24	kw-hr/day	=	8760	kw-hr/yr	
								0.09	/kw	
								$788	yr	
								Monthly Electric Usage		**$66**
Maintenance (assume $500 per year)										**$42**
								Total System O&M		**$107**

SSDS5 **Air quality sampling**

Assume 1 air sample per year per building, collected as part of treatment system O&M

2 sample x	$300 x	1 year	=	**$600**

DR Deed Restrictions

Filing of the necessary paperwork to place deed restrictions
involves properties affected by the plume

Assume 1 persons for 1 month.
Assume salary rate of $60/hour.
Assume salary multiplier of 3.

= 1 person x $ 60 /hour x 40 hours/week x 4.2 weeks/month : 1 month x 3 multiplier

= $ 30,240

Assume: $ 30,300

Present Worth Calculations

Assume discount rate is 5%: **0.05**

No. 0 **Total Annual O&M Costs**

This is a recurring cost every year for 30 years
This is a problem of finding P given A, i, n, or (P/A,i,n)
P = Present Worth
A= Annual amount
i = interest rate
Assume 5%

$$P = A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

n =	30
i =	0.050
The multiplier is =	15.372

Table A-4

Alternative 4: Enhanced Hydraulic Containment with Current System - Cost Estimate Summary

Apple Valley Shopping Center Site-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring/Pumping Well Installations (6 new wells)*	1	$ 93,370	LS	$ 93,370
BFE	*Bedrock Fracture Enhancement (2 wells)*	1	$ 12,715	LS	$ 12,715
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*Groundwater Monitoring FirstYear(quarterly)*	4	$ 22,000	LS	$ 88,000
	Subtotal Subcontractor Costs				**$ 239,218**
	General Contractor (15% subcontractor)				$ 35,883
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				**$ 275,101**
	Design Engineering (15% construction)				$ 41,265
	Contingency (20%)				$ 55,020
	TOTAL CAPITAL COSTS				**$ 371,386**
ANNUAL O&M COSTS					
MWI	***Annual Groundwater Monitoring (16 wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	quarter	$ 1,700
GW2	Field Sampling Labor	1	$ 5,400	quarter	$ 5,400
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 2,400	quarter	$ 2,400
GW4	Sample Analysis and Data Validation (15 VOCs)	1	$ 8,300	quarter	$ 8,300
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	LS	$ 4,200
SysOp	***Treatment System O&M***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (System Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 1,200	month	$ 14,400
SSDS	***Sub-Slab Depressurization System***				
SSDS4	Depressurization System O&M	12	$ 107	month	$ 1,288
SSDS5	Air quality monitoring	1	$ 600	year	$ 600
	Total Annual O&M Costs (Long-term monitoring)				$ 75,488
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 371,386
	Annual O&M Costs (Long term monitoring for 30 years)				$ 1,160,442
	TOTAL PRESENT WORTH				**$ 1,531,828**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,532,000**

MWI Monitoring/Pumping Well Installations (6 new wells)

Assume the installation of 4 new monitoring wells along western site boundary, and
Assume 2 new pumping wells to enhance capture zone
Assume Bedrock at 20' below grade
Assume WT at 20' below grade
All wells are assumed to be 120' each
Capture zone enhancement wells assumed to be up to 120' each

Driller Procurement and Statement of Work Preparation

$ 30 per hour x	40 hours x	3 multiplier =	$	3,600

Shallow and Deep Site-Boundary Monitoring Wells

Assumes an average depth of 120 ft Total Number of Wells 4

12-inch borehole drilling (HSA to top of Bedrock)	20 ft	x	$ 26	per LF	$	520
8-inch borehole drilling (Air rotary, hammer, or cable)	100 ft	x	$ 17	per LF	$	1,700
8-inch carbon steel casing (from grade to 5 ft into rock)	28 ft	x	$ 30	per LF	$	840
[assume open borings] 4-inch SS casing (top of screen to grade)	0 ft	x	$ 30	per LF	$	-
[assume open borings] Well completion materials	0 ft	x	$ 8	per LF	$	-
[assume open borings] 4-inch SS 10 slot screen	0 ft	x	$ 55	per LF	$	-
5' Steel protective casing	1 LS	x	$ 225	each	$	225
Well development (3 well volumes per well)	4 hr	x	$ 160	per hr	$	640
Decon of equipment (200 gallons per well)	1 hr	x	$ 180	per hr	$	180
Drum (Cuttings and Decon, includes filling, staging)	10 each	x	$ 100	per hr	$	1,000
				Total for One Monitoring Well	**$**	**5,105**

Capture Zone Enhancement Wells

Assume an average depth of 120 ft Total Number of Wells 2

12-inch borehole drilling (HSA to top of Bedrock)	20 ft	x	$ 26	per LF	$	520
8-inch borehole drilling (Air rotary, hammer, or cable)	100 ft	x	$ 17	per LF	$	1,700
8-inch carbon steel casing (from grade to 5 ft into rock)	28 ft	x	$ 30	per LF	$	840
4-inch SS casing (top of screen to grade)	110 ft	x	$ 30	per LF	$	3,300
Well completion materials	120 ft	x	$ 8	per LF	$	960
4-inch SS 10 slot screen (2 5ft sections per well)	10 ft	x	$ 55	per LF	$	550
5' Steel protective casing	1 LS	x	$ 225	each	$	225
Well development (10 well volumes per well)	4 hr	x	$ 160	per hr	$	640
Decon of equipment (200 gallons - 4 drums per well)	1 hr	x	$ 180	per hr	$	180
Drum (decon & cuttings, includes drum, filling, and sta	10 each	x	$ 100	drum	$	1,000
				Total for One Capture Enhancement Well	**$**	**9,915**

Misc Items

Drum disposal (decon fluids and cuttings)	60 each	x	$ 120	each	$	7,200
Decon water & decon fluid disposal	15200 gal	x	$ 0.35	per gal	$	5,320
Driller oversight	12 day	x	$ 1,000.00	per day	$	12,000
Driller mobilization	1 LS	x	$ 2,000	each	$	2,000
Baker tank rental	1 tank	x	$ 8,000	each	$	8,000
Downhole Geophysics (caliper, video, gamma logs)	2 each	x	$ 2,500	well	$	5,000
Packer Tests	2 each	x	$ 2,500	well	$	5,000
Pumps&fittings (for containmant wells)	2 each	x	$ 1,000	well	$	2,000
Trench &piping (from wells to treatment system)	2 each	x	$ 1,000	well	$	2,000
Plumbing hook ups (licensed plumber at $100/hr)	1 ls	x	$ 500	ls	$	500
Electrical hook ups(licensed electrician @$100/hr)	1 ls	x	$ 500	ls	$	500
				Total misc.	**$**	**49,520**
				Total Cost	**$**	**93,370**

Support Calulations

	Purge Volume calcs (wt at 20' bg)				Cuttings Volume			
pi*r² (r=4")	0.348	0.348	0.348	ft²	0.348	0.348	0.348	
h		100	100	ft		120	120	
#wells		4	2			4	2	
#well volumes		10	10			1	1	
	0.00	1393.47	696.74	ft³	0.35	167.22	83.61	250.83 ft³
conversion factor	7.25	7.25	7.25	gal/ft³				ft³
	0.00	10102.67	5051.34		0	6	3.10	9.29 yds³
			15154	gallons		22	11	33 drums

BFE Bedrock Fracture Enhancement (2 wells)

Pneumatic Fracturing is assumed for fracture enhancement at the site.
It is assumed that the two containment enhancement wells would be pneumatically fractured.

Pre-mobilization Coordination	1	x	$1,000	event	=	$1,000
Technical Support/Project Report Addendum's	1	x	$2,000	event	=	$2,000
Mobilization/Demobilization	1	x	$715	event	=	$715
Contractor Oversight of fracturing procedures	2	x	$1,000	days	=	$2,000
Pneumatic Fracturing Operations	2	x	$1,500	well	=	$3,000
Data Evaluation	2	x	$2,000	days	=	$4,000
Total Bedrock Fracture Enhancement Cost						**$12,715**

SysOp Treatment System O&M

Assumes 1 visit per month to collect influent and effluent samples, system operations parameters and provide maintenance as needed. System continues to operate at 20gpm.

S01 Organization of Monthly Event (e.g., Staffing, Lab Procurement, Obtaining Equipment)
Assume 1 Project Manager @ $40 per hour for 1 hours
Assume 1 Engineer @ $30 per hour for 2 hours
Assume 1 Technician @ $20 per hour for 4 hours
Assume salary multiplier of 3

=	$	40	per hour x	1	hours x	3	multiplier +
	$	30	per hour x	2	hours x	3	multiplier +
	$	20	per hour x	4	hours x	3	multiplier
=	$	540	per sampling event				
Assume:	**$**	**500**	**per sampling event**				

S02 O&M Labor
Assume 1 persons for 1 - 10 hour day @ $20 per hour
Assume salary multiplier of 3

1 persons x 10 hours/day 1 days x $ 20 / hour x 3 multiplier
= $ **600 per sampling event**

S03 Sampling Equipment
Assume sample shipping cost of $100 per day
Assume sampling equipment (e.g., bags, pumps) @ $50 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $25 per day

Shipping	$	100	per day x	1	days =	$	100
Sampling Equipment	$	25	per day x	1	days =	$	25
Monitoring Equipment	$	50	per day x	1	days =	$	50
PPE	$	20	$20 per set	1	days =	$	20
Vehicle Rental	$	70	per day x	1	days =	$	70
Per Diem	$	100	per person	1	man days	$	100
Misc	$	25	per day x	1	days =	$	25

= $ **390 per sampling event**
Assume: $ 400 per sampling event

S04 Sampling Analysis and Validation (3 VOCs)
Assume 3 samples will be collected; analyzed for VOCs
Total No. of Samples: 3 Total Samples Per Sampling Event

Assume $ 150 per sample for VOC analysis by ASP-CLP with full Class B deliverables
$ 150 Total sample cost

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 6 hours x 3 multiplier + $ 540

Analysis (3 samples x $ 150
= $ 450 per sampling event

Total Analysis & Valid $ 990
Assume: $ 1,000

S05 Data Review & Reporting (System Monitoring)
Assume 1senior engineers/chemists at $35 per hour for 40 hours per sampling event
Assume 1junior engineer/scientist at $25 per hour for 40 hours per sampling event
Assume salary multiplier of 3

1	person x	$	35	per hour x	40	hours x	3	multiplier	= $4,200
1	person x	$	25	per hour x	40	hours x	3	multiplier	= $3,000

= $ 7,200

S06 Other costs (electrical, replacement parts)

Electrical Usage fee	700	mo
Relplacement items	500	mo
=	$1,200	

SSDS **Sub-Slab Depressurization System**

Assume retrofitting of existing structures with sub-slab depressurization system
Assume 1 well point and 1 100 watt blower per 1280 sq ft of building
Assume venting to outside with no treatment

SSDS1 **Sub-Slab Depress. Sys. Design and Installation**

Assume 1 Project Manager @ $40 per hour for 8 hours
Assume 1 Engineer @ $30 per hour for 24 hours
Assume 1 Technician @ $20 per hour for 8 hours per well point installing one vent per day
Licensed electrician at $100 per well point for blower hookups
Assume salary multiplier of 3

Labor

=	8 hrs x	$40 $/hr x	3 multiplier	=		$960
=	24 hrs x	$30 $/hr x	3 multiplier			$723
=	8 hrs x	$20 $/hr x	3 multiplier	x wellpoint	10 =	$4,800
=		$100 per well		xwells	10 =	$1,000
					Total Labor	$7,483

SSDS2 **Sub-Slab Depress. Sys. Materials**

Core drill	$100 day	10 days	$1,000
Blower unit	$200 point	10 points	$2,000
Plumbing fixtures	$50 point	10 points	$500
Roof vents and mounting	$120 point	10 points	$1,200
Slab sealant	$25 point	10 points	$250
		Total Equipment Cost	$4,950
		Total Installation cost	**$12,433**

SSDS3 **Building Air Quality Testing First Year (quarterly)**

2 sample x	$300 x	4 quarters	=	$2,400

SSDS4 **Depressurization System O&M**

Electricity

10	blowers x	100	watts@	=	24	kw-hr/day	=	8760	kw-hr/yr	
								0.09	/kw	
								$788	yr	
								Monthly Electric Usage		$66
Maintenance (assume $500 per year)										**$42**
								Total System O&M		**$107**

SSDS5 **Air quality monitoring**

Assume 1 air sample per year per building, collected as part of treatment system O&M

2 sample x	$300 x	1 year	=	**$600**

AGWM Annual Groundwater Monitoring (16 wells)

Assume annually monitoring on long-term basis
Assume 16 monitoring wells to be sampled (6 new wells, 10 existing wells)
Existing 10 monitoring wells are assumed to be AV-1, AV-2, MW-1, MW-2, MW-3, MW-4a, MW-4b, MW-5 and two residential wells

No. GW1 Organization of Sampling Event (e.g., Staffing, Lab Procurement, Obtaining Equipment)

Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

=	$	40	per hour x	4	hours x	3	multiplier +
	$	30	per hour x	8	hours x	3	multiplier +
	$	20	per hour x	8	hours x	3	multiplier
=	$	1,680	per sampling event				
Assume:	**$**	**1,700**	**per sampling event**				

No. GW2 Sampling Labor

Assume 2 persons for 3 - 10 hour days @ $30 per hour
Assume 5 wells per day including purging and sampling
Two Sampling personnel and one Sample Management Organizer/Field Team Leader
Assume salary multiplier of 3

= 2 persons x 10 hours/day x 3 days x $ 30 / hour 3 multiplier
= $ **5,400 per sampling event**

No. GW3 Sampling Equipment

Assume sample shipping cost of $200 per day
Assume sampling equipment (e.g., bailers and pumps) @ $100 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $100 per day

Shipping	$	200	per day x	3	days =	$	600
Sampling Equipment	$	100	per day x	3	days =	$	300
Monitoring Equipment	$	100	per day x	3	days =	$	300
PPE	$	40	$20 per set/2 set /da	3	days =	$	120
Vehicle Rental	$	70	per day x	3	days =	$	210
Per Diem	$	100	Per person/day	6	man days =	$	600
Misc	$	100	per day x	3	days =	$	300
=	$	2,430	**per sampling event**				
Assume:	**$**	**2,400**	**per sampling event**				

No. GW4 Sampling Analysis and Validation

Assume groundwater samples will be collected from 16 wells; analyzed for VOCs

Total No. of Samples:	16 samples	
	1 field duplicate	
	2 MS	1per SDG per analysis suite
	2 MSD	1per SDG per analysis suite
	1 Field Blank	
	3 Trip Blanks	
	25 Total Samples Per Sampling Event	

Assume	$	150	per sample for VOC analysis by ASP-CLP with full Class B deliverables
		-	per sample for natural attenuation parameter analysis
	$	150	Total sample cost

Validation Cost:

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 50 hours x 3 multiplier
= $ 4,500

Analysis Cost: 25 samples x $ 150
= $ 3,750 per sampling event

Total Analysis & Validatior $ 8,250
Assume: $ 8,300

No. GW5 Data Review & Reporting

Assume 2 senior engineers/chemists at $35 per hour for 40 hours per sampling event
Assume salary multiplier of 3

2 person x $ 35 per hour x 20 hours x 3 multiplier
= $ **4,200 per sampling event**

DR Deed Restrictions

Filing of the necessary paperwork to place deed restrictions
involves properties affected by the plume

Assume 1 persons for 1 month.
Assume salary rate of $60/hour.
Assume salary multiplier of 3.

= 1 person x $ 60 /hour x 40 hours/week x 4.2 weeks/month : 1 month x 3 multiplier

= $ 30,240

Assume: $ 30,300

PRESENT WORTH CALCULATIONS

Assume discount rate is 5%: **0.05**

No. 0 **Total Annual O&M Costs**

This is a recurring cost every year for 30 years
This is a problem of finding P given A, i, n, or (P/A,i,n)
P = Present Worth
A= Annual amount
i = interest rate
Assume 5%

$$P = A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

n =	30
i =	0.050
The multiplier is =	15.372

Table A-5
Alternative 5: In-Situ Oxidation - Cost Estimate Summary
Apple Valley Shopping Center-Feasibility Study

Item	Item Description	Quantity	Unit Cost	Unit	Extension
CAPITAL COSTS					
Subcontractor Costs					
MWI	*Monitoring Well Installation (7 monitoring wells)*	1	$ 97,454	LS	$ 97,454
BFE	*Bedrock Fracture Enhancement (15 wells)*	1	$ 35,215	LS	$ 35,215
PT	*Pilot Test*	1	$ 65,332	LS	$ 65,332
ISDO	*In-Situ Direct Oxidation*	1	$ 331,600	LS	$ 331,600
SSDS1	*Sub-Slab Depress. Sys. Design and Installation*	1	$ 7,483	LS	$ 7,483
SSDS2	*Sub-Slab Depress. Sys. Materials*	1	$ 4,950	LS	$ 4,950
SSDS3	*Building Air Quality Testing First Year (quarterly)*	1	$ 2,400	LS	$ 2,400
DR	*Deed Restrictions*	1	$ 30,300	LS	$ 30,300
GWM	*GW Monitoring First Year (quarterly - VOCs/Metals/MNAs)*	4	$ 36,000	quarter	$ 144,000
	Subtotal Subcontractor Costs				**$ 718,734**
	General Contractor (15% subcontractor)				$ 107,810
	Subtotal Construction Costs (Subcontractor + Gen. Contr.)				**$ 826,544**
	Design Engineering (15% Construction)				$ 123,982
	Contingency (20%)				$ 165,309
	TOTAL CAPITAL COSTS				**$ 1,115,834**
ANNUAL O&M COSTS					
AGWM	***Annual Groundwater Monitoring (17 wells)***				
GW1	Project Planning and Organizing	1	$ 1,700	year	$ 1,700
GW2	Field Sampling Labor	1	$ 7,200	year	$ 7,200
GW3	Sampling Equipment, Shipping, Consumable Supplies	1	$ 3,200	year	$ 3,200
GW4	Sample Analysis and Data Validation (17 VOCs)	1	$ 8,650	year	$ 8,650
GW5	Data Evaluation and Reporting (Annual Report)	1	$ 4,200	year	$ 4,200
	Total Annual O&M Costs				**$ 24,950**
OTHER COSTS (O&M on PT and SSDS for 5 years)					
SysOp	***Pumping and Treatment System O&M***				
S01	Organization of Monthly Event	12	$ 500	month	$ 6,000
S02	O&M Labor	12	$ 600	month	$ 7,200
S03	Sampling Equipment	12	$ 400	month	$ 4,800
S04	Sampling Analysis and Validation (3 VOCs)	12	$ 1,000	month	$ 12,000
S05	Data Review & Reporting (System Monitoring)	1	$ 7,200	year	$ 7,200
S06	Other costs (electrical, replacement parts)	12	$ 900	month	$ 10,800
SSDS	***Sub-Slab Depressurization System***				
SSDS4	Sysops & O&M Costs	12	$ 107	month	$ 1,288
SSDS5	Air quality sampling	1	$ 600	year	$ 600
	Total Other Costs				**$ 49,888**
PRESENT WORTH CALCULATIONS					
	Total Capital Costs				$ 1,115,834
	Annual GW Monitoring Costs (20 year duration)				$ 310,932
	Annual Containment and SSDS O&M Costs (assumed 5 years)				$ 215,991
	TOTAL PRESENT WORTH				**$ 1,642,757**
	COST TO IMPLEMENT REMEDIAL ACTION ALTERNATIVE			**Assume:**	**$ 1,643,000**

MWI **Monitoring Well Installation (7 monitoring wells)**

Assume installation of 4 new property boundary monitoring wells along western site boundary
Assume installation of 3 new wells to monitor the unfractured zone below the fracture enhanced zone

Property Boundary wells are assumed to be 120' each
Unfractured zone deep wells are assumed to be 150' each

Driller Procurement and Statement of Work Preparation

$ 30	per hour x	40	hours x	3 multiplier =	$	3,600

Shallow and Deep Site-Boundary Monitoring Wells
Assumes an average depth of 120 ft — Total Number of Wells: 4

12-inch borehole drilling (HSA to top of Bedrock)	20 ft	x	$	26 per LF	$	520
8-inch borehole drilling (Air rotary, hammer, or cable)	100 ft	x	$	17 per LF	$	1,700
8-inch carbon steel casing (from grade to 5 ft into rock)	28 ft	x	$	30 per LF	$	840
assume open borings: 4-inch SS casing (top of screen to grade)	0 ft	x	$	30 per LF	$	-
Well completion materials	0 ft	x	$	8 per LF	$	-
4-inch SS 10 slot screen	0 ft	x	$	55 per LF	$	-
5' Steel protective casing	1 LS	x	$	225 each	$	225
Well development (3 well volumes per well)	4 hr	x	$	160 per hr	$	640
Decon of equipment (200 gallons per well)	1 hr	x	$	180 per hr	$	180
Drum (decon & cuttings, includes drum, filling, and stagi	10 each	x	$	100 drum	$	1,000
Total for One Well				Cost per Property Boundary Well	$	5,105

Capture Zone Enhancement Wells
Assume an average depth of 120 ft — Total Number of Wells: 0

12-inch borehole drilling (HSA to top of Bedrock)	0 ft	x	$	26 per LF	$	-
8-inch borehole drilling (Air rotary, hammer, or cable)	0 ft	x	$	17 per LF	$	-
8-inch carbon steel casing (from grade to 5 ft into rock)	0 ft	x	$	30 per LF	$	-
4-inch SS casing (top of screen to grade)	0 ft	x	$	30 per LF	$	-
Well completion materials	0 ft	x	$	8 per LF	$	-
4-inch SS 10 slot screen (2 5ft sections per well)	0 ft	x	$	55 per LF	$	-
5' Steel protective casing	0 LS	x	$	225 each	$	-
Well development (10 well volumes per well)	0 hr	x	$	160 per hr	$	-
Decon of equipment (200 gallons - 4 drums per well)	0 hr	x	$	180 per hr	$	-
Drum (decon & cuttings, includes drum, filling, and stagi	0 each	x	$	100 drum	$	-
				Cost Per Captzure Zone Enhancement Well	$	-

Unfractured Zone Monitoring Well
Assume an average depth of 150 ft — Total Number of Wells: 3

12-inch borehole drilling (HSA to top of Bedrock)	20 ft	x	$	26 per LF	$	520
8-inch borehole drilling (Air rotary, hammer, or cable)	130 ft	x	$	17 per LF	$	2,210
8-inch carbon steel casing (from grade to 5 ft into rock)	25 ft	x	$	30 per LF	$	750
4-inch SS casing (top of screen to grade)	140 ft	x	$	30 per LF	$	4,200
Well completion materials	150 ft	x	$	8 per LF	$	1,200
4-inch SS 10 slot screen	10 ft	x	$	55 per LF	$	550
5' Steel protective casing	1 LS	x	$	225 each	$	225
Well development (3 well volumes per well)	4 hr	x	$	160 per hr	$	640
Decon of equipment (200 gallons per well)	1 hr	x	$	180 per hr	$	180
Drum (Cuttings and decon, includes filling, staging)	11 each	x	$	100 per hr	$	1,100
Total for One Well				Cost per deep unfractured zone well	$	11,575

Miscellaneous Items

Drum disposal (decon fluids and cuttings)	64 each	x	$	120 each	$	7,680
Decon water & decon fluid disposal	25797 gal	x	$	0.35 per gal	$	9,029
Driller oversight	11 day	x	$	1,000.00 per day	$	11,000
Driller mobilization	1 LS	x	$	2,000 each	$	2,000
Baker tank rental	1 tank	x	$	8,000 each	$	8,000
Contingency	1 LS	x	$	1,000 each	$	1,000
				Total misc.	$	38,709
Total Cost				TOTAL WELL INSTALLATIONS COST	$	97,454

	Purge volume calcs (assumes wt at 20' bg)				Cuttings			
pi*r² (r=4")	0.348	0.348	0.348	ft²	0.348	0.348	0.348	
h		100	130	ft	120	120	150	
#wells		6	3		2	4	3	
#well volumes		10	10		1	1	1	
	0.00	2090.21	1358.64	ft³	83.61	167.22	156.77	ft³
conversion factor	7.48	7.48	7.48	gal/ft³				ft³
	0.00	15634.76	10162.59		3.10	6.19	5.81	yds³
			25797	gallons			0.28	yd/drum
					11	22	21	43 drums

BFE Bedrock Fracture Enhancement (15 wells)

BFE1 Capture Zone Enhancement well fracturing

Pre-mobilization Coordination	0	x	$1,000	event	=	$0
Technical Support/Project Report Addendum's	0	x	$2,000	event	=	$0
Mobilization/Demobilization	0	x	$715	event	=	$0
Contractor Oversight of fracturing procedures	0	x	$1,000	days	=	$0
Pneumatic Fracturing Operations	0	x	$1,500	well	=	$0
Data Evaluation	0	x	$2,000	days	=	$0
Sub Total MWI Bedrock Fracture Enhancement Cost						**$0**

BFE2 Injection Well Fracturing

Pneumatic Fracturing is assumed for fracture enhancement at the site.
It is assumed that 15 pneumatic fracturing locations are required.

Pre-mobilization Coordination	1	x	$1,000	event	=	$1,000
Technical Support/Project Report Addendum's	1	x	$2,000	event	=	$2,000
Mobilization/Demobilization	1	x	$715	event	=	$715
Contractor Oversight of Well Installation	5	x	$1,000	days	=	$5,000
Pneumatic Fracturing Operations	15	x	$1,500	well	=	$22,500
Data Evaluation	2	x	$2,000	days	=	$4,000
SubTotal Injection Well Bedrock Fracture Enhancement Cost						**$35,215**

TOTAL BFE Costs $35,215

SSDS **Sub-Slab Depressurization System**

Assume retrofitting of existing structures with sub-slab depressurization system
Assume 1 well point and 1 100 watt blower per 1280 sq ft of building
Assume venting to outside with no treatment

SSDS Sub-Slab Depress. Sys. Design and Installation

Assume 1 Project Manager @ $40 per hour for 8 hours
Assume 1 Engineer @ $30 per hour for 24 hours
Assume 1 Technician @ $20 per hour for 8 hours per well point installing one vent per day
Licensed electrician at $100 per well point for blower hookups
Assume salary multiplier of 3
Labor

=	8 hrs x	$40 $/hr x	3 multiplier	=		$960
=	24 hrs x	$30 $/hr x	3 multiplier			$723
=	8 hrs x	$20 $/hr x	3 multiplier	x wellpoin	10 =	$4,800
=		$100 per well		xwells	10 =	$1,000
					Total Labor	$7,483

SSDS2 Sub-Slab Depress. Sys. Materials

Core drill	$100 day	10 days	$1,000
Blower unit	$200 point	10 points	$2,000
Plumbing fixtures	$50 point	10 points	$500
Roof vents and mounting	$120 point	10 points	$1,200
Slab sealant	$25 point	10 points	$250
		Total Equipment Cost	$4,950
		Total Installation cost	**$12,433**

SSDS3 **Building Air Quality Testing First Year (quarterly)**

2 sample x $300 x 4 quarters = $2,400

SSDS4 **Sysops & O&M Costs**

Electricity

10	blowers x	100	watts@	=	24	kw-hr/day	=	8760	kw-hr/yr
								0.09	/kw
								$788	yr

Monthly Electric Usage **$66**

Maintenance (assume $500 per year) **$42**

Total System O&M **$107**

SSDS5 **Air quality sampling**

Assume 1 air sample per year per building, collected as part of treatment system O&M

2 sample x $300 x 1 year = **$600**

SysOp Pumping and Treatment System O&M

Assumes 1 visit per month to collect influent and effluent samples, system operations parameters and provide maintenance as needed. System continues to operate at 20gpm.

S01 Organization of Monthly Even (e.g., Staffing, Lab Procurement, Obtaining Equipment)
Assume 1 Project Manager @ $40 per hour for 1 hours
Assume 1 Engineer @ $30 per hour for 2 hours
Assume 1 Technician @ $20 per hour for 4 hours
Assume salary multiplier of 3

=	$	40	per hour x	1	hours x	3	multiplier +
	$	30	per hour x	2	hours x	3	multiplier +
	$	20	per hour x	4	hours x	3	multiplier
=	$	540	per sampling event				
Assume:	**$**	**500**	**per sampling event**				

S02 O&M Labor
Assume 1 persons for 7 - 10 hour days @ $20 per hour
Assume salary multiplier of 3

1	persons x	10	hours/da	1	days x	$	20	/ hour x	3 multiplier
= $	600	**per sampling event**							

S03 Sampling Equipment
Assume sample shipping cost of $100 per day
Assume sampling equipment (e.g., bags, pumps) @ $50 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $25 per day

Shipping	$	100	per day x	1	days =	$	100
Sampling Equipment	$	25	per day x	1	days =	$	25
Monitoring Equipment	$	50	per day x	1	days =	$	50
PPE	$	20	$20 per se	1	days =	$	20
Vehicle Rental	$	70	per day x	1	days =	$	70
Per Diem	$	100	per person	1	man day:	$	100
Misc	$	25	per day x	1	days =	$	25
=	**$**	**390**	**per sampling event**				
Assume:	**$**	**400**	**per sampling event**				

S04 Sampling Analysis and Validation (3 VOCs)
Assume 3 samples will be collected; analyzed for VOCs
Total No. of Samples: 3 Total Samples Per Sampling Event

Assume $ 150 per sample for VOC analysis by ASP-CLP with full Class B deliverables
$ 150 Total sample cost

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 6 hours x 3 multiplier + $ 540

Analysis 3 samples x $ 150
= $ 450 per sampling event

Total Analysis & Val: $ 990
Assume: $ 1,000

S05 Data Review & Reporting (System Monitoring)
Assume 1 senior engineers/chemists at $35 per hour for 40 hours per sampling event
Assume 1senior engineers/chemists at $25 per hour for 40 hours per sampling event
Assume salary multiplier of 3

1	person x	$	35	per hour ›	40	hours x	3 multiplie	= $4,200
1	person x	$	25	per hour ›	40	hours x	3 multiplie	= $3,000
= $	7,200							

S06 Other costs (electrical, replacement parts)
Electrical Usage fee 400 mo
Relplacement items 500 mo
= $900

PT Pilot Test

Assume Permanganate is the selected oxidation reagent
Cost of fracturing injection wells include in cost of Full-scale DO Program

Permanganate Reagent Pilot Study Cost

Design Cost	1	ls	x	$4,160	ls	$4,160
(Includes Injection System Design, Work Plan, H&S Plan)						
Installation of Injection Wells/Points						
Permanganate Reagent Injection Well/Point cost						
Number of Well Injection Points	1					
Number of Observation Points	3					
Installation of Injection Wells/Points	4	unit	x	$5,000	each	$20,000
Speciality subcontractor oversight	8	day	x	$1,000	each	$8,000
Permanganate Reagent Injection costs						
Chemical cost	2,300	lb	x	$4.00	each	$9,200
Engineering Services	1	ls	x	$5,850	each	$5,850
Equipment Cost	3	day	x	$700	each	$2,100

Sampling Program - Permanganate Reagent Treatment Area
Assume 3 samples to be collected and analyzed from each of the 4 sampling locations (injection well and three observation wells) within treatment area
Pre-injection; 7 days after; 30 days after original injection

Total # of samples	12					
VOCs	12	Sampl	x	$150	per sample	$1,800

Sampling Labor
Assume 4 groundwater samples per day
2 technicans provided by the contractor

=	2 people	x	$50 /hr	x	3	days	8 hr/day	$2,400
Shipping costs			$200 /day	x	3	days		$600

Project Documentation	1	ls	x	$3,450	ls	$3,450
(Includes Effectiveness Evaluation Report, Injector Construction Details, Monitoring Data)						
Mobilization and Demobilzation	1	ls	x	$7,772	per sample	$7,772
Total Pilot Study Cost						**$65,332**

PERMANGANATE QUANITIY ESTIMATE

Permanganate quantity calculations
Assume Impact zone at 20' radius circle
Assume DNAPL in 1% of available pore space of impact zone from 50-90 feet below grade.
Assume Effective porosity of rock at 1%
Volume of DNAPL = 20^2 x pi x 40ft x 0.01 x .01 = 5 ft^3

36.24	gallons		
1.62	sg	=	12.96 lbs per gallon
469.67	pounds		
2300.0	5:1	recommended stocihiometric factor	
34500	15	TOTAL REAGENT needed to oxidize DNAPL	

ISDO In-Situ Direct Oxidation

Assume a general construction contractor to perform the work
For cost purposes, permangante is the assumed agent
Assume 3 samples to be collected and analyzed from each of the 15 injection locations within treatment area
Pre-injection; 7 days after; 30 days after original injection

Permanganate Reagent Injection Cost for Entire Site

Installation of Injection Wells/Points
Permanganate Reagent Injection Well/Point cost

Total Number of Well Injection Points	15	-		4	Wells installed in pilot test		
Installation of Injection Wells/Points	11	unit	x	$5,000	each		$55,000
Injection Well Installation Oversight	22	day		$1,000	day		$22,000

Initial Injection (50% of total)
Permanganate Reagent Injection costs

Chemical cost	17,250	lb	x	$4.00	each	$69,000
Equipment Cost (assumed injection rate of 4000lbs/day)	4	day	x	$2,800	each	$11,200
Oversight (1 Jr E/S@$30/hr 10hr/day)	4	day		$1,000		$4,000

Sampling Program - Permanganate Reagent Treatment Area
Assume 3 samples to be collected and analyzed from each of the 15 injection locations within treatment area
One sample collected at each injection point, Pre-injection; at 7 days ; and at 30 days after injection

Total # of samples	15 IPs	x	3 per IP	=			
VOCs	45	Samples	x	$150	per sample		$6,750

Sampling Labor
Assume 4 samples per day
2 technicans provided by the contractor

=	2 people	x	$50 /hr	x	11	days	8 hr/day	$9,000
Shipping costs			$200 /day	x	11	days		$2,250

Project Documentation	1	ls	x	$10,800	ls	$10,800

Assumes 1 Sr and 1 Junior engineer/Scientist for 60hrs@ at average rate of $30per/hr with a multiplier of 3
Includes Effectiveness Evaluation Report, Injector Construction Details, Monitoring Data

2 **Reinjection (25%)**

Permanganate Reagent Injection costs

Chemical cost	8,625	lb	x	$4.00	each	$34,500
Equipment Cost	2	day	x	$2,800	each	$5,600
Oversight	2	day	x	$900	day	$1,800

Sampling Program - Permanganate Reagent Treatment Area
One sample collected at each injection point, Pre-injection; at 7 days ; and at 30 days after injection

	15 * 3					
Total # of samples	45					
VOCs	45	Samples	x	$150	per sample	$6,750

Sampling Labor
Assume 4 groundwater samples per day
2 technicans provided by the contractor

=	2 people	x	$50 /hr	x	11	days	8 hr/day	$9,000
Shipping costs			$200 /day	x	11	days		$2,250

Project Documentation	1	ls	x	$7,200	ls	$7,200

Assumes 1 Sr and 1Junior engineer/Scientist for 40hrs@ at average rate of $30per/hr with a multiplier of 3
Includes Effectiveness Evaluation Report, Monitoring Data Analysis

3 **Final Reinjection (25%)**

Permanganate Reagent Injection costs

Chemical cost	8,625	lb	x	$4.00	each	$34,500
Equipment Cost	4	day	x	$2,800	each	$11,200
Oversight	4	day	x	$900	day	$3,600

Sampling Program - Permanganate Reagent Treatment Area
Assume 3 samples to be collected and analyzed from each of the 24 sampling locations within treatment area
Pre-injection; 7 days after; 30 days after original injection

Total # of samples	45					
VOCs	45	Samples	x	$150	per sample	$6,750

Sampling Labor
Assume 4 groundwater samples per day
2 technicans provided by the contractor

=	2 people	x	$50 /hr	x	11	days	8 hr/day	$9,000
Shipping costs			$200 /day	x	11	days		$2,250

Project Ducumentation	1	ls	x	$7,200	ls	$7,200

Assumes 1 Sr and 1 Junior engineer/Scientist for 40hrs@ at average rate of $30per/hr with a multiplier of 3
Includes Effectiveness Evaluation Report, Injector Construction Details, Monitoring Data

Total Cost for Site $331,600

TOTAL REAGENT INJECTION COST FOR THE WHOLE SITE $331,600

DR Deed Restrictions

Filing of the necessary paperwork to place deed restrictions
involves properties affected by the plume
Assume 1 persons for 1 month.
Assume salary rate of $60/hour.
Assume salary multiplier of 3.

=	1 person x	$	60	/hour x	40 hours/week x	4.2 weeks/month x	1 month x	3 multiplier
	=	$	30,240					
	Assume:	$	**30,300**					

AGWM Annual Groundwater Monitoring (17 wells)

Assume annual monitoring on for 5 years
Assume 16 monitoring wells to be sampled (4 property-boundary, 3 additional deep, & 10 existing wells)
Existing 10 monitoring wells are assumed to be AV-1, AV-2, MW-1, MW-2, MW-3, MW-4a, MW-4b, MW-5 and two residential wells

GW1 Organization of Sampling E (e.g., Staffing, Lab Procurement, Obtaining Equipment)

Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

=	$	40	per hour x	4	hours x	3	multiplier +
	$	30	per hour x	8	hours x	3	multiplier +
	$	20	per hour x	8	hours x	3	multiplier
=	$	1,680	per sampling event				
Assume:	**$**	**1,700**	**per sampling event**				

GW2 Sampling Labor

Assume 2 persons for 4 - 10 hour days @ $30 per hour
Assume 5 wells per day including purging and sampling
Two Sampling personnel and one Sample Management Organizer/Field Team Leader
Assume salary multiplier of 3

= 2 persons x 10 hours/day x 4 days x $ 30 / hour 3 multiplier
= $ 7,200 **per sampling event**

GW3 Sampling Equipment

Assume sample shipping cost of $200 per day
Assume sampling equipment (e.g., bailers and pumps) @ $100 per day
Assume PPE @ $20 per person per day
Assume miscellaneous materials @ $100 per day

Shipping	$	200	per day x	4 days =	$	800
Sampling Equipment	$	100	per day x	4 days =	$	400
Monitoring Equipment	$	100	per day x	4 days =	$	400
PPE	$	40	$20 per set/2 set /day x	4 days =	$	160
Vehicle Rental	$	70	per day x	4 days =	$	280
Per Diem	$	100	Per person/day	8 man days =	$	800
Misc	$	100	per day x	4 days =	$	400

= $ 3,240 **per sampling event**
Assume: $ 3,200 per sampling event

GW4 Sampling Analysis and Validation

Assume groundwater samples will be collected from 16 monitoring wells; analyzed for VOCs and natural attenuation parameters

Total No. of Samples:
17 samples
1 field duplicate
2 MS
2 MSD
1 Field Blank
4 Trip Blanks
27 Total Samples Per Sampling Event

Assume	$	125	per sample for VOC analysis
	$	125	per sample for Inorganics analysis
	$	300	per sample for natural attenuation parameter analysis
	$	550	Total sample cost

Assume samples validated @ 2 hrs per sample
$ 30 per hour x 54 hours x 3 multiplier + $ 4,860

Analysis Cost: 27 samples x $ 550
= $ 14,850 per sampling event

Total Analysis & Validation: $ 19,710
Assume: $ 19,700

GW5 Data Review & Reporting (Annual Monitoring)

Assume 2 senior engineers/chemists at $35 per hour for 40 hours each per sampling event
Assume salary multiplier of 3

= 2 person x $ 35 per hour x 20 hours x 3 multiplier
= $ 4,200

PRESENT WORTH CALCULATIONS

Assume discount rate is 5%: **0.05**

No. 0 **Total Annual O&M Costs**

This is a recurring cost every year for 20 and 5 years
This is a problem of finding P given A, i, n, or (P/A,i,n)
P = Present Worth
A= Annual amount
i = interest rate
Assume 5%

$$P= A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

n =	20
i =	0.050
The multiplier is =	12.462

No. 1

$$P= A^* \frac{(1+i)^n - 1}{i(1+i)^n}$$

n =	5
i =	0.050
The multiplier is =	4.329