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July 10, 1992

Lester Feldman
Regional Water Quality Control Board
1800 Harrison, Suite 700
Oakland, CA 94621

Re: Livermore Arcade PCE Cleanup -- Draft Feasibility Study Report

Dear Mr. Feldman:

Enclosed is a copy of the Draft Feasibility Study/ Remedial Action Plan for the Livermore Arcade cleanup. As provided in the National Contingency Plan, we are initiating a 30 day public comment period on this report, and will respond to any comments in a responsiveness summary and record of decision which will memorialize the selection of cleanup remedy at the site.

Based upon the success of the soil vapor extraction ("SVE") pilot study, the feasibility study has concluded that SVE is the most cost-effective cleanup technology for this site.

If possible, we would like to meet with representatives of your office next week to obtain your initial response to our proposal so that cost recovery discussions with the responsible parties and implementation of the cleanup can proceed promptly.

Thank you for your attention to this matter. Mike Wright of H+GCL will be contacting you regarding a meeting.

Sincerely,

Alan Waltner

Enclosure

cc:

Eva Chu
Alameda County Health Agency
Division of Hazardous Materials
80 Swan Way, Room 200
Oakland, CA 94621

DRAFT

FEASIBILITY STUDY

REMEDIAL ACTION PLAN

LIVERMORE ARCADE SHOPPING CENTER

PCE GROUNDWATER CLEANUP

07/09/92

Prepared For:

Grubb & Ellis Realty Income Trust

One Montgomery Street

San Francisco, California

And

California Regional Water Quality Control Board

Prepared By:

H+GCL, Inc.

2200 Powell Street, Suite 880

Emeryville, California 94608

July 9, 1992

Project No. 48016.12

DRAFT

FEASIBILITY STUDY

REMEDIAL ACTION PLAN

LIVERMORE ARCADE SHOPPING CENTER

PCE GROUNDWATER CLEANUP

SUBMITTED BY: **DATE**

Michael Wright — July 10, 1992

H^+GCL Project Manager

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EXECUTIVE SUMMARY

At the Livermore Arcade in Livermore, California, soils and groundwater contain concentrations of PCE in excess of regulatory standards. Evidence demonstrates that PCE entered the subsurface from a floor drain and sewer pipe breach at Mike's Cleaners. This release ceased in 1987 when PCE began being properly removed from the site on a regular basis. The plume geometry, the hydrogeologic characteristics of the site, and information concerning the waste disposal practices prior to 1987 lead to the conclusion that the release began in 1982.

During the initial periods of the release, the groundwater level was approximately 20 feet below land surface, saturating a coarse-grained sand and gravel unit which overlies the dominantly clay-rich sediments. In this coarse-grained unit, a groundwater flow velocity of several hundred feet per year is expected. Information about site operations suggest that the largest volume of PCE was released at this same time from leaking equipment. In 1984, groundwater levels declined resulting in a groundwater flow velocity of less than 10 feet per year in the clay-rich sediments of the shallow water-bearing unit. We conclude that the majority of PCE transport occurred during the short period of time when groundwater saturated the course-grained unit and the PCE release rate was the greatest.

Aquifer testing and long-term (2 year) chemical monitoring of groundwater demonstrate that the PCE in clay-rich, saturated sediments is not migrating down-gradient at a rate greater than 3 feet per year. Well logs document the presence of a clay aquitard between the shallow water-bearing zone and the underlying deep aquifer which is used as a potable water supply. Chemical analyses of soil samples taken from this aquitard show that PCE has not migrated into this unit. Chemical analyses of groundwater from adjacent public water supply wells also document the absence of PCE in this important deep aquifer. We conclude that PCE is restricted to the clay-rich, saturated sediments underlying the site. The PCE plume is approximately 400 feet wide and 1000 feet long. The plume is essentially static and does not present an immediate threat to human health and the environment providing that groundwater levels do not rise into the coarse-grained unit.

A risk assessment, which considers the hydrogeological conditions, land use, toxicity of PCE and other factors, found an increased risk to human health through the groundwater pathway. Risks associated with human exposure from site soils and vapors were not considered significant. Thus, the feasibility study examined potential restoration of site groundwater.

Natural restorative processes of biotransformation and volatilization remove PCE from the groundwater and sediments at the site. Very low concentrations of PCE are released into the atmosphere through various pathways at the site, such as cracks in the pavement, landscaped areas and other areas which are not paved. Microorganisms in the subsurface metabolize PCE to non-toxic compounds such as carbon dioxide and water. Previous studies of similar sites suggest that PCE will be naturally removed from groundwater. PCE "half lives" of 0 .1 to 2 years have been reported for areas where the concentration of PCE is relatively low. A "half-life" of 6 months has also been measured for PCE in an experiment in the Baylands aquifer in Palo Alto. However, in areas where the PCE concentrations in groundwater are high the natural removal process is expected to be less efficient. Although removal rates vary from site to site, we conclude that natural processes will reduce PCE concentrations of 100 ppb or less to acceptable levels (<5ppb) in about 5 years.

Near the release, where concentrations are high in soil and groundwater, the transformation of PCE into non-toxic compounds is more problematic. We conclude that natural processes will be insufficient to eliminate PCE from the subsurface in a reasonable amount of time. Additionally, we conclude that high concentrations of PCE in soil and groundwater near the release site will continue to act as a source of PCE - inhibiting the natural remediation processes proposed for much of the site.

If groundwater levels rise at the site, PCE presently fixed to the unsaturated sediments near the release may be dissolved into groundwater, elevating concentrations above that which is presently observed. If the uppermost coarse-grained unit becomes saturated, this dissolved PCE could then migrate down-gradient at a rate of several hundred feet per year. Away from the release site, where soils contain significantly lower concentrations of PCE, we conclude that groundwater quality would remain unchanged during such a rise in groundwater levels.

This feasibility study examined several alternatives for the restoration of groundwater quality. These alternatives ranged from "no-action" to active pumping and treatment of groundwater. Whereas natural processes will effectively restore groundwater quality to acceptable levels within 5 years in areas of low PCE concentration; a rise in groundwater can create a threat to human health and the environment unless action is taken to remove PCE from the soil and groundwater near the release site. Thus, a "no-action" alternative is not recommended at this site. Evaluation of active remedial systems showed that soil vapor-extraction (SVE) and in situ air sparging extraction proved to be the most cost efficient alternatives to eliminate the threat caused by high concentrations of PCE near and immediately down-gradient from the release site.

Presently, a pilot-scale SVE system is operating at the site and initial data demonstrate the effectiveness of the system. Approximately 0.4 pounds of PCE are removed by this one-well pilot-scale system each day. Subsurface pressure readings show that the radius of influence from this system is greater than 50 feet. The majority of this mass is derived from the contaminated unsaturated soils near the release site. No improvement of groundwater quality is observed, nor is any improvement expected during the course of the pilot test. However, at this rate of removal, less than 2 years of operation will remove sufficient quantities of PCE from soil to eliminate the threat to groundwater quality in the event of a rise in groundwater levels. Thus, we propose installation of a SVE system as a final remedy to eliminate the threat of groundwater contamination in the event groundwater levels rise.

The feasibility study also showed that the addition of air-sparging to the SVE system would restore groundwater quality in the area of Mike's Cleaners in a relatively short period of time. Injection of air into the saturated sediments in the area of Mike's Cleaners would also accelerate the process of soil restoration. We purpose the addition of air injection wells to add air sparging to the remedial plan.

The proposed system consists of a portable SVE/sparging unit and up to 12 vapor-extraction/air sparging points. Exhausted vapors would be treated with granular activated carbon to remove PCE. The portable unit would be moved from well to well on a one to two month basis. The vapor-extraction/sparging wells will consist of the existing monitor wells and up to eight new wells proposed for the site. Other systems selected for detailed evaluation were SVE/air sparging with direct discharge to ambient air, SVE with carbon adsorption, SVE with direct discharge to ambient air, groundwater extraction and treatment, groundwater extraction and disposal and subsurface bioremediation.

The estimated cost for the proposed SVE/air sparging with carbon adsorption is $282,480. This cost compares favorably with the cost of the other systems evaluated for this site. The SVE/air sparging system was selected due to the demonstrated effectiveness of air sparging to restore groundwater contaminated by volatile organic compounds. Air sparging should be added to the existing pilot-scale SVE system for a preliminary evaluation of its ability to reduce concentrations of PCE and the other identified chlorinated compounds in the groundwater.

Unfortunately, the pilot test also showed that PCE is not the only contaminant removed from the subsurface. An adjacent service station has released gasoline to the subsurface, resulting in contamination of soil and groundwater. The pilot system is removing benzene and other volatile petroleum hydrocarbons. The existing pilot-scale SVE system captures the PCE and other hydrocarbons in granular activated carbon before they are exhausted into to the atmosphere.

The feasibility study demonstrated that such treatment is not required by regulation if the mass loading to the atmosphere is limited to less than 0.5 pounds per day or 1 pound per day combined listed compounds or 15 pounds of total organic compounds (TOC). These other contaminants cause the loading rate to exceed this threshold, in addition to fouling the air treatment system. This contamination caused by others may result in a requirement to treat exhausted vapors and expand the capability of the carbon system to adequately treat the vapors prior to exhaust. It is our opinion that this off-site gasoline problem is interfering with the planned remediation at the Livermore Arcade and a response action by the responsible party is required.

1.0 INTRODUCTION

This Feasibility Study Report and Remedial Action Plan addresses remedial options for the Livermore Arcade Shopping Center PCE Groundwater Cleanup Site ("Arcade") in Livermore, California. H^+GCL (formerly Hygienetics, Inc.) prepared the Feasibility Study (FS) under contract with Grubb and Ellis Realty Income Trust (Grubb and Ellis) who intends to undertake a private party cleanup at the site.

The California Regional Water Quality Control Board ("CRWQCB") requested a work plan for a Remedial Investigation and Feasibility Study at a December 6, 1991, meeting with representatives of Grubb & Ellis. The work plan was completed and circulated to interested parties in January, 1992 (H^+GCL 1992a). Sampling and other activities described in the work plan were carried out during January and February of 1992. A remedial investigation (RI) report was completed and circulated for public comment in March, 1992 (H^+GCL 1992b).

1.1 Purpose

H^+GCL based this FS on data presented in the RI report. The purpose of the FS is to identify and evaluate various alternatives that will reduce the threat to human health and the environment at the site. The threat is specifically from the observed tetrachloroethylene (also referred to as perchloroethylene or PCE) in site soils and groundwater.

This FS was developed to comply with the provisions of the following: the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA") (42 U.S.C. §9601, et. seq.); the National Contingency Plan ("NCP") (40 CFR §300 et. seq.) with revisions effective February 6, 1990; "Guidance for Conducting Remedial Investigations and Feasibility Studies" (OSWER Directive 9355.3-01, October 1988); Sections 25250 and 25356.1 of the California Health and Safety Code; and the State Water Resource Control Board Resolution No. 68-16. The RI/FS also conforms generally to the Expenditure Plan for the Hazardous Substance Cleanup Bond Act of 1984, originally published January 1985, as revised.

H^+GCL developed this document to facilitate its public review and to facilitate submission of comments to Grubb & Ellis. References are provided in appendix A, and a glossary of terms has been included in appendix B to assist the reader in interpreting this document. Appendix C contains the soil-vapor-extraction pilot test results. Based on the evaluation of the alternatives and on public comments, Grubb & Ellis will select an alternative (or alternatives) to implement at the site. The alternative(s) selected will be protective of human health and the environment, will attain Federal and State legal requirements, and will be cost-effective.

1.2 Site Background

The Livermore Arcade Shopping Center ("Arcade") was first developed in 1972. The portion of the Arcade presently occupied by Mike's Cleaners was previously operated by a pet shop. Records indicate that significant alterations, including plumbing work, occurred in late 1981 and early 1982 when Mike's Cleaners was established by Perry J. Neely and Michael Neely ("the Neelys"). In 1987 operation of Mike's Cleaners was taken over by the current operator, Steven Song.

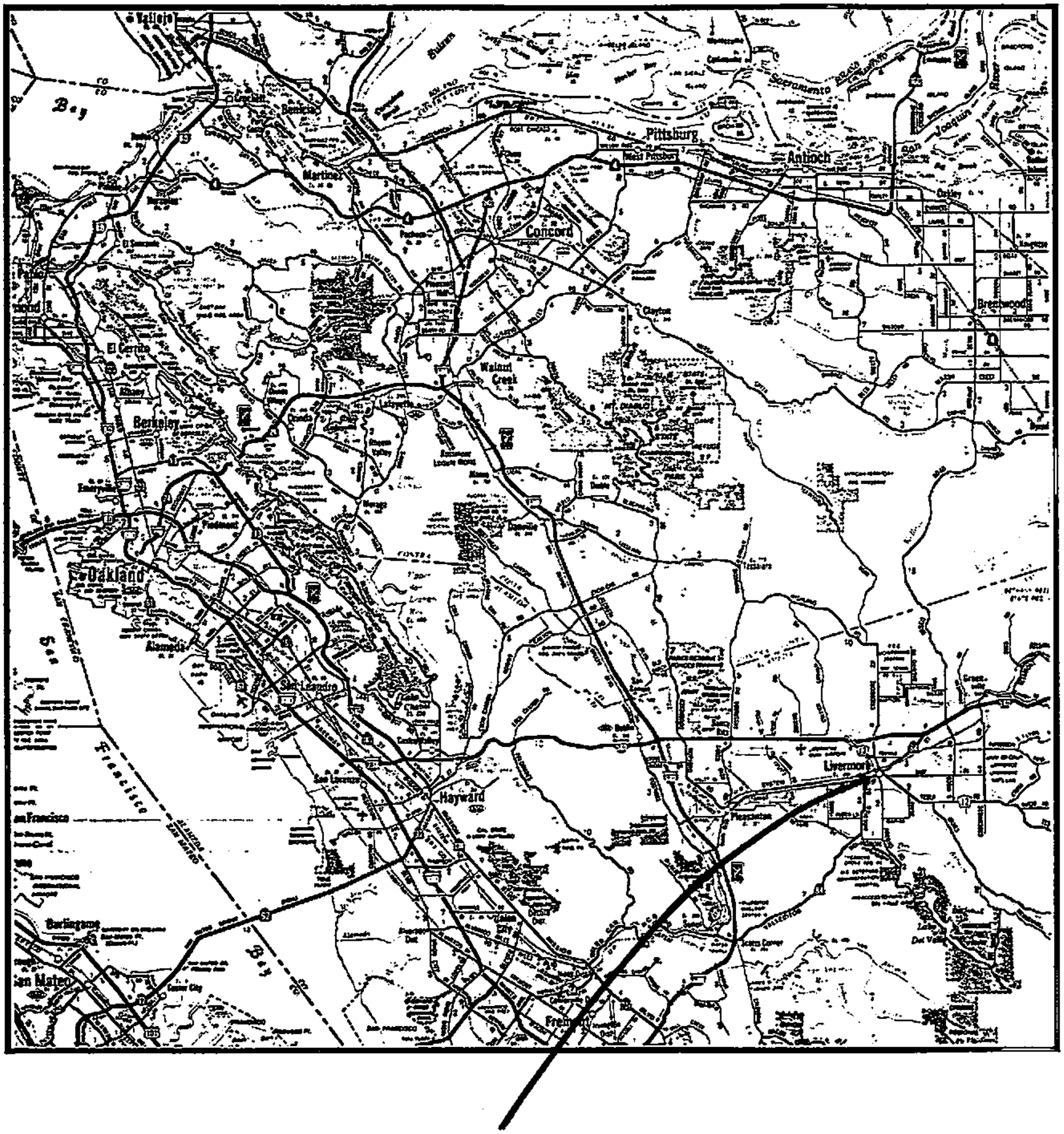
In 1979, Southern Pacific Land Company (now known as Catellus) purchased the property and sold it to Stark Investment Company ("Stark") in 1983. Grubb and Ellis Realty Income Trust bought the property in December 1988 and transferred the property to Grubb & Ellis Realty Income Trust, Liquidation Trust on May 14, 1992. The PCE contamination was discovered during investigations undertaken towards a potential sale of the property in 1990 (H^+GCL , April 3, 1992).

1.2.1 Site Location and Description

The City of Livermore, California is located approximately 25 miles east of San Francisco Bay (Figure 1). The Livermore Arcade Shopping Center is located on an 11.475 acre site situated at the northwest corner of First Street and South "P" Street in the City of Livermore (Figure 2). It is improved with five single-story buildings housing 15 businesses, including Safeway, Sears Roebuck, Orchard Supply, and Long's Drugs. It also contains a number of smaller businesses, including Mike's Cleaners discussed below. The center has a paved parking area for 558 cars. The topography slopes gently to the north and west. Ornamental vegetation on the property consists of grass, bushes and small trees.

The Site is located in a "critical" groundwater recharge area according to the CRWQCB. Six California Water Service (CWS) drinking water supply wells are located within a one-mile radius of the site. Wells CWS #3 and CWS #8 are closest to the site, located on the west and northeast boundaries of the PCE plume, respectively; but the wells are producing water from a lower aquifer which is separated by a clayey aquitard (Figure 3). These wells produce water used for the city drinking water supply.

Figure 1: Location Map

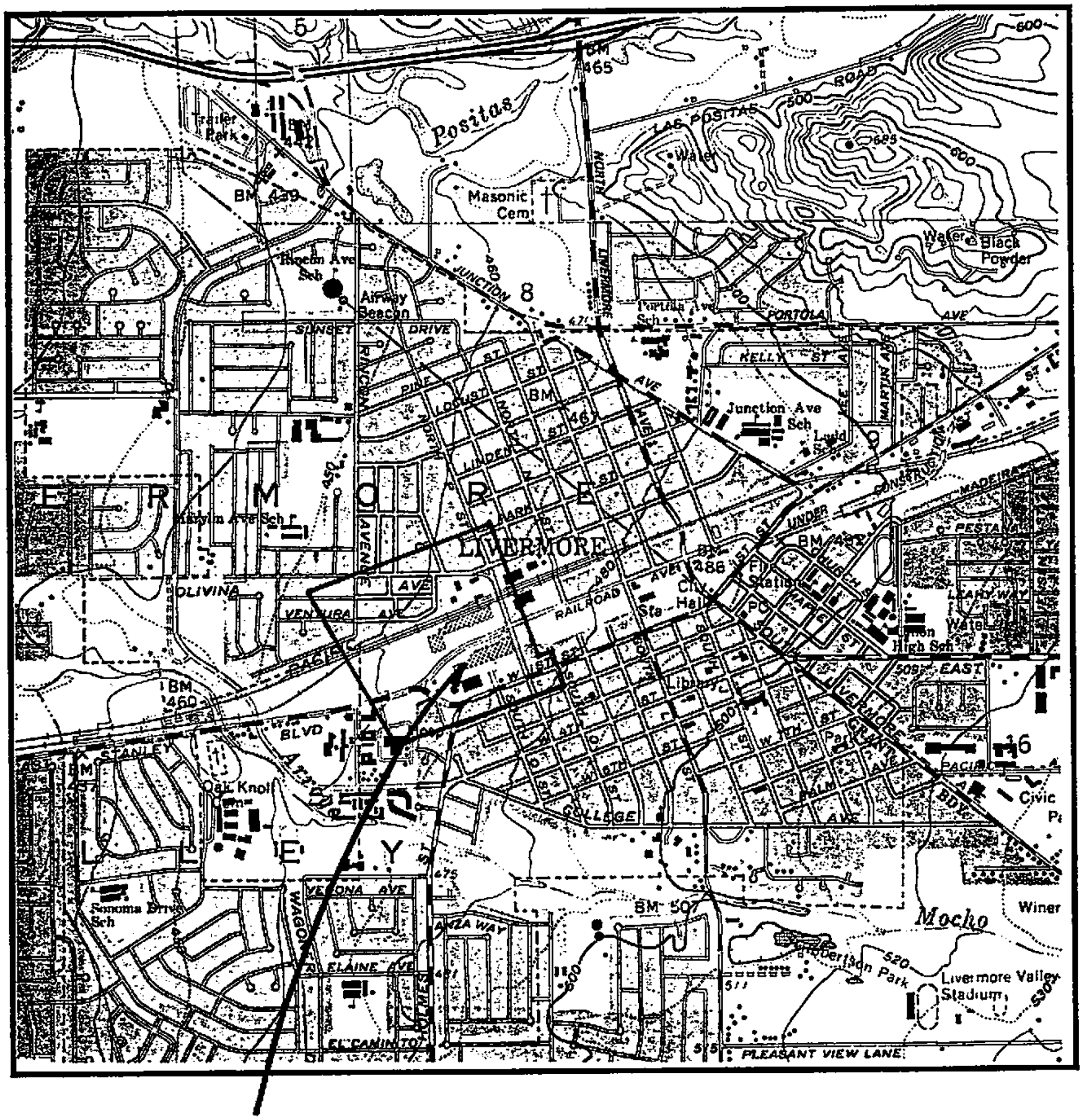


Scale: 0 5 Miles 10 Miles

N

Source: California State Automobile Association, Bay and River Area, 1989

Figure 2: Site Vicinity Map



Area of Site Investigation

Scale: 0 24,000 feet 48,000 feet

N

Source: USGS Livermore Quadrangle, Alameda County, 1961, Photorevised 1980.

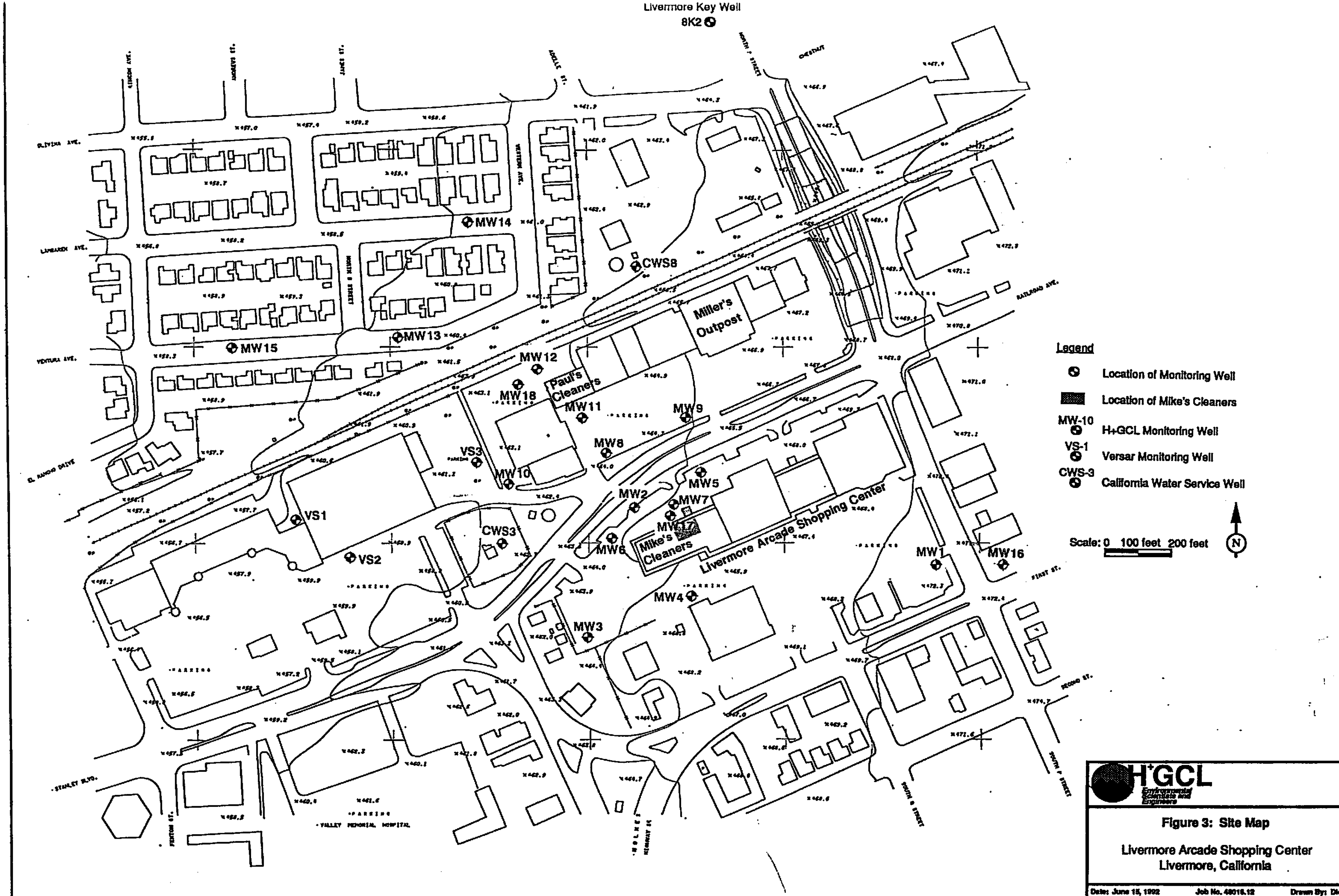


Figure 3: Site Map

Livermore Arcade Shopping Center
Livermore, California

1.2.2 *Previous Site Investigations*

In 1990, Grubb & Ellis contracted for groundwater sampling, which identified a plume of PCE in the groundwater and soil beneath Mike's Cleaners (H+GCL , April 3, 1990). Following this discovery, Alameda County Hazardous Materials Division along with the California Regional Water Quality Control Board (CRWQCB) directed Grubb & Ellis to install additional monitoring wells. This activity was to determine the hydrogeological conditions beneath the site and the vertical and horizontal extent of the PCE contamination.

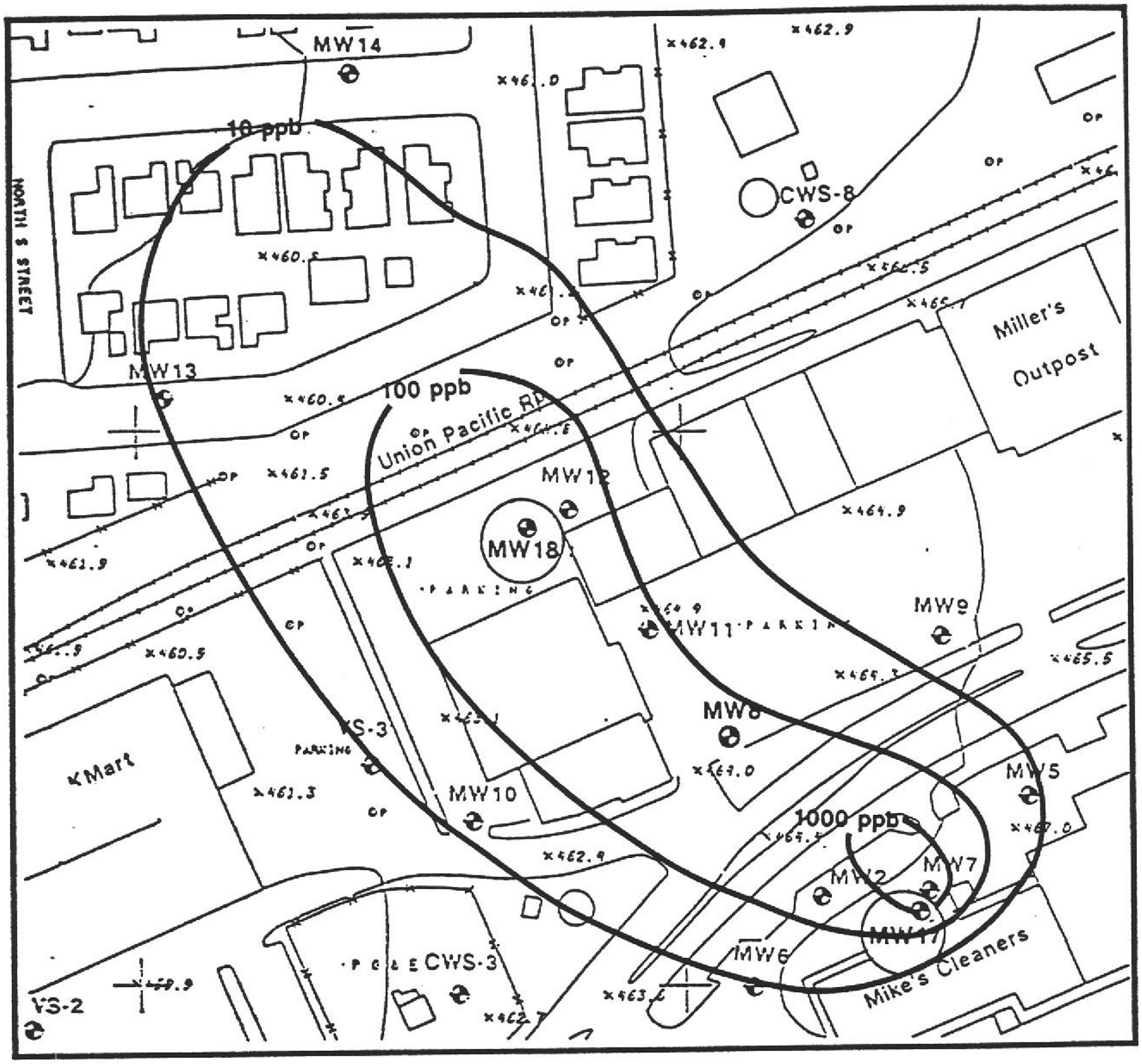
H+GCL 's subsurface investigation (H+GCL , October 12, 1990) found dissolved-phase PCE contamination in the shallow groundwater located about 40 feet below ground surface (bgs). No detectable levels of PCE or other organic contaminants were found in CWS-3 and CWS-8 which are screened in the deeper aquifers (120 to 400 feet bgs) and located adjacent to the PCE plume. The presence of clay layers at depths of approximately 75 to 110 feet bgs (H+GCL , October 12, 1990, and CWS well boring logs) have apparently prevented vertical migration of PCE.

A floor drain at Mike's Cleaners at the Livermore Arcade Shopping Center was identified as a principal source of the PCE detected in the soil and groundwater. The floor drain leads to a disjointed four-inch diameter sewer line which released the PCE into the soil. Wastewater constantly flowed through the line, transporting PCE through the soil and into the groundwater. PCE then migrated north, in the direction of groundwater movement (figure 4).

H+GCL 's groundwater monitoring throughout 1990 consistently documented shallow groundwater at approximately 42 feet bgs. We defined the extent of contamination in the groundwater and verified that the plume was mobile in the saturated zone; therefore, preliminary discussions with the CRWQCB and Alameda County focused on pumping and treating the contaminated groundwater as a remedy. The CRWQCB specified that the groundwater should be remediated until PCE concentrations were at 5 ppb or less.

In the latter half of 1991, H+GCL discovered a significant decrease in the groundwater table. The November 1991 quarterly monitoring reported that groundwater levels were at 65 feet. This was below the total depth of the deepest monitoring wells at the site. Thus pumping and treating contaminated groundwater no longer appeared feasible or effective. H+GCL collected data from supplemental testing and evaluated other potential cleanup options under this changed groundwater regime. As a result, Grubb & Ellis again met with the CRWQCB to propose additional testing and to evaluate a

Figure 4: PCE Ground Water Plume



Legend

MW-10 H+GCL Monitoring Well

VS-1 Versar Monitoring Well

CWS-3 California Water Service Well

10 ppb PCE Concentration Contours 1990-1991 (parts per billion)

MW-17 Latest Monitoring Well

Scale: 0 100 feet 200 feet

N

vapor-extraction system as a prominent remedial option. The CRWQCB concurred and a work plan was prepared. H^+GCL performed a remedial investigation, and the results of the supplemental testing were presented in the RI report. This FS was based on results of the RI.

The RI was conducted to provide site-specific data for evaluating the remedial action alternatives (H^+GCL, April 1992). The investigation included the evaluation of current soil and groundwater conditions, the hydraulic properties of the shallow water-bearing zone, and the volatile organic compound (VOC) content of the vadose zone soil vapors. The RI report also included a Health Risk Assessment (HRA).

H^+GCL installed two deeper monitoring wells that extended to the top of the first continuous underlying clay layer. Soil and groundwater sampling and analysis indicated that PCE had been retained within the vadose zone of the upper aquifer. This zone was newly formed when the water table receded, leaving only a few feet of groundwater present above the clay aquitard. The hydraulic gradient of the shallow aquifer, determined from on-site monitor wells, was approximately 0.008 feet per foot in a north-northwest direction (as measured from Mike's Cleaners).

H^+GCL performed a groundwater pumping study in March 1992 (H^+GCL, April 1992). Transmissivity calculations indicated 119 gallons per day per foot for the saturated sediments near MW-17 and MW-7. Hydrogeologists calculated the groundwater flow velocity to be 3 feet per year at approximately 405 to 391 feet MSL.

Field staff used a portable field gas chromatograph for soil-vapor sampling and analysis, which indicated the presence of PCE in the vadose zone soils at the site. The highest concentrations were detected in well MW-7, near Mike's Cleaners, and in well MW-12, located near Paul's Cleaners, at the Miller's Outpost Shopping Center across the street.

The HRA evaluated the relative health risks associated with ingestion, inhalation, and dermal absorption of all contaminants identified in the on-site soil, soil vapors, and groundwater. The significant threats to human health and the environment were determined to be (1) direct ingestion of groundwater in the upper aquifer and (2) the possibility that PCE and its degradation products could impact the lower drinking water aquifers used by the City of Livermore. These drinking water aquifers are located directly below the site, but are separated from the contaminated upper aquifer by a series of clay layers. While benzene concentrations detected in the groundwater at MW-1 accounted for the highest cancer risk at the site, PCE posed the highest risk of impacting the city drinking water aquifer.

The RI concluded that soil-vapor-extraction should be further evaluated as a remedial measure based on its apparent capability to reduce PCE contamination throughout the site to acceptable levels. H+GCL's April 1992 soil sampling analysis showed that the vadose zone soils retained PCE after the groundwater declined. Soil-vapor-extraction can effectively reduce the PCE loading in the vadose zone so that if the groundwater rises in the future, PCE concentrations will not increase in the water. Soil-vapor-extraction is particularly applicable at the current time due to the low groundwater table.

1.2.3 Agency Action

Due to Grubb & Ellis' initiative in addressing the site contamination, regulatory agencies have deferred to private action. Therefore, the site has not been listed on either State or Federal priority lists for cleanup. The CRWQCB has taken an active role in overseeing Grubb & Ellis' cleanup activities.

1.3 Nature and Extent of Contamination

H+GCL first evaluated the subsurface conditions by reviewing previous studies of the Livermore Groundwater Basin and subsurface investigation reports of the Arcade site. The early evaluations of the nature and extent of groundwater and soil contamination were based on H+GCL studies completed prior to mid-1990, before the groundwater table receded. Table 1.1 lists locations and concentrations of contaminants discovered in the groundwater during previous investigations.

The California Water Service collected samples from CWS-3 and CWS-8 in December 1991, according to Mr. Craig Gilmore of the CWS Laboratory in San Jose, California. Laboratory results showed VOCs were detected at that time. In the past, VOCs have been detected in CWS-10, located approximately one mile north of the site. CWS currently samples for VOCs on a monthly basis. PCE was detected in CWS-10 at 1.1 ug/L as recently as May 1992. All concerned parties agree that the PCE concentrations detected in this well are not associated with the Arcade site. H+GCL sampled CWS-3 and CWS-8 on a number of occasions since January 1992. PCE has not been detected in any of the samples thus far. The analytical results from these sampling events are presented in the RI.

TABLE 1.1

GROUNDWATER CONTAMINANTS, LIVERMORE ARCADE SHOPPING CENTER

Contaminant	Maximum Concentration (ug/L)	Location	Drinking Water Standard (ug/L)
TPH-gasoline	84,000	MW-1	NA
Benzene	14,000	MW-1	1.0 (b)
Ethyl Benzene	35,000	MW-1	680 (b)
Toluene	25,000	MW-1	100 (c)
Total Xylene Isomers	20,000	MW-1	1,750 (b)
Tetrachloroethylene (PCE)	900	MW-7	5 (a)
cis 1,2 - Dichloroethene	190	MW-17	6 (b)
Trichloroethene	230	MW-7	5 (a)
Chloroform	20	MW-9	100 (b)
Bromodichloromethane	10	MW-9	100 (a)
Bromoform	2	MW-9	100 (a)
Dibromochloromethane	7	MW-9	100 (a)
Methylene Chloride	6	MW-14	5 (a)
Dichlorodifluoromethane (Freon 12)	7	MW-18	0.19 (d)
Phenol	5	MW-17	4000 (e)
bis (2-ethyhexyl) Phthalate	20	MW-17	4 (a)

ug/L : micrograms per liter

NA: Not Applicable

MW: Monitor Well

TPH: Total Petroleum Hydrocarbons

(a): USEPA Maximum Contaminant Level (MCL)

(b): California Department of Health Services Drinking Water Standard

(c): No California MCLs currently exist for toluene, however, a standard of 100 ug/L has been utilized by RWQCB

(d): USEPA Oral Reference Dose (RfD)

(e): USEPA Suggested No-Adverse Response Level (SNARL)

PCE, cis-1,2 dichloroethene, and trichloroethene were among the contaminants detected in the groundwater. The highest concentrations were found in monitoring well MW-7 and MW-17, which are both located in close proximity to Mike's Cleaners. The volume of PCE that has leaked into the soil and reached the groundwater is estimated to be less than 5 gallons, or 68 pounds. In 1990, H^+GCL, defined the PCE plume in to be approximately 900 feet in length, extending north of Mike's Cleaners. The RI (H^+GCL, April 1992) defined the PCE plume to be approximately 950 feet in length and 400 feet in width. H^+GCL, verified that the plume originates at Mike's Cleaners and extends in a north-northwest direction.

Groundwater along the eastern edge of the Arcade site is impacted with gasoline. The gasoline plume is clearly impacting the Arcade property from an off-site source. Components of gasoline (i.e. benzene, toluene, ethylbenzene and total xylene isomers) were detected in the groundwater in monitoring well MW-1, located on the southeast corner of the Arcade property, and in MW-16 located across North P Street, east of MW-1. Gasoline probably leaked from underground storage tanks or piping at a Beacon Oil Service Station located just southeast and up-gradient of the site. It was not within the scope of the RI to verify the source of gasoline or determine the extent of contamination.

Chloroform, bromoform, bromodichloromethane, and dibromochloromethane were detected in the groundwater, with the highest concentrations found in monitoring well MW-9. These chemicals are common products of chlorine degradation in drinking water disinfection processes and have also been detected as remnants of analytical processes.

1.3.1 Definition and Toxicity of Tetrachloroethene (PCE)

Tetrachloroethene (PCE), also called perchloroethylene, is a clear , colorless volatile liquid with an ether-like odor. PCE has the chemical formula of C_2Cl_4. It is non-combustible, slightly soluble in water, has vapors heavier than air, and the liquid is denser than water. It is used as a dry cleaning and vapor degreasing solvent, a drying agent for metals, and it is also used for the manufacture of other chemicals. PCE used as an anthelmintic in veterinary medicine, and has been used as an oral treatment for hookworms in humans. The vapors are irritating to skin, eyes, and the upper respiratory tract. NIOSH classifies PCE as an occupational carcinogen. The OSHA exposure limit for an 8 hour time weighted average is 25 parts per million. The toxic properties of PCE target the following organs and systems within the human body: liver, kidneys, upper respiratory system, and central nervous system.

1.3.2 Contaminant Fate and Transport

A contaminant fate and transport study concluded that PCE was discharged into the floor drain at Mike's Cleaners from 1982 to 1987. PCE entered the soil and groundwater during this period via a breach in the sewer line located between Mike's Cleaners and the main sewer line near MW-7. During the early 1980s, the shallow groundwater table was high enough to saturate the uppermost, continuous, clean gravel unit observed at the site. PCE transport was probably rapid during this time period due to the relatively high hydraulic conductivity of clean gravel units. When groundwater levels dropped in the latter half of the 1980s, transport occurred within the lower, clay rich zones with a significantly lower hydraulic conductivity. The data suggest that the horizontal movement of the PCE is now in dynamic equilibrium as a result of biotransformation and volatilization.

H^+GCL has calculated the transport rate of PCE in groundwater under current hydrogeologic conditions to be less than 10 feet per year. The transport rate of PCE in saturated clean gravels under previous conditions was conservatively estimated to be over 200 feet per year. If groundwater rises again and saturates the uppermost clean gravel unit, H^+GCL expects a 200 foot per year PCE transport velocity. This condition would result in an extension of PCE-contaminated groundwater, soil, and soil vapor beyond the currently identified limits.

1.3.3 Soil-Vapor-Extraction Pilot Study

H^+GCL, recommended soil-vapor-extraction (SVE) pilot study at the conclusion of the RI. As the groundwater table declined, PCE was retained in the vadose zone soil. SVE was considered to be a serious remedial action alternative because of its proven effectiveness and efficiency at removing VOCs from the vadose zone.

H^+GCL performed an SVE pilot test at the site. Near the source of the release, vacuum was created in the soil with a vacuum blower attached to MW-17. Staff obtained measurements of vacuum in the soil from piezometers located at measured distances from MW-17. Measurements of the vacuum pressure within MW-17 and velocity measurements of the air flow exiting the system were also obtained.

Appendix C of this report presents the specific details of the SVE pilot test and results of soil permeability of 0.28 Darcy and a radius of influence in 43 feet of MW-17. The study concluded that the subsurface material beneath the site is conducive to soil-vapor-extraction.

The SVE unit has been operating at the site since the last week of May 1992. Staff have collected vapor samples each week to test the effectiveness of the system. For this pilot study, the system is equipped with two vapor-phase carbon adsorption drums connected in series (a scrubber and a polisher). The BAAQMD was notified and has approved of these activities. Preliminary sample analysis results indicate that with 24-hour-per-day operation of the SVE system, between 0.7 and 0.8 pounds per day PCE can be removed. Presently the system is set up to operate a total of 14 hours per day and is expected to remove 0.47 lbs/day.

Trichloroethene (TCE), benzene, and cis 1,2, dichloroethene (DCE) have also been detected in the samples at concentrations several orders of magnitude lower than PCE concentrations. In addition, petroleum hydrocarbon compounds characteristic of gasoline were detected in the extracted vapors from MW-17. The latest TPH concentration detected was 3882 ppm (Table 1.2). TPH is therefore a significant presence in addition to the PCE.

TABLE 1.2

SVE PILOT TEST-VOLATILE ORGANICS ANALYSIS RESULTS

COMPOUNDS	CONCENTRATIONS (ppm)			
	May 19, 1992	June 1, 1992	June 11, 1992	June 27, 1992
Benzene	NA	NA	1.00	1.70
cis-1,2,DCE	0.590	2.17	3.43	5.52
PCE	142	177	194	196
TCE	0.850	1.69	1.72	2.46
1,2 DCA	ND	ND	---	0.77
1,2-dichloropropane	0.060	0.42	1.10*	---
2,2,3 Trimethylpentane	NA	---	262	479
Methylcyclohexane	NA	---	241	422
2,3 Dimethylhexane	NA	NA	156	---
Cyclohexane	NA	NA	142	276
2 Methylpentene	NA	NA	137	545
2 Methylhexane	NA	NA	130	246
3 Methylhexane	NA	NA	122	---
Hexane	NA	NA	117	252
2 Methylpentane	NA	NA	---	545
Methylpentane	NA	NA	104	243
2 Methylbutane	NA	NA	90.1	260
Total C3-C10 Range Hydrocarbons	134	1123	2774	3882

NA: Not Analyzed

ND: None Detected

* Potential interference from co-eluding non-target compound

— : not identified

The effectiveness of the SVE unit was determined from mass balance calculations using analytical data obtained during the pilot study. Analytical results from the most recent sampling event on June 11, 1992, revealed the highest concentrations of the various compounds removed from the vadose zone by the SVE system. The removal rate of each compound, in pounds per day (lbs/day), was calculated using the measured flow rate of 159.3 liters/minute, the analytical results from the June 25, 1992, sampling event (Table 1.2), and the current daily operating time of 14 hours/24 hours. The SVE removal rates are as follows:

PCE = 0.42 lbs/day
Combined (Benzene, TCE, cis 1,2 DCE) = 0.01 lbs/day
TPH - gasoline = 44 lbs/day

It is apparent from these results that the SVE system is effectively removing VOCs from the vadose zone.

Groundwater samples were recently collected from MW-7, MW-17 and MW-18. The results do not show an effect of the SVE system on reducing PCE concentrations in groundwater. More monitoring over time is required. The results are presented in Table 1.3

TABLE 1.3

GROUNDWATER ANALYSIS

	SAMPLE LOCATIONS				
	MW-7	MW-17	MW-18	CWS-3	CWS-8
COMPOUNDS	CONCENTRATIONS (ppb)				
Bromochloromethane	ND	ND	ND	0.2	ND
Bromodichloromethane	ND	ND	ND	20	ND
Benzene	1000	870	ND	ND	ND
Bromoform	ND	ND	1	1.4	ND
Chloroform	ND	ND	ND	21	0.4
Dibromochloromethane	ND	ND	ND	12	ND
Ethylbenzene	93	56	ND	ND	ND
Tetrachloroethene	120	1300	170	ND	ND
Trichloroethene	110	150	1	ND	ND
Toluene	29	40	ND	ND	0.3
Total Xylene Isomers	92	71	ND	ND	ND
cis-1,2 - Dichloroethene	630	600	ND	ND	ND
Semi Quantified C5-C13 Hydrocarbon Matrix	10,000	6,000	ND	NA	NA

ND: None Detected

NA: Not Analyzed

CWS: California Water Service Well

MW: H+GCL Monitor Well

1.3.4 *Risk Assessment*

The HRA identified benzene in MW-1 as the the highest cancer risk at the site. The source of benzene and other aromatic organic compounds identified in the RI is an off-site gasoline release. With respect to potential effects on human health and the environment at the Livermore Arcade site, the primary chemical of concern is PCE. This compound was detected in shallow groundwater, soils, and the vadose zone soil vapors. Potential pathways for contaminants to impact human health are ingestion, inhalation and dermal exposure. No human exposures of any kind have been reported at the Arcade site.

The HRA identified the possibility that PCE and its degradation products could impact the drinking water aquifers used by the City of Livermore and that this would represent a significant threat to human health and the environment at the site. Two water supply wells operated by CWS-3 and CWS-8 are located in close proximity to the Arcade site. The wells pump groundwater from several deep (120-400 feet bgs) aquifers. If improperly installed, these wells can act as conduits allowing the PCE to enter the deeper aquifers. These wells have been sampled periodically by Grubb & Ellis contractors and by CWS, and no PCE or other organic contaminants have been detected.

The PCE contamination in the shallow surface soil near the source of the PCE release does not present a significant direct risk. Much of the surface area overlying the PCE contamination is paved with asphalt and concrete. Dermal exposure to PCE contamination would be limited to field personnel involved with investigative drilling and sampling programs at the site. All personnel involved with those activities will be trained in hazardous materials handling procedures and will be equipped with the appropriate protective gear. The risk of human exposure by inhalation of PCE vapors is insignificant (lifetime cancer risk = 1.0×10^{-7}).

As discussed more fully in the remedial investigation report, the following exposure pathways were selected for detailed evaluation in the risk assessment:

- Exposure to residents via ingestion, inhalation, and dermal absorption of PCE-contaminated water, assuming consumption and use of groundwater at either the current maximum or 95% of the upper-confidence limit (UCL) concentrations present in the shallow aquifer.

- Exposure to residents via ingestion, inhalation, and dermal absorption of PCE-contaminated water, assuming consumption and use of groundwater at PCE concentrations above current maximums. This would be expected to occur if groundwater levels rise and PCE is desorbed from unsaturated soils and transferred into the groundwater.

- Exposure to residents via inhalation of ambient air.

- Exposure to children via direct contact (i.e., soil ingestion, dermal adsorption) with PCE-contaminated soil in non-residential areas (i.e., vacant lots).

H+GCL selected the water ingestion pathways for their likelihood and frequency of occurrence, and for their potential exposure to PCE levels that may be of concern to human health. The air and soil exposure pathways were included in the analysis in order to provide a comprehensive evaluation, although these pathways were considered from the outset to have only a remote minimal significance.

The potentially exposed population includes 56,741 individuals (1990 census) who reside in Livermore and workers who may be employed in the town. The Livermore population is relatively stable and growing. In 1990, approximately 8.4 percent of the Livermore population was under 5 years of age and 7.1 percent was over 65 years of age. 22.9 percent of the population in 1990 was between 5 and 20 years of age. Of these individuals, approximately 17,000 are served by the California Water Service wells in the vicinity.

CWS is a private company that delivers potable water to the city of Livermore. They operate numerous groundwater wells within Livermore and also purchase surface water from Alameda county Zone 7 to supplement their supplies.

The exposure pathway presenting the most significant potential risk to human health is consumption of the deeper groundwater. Therefore, H+GCL developed remedial alternatives that focused on contaminated subsurface areas with the highest potential for releasing PCE into the deeper groundwater.

H+GCL characterized risks from the above pathways by first comparing information on the air, soil, and groundwater PCE concentrations to Applicable or Relevant and Appropriate Requirements (ARARs) identified for the Livermore Arcade PCE site. In this evaluation, investigators combined estimates of potential PCE exposures through each pathway with PCE-specific toxicity values. They were then able to predict potential risks associated with the site. For each pathway, the investigators developed an exposure scenario based on assumptions about the environmental behavior and transport of PCE, and the extent, frequency and duration of exposures. These factors were used to predict potential risks from exposure to PCE in both average and maximum plausible exposure cases.

Excess lifetime cancer risks are determined by multiplying the intake level with the cancer potency factor. These risks are probabilities that are generally expressed in scientific notation (e.g. 1×10^{-6} or 10^{-6}). An excess lifetime cancer risk of 1×10^{-6} indicates that, as a plausible upper bound, an individual has a one in one million chance of developing cancer as a result of site-related exposure to a carcinogen. This is calculated for a 70-year lifetime under the specific exposure conditions at a site.

TABLE 1.4

SUMMARY OF EXCESS INDIVIDUAL LIFETIME CANCER RISKS FOR EXPOSURE TO PCE AT THE LIVERMORE ARCADE SITE

Exposure Pathway	(Adult)	(Child/Adult)
Soil Ingestion	1×10^{-8}	3×10^{-8}
Dermal Adsorption	2×10^{-7}	2×10^{-7}
Soil Gas Inhalation	1×10^{-7}	2×10^{-7}
Groundwater Ingestion	3×10^{-7} to 4×10^{-3}	5×10^{-7} to 5×10^{-3}

1.3.5 Extent of Remediation

Section 2.0 develops alternatives that address remediation of the PCE presently located in the vadose zone and in the groundwater beneath the site. The most significant amount of PCE contamination in the soil and in the groundwater is present in the vicinity of Mike's Cleaners. This FS evaluates remedial action alternatives that primarily address PCE in the soil and groundwater in that area. PCE in soil and groundwater below a determined concentration will be remediated naturally by biotransformation and volatilization.

Natural Volatilization

Chlorinated solvents such as those discovered at the Arcade Site have a strong tendency to move from the liquid and dissolved phase into the vapor phase. This tendency is based upon the following physical properties presented in Table 1.5.

TABLE 1.5
PHYSICAL PROPERTIES OF
TRICHLOROETHYLENE AND TETRACHLOROETHYLENE

Parameter (1)	TCE (2)	PCE (2)
Molecular weight[a] (g/mole)	131.40	165.85
Boiling Pt. (°C at 260 mm Hg)	86.7	121
Density[a] (g/cm^3 at 20° C)	1.4649	1.6230
Viscosity[b] (Centipoise)	0.55 (25° C)	0.90 (20°C)
Log Octanol: water partition		
co-efficient, [c] (dimensionless)	2.29	2.60
Vapor pressure[d] (mm Hg at 20° C)	60	14
Solubility in water[e] (mg/L at 20° C)	1,080	149
Henry's constant[e] (20° C dimensionless)	0.32	0.57

[a](the Merck 1976).
[b]Flick (1985).
[c]Roberts et. al. (1982).
[d]Verschueren (1983).
[e]Munz and Roberts (1987).

Bates et al, found that "significant volatilization" of suspended PCE and TCE took place in an unsaturated soil column. Although not quantified, this finding confirms theoretical expectations. It is expected that significant volatilization is occurring in solvents suspended in the vadose zone at the Arcade. This process will cause a dilution of solvent concentrations enhancing natural biotransformation throughout the site. Therefore, combining these natural processes with the ultimate cleanup goal of 5 ppb, the initial cleanup target will be 100 ppb in the shallow groundwater. Dilution that would occur if groundwater levels rise would provide an additional margin of safety.

1.4 Feasibility Study Process

The objective of this FS is to develop a range of remedial alternatives that protect human health and the environment by minimizing the potential exposure to PCE. The FS provides sufficient information to allow Grubb & Ellis, in consultation with regulatory agencies and the public to select the most appropriate remedial action or actions. The FS is conducted in three phases in accordance with the Interim Final Guidance for Remedial Investigation and Feasibility Studies under CERCLA, October 1988 (EPA, 1988c).

- Phase I: Identify technologies and develop remedial action alternatives.
- Phase II: Refine the alternatives and the selection of alternatives for detailed analysis.
- Phase III: Perform detailed analyses of the selected remedial alternatives.

1.4.1 Phase I

Under Phase I, remedial action objectives are established which will be achieved by the proposed remedial action alternatives. These objectives are typically defined in terms of a contaminant of concern in a specific medium, an exposure route and receptor, and an acceptable contaminant level for the exposure route and receptor (i.e. cleanup goal). Where possible, acceptable contaminant levels are determined by the Risk Assessment, and/or the Applicable or Relevant and Appropriate Requirements (ARARs). General response actions are then developed to satisfy the remedial action objectives. Some examples of general response actions include collection, treatment, containment, and disposal.

The next step of Phase I involves the identification and screening of technology types, a subcategory of general response actions. Chemical, thermal, and biological treatment are all examples of technology types under the treatment general response action. Technology types are screened on the basis of their applicability to the waste type and form. Process options, a subcategory of technology types, are then identified for the technology types that remain after screening. For the thermal treatment technology type, examples of process options are rotary kiln incineration, advanced electric reactor, and vitrification. The process options are screened on the basis of effectiveness, implementability, and cost relative to other process options within the same technology type. The goal of this level of screening is to arrive at one to two representative process options for each technology type.

The final step in Phase I is the development of alternatives. This step is accomplished by combining process options that, together, meet the remedial action objectives. For the Livermore Arcade PCE site, alternatives will be developed that range from no action, to remediation of all soils, soil vapors, and groundwater in accordance with the most stringent ARAR. Phase I is documented in Section 2.0 of this FS.

1.4.2 Phase II

The purpose of Phase II is to select remedial action alternatives to be analyzed in greater detail from those developed under Phase I. This is accomplished by refining the Phase I alternatives and then evaluating the alternative as a whole on the basis of effectiveness, implementability, and cost. Screening of the alternatives then occurs by comparing the results of the evaluations. Remedial alternatives with the most favorable overall evaluations are retained to undergo detailed analysis. The screening procedure should attempt to maintain representation from the full range of treatment and containment technologies developed in Phase I. The screening procedure is provided in Section 3.0 of the report.

1.4.3 Phase III

Phase III provides the basis for determining which remedy to implement. It consists of the same steps as those taken in Phase II. Since fewer remedial alternatives remain to be evaluated, the analysis is undertaken in greater detail. Nine criteria are evaluated for each alternative:

- Protection of human health and the environment
- Compliance with ARARs
- Reduction of mobility, toxicity, or volume
- Short-term effectiveness
- Long-term effectiveness
- Implementability

- Cost

- Community acceptance

- State and local agency acceptance

For California state law purposes as part of the remedial action plan, the following criteria will be considered to the extent consistent with the NCP, as provided in Health and Safety Code Section 25356.1:

- The health and safety risks at the site;

- The effect of contamination on present, future, and probable beneficial uses of the threatened resources;

- The effect of alternative remedial action measures on the reasonable availability of groundwater for present, future, and probable beneficial uses;

- The site-specific characteristics;

- The cost effectiveness of the alternative remedial action measures, including the potential for rapidly escalating costs if action is deferred; and

- The potential environmental impacts of the alternative remedial action measures.

The results of the Phase III assessment are presented in Section 4.0 of the FS report. Section 5.0 presents the preferred alternative or alternatives based on the feasibility study documented in this report.

A public comment period will take place allowing interested parties an opportunity to comment on this report. The alternatives passing the detailed evaluation will proceed through a public and agency comment period and be refined based on comments received. Grubb & Ellis will then issue a Record of Decision (ROD) in which the preferred Remedial Action is selected based on the comments received from the public and regulatory agencies.

2.0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES (PHASE I)

2.1 Criteria For Developing Remedial Action Alternatives

This section provides the methodology and rationale used to develop the site remedial action alternatives. The development and evaluation of alternatives follows the guidelines set forth in the following references:

- National Contingency Plan (NCP), in particular, 40 CFR, Section 300.430.

- U.S. EPA (1988c), Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, October 1988.

CERCLA provides for selecting a remedial action that is protective of human health and the environment, that is cost-effective, and that attains Federal and State requirements that are applicable or relevant and appropriate. In addition, the remedial action should utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Finally, the lead agency is required to give preference to treatment remedies which permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances.

Section 2.2 identifies all ARARs which, in part, are used to develop the remedial action objectives presented in Section 2.3. Appropriate general response actions are identified in Section 2.4 which meet the remedial action objectives. Corresponding technology types and process options are identified in Section 2.5. Remedial action alternatives are assembled in Section 3.0 from the appropriate process options.

2.2 Applicable or Relevant and Appropriate Requirements

A critical determination in any site cleanup is the question of "how clean is clean." Under CERCLA, remedial actions must attain a degree of clean-up which assures protection of human health and the environment. Additionally, remedial actions that leave any hazardous substance, pollutant, or contaminant on-site must meet a level or standard of control that at least attains federal and more stringent state standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. These requirements, known as "ARARs", may be waived in certain instances, but not by private parties undertaking private party cleanups.

Additionally, with regard to private party cleanups, both substantive and administrative federal and state requirements need to be followed.

ARARs are derived from both Federal and State laws. Under CERCLA, the Federal ARARs for a site could include requirements under any of the Federal environmental laws (e.g., the Clean Air Act, the Clean Water Act, and the Safe Drinking Water Act). State ARARs include promulgated requirements under the State environmental or facility siting laws that are more stringent than Federal ARARs and have been identified by the State in a timely manner.

Remedial actions not meeting ARARs can still be selected under certain circumstances, in particular, if (1) The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement; (2) Compliance with the requirement will result in greater risk to human health and the environment than other alternatives; or (3) Compliance with the requirement is technically impracticable from an engineering perspective (40 C.F.R. § 300.430(f)(2)).

Types of ARARS

There are three types of ARARs. The first type includes contaminant-specific requirements. These ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the environment. Examples of this type of ARAR are ambient water quality criteria and drinking water standards.

The second type of ARAR includes location-specific requirements that set restrictions on certain types of activities based on-site characteristics. These include restrictions on activities in wetlands, floodplains, and historic sites. No location-specific ARARs have been identified for this site.

The third type of ARAR includes action-specific requirements. These are technology-based restrictions which are triggered by the type of action under consideration. Examples of action-specific ARARs are Resource Conservation and Recovery Act (RCRA) regulations for waste treatment, storage and disposal, and permits required for air pollutant emissions into the ambient air.

ARARs must be identified on a site-specific basis from information about specific contaminants at the site, specific features of the site location, and actions that are being considered as remedies. The discussion below outlines the ARARs and other information that Grubb & Ellis considered for this site. Then it will compare the alternatives with one another regarding these ARARs.

There are ARARs that apply to both the water and air for this response action. These can be separated into chemical specific and primary action specific ARARs. The ARARs identified for this Feasibility Study are the substantive provisions of the following:

Contaminant-Specific ARARs

Water ARARs: There are chemical specific ARARs for water which will be described here. First, the ARARs for the water are the Safe Drinking Water Act Maximum Contaminant Levels (MCLs). In accordance with the EPA "Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements (OSWER Directive 9234.0-05)," the MCLs are considered the chemical-specific ARARs because they are the enforceable drinking water standards. They are required to be set as close to the Maximum Contaminant Level Goals (MCLGs) as is feasible, taking into consideration the best available technology, treatment techniques and other factors including cost). They are also protective of public health to within EPA's acceptable carcinogen risk range of 10^{-4} to 10^{-7}.

The MCL of particular importance for this response action is the MCL of 5 ppb for PCE. EPA's regulations describe this standard as follows:

> Tetrachloroethylene. The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that tetrachloroethylene is a health concern at certain levels of exposure. This organic chemical has been a popular solvent, particularly for dry cleaning. It generally gets into drinking water by improper waste disposal. This chemical has been shown to cause cancer in laboratory animals such as rats and mice when the animals are exposed at high levels over their lifetimes. Chemicals that cause cancer in laboratory animals also may increase the risk of cancer in humans who are exposed over long periods of time. EPA has set the drinking water standard for tetrachloroethylene at 0.005 part per million (ppm) to reduce the risk of cancer or other adverse health effects which have been observed in laboratory animals. Drinking water that meets this standard is associated with little to none of this risk and is considered safe with respect to tetrachloroethylene (40 CFR §141.32(a)(48)).

Grubb & Ellis also considered the California DHS's Action Levels for VOCs, a few of which are more stringent than the MCLs or for which no MCL has been established. While the DHS action levels are not promulgated standards and are not, therefore, ARARs, they have been taken into consideration during development of remedial action alternatives as allowed for in the NCP. In addition, DHS has recently proposed MCLs for a number of VOCs. Of particular significance, the MCL for PCE is 5 ppb, which is just slightly higher than the current DHS action level (SAL) of 4 ppb.

Table 1.1 lists the federal MCLs for the primary contaminants detected in the site area. The remedial action selected will meet the proposed state MCL for PCE (5ppb) as discussed below in Section 4.3.4.

It is proposed that to the extent practicable the cleanup be to a residual groundwater level of the MCL for PCE, which is 5 parts per billion. This level has been identified by correspondence from the CRWQCB, dated December 14, 1990 (Appendix A, Reference No. 7). The CRWQCB has also identified as applicable the policies contained in Resolution 68-16, which generally prohibits degradation of waters of the state (including groundwater) such that beneficial uses are impaired.

As discussed below in the section on alternatives, H^+GCL has concluded that the proposed remedial system will reduce PCE levels in soil and shallow groundwater to this 5 ppb level in the most cost-effective manner. No beneficial uses will be impaired if the cleanup is undertaken as proposed and thus Resolution 68-16 will be satisfied. Failure to undertake the cleanup as proposed could result in loss of beneficial use of groundwater for drinking water purposes. The cost of replacing this drinking water supply would significantly exceed the cost of the proposed cleanup.

Location-Specific ARARs

Since the site is not in a historic, wetlands, floodplain, earthquake special studies, fire protection, or similar zone, no location-specific ARARs apply.

Action-Specific ARARs

The principal ARARs for the site are action specific, and derive from both hazardous waste and air pollution control requirements.

Hazardous Waste Control Requirements

In order to determine whether hazardous waste control requirements apply to a treatment activity, it must first be determined whether a material being handled is a hazardous waste. Generally speaking, the federal and state definitions of hazardous waste are similar, although the California definitions are somewhat broader in certain instances.

A solid waste can be a hazardous waste either through meeting regulatory characteristics for hazardous waste, or through being on a list of hazardous wastes. Each of these facets of the definition are discussed below.

Once extracted or excavated, soils or groundwater that produce a Toxicity Characteristic Leaching Procedure ("TCLP") concentration of greater than 0.7 mg/l PCE are identified as characteristic hazardous wastes under 40 CFR § 261.24 and 22 CCR § 66261.24. As identified in the RI report, portions of the site have soils or groundwater anticipated to be above this level.

It is not anticipated that soils will be excavated due to practical difficulties and cost; those soils therefore will not become "wastes" and in any event they would not be generated, treated, stored or disposed. No hazardous waste generation, treatment, storage, or disposal requirements will apply to the soils that remain in place at the site.

Under certain alternatives, groundwater may be extracted, and if producing a TCLP for PCE in excess of 0.7 mg/l, that groundwater would normally constitute a characteristic hazardous waste. However, so long as wastewater containing PCE is discharged to the local treatment works it is not considered a hazardous waste provided that certain requirements are met, although that discharge is subject to any requirements of the local POTW as discussed below. 40 CFR § 261.3 (a) (2) (iv) (A) and 22 CCR § 66261.3 (a) (2) (E) (1).

The TCLP procedure does not apply to contaminated vapors and therefore the vapors will not be characteristic wastes. Concentrations of solvents in the extracted vapors are anticipated to be low in any event. Since extracted vapors are not anticipated to be a characteristic waste, treatment or disposal of those vapors is not subject to hazardous waste permitting requirements.

Since the original concentration of PCE is unknown, the F002 hazardous waste listing, which requires an original 10% or greater concentration of PCE, does not apply. 40 CFR § 261.3 (a) , 22 CCR § 66261.31.

EPA has previously taken this approach at the San Fernando Valley, CA Superfund Site, where inadequate documentation existed to characterize the original waste. "San Fernando Valley Area 1 Superfund Site, Record of Decision for the Burbank Well Field Operable Unit" USEPA, 1989, NTIS No. PB90-114844. See OSWER Directive 9347.3-05FS, July 1989, "Determining when Land Disposal Restrictions (LDRs) are applicable to CERCLA Response Actions". The U210 listing also does not apply since (1) the material discharged to the sewer at Mike's Cleaners is not believed to be a commercial chemical product or an off- specification material, and (2) even if it were, there is no presently available evidence that PCE was the sole active ingredient, or that the PCE was commercially pure or of a technical grade. 40 CFR § 261.33 , 22 CCR § 66261.33.

If the original waste were a listed waste, wastes derived from that waste (including excavated soils and extracted groundwater below the TCLP threshold and extracted vapors) could be considered to be hazardous wastes in certain circumstances. 40 CFR § 261.3 (d) (2), 22 CCR § 66261.3 (d) (2). This "derived from" rule applies only to listed wastes; wastes derived from purely characteristic wastes are no longer hazardous wastes when they no longer meet the TCLP threshold.

This only presents an issue concerning the treatment of extracted vapors with carbon adsorption. First, as discussed above, site soils (both above and below the TCLP threshold) are not anticipated to be generated, treated, stored, or disposed. Second, all extracted groundwater is anticipated to be discharged to the POTW in accordance with the pre-treatment requirements; under the definition discussed above, which also applies to wastes derived from listed wastes; none of the extracted groundwater would be a hazardous waste when so discharged. As to the soil vapors, no regulation would apply until the vapors were "contained", by the virtue of the definition of solid waste in RCRA. 42 USC § 6903(27). This will occur at the earliest when the vapors reach the extraction pipe.

Even apart from the lack of "containment", vapor-extraction alone does not represent treatment of a hazardous waste; specifically, treatment is defined as "any method, technique, or process which changes or is designed to change the physical, chemical, or biological character or composition of any hazardous waste or any material contained therein, or removes or reduces its harmful properties or characteristics for any purpose, including, but not limited to, energy recovery, material recovery, or reduction in volume". Id. No change in character or composition of the soil vapors will occur merely by extraction. See CERCLA Compliance with Other Laws Manual, Draft Guidance, USEPA, August 8, 1988, NTIS #PB90 272535 at 2-14, 2-15, 2-16 (in situ treatment not subject to RCRA permitting). Venting of extracted vapors is not disposal under the applicable definition, since disposal is limited to discharge to land or water, not the ambient air. Id.

However, if the original waste was a listed waste, the carbon adsorption of the extracted vapors could be considered treatment of a waste "derived from" a listed waste, and subject to permit requirements. H+GCL has been informed that no permit by rule presently applies to treatment of contaminated soil vapors, so a full RCRA permit application would be required in that instance. As discussed above, in the absence of direct information demonstrating that the original dry cleaning solvent was a listed waste, EPA policy does not require a presumption in the Superfund context that the waste was a listed waste subject to the "derived from" rule, and this FS proposes to treat the original waste as a characteristic waste only. Declining to apply such a presumption is particularly appropriate here since the delay of the cleanup to await a permit would result in increased risks of shallow groundwater recontamination.

In addition, EPA's "derived from" rule was recently vacated because inadequate notice and comment procedures had been followed. Shell Oil Company v. EPA, 950 F.2d 741 (D.C. Cir. 1991). A recent decision of the Eight Circuit held Shell Oil to be both prospective and retroactive in application. United States v. Goodner, 1992 WL 117148, No. 91-2466 (8th Cir., June 4, 1992). Although EPA recently re-promulgated its derived from rule on an "interim" basis, it did so again without notice and comment and the validity of that action is doubtful in light of the D.C. Circuit's action.

Even if the original waste is discovered to be a listed waste, permitting delay can be avoided by eliminating the carbon adsorption of extracted vapors. As discussed below, carbon adsorption may not be necessary if PCE emissions are below 0.5 pounds per day. Although carbon adsorption of extracted vapors provides environmental benefits, the delay resulting from undertaking a permit process for the carbon adsorption system is unwarranted in light of the risks of shallow groundwater recontamination; faced with this tradeoff, it is likely that the greatest environmental benefit would result from continuing the cleanup at less than 0.5 pounds of PCE per day rather than delaying clean-up to apply for a permit if one is indeed necessary.

We conclude, however, that the collected vapors need not be considered a waste "derived from" a listed waste in this context and that the collected vapors are therefore not a hazardous waste. As a result, treatment of those vapors by way of carbon adsorption does not require a RCRA or equivalent state permit. If contrary comments are received from the agencies with jurisdiction and a permit requirement is asserted, it is proposed that the cleanup proceed without treatment of collected vapors until a permit can be obtained. Failure to move forward with the cleanup at a reduced pace would risk missing the window of opportunity presented by the currently low groundwater levels.

Although the soil vapors themselves will not be characteristic hazardous wastes since the TCLP does not apply to gases, it is anticipated that the PCE-laden carbon resulting from carbon adsorption of extracted soil vapors would be a characteristic waste under the TCLP and, if so, it will be manifested and treated or disposed as a hazardous waste at an off-site facility.

Grubb & Ellis must apply for a permit and meet applicable requirements of the local POTW if extracted groundwater is discharged to the local sewage treatment system. The City of Livermore system has established a general limit on discharges of 1.0 mg/l of total organics, although an application must be made and lower limits can be established on a case-by-case basis. (Pers. Comm. Darren Greenwood, February 11, 1992). In this instance, it is not anticipated that contaminated groundwater in excess of this level will be discharged, and given the relatively small amount of total PCE to be remediated, it is not expected that the City of Livermore will impose a more stringent requirement. In any event, the application requirement is applicable in this instance, and an application to the POTW will need to be made and appropriate requirements complied with if groundwater is discharged.

Air ARARs:

For the air discharge there are primary action-specific ARARs that will affect this response action. In California, the authority to regulate stationary sources of emissions has been delegated to local air quality management districts. The site is located in the BAAQMD. Therefore, BAAQMD regulations constitute generally applicable, promulgated State requirements under State environmental law, which apply under CERCLA.

The BAAQMD rules require a permit to operate and an authority to construct where any "article, machine, equipment or other contrivance . . . may cause . . . the emission of air contaminants." (Rule 2-1-301) However, a number of miscellaneous operations are exempt from these requirements, including "Aeration of soil, provided that duration of aeration does not exceed three months." Unless this exemption applies, an authority to construct and a permit to operate will need to be obtained from the BAAQMD. The BAAQMD has established a streamlined process for such permit applications, although several weeks may be required. (Pers. Comm. Larry Chaset, BAAQMD, February 11, 1992). Grubb & Ellis initiated this permit process has begun with the implementation of the SVE pilot study.

In addition to the general authority to construct/permit to operate requirements, specific source category rules apply to PCE cleanup sites using soil aeration or vapor-extraction.

Whether a site must apply these source-specific BAAQMD rules is determined by the quantity of PCE and other listed compounds emitted from the system. It is estimated that if there are no emission controls, the vapor-extraction system considered for the site would emit no more than 0.80 pounds per day of chlorinated hydrocarbons to the atmosphere. This estimate does not include other hydrocarbon compounds that may be present at the site from the nearby gasoline spill.

Vapor-extraction systems are regulated directly under BAAQMD Regulation 8, Rule 47, which provides in pertinent part as follows:

8-47-101 **Description:** The purpose of this Rule is to limit emissions of organic compounds from contaminated groundwater and soil. The provisions of this rule shall apply to new and modified air stripping and soil vapor-extraction equipment used for the treatment of groundwater or soil contaminated with organic compounds.

8-47-109 **Exemption, Small Operations:** The provisions of Section 8-47-301 shall not apply to operations that satisfy both of the following requirements:

109.1 Operations that emit no more than one of the following compounds: benzene, vinyl chloride, trichloroethylene, perchloroethylene or methylene chloride, and

109.2 Benzene emissions do not exceed 0.05 pounds per day, vinyl chloride emissions do not exceed 0.2 pounds per day or trichloroethylene, perchloroethylene or methylene chloride emissions do not exceed 0.5 pounds per day.

8-47-113 Exemption, Air Stripping and Soil Vapor-Extraction Operations Less than 1 pound per day: The provisions of Section 8-47-301 shall not apply to operations with total emissions of less than 1 pound per day of benzene, vinyl chloride, perchloroethylene, methylene chloride and/or trichloroethylene provided the requirements of Section 8-47-402 are satisfied. Once an exemption pursuant to this section is granted, if the emissions of an operation exceed 1 pound per day then that operation is subject to Section 8-47-301. The operator of the source may submit a petition to the BAAQMD in writing requesting review under this exemption (if uncontrolled emissions have been shown, due to sustained remediation activities, to have dropped to a constant emission rate of less than 1 pound per day).

8-47-301 Emission Control Requirement, Specific Compounds: Any air stripping and soil vapor-extraction operations which emit benzene, vinyl chloride, perchloroethylene, methylene chloride and/or trichloroethylene shall be vented to a control device which reduces emissions to the atmosphere by at least 90% by weight.

8-47-302 **Organic Compounds:** Any air stripping and soil Vapor-Extraction operations with a total organic compound emission greater than 15 pounds per day shall be vented to a control device which reduces the total organic compound emissions to the atmosphere by at least 90% by weight.

8-47-402 **Less Than 1 Pound Per Day Petition:** Any person seeking to satisfy the conditions of Section 8-47-113 shall:

402.1 Submit a petition to the APCO in writing requesting review and written approval of a risk analysis for the benzene, vinyl chloride, perchloroethylene, methylene chloride and/or trichloroethylene organic compound emissions that are less than 1 pound per day.

Other provisions of the BAAQMD rules could be applicable to the potential cleanup options. Regulation 8, Rule 40 regulates the aeration of contaminated soil, but it is not anticipated that soil will be removed or subjected to aeration as defined in that rule. Under Regulation 8, Rule 17, dry cleaning operations as such are controlled if solvent usage is in excess of 2,642 gallons per year, but the remedial alternative methods being considered do not appear to fit the definition of dry cleaning operations, even though the solvents originated from a dry cleaning facility.

Miscellaneous requirements

California Environmental Quality Act, Health and Safety Code Section 27000 et seq; 14 CCR Section 15000 et seq. ("CEQA").

CEQA generally is not considered to be an ARAR for Federal hazardous waste cleanups, although State lead agencies generally follow CEQA procedural requirements in connection with cleanup decisions. For the most part, State agencies comply with CEQA by filing notices of exemption from the EIR requirement. At the Arcade site, there is no possibility of significant environmental impacts from the cleanup action. Moreover, CEQA only applies to discretionary approvals of private actions by public bodies. In this instance, no discretionary government approvals are likely to be required. If the CRWQCB or another agency becomes involved in this cleanup, it is urged that a notice of exemption be filed.

Occupational Safety and Health Act (OSHA) regulations, 29 C.F.R. 1910.1000 and 1910.1001.

OSHA has set a Permissible Exposure Limit (PEL) for PCE of 25 ppm for occupationally exposed workers. The PEL was intended for workplace exposures (8 hours per day, 40 hours per week, 52 weeks per year) and not for continuous ambient exposures. The PEL is an ARAR as an upper limit for all exposures, but would not be protective for the exposure scenarios used in the risk assessment. The selected remedy will ensure that actual ambient exposure levels are significantly lower than the limit established by this ARAR, and that levels are protective of human health and the environment. This ARAR could also be categorized as a contaminant-specific ARAR, since it is PCE-specific.

Well Completion Requirements.

Alameda County Department of Water Resources, Zone 7 (Zone 7), requires that a permit be obtained prior to the installation of a groundwater monitoring well. Zone 7 will also need to review and approve proposed specifications for both groundwater monitoring wells and extraction wells.

2.3 Remedial Action Objectives and Cleanup Goals

2.3.1 *Objectives*

The risk assessment (Section 1.3.4) concluded that a significant cancer and chronic risk was associated with the ingestion of groundwater from the contaminated upper aquifer, although it aquifer is not used as a drinking water source. H⁺GCL developed the following general remediation objectives for the Livermore Arcade PCE Site to protect human health and the environment:

General remedial objectives include the following:

- Protect public health and the environment.

- Satisfy applicable or relevant and appropriate requirements (ARARs).

- Provide practical, cost-effective remediation.

- Utilize permanent remedies, completed in the shortest feasible time frame.

- Address contamination resulting from on-site sources only.

Site specific remedial objectives include the following:

- Prevent the near term and future exposure of human receptors to contaminated groundwater on- and off-site.

- In soil and groundwater emanating from the site, reduce contaminant levels to those which protect human health and environment.

- Control contaminant migration to prevent further spreading.

- Monitor groundwater to verify effectiveness of the remedial measures.

- Avoid interference with potential future cleanups of other neighboring sites.

The following rationale describes the development of specific remedial action criteria and cleanup goals for this site.

2.3.2 *Cleanup Rationale*

The RI report (H^+GCL, 1992b) concluded that PCE contamination is located principally in the shallow groundwater, the soil and vadose zone soil vapors beneath the site. No PCE has been found in the deeper aquifer through sampling of the CWS wells, CWS-3 and CWS-8. The shallow groundwater is not currently used as a drinking water supply, although migration pathways to the deeper groundwater (which is a significant drinking water supply) are not fully characterized, and there is a potential for migration from shallow to deep aquifers. The HRA determined the lifetime cancer risk from all pathways except consumption of groundwater beneath the site to be less than 10^{-6}.

There is a relatively small amount of contamination, and the ratio of contaminated groundwater to usable deep groundwater is low. Even if migration pathways do exist, dilution by the deeper aquifer is expected to reduce any contamination to levels below all ARARs, unless significant recontamination of the shallow aquifer occurs.

The principal goal of remediation at this site is to reduce the threat of human exposure to contaminants that could migrate to the deeper aquifer. Given the relatively small amount of contamination present at the site, clean-up is proposed to reduce the total loading of PCE in the vadose zone vapors as a means of reducing any potential for future groundwater contamination. To effectively reduce the concentration of PCE in the groundwater to below 5 ppb by natural processes, it will be necessary to first reduce the PCE contamination in the highest concentrated areas. This, coupled with monitoring of the shallow and deep aquifers, should eliminate any significant risk to public health or the environment from this contamination.

2.3.3 *Cleanup Goal*

The cleanup goal will be to eliminate human exposure to PCE-contaminated water at levels greater than the MCL for PCE of 5 ppb. This goal should be appropriate for all other contaminants at the site with the exception of benzene. Benzene contamination from the nearby Beacon Service Station should be addressed by others as a separate cleanup process.

All of the remedial action alternatives will be evaluated on the same basis. To achieve the clean-up goal of 5ppb, PCE in the groundwater will be remediated to 100 ppb. Then natural remediation processes, such as biotransformation and volatilization, will reduce the PCE concentrations to below 5 ppb over time. During the time of actual remediation, PCE concentrations below 100 ppb will not threaten the groundwaters, public wells or the underlying drinking water aquifers, because the plume is presently stable, and if and when the contamination spreads, the concentrations would be diluted to non-detectable levels. Each of the remedial action alternatives, except for no action, will be evaluated on the basis of an initial groundwater clean-up target of 100 ppb. The area within the 100 ppb isopleth will be considered the treatment zone when discussing and evaluating the remedial action alternatives. With the no action alternative, natural degradation processes and dilution will be counted on to achieve a reduction in PCE concentrations to below 5 ppb.

2.4 General Response Actions

General response actions are defined as those measures that will satisfy the remedial action objectives and cleanup goal described in Section 2.3. General response actions include no action, institutional actions, and the collection, treatment, disposal, and containment of contamination. A variety of these actions are theoretically available at the site, but considerations of cost, feasibility and incremental effectiveness dictate against application of some, as discussed below.

2.4.1 No Action

SARA requires that "no action" be carried through the entire feasibility study for the purpose of providing a baseline for comparison of the action alternatives. Under "no action," the current status of the site would not change. The potential for migration of the PCE to the drinking water aquifer, and resulting ingestion through that pathway, would remain unchanged.

Based upon the low potential for further migration of the site contaminants under current conditions, a no action alternative would be acceptable if those conditions continued. If groundwater levels rise, however, the potential for future migration makes the no action alternative less attractive.

2.4.2 Institutional Actions

Institutional response actions are legally enforceable actions developed to protect human health and the environment. Most institutional actions are in the form of deed or access restrictions. They may range from simple actions, such as warning signs, to severe actions, such as property condemnation and relocation. Institutional response actions are rarely successfully implemented, and cannot preclude continued human exposure to site contaminants.

At the Arcade site, direct contact with soils has effectively been precluded through the developed status of the site as a shopping center with large paved and built areas. The owners do not anticipate converting the site to other uses that might allow greater risk of soil exposure to the public during the period that contamination is anticipated to remain on-site. Therefore, institutional actions regarding zoning, deeds, etc., are not anticipated. Contact through ingestion of contaminated groundwater could be addressed through institutional restrictions. Should contamination be detected, use of the presently producing deep wells could be restricted, and new wells into the shallow aquifer could be prohibited. Such institutional actions are feasible for the Livermore Arcade Site.

2.4.3 *Collection*

Collection options generally include such measures as soil excavation, groundwater extraction, or soil vapor-extraction, which physically remove contaminants from the site. Groundwater extraction includes the installation of wells and pumping systems to remove contaminated groundwater. Soil vapor-extraction utilizes these same wells and pumping systems.

In this instance, soil excavation generally appears economically and practically infeasible because the soils are covered with pavement and structures. Soil-vapor and groundwater extraction are both technically feasible alternatives if used with specific treatment options.

2.4.4 *Treatment*

In situ and collected materials can be treated (soil, water, or vapor). In situ treatment includes either natural or enhanced subsurface bioreclamation. Collected soils can be treated through such measures as soil aeration, retorting, or chemical treatment. Contaminated groundwater can be addressed through air stripping, carbon adsorption or similar measures. Vapors can be treated through incineration (with or without supplemental fuels, depending upon composition) or carbon adsorption.

Most of these treatment options are technically feasible at this site.

2.4.5 *Containment*

In containment actions, contaminant migration is reduced, minimized or eliminated with a physical barrier. Containment response actions can be implemented both in situ and above ground. In situ containment generally covers the contaminants, above ground containment generally removes the media and places it in a contained system such as drums, tanks, or storage bins for storage either on or off-site.

At the Arcade site, all feasible containment to prevent infiltration of precipitation and the formation of leachate is presently in effect. The contaminated area is covered by largely impermeable surfaces that restrict direct contact. The shallow aquifer is underlain by a clay layer that appears to have effectively prevented migration of contaminants from the shallow to the deep aquifer. Therefore, barrier or slurry walls would not add to overall effectiveness. Horizontal migration pathways are not a significant threat. Physical horizontal containment methods would generally be infeasible due to the developed character of the site and its vicinity. Hydraulic containment is a theoretical option, but again, it appears to be unnecessary.

The principal containment option will be the preservation of the current containment features of the site during any remedial action. In particular, preservation of the clay layer below the shallow groundwater will be a principal feature of any cleanup option.

2.4.6 Disposal

Disposal response actions involve removing the contaminated media, placing it in containers (optional), and securing it in an enclosure. For CERCLA site soils, the most common disposal method is transport to a RCRA landfill.

However, as discussed above, removal of contaminated soils is not practical at the site. Disposal of contaminated (or treated contaminated) groundwater is feasible either through reinjection or disposal to the local POTW. Disposal of untreated or treated vapors to the ambient air is anticipated for any vapor-extraction remedial response.

2.5 Identification and Screening of Remedial Action Technology-types and Process Options

Remedial action technology types are defined as subcategories of general response actions that encompass a number of remedial action process options. Process options are defined as specific processes, systems, or actions that may be used to clean up or mitigate site hazards. Process options are frequently combined to form the remedial action alternatives. In some cases, a process option by itself may be considered an alternative if it can clean up or mitigate site hazards, which is often the case at sites where only one contaminant and/or media is present.

A list of the general response actions, technology types, and process options is presented in Table 2.1. Table 2.2 presents a screening of process options for their respective technology types. The process options in this table are screened on three criteria: effectiveness, implementability, and cost. The ratings of low, medium, and high are used for all three criteria.

Effectiveness refers to the ability of the process option to meet the remedial action objectives, in whole or part. Effectiveness is measured in terms of the incremental benefits each additional time the measure is implemented. For example, since the site is effectively capped, the incremental effectiveness of capping is low.

The second criterion, implementability, refers to the physical ability to construct or perform the process option. Here, the built-up nature of the site is the principal restriction to implementing of several process options.

The third and final criterion, cost, is a relative measure used to discriminate between process options within the same technology type. The two components of this criterion, capital and O&M, are combined into present worth cost for the life of the process.

The universal screening of technology types identified 23 process options to be considered for the site (Table 2.2). Each of these options is described below.

The no action-groundwater monitoring option is applicable to the site because the soil contamination is apparently isolated and the groundwater contamination has apparently equalized. Therefore, further movement of the groundwater contamination plume is limited under current conditions. This option is selected for further evaluation.

Institutional actions are generally not appropriate because of the difficulty of enforcing them. The access restriction and new well prohibition options could be effective, but their implementation cannot be guaranteed. The new community wells option would be effective if the potable aquifer became contaminated. Since the contamination is apparently isolated and is not expected to affect the lower aquifer, this option will probably not be necessary and is not considered appropriate at this time.

Groundwater extraction and vapor-extraction are both feasible at the site, and existing groundwater monitor wells can be used as either groundwater or vapor-extraction wells. Groundwater extraction is a traditional method that is appropriate under certain circumstances but is considered to be of low effectiveness at this site. This is because the pumping rate will be low at the Arcade site, and groundwater extraction systems typically experience slow remediation rates. Vapor-extraction is very effective in removing vapors from the vadose zone over a relatively short period of time. Both options have a high implementability because they can use existing wells. Both options are considered medium in cost, because they require either pumping equipment or a vacuum blower. Both options are selected for further consideration.

Table 2.1

LISTING OF GENERAL RESPONSE ACTIONS TECHNOLOGY TYPES AND PROCESS OPTIONS

Medium: GROUNDWATER

Purpose: To reduce the risk of public exposure to contaminated groundwater through prevention of direct use and/or contaminant migration to deeper groundwater

General Response Action	Technology Type	Process Options
No Action	No Action	Groundwater monitoring
Institutional	Deed restrictions	New well prohibitions
	Alternative water	New community wells
Collection	Groundwater collection	Groundwater extraction wells
	Vadose vapor collection	Vapor-extraction wells
	Enhancement	In situ air sparging
Treatment	Physical treatment	Air stripping
		Carbon adsorption
	Biological treatment	Surface bioremediation
		Subsurface bioremediation
	Thermal treatment	Vapor incineration/catalytic oxidation
Disposal	Off-site discharge	Water discharge to POTW
	On-site discharge	Water injection wells
Containment	Capping	Asphalt/concrete cover
	Horizontal barriers	Clay layers, synthetic liners
	Vertical barriers	Slurry walls, sheet piling

Table 2.1 (cont'd)

LISTING OF GENERAL / RESPONSE ACTIONS / TECHNOLOGY TYPES AND PROCESS OPTIONS

Medium: SOIL

Purpose: To reduce direct exposure and to reduce the risk of migration to deeper aquifer

General Response Action	Technology Type	Process Options
No action	No Action	Groundwater monitoring
Institutional	Deed restrictions	Access restrictions
Collection	Vadose vapor-extraction	Vapor-extraction wells
	Soil removal	Soil excavation
Treatment	Physical treatment	Stabilization/immobilization Vapor carbon adsorption Soil processing & replacement
	Biological treatment	Subsurface bioremediation Surface bioremediation
	Thermal treatment	Vapor incineration/ catalytic oxidation Soil thermal processing
Disposal	Off-site disposal	Soil excavation Vapor discharge to air
Containment	Capping Vertical barriers Horizontal barriers Surface controls	Asphalt/concrete cover Clay liner Synthetic membrane

Table 2.2

UNIVERSAL SCREENING OF PROCESS OPTIONS

Process Option	Effectiveness	Implementability	Cost
Groundwater monitoring	low	high	medium
Access restrictions	low	low	low
New well prohibitions	low	medium	low
New community wells	low	low	high
Groundwater extraction wells	low	high	medium
Vapor-extraction wells	high	high	medium
Subsurface GW bioremediation	high	medium	high
Surface GW bioremediation	medium	low	high
Subsurface soil bioremediation	high	medium	high
Surface soil bioremediation	medium	low	high
Groundwater air sparging	high	high	medium
Groundwater w/air stripping	medium	high	high
Vapor carbon adsorption	high	high	medium
Vapor incineration/oxidation	high	high	high
Groundwater discharge to POTW	medium	low	medium
Groundwater injection wells	low	low	medium
Asphalt/concrete cover	low	low	high
Clay layers, synthetic liners	low	low	high
Slurry walls, sheet piling	low	low	high
Soil excavation	low	low	high
Soil stabilization/immobilization	low	low	high
Soil processing & replacement	low	low	high
Soil thermal processing	low	low	high

Bioremediation is among several treatment options that are potentially feasible at the site. Bioremediation is divided into four categories: (1) subsurface groundwater bioremediation, (2) surface (above-ground) groundwater bioremediation, (3) subsurface soil bioremediation, and (4) surface (above-ground) soil bioremediation. The surface bioremediation options are excluded from further consideration because the processes require more space than available at the site. Subsurface bioremediation that takes place in-situ with little equipment above-ground is effective for both soil and groundwater. A single system can treat both contaminated soil and groundwater; therefore, subsurface soil and groundwater bioremediation will be considered together for further evaluation.

Groundwater air sparging is a very effective complementary technology to vapor-extraction. While vapor-extraction is very effective in removing vapors from the vadose zone, it is not effective in removing soil contaminants that are below the water table. Air sparging strips volatiles from the groundwater so they can be removed by a vapor-extraction system. Air sparging is selected for further consideration.

Air stripping is a groundwater treatment process that removes volatiles from the water after the water has been extracted from the ground. It is an effective technology, but it transfers volatiles from water to air. Treatment of the exhaust vapors must be considered. This process is selected for further consideration.

Vapors removed from soil by a vapor-extraction system or from groundwater by an air stripper must often be treated before being released to the ambient air. This treatment is generally accomplished with vapor-phase activated carbon or by thermal treatment methods. Thermal treatment systems, which include vapor incinerators and catalytic oxidizers, are expensive to install and operate, and are best suited to highly contaminated situations. Activated carbon, although relatively expensive, is suitable for smaller systems and is very effective in removing organics from an air stream. Both vapor carbon adsorption and vapor thermal treatment are selected for further consideration.

Groundwater disposal options include off-site discharge to the local POTW and on-site disposal into the ground through water injection wells. On-site disposal is not further considered because permit requirements are difficult and could adversely affect the hydraulics of the existing groundwater contamination plume. Disposal to the POTW is an applicable option that is selected for further consideration.

The remaining process options listed in Table 2.2 are concerned with containment of the contamination. These options require excavation or construction of facilities that essentially are not possible because of the developed nature of the site. None of the containment options will be further considered for application at the site.

The nine process options selected for further consideration, as described above, are listed in Table 2.3, and are discussed below in detail.

Table 2.3

PROCESS OPTIONS CARRIED FORWARD INTO THE ALTERNATIVES ANALYSIS

No Action with Long-Term Monitoring
Groundwater Extraction
Vapor-Extraction
Air Sparging
Subsurface Bioremediation
Air Stripping of Contaminated Groundwater
Carbon Adsorption of Contaminated Groundwater
Carbon Adsorption of Extracted Vapors
Thermal Degradation of Extracted Vapors
Water Discharge to POTW

2.5.1 No Action with Long Term Monitoring

At present, groundwater contamination at the site does not pose an immediate threat to human health and the environment. This is due in part to the absence of receptor organisms and favorable aquifer conditions.

No remedial action with long-term monitoring of groundwater contaminants at the site is considered a viable option as a long-term corrective action strategy. This would be a continuation of current monitoring activities at a reduced level to monitor the potential migration of contaminants at strategic locations within and down-gradient of the plume.

Natural biodegradation of contaminants within the plume is a continuing process and natural equilibrium occurs when the plume ceases to propagate even though the groundwater continues to flow. Groundwater monitoring will determine if equilibrium has indeed been reached at the site. Evidence of equilibrium would support a no action alterative as appropriate.

The half-life for PCE biotransformation at the Arcade site near Mike's Cleaners is estimated to be 2.5 years or more while the half-life in less contaminated areas is estimated at 1 year. Thus higher the concentration of PCE, the longer the half-life. If the half life is not longer than 2.5 years in the areas of highest concentration, it may take 20 years for the PCE to be reduced to below 5 ppb.

The concern with the no action alternative is that the water table is likely to rise changing the conditions upon which this choice was based. Hydrographs of the Livermore key well, located near the Arcade site, show annual fluctuations in the groundwater table, which will impact PCE contaminated soil. As the groundwater rises through the vadose zone soil, contaminant concentrations may increase in the water phase. If the groundwater rises into the upper clean gravels, the potential for significant horizontal movement increases.

2.5.2 Groundwater Extraction

Groundwater extraction technologies have been used extensively for aquifer restoration and control of contaminant migration at sites where groundwater contamination has occurred. Groundwater extraction provides hydraulic recovery and containment based on the principles of well hydraulics. It may be accomplished with groundwater recovery systems such as underground drains, infiltration galleries, well points, or wells. Hydraulic recovery occurs when groundwater withdrawal proceeds at a rate sufficient to capture all, or a portion of, a contaminant plume and to arrest down-gradient contaminant migration.

Groundwater extraction systems for aquifer restoration have generally been used in conjunction with above-ground treatment systems. This is because withdrawn groundwater must be treated prior to discharge to the environment if contaminant concentrations exceed regulatory criteria. Options for disposal of recovered groundwater include artificial recharge (i.e., infiltration percolation basins, injection wells, or other means); discharge to receiving waters; discharge to a POTW; or off-site transport and disposal in accordance with State and Federal regulations. For the Livermore Arcade site, the only practical means of disposal is to a POTW.

If groundwater is to be recovered, the system is situated where contaminant concentrations are highest to extract the maximum mass of contamination with each gallon of water withdrawn. Barrier technologies such as slurry walls, grout curtains, or sheet piling are often used in conjunction with groundwater recovery systems to minimize the amount of uncontaminated groundwater recovered by the system. Hydraulic recovery systems generally remain in operation until aquifer contaminant concentrations are reduced to an approved level, or until further remediation is not technically practical.

Under a hydraulic containment scenario, groundwater recovery systems are usually placed along the leading edge of the contaminant plume to arrest down-gradient migration of contaminants. Hydraulic containment systems require a permanent commitment to the associated energy, maintenance, and operation costs, because down-gradient migration of contaminants will resume without concurrent source remediation.

Groundwater withdrawal rates can be varied and the hydraulic recovery and containment system configurations can be expanded or diminished to suit site-specific conditions. Continual monitoring of aquifer response and water quality variations is necessary to assure that groundwater recovery systems function properly and that hydraulic control is maintained. Long-term energy, maintenance, and operation costs are the most significant disadvantage to hydraulic recovery and containment technologies.

Practical applications of groundwater extraction have often been disappointing when treatment time requirements extend far beyond the estimates. Remediation can be extremely slow due to the equilibrium achieved between the dissolved and adsorbed phases of contamination, with low levels of contamination remaining in the soil to continually leach into the water (Angell, P.E., Keith G. "In Situ Remedial Methods: Air Sparging", The National Environmental Journal, January/February 1992).

Groundwater extraction is expected to be marginally effective at the Livermore Arcade site. Aquifer analyses indicate that the groundwater can be removed at a rate of about one gallon per minute and that the groundwater is moving at a rate of about one foot per year. Pumping at this low rate from selected wells may inhibit further movement of the plume, but this slow rate of removal will require a long time for complete groundwater remediation. At the present low water level, this option will have limited effectiveness. If the groundwater level should rise, however, this option may become appropriate.

2.5.3 Vapor-Extraction

Soil-vapor-extraction works above the water table, and is a simple, proven technology for removing volatile contaminants from soil. An SVE system induces an air flow through areas of contamination by applying a vacuum that volatilizes and removes VOCs and supplies oxygen to support biodegradation. The system is effective as long as the air flow contacts the contaminated soils. Proper air flow is maintained by careful spacing of vapor-extraction points and by screening the vapor-extraction wells within the zone of contamination. Groundwater quality is also improved by SVE.

Vertical extraction wells or horizontal collectors placed in the contaminated zones are connected to transfer pipes manifolded to a high capacity vacuum blower. The withdrawn soil-vapor is often discharged to the air untreated, but regulations do not always allow this. The soil vapors may have to be treated, usually by granular-activated carbon adsorption or catalytic incineration, but bioremediation treatment may also be allowed.

Vapor-extraction wells must be screened, at least partially, in the vadose zone. Existing monitor wells and groundwater extraction wells can be used as vapor-extraction wells if they are screened above the water table, as well as below. In most cases, suitably located existing wells can be converted for vapor-extraction by merely connecting a vacuum blower to the well casing with PVC pipe.

Vapor-extraction is highly suited to the Livermore Arcade site since most of the contaminants are held in the vadose zone soil, having become trapped in the soil as the groundwater level receded. This should be a very effective option as long the groundwater level remains below the zone of contaminated soil. If the groundwater should rise, the effectiveness of vapor-extraction can be restored by the addition of air sparging as described below. Several monitor wells at the Livermore Arcade were designed with this contingency in mind. Most all wells at the site could be used as part of an extraction system, if necessary.

Discharge of harmful vapors directly to the atmosphere is prohibited in most urban settings, and exhaust from a vapor-extraction system must usually be treated prior to discharge to the ambient air. If the vapor concentrations are sufficiently low, however, it may be appropriate to discharge directly to the air. At Livermore, air emissions are regulated by the BAAQMD. Their regulations provide an exemption for small operations that emit no more than 0.5 pounds per day of PCE to the atmosphere or less than 1.0 pounds per day of combined listed compounds or 15 pounds of TOC. If emissions are limited to these levels, this option will provide a low cost and highly reliable vapor discharge system.

2.5.4 Air Sparging

Air sparging targets VOCs below the water table. The approach enhances VOC collection by effectively creating a crude air stripper in the subsurface, with soil acting as the packing. Air is injected into the aquifer and allowed to flow through the water column over the soil packing. Air bubbles that contact dissolved and adsorbed-phase contaminants in the aquifer cause the VOCs to volatilize. The organics are then carried by the air bubbles to the vadose zone where they are captured by a vapor-extraction system or allowed to escape through the ground surface. Aerobic biological activity can also take place within this soil packing and is enhanced by the availability of oxygen from the injected air.

Air sparging induces movement of groundwater within the aquifer and increases the concentration of vapors in the soil. Therefore, air sparging is usually operated in conjunction with an SVE system in order to control the movement of vapors in the soil. The combined techniques of soil-vapor-extraction and air sparging can provide very effective remediation within a short time and at a reasonable cost.

Air sparging wells must be screened only below the surface of the aquifer to allow pressurization of the well and to enhance the transfer of air into the aquifer. A high pressure air blower is used to force air into the aquifer. A variation of this technique uses air in the form of micro-bubbles that are added to a water stream and injected into the aquifer. Nutrients and microorganisms can also be injected into the aquifer to support bioremediation.

Existing groundwater monitor wells and recovery wells may be used for air sparging if they are screened below the groundwater table only and are appropriately located. Small diameter pipes or well points driven into the ground can also serve as air injection points.

The applicability of air sparging with respect to the removal of particular components from soil and groundwater can be initially evaluated by examining physical properties of those components. The partitioning coefficient and the Henry's Law Constant should be examined. The partitioning coefficient will yield information as to the relative fractions of the component in the soil and groundwater. When the partitioning coefficient exceeds unity, then the contamination resides principally in the soil and sparging is deemed applicable. (Angel, G.E., 1992). The strippability of a component can be determined by the Henry's Law Constant. Contaminants with a Henry's Law Constant greater than $1x10^{-5}$ (atm-m^3-mole) indicates that the component is a strippable volatile constituent (Brown, R. A., et al, 1991). PCE exceeds both the strippability and partitioning coefficient guideline values which indicates that air sparging can effectively enhance the removal of PCE from the groundwater and soil.

In practical applications, air sparging has often provided excellent results. An example is a site in Rhode Island that contained volatile organic hydrocarbons in both soil and groundwater, and where groundwater extraction and soil-vapor-extraction systems were installed in 1985. The vapor-extraction system removed the vadose zone vapors very quickly while the groundwater contaminants remained above action levels after five years of pumping. An air sparging system was installed in 1991. Target levels in the groundwater were reached in three weeks, and quarterly monitoring has verified that the site has remained clean after the system ceased operation.

Air sparging can be effectively applied to the Livermore Arcade site as a supplement to a vapor-extraction system, collecting PCE from the groundwater if needed. It will be particularly applicable if groundwater rises into the contaminated vadose zone. It will also be effective in reducing existing groundwater contamination to prevent the plume from moving further down-gradient. Air sparging in combination with vapor-extraction could be applied to areas of the site to accomplish treatment in specific zones, if necessary.

2.5.5 Subsurface Bioremediation

Bioremediation uses natural microorganisms to metabolize contaminants in both soil and water. It can be used in situ along with aeration and other methods to provide efficient and economical treatment. In

2.5.6 Air Stripping of Contaminated Groundwater

Packed-tower air strippers utilize packing material to enhance the transfer rate of VOCs from the water phase to the air phase. The water is passed through a cylindrical tower filled with column packing material. Air is blown up through the packed tower causing the air to flow counter current to the water. Mass transfer of the VOCs is enhanced by breaking up the water flow stream by passing it through the packing material. This increases the exposed surface area of the water and allows for more efficient mass transfer. The selected packing material should have both a large void space and surface area. This configuration allows for high surface area exposure of the water, and it minimizes the air pressure drop in the column. Compounds with a low Henry's Law constant and/or greater contaminant removal requirements require a greater depth of packing material and/or air flow. Because of their ease of construction and operation and their proven removal of VOCs, packed towers are used more often for groundwater remediation of VOCs than other aeration processes.

Depending upon the ultimate disposition of the treated water, a final carbon polishing of the effluent from the air stripper may be required. Carbon polishing is achieved by passing the effluent water from the air stripper through granular activated carbon beds (liquid phase carbon). This final treatment step ensures that the water is sufficiently treated for discharge to the ground or to a public wastewater treatment system.

The removal of VOCs from the aeration unit's air exhaust stream may also be required, depending on the levels of emissions. If treatment is required, it can be accomplished by several methods, including vapor-phase carbon adsorption, direct thermal degradation, and catalytic incineration.

Air stripping is a viable and cost-effective method of removing VOCs from water. Air stripping used in conjunction with groundwater extraction would be readily applicable to the Livermore Arcade site. The low flows from the aquifer would require a relatively small air stripper. Vapors emitted from the stripper could be discharged directly to the ambient air or treated by vapor-phase carbon adsorption or thermal degradation processes.

2.5.7 Carbon Adsorption of Contaminated Groundwater

Purification of water with both powdered and granular activated carbon filtration is an established treatment technology. Activated carbon has been used to remove color, taste, and odor-producing dissolved organic compounds from potable water sources and from process water. Over the past decade, granular activated carbon has also been shown to be an effective and economical technology for removing trace and low concentrations of organic contaminants from extracted groundwater. Granular activated carbon is normally chosen over powdered activated carbon due to the low pressure drops in flow-through configurations. Organic compounds that can typically be removed from water by activated carbon include chlorinated solvents such as tetrachloroethylene and 1,1,1-trichloroethane; petroleum hydrocarbons such as benzene, toluene, xylene, and other petroleum fuel constituents; and other organics such as pesticides and ethers.

Activated carbon adsorption is a physical treatment technique that relies on adsorption to remove organic compounds from water. Adsorption is a surface attraction phenomenon whereby molecules are weakly attracted to surface sites on the carbon substrate. The adsorption capacity of activated carbon is directly related to the number of surface sites available for contaminant removal. Molecular factors such as polarity, structure, and size can also influence the effectiveness of activated carbon. Each of these factors is discussed in greater detail below.

The number of available adsorption sites on a given carbon substrate is directly related to the total surface area. The available surface area is a function of the porosity and the quantity of the carbon within the treatment process. It is also related to the type of raw material used in the production of the activated carbon. Raw materials used for production of activated carbon include coal, wood, nut shells, sewage sludge, and petroleum residues. Each of these raw materials will produce a carbon with different adsorption characteristics. The characteristics of primary concern for water treatment are the average pore size and the surface area per unit volume (or per unit weight). These characteristics will determine the suitability of a carbon material for a specific application. Virgin carbon usually has a better adsorption characteristic than regenerated carbon. Attrition and degradation during handling reduces the adsorption characteristic of the regenerated carbon. Also, contaminants cannot be entirely eliminated from a used carbon substrate by regeneration processes; thus, some of the adsorption sites remain occupied. Carbon hardness will influence the attrition losses due to abrasion during handling processes and the raw material used will determine the hardness of the carbon product.

The solubility of an organic compound will determine its rate of adsorption. Less soluble organics will diffuse into the carbon granule at a greater rate than the more soluble organics. Therefore, compound properties which affect solubility, such as polarity, will determine how susceptible compounds are to adsorption.

Molecular structure and size can also physically affect the adsorption process. As mentioned earlier, pore size is a carbon characteristic of primary concern. The pores in a carbon substrate increase the surface area per unit volume of carbon. However, this surface area is only available if the contaminant molecules can reach it. The molecular size and structure of a contaminant may limit its ability to penetrate smaller pores and use the active sites deep within the carbon. Thus, large molecules and small molecules with large functional groups attached can be more difficult to remove using activated carbon adsorption.

The contaminants of concern at the Livermore Arcade site can be readily removed from the groundwater by activated carbon and this may be an appropriate technology, considering the low flow rates and high residence times that would be encountered. In general, liquid phase carbon adsorption is a less efficient treatment method than air stripping with vapor phase carbon treatment. The main advantage of this option is the containment of contamination within the carbon canisters, thereby eliminating air emissions and possible air permit requirements. A major disadvantage is the requirement to dispose of the carbon, which may be characterized as a hazardous waste.

2.5.8 Carbon Adsorption of Extracted Vapors

The use of activated carbon adsorption to remove the volatiles from exhaust air streams (vapor-phase carbon) has proven to be an effective removal process. The exhaust air stream from the aeration system is passed through carbon beds composed of cylindrical shaped units.

Vapor-phase carbon adsorption of volatile compounds is more efficient than liquid-phase adsorption. Contaminated water is treated with aeration, followed by vapor-phase carbon adsorption, which is much more cost effective than treating the water with only liquid-phase carbon adsorption. This efficiency is the result of the carbon units' capacity to hold more contaminants before they become saturated. Because of the aeration process, other chemicals that might compete for available adsorption sites cannot be transferred from the liquid phase into the vapor phase, allowing more space for the contaminants.

Pre-treating of the exhaust air stream from the aeration unit with dehumidifiers will also increase the adsorption efficiency of the carbon. The increase in efficiency is a result of reduced competition for adsorption sites on the carbon surface due to a reduction in the water vapor content.

The spent carbon in a vapor-phase adsorption system can be disposed off-site by incineration or landfill burial, or can be regenerated on-site or off-site. Off-site regeneration is most commonly performed at a commercial facility. On-site regeneration methods include steam stripping, followed by thermal destruction of the off-gassed VOCs.

At the Livermore Arcade site, vapor-phase activated carbon treatment would be suitable for treating both extracted soil vapors and air stripper-generated vapors.

2.5.9 *Thermal Degradation of Extracted Vapors*

Thermal degradation of VOC contaminants may be accomplished by incinerating the air stream emitted from an aeration unit. This removal system is attractive because it completely destroys VOCs in the exhaust stream in one step. The disadvantage to this system is that thermal degradation by-incineration may produce hydrochloric acid vapor (HCl) emissions. The levels of HCl generated vary with the concentration of the VOCs being removed. Depending on the HCl levels in the air stream, additional treatment may be required. Another disadvantage of thermal destruction is the cost of the fuel to heat the air stream (temperatures as high as 1,600° F must be generated).

Catalytic oxidation is another option for direct thermal degradation of the contaminants emitted from an aeration unit. Catalytic oxidation is similar to thermal degradation, except that equivalent destruction can be achieved at lower temperatures. The exhaust air stream from the aeration process is passed through a de-mister to the catalytic oxidizer where it is heated and then passed through a catalyst bed. The catalyst reduces the activation energy required for oxidizing the contaminant. The catalysts structures are generally proprietary in nature, but are typically comprised of low weight loadings of platinum or palladium on metal or metal oxide substrates. From the catalytic oxidation chamber, the air stream may pass through a scrubber to remove any hazardous by-products resulting from the oxidation process.

Thermal degradation may be applicable to the Livermore Arcade site for treatment of vapors emitted from both a vapor-extraction system and an air stripper. The relatively small amounts of contaminants that H+GCL expects to collect, however, will probably make this option less appropriate than vapor-phase carbon. The major advantage of this option is its ability to destroy the contaminants, eliminate their discharge into the atmosphere or their transfer to another medium, such as carbon. Disposal problems are eliminated but air permitting may be required.

2.5.10 Water Discharge to POTW

The process option of discharging directly to a POTW would be used in conjunction with the groundwater extraction process option. The POTW operating authority sets the limits on contaminant levels that may discharged into a sewer. Treatment is often required prior to discharging contaminated water to a POTW, and a permit is usually required. The Safe Drinking Water Act Maximum Contaminant Level for PCE is 5 ppb, and this is proposed to be the groundwater cleanup standard for the site. It would be appropriate to discharge wastewater that meets this criteria directly to a POTW, and higher levels may be discharged if allowed by the POTW. This option would be very low in cost and high in reliability.

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

The technology types and process options that remain from the initial screening are next combined to form preliminary alternatives that may be appropriate to the site. These alternatives are essentially developed by matching extraction processes with appropriate treatment and disposal processes for both soil and groundwater media. These alternatives will then be screened on the basis of effectiveness, implementability, and cost.

3.1 Development of Alternatives

From the screening of technology types and process options, the following eight alternatives were developed:

1. No action
2. Vapor/extraction with control of extracted vapors
3. Vapor-extraction with direct discharge to ambient air
4. Air sparging and vapor/extraction with carbon adsorption of extracted vapors
5. Air sparging and vapor/extraction with direct discharge to ambient air
6. Groundwater extraction with air stripping or liquid-phase carbon adsorption and disposal to POTW
7. Groundwater extraction with direct disposal to POTW
8. Subsurface bioremediation

Groundwater monitoring would be required for all of these alternatives to varying degrees. Also, these alternatives are not all mutually exclusive, and additional alternatives that are combinations of the above listed items may also be considered if the screening process indicates this to be appropriate.

The eight major alternatives developed will be screened in this section on the basis of effectiveness, implementability, and cost. The alternatives passing this screening will be evaluated in detail in Section 4.0 on the basis of the following criteria:

- Protection of human health and the environment
- Compliance with legally applicable, or relevant and appropriate requirements (ARARs)
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Long-term effectiveness and performance
- Implementability
- Cost
- Community acceptance
- State and local agency acceptance

For State law purposes as part of the remedial action plan, the following criteria will be considered to the extent consistent with the National Oil and Hazardous Substance Contingency Plan (NCP), as provided in Health and Safety Code Section 25356.1:

- The health and safety risks at the site
- The effect of contamination on present, future, and probable beneficial uses of the threatened resources
- The effect of alternative remedial action measures on the reasonable availability of groundwater for present, future, and probable beneficial uses

- The site-specific characteristics

- The cost-effectiveness of the alternative remedial action measures, including the potential for rapidly escalating costs if action is deferred

- The potential environmental impacts of the alternative remedial action measures

The alternatives passing the detailed evaluation will proceed through a public and agency comment period and be refined based on comments received.

3.2 Description of Alternatives

The eight alternatives, described below in detail, were developed in accordance with the requirements of the NCP (40 CFR Part 300) and CERCLA.

3.2.1 Alternative No. 1 - No Action

The no action alternative is appropriate if site soil and groundwater contamination will be significantly reduced over time as a result of naturally occurring processes, and if groundwater is sufficiently restricted from further movement.

The soil column contains a significant amount of clay. PCE has sorbed to clay particles in the unsaturated zone as the contaminated groundwater moved through the soil in response to the groundwater level decline. PCE that remains in the unsaturated soil zone will biodegrade and volatilize to acceptable levels over time.

Since the flow of groundwater is estimated to be no more than one to three feet per year, it is likely that equilibrium between the rate of degradation and rate of PCE transport has already been established and that the contamination plume has effectively ceased to move any further. Also, since there is no evidence of contamination of the lower aquifer and overlying aquitard, contamination is apparently isolated in the shallow aquifer. It will probably remain isolated, allowing biodegradation to naturally decay the contaminants. These assumptions would be confirmed by a groundwater monitoring program that would continue until cleanup standards in the shallow zone have been met.

However, several issues arise that make this option less desirable. Historical hydrographs presented in the RI report show that the groundwater table rose to fifteen feet bgs in the vicinity of the site in 1983. If the current drought conditions cease, and natural and artificial recharge occurs, the groundwater table will likely rise, allowing the contaminants now held in the soil to move into the groundwater. If the groundwater rises into the upper clean gravel unit, the potential for significant horizontal spreading of the contaminants will increase. The other concern is that the State of California, specifically the CRWQCB, will disallow the no action alternative.

3.2.2 *Alternative No. 2 - Vapor-Extraction with Control of Extracted Vapors*

This alternative would involve the construction of a vapor-extraction unit and the installation of a high power vacuum blower and vapor treating equipment. Existing monitor wells would be used for the vapor-extraction unit, because they are located within the contaminated zone and are screened above the water table. This would allow for extraction of vapors from the vadose zone. Additional vapor-extraction wells or trenches could be added if required to provide additional coverage.

Since the majority of the contaminated groundwater appears to be bound in the soil pores, vapor-extraction in the most highly contaminated zones should be very effective. Vapor-extraction in the vicinity of Mike's Cleaners would prevent recontamination of the groundwater if the groundwater should eventually rise to its previous position.

A pilot study was conducted by installing and operating a portable SVE unit at the site (appendix C). A soil permeability of 0.28 Darcy and a radius of influence at MW17 of 43 feet were calculated from the preliminary pilot test data. The latest pilot test data shows a radius of influence of 75 feet. These results indicated that the soil at the site would be conducive to soil-vapor-extraction.

Vapor samples were collected at the SVE system blower on different occasions. The samples were collected in Tedlar Bags and delivered to a certified analytical laboratory by chain-of-custody procedures (Table 1.2). Using a measured flow rate of 5.4 cubic feet per minute (cfm) and PCE concentration of 194 ppm, the removal rate of PCE was calculated to be 0.73 pounds per day, based on a 24 hour per day operation. The system is currently set to operate a total of 14 hours per day, resulting in a PCE removal rate of 0.42 lbs/day.

Control of extracted vapors will be required if more than 0.5 pounds per day of PCE , more than 1.0 pound per day combined listed compounds, or more than 15 pounds per day TOC, are emitted from the vapor-extraction system. This treatment is normally provided by passing the vapor stream through either a vapor-phase activated carbon adsorption system or a thermal destruction system. Both of these treatment systems are effective in meeting emission standards, but the concentrations of PCE in the vapor stream will not be sufficient to warrant the excessive expense of a thermal destruction system (about $20,000 capital cost plus significant operating costs for supplemental fuel). Therefore, only activated carbon adsorption will be further considered in this situation. Thermal or biological destruction may be reconsidered, however, if disposal costs for the spent carbon should become excessive.

3.2.3 *Alternative No. 3 - Vapor-Extraction with Direct Discharge to Ambient Air*

This alternative would involve the construction of a vapor-extraction unit and installation of a high power vacuum blower identical to that of Alternative 2, but no control equipment would be included. Both initial costs and operating costs would be decreased without the use of a vapor control system. This alternative could be allowed at the Livermore Arcade site if PCE is the only contaminant that is present and if no more than 0.5 pounds per day are emitted. Petroleum hydrocarbons have been detected during the SVE pilot test in concentrations exceeding PCE concentrations.

It is still possible that an exemption would apply and that this alternative would be appropriate. The contribution of the extracted hydrocarbons will limit the total daily discharge of PCE. The contaminant removal rate, or the length of the SVE system's daily operation, must be reduced to comply with BAAQMD requirements. A major advantage of this alternative is that discharging vapors directly to the atmosphere, eliminates spent carbon as a waste.

3.2.4 *Alternative No. 4 - Air Sparging and Vapor-Extraction with Carbon Adsorption of of Extracted Vapors*

This alternative would require the installation of air injection points through which compressed air would be forced into the aquifer. It would also require a high power air blower or compressor to supply the necessary air. Air sparging would be appropriate at the Livermore Arcade site if vapor-extraction alone is found to be inadequate in reducing the concentration of PCE in the groundwater. It would strip the PCE from the groundwater and wetted soils below the water table, and the stripped vapors would be collected by the vapor-extraction system of Alternative 2 . Vapor-extraction must be used along with air sparging to prevent uncontrolled movement of vapors in the soil.

3.2.5 *Alternative No. 5 - Air Sparging and Vapor-Extraction with Direct Discharge to Ambient Air*

This alternative consists of air sparging combined with alternative 3, vapor-extraction with direct discharge of extracted vapors into the ambient air. The advantages of air sparging are the same as discussed in Section 3.2.4. The advantage and disadvantages of direct discharge are the same as discussed in Section 3.2.3.

3.2.6 *Alternative No. 6 - Groundwater Extraction with Air Stripping or Liquid-Phase Carbon Adsorption, and Disposal to POTW*

This alternative would involve constructing extraction wells and installing pumping and treating equipment. H^+GCL would select groundwater extraction well locations to provide cones of depression that would adequately capture the contamination plume. Aquifer modeling, based on previous aquifer pump test data, would be required to properly design the extraction system.

The groundwater can be treated either by air stripping or carbon adsorption. PCE is volatile and easily removed by an air stripper. The stripped vapors may require treatment and can then be effectively trapped in a vapor-phase activated carbon adsorption system if required. PCE can be removed directly from the water by passing it through a liquid-phase activated carbon adsorption system with no air emissions, although this is not as efficient as air stripping followed by vapor-phase carbon adsorption. Either treatment option would be suitable at the Livermore Arcade site, with final selection probably depending on permitting requirements.

Groundwater extraction and treatment, as originally reviewed by Alameda County and the CRWQCB, may not be appropriate if there is not enough groundwater above the clay aquitard to allow adequate pumping. If a sufficient quantity of contaminated groundwater is present and must be remediated, then groundwater extraction and treatment may be an appropriate remedial action alternative.

3.2.7 *Alternative No. 7 - Groundwater Extraction with Direct Disposal to POTW*

This alternative would involve constructing extraction wells and installing pumping equipment, but no treatment equipment would be provided. This would be acceptable only if the water discharged to the POTW meets requirements of the POTW operating authority. The required discharge permit would define the levels of contamination allowed for discharge. Without the need for treatment, this option would be low in cost, high in reliability, and would produce no additional waste products. The Livermore POTW authority requires treatment prior to discharge into the system.

3.2.8 *Alternative No. 8 - Subsurface Bioremediation*

Subsurface bioremediation would provide enhanced stimulation of the natural biological processes that occur underground. This would require adding oxygen and nutrients to the underground media to support the natural conversion of PCE to harmless by-products. An above-ground bioreactor is often used to grow a culture of micro-organisms and to add oxygen and nutrients to the extracted groundwater, which is subsequently injected back into the aquifer. Extraction and re-injection is required to establish a flow pattern within the bioremediation cell. Injection of enriched water without an equal amount of extraction would risk uncontrolled movement of the contamination plume and is not recommended. Subsurface bioremediation is a very effective process, but it is expensive to initiate and is most appropriate for large, long-term remediation projects.

3.3 Criteria for Initial Screening

The eight alternatives identified above as potentially feasible will now be screened for applicability to the site. The screening described in this section is based on an evaluation of effectiveness, implementability and cost, like the process option screening, but this screening is used to evaluate alternatives for site-specific benefits. The evaluation criteria are defined as follows:

3.3.1 *Effectiveness*

Effectiveness is defined as the ability to meet the remedial action objective(s) for both short-term and long-term durations. Short-term refers to the construction/implementation period and long-term refers to the period after the remedial action is complete until the end of the design life (30 years).

In specific terms, effectiveness is the measure of protectiveness to human health and the environment. Protectiveness is achieved through the reduction of toxicity, mobility, or volume. The measure of protectiveness is the level to which toxicity, mobility, or volume can be reduced.

Therefore, in this study, effectiveness is defined as the reduction in quantity or mobility of PCE that will minimize the potential for ultimate direct human contact. This contact would result from migration of the contaminants into the deeper drinking water aquifer.

3.3.2 *Implementability*

Implementability is defined as the technical and administrative feasibility of constructing/implementing, maintaining, and operating a remedial action alternative. Technical feasibility refers to the availability of technologies/process options, materials, equipment, skilled personnel, etc. that each alternative would employ. Administrative feasibility refers to the ability to obtain permits for off-site actions and support from other offices and agencies to implement, operate, and maintain the alternatives.

3.3.3 *Cost*

Capital and operation and maintenance (O&M) cost have been estimated and used to determine the present worth costs. For the purposes of this FS, the total capital cost includes indirect costs estimated at 20 percent of direct costs, mobilization at 25 percent of the subtotal capital cost, and a 20 percent contingency in addition to 15 percent for engineering and construction management services. The mobilization cost includes all health and safety requirements in addition to the typical mobilization costs.

The following equations describe the total capital cost estimating procedure:

Direct Cost	=	A		
Indirect Cost	=	A (0.2)		
Subtotal Capital Cost	=	B		

and,

Mobilization	=	B(0.25)	=	C
Contingency	=	B(0.20)	=	D
Engineering	=	B(0.15)	=	E

B + C + D + E = Total Capital Cost

The detailed costs for each of the eight alternatives is presented in Appendix D.

3.4 Initial Screening of Alternatives

The initial screening of each of the eight alternatives, based on the above criteria, is described below.

3.4.1 *Alternative No. 1 - No Action*

Description

Under this alternative, no remedial action would occur at the site to minimize the threat to human health and the environment. Periodic monitoring would be the only activity that would occur at the site. Quarterly groundwater monitoring may be required for 30 years, which is approximately the period expected to be required for natural remediation and dilution to reduce the PCE concentrations throughout the site to 5 ppb.

Effectiveness

This alternative always serves as a baseline for comparison of other remedial alternatives. The risk at the site is limited to the potential for migration of contamination to the deep drinking water aquifer. The no action alternative would not reduce this risk of exposure in the short term.

Implementability

Since monitoring is the only activity that would be conducted, implementability would be straightforward. At this stage, it is not known whether State or local agencies would accept the no action alternative.

Cost

The present worth cost of the no action alternative is estimated to be $322,900. Costs include quarterly groundwater sampling in both the shallow and deep aquifers for a period of 30 years at an annual cost of $18,000. The no action alternative, however, also risks spread of contamination, resulting in increased cleanup costs. When these risks are taken into account, the effective cost of this option is much higher. Also, given the high cost of replacing the existing CWS groundwater resources, even a small percentage risk of contamination to the deep aquifer carries a high economic risk. Assuming a 1% chance of replacing water resources worth $5,000,000 raises the cost of this alternative by $50,000.

3.4.2 Alternative No. 2 - Vapor-Extraction with Carbon Adsorption of Extracted Vapors

Description

Under this alternative, a vapor-extraction system would be installed using existing monitor wells as vapor-extraction wells. Extracted vapors would be treated with carbon adsorption to reduce PCE emission levels to negligible amounts. The purpose would be to remove the remaining source of PCE in the vadose zone soil.

As with the no action alternative, continued groundwater monitoring would be undertaken in concert with vapor monitoring to assess the effectiveness of this alternative to reduce contaminant levels and to prevent the migration of contamination to the deeper aquifer. The vapor-extraction system may not effect the PCE in the groundwater successfully. Long term monitoring may be required to supplement this alternative.

Effectiveness

This alternative would be effective in reducing contaminants and preventing human exposure to contaminated groundwater or to PCE vapors released to the ambient air. The alternative, if implemented alone, would not aggressively remediate the remaining contaminated groundwater at the site. However, given the amounts of PCE involved, estimated to be 68 pounds, it is not anticipated that these residual contaminants will present any risk to health, welfare or the environment because of biotransformation, volatilization and dilution. High concentrations of contaminants left in groundwater may inhibit efficiency of natural processes to achieve ARARs. This alternative would be expected to remove greater than 90% of the PCE from the vadose zone soil within the treatment zone, in less than six months. Results of the SVE pilot test confirm that 0.42 pounds per day of PCE can be removed.

Implementability

This alternative can be implemented with relative ease. When compared to Alternative 3, this option has reduced environmental impacts in terms of the decreased venting of PCE to the ambient air. However, this alternative has increased impacts from use of activated carbon, with resulting disposal problems and potential RCRA permitting delays.

Implementability of Alternative 2 is dependent upon the groundwater remaining below historic levels, leaving most of the contaminants in the vadose zone. Should the drought end and groundwater levels rise through artificial or natural recharge, this alternative alone may not be implementable.

Cost

The present worth cost of Alternative 2 is estimated to be $284,270. Capital costs are estimated to be $134,400 and include the costs of the vapor-extraction system and one above-ground treatment facility. O&M costs are anticipated to be $41,040 per year over 2 years plus $18,000 per year for the 5-year groundwater monitoring program. Detailed costs for this alternative are presented in Appendix D.

3.4.3 *Alternative No. 3 - Vapor-Extraction with Direct Discharge to Ambient Air*

Description

Under this alternative, a vapor-extraction system would be installed similar to that of Alternative 2. Extracted vapors would not be controlled, but instead would be vented to the ambient air.

Groundwater would be continually monitored to assess the effectiveness of vapor-extraction in reducing contaminant levels and preventing the migration of contamination to the deeper aquifer. Long-term monitoring may be required to supplement this alternative.

Effectiveness

This alternative would be effective in reducing contaminants and preventing human exposure to contaminated groundwater by reducing PCE loading in the vadose zone. It would be less effective in preventing exposure to PCE vapors released to the ambient air. If reduced amounts of PCE are vented, BAAQMD regulations may not require additional treatment such as included in Alternative 2. A risk assessment would be required by the BAAQMD to successfully obtain a BAAQMD permit. This alternative would be expected to remove greater than 90% of the PCE from the vadose zone soil within the treatment zone. It is not anticipated that the residual contaminants will present any risk to human health or the environment with the effects of biotransformation volatilization and dilution. This alternative, like alternative 2, would not aggressively remediate the contaminated groundwater at the site.

Implementability

This alternative can be readily implemented. When compared to Alternative 2, this option has increased environmental impacts in terms of the venting of PCE to the ambient air. However, this alternative does not require supplemental fuel for incineration, nor activated carbon, with resulting disposal problems. Since groundwater extraction systems are typically inefficient, this approach would likely take less time than Alternatives 5 or 6 to address the problem at the site.

As with Alternative 2, implementability of Alternative 3 is dependent upon the groundwater table remaining below historic levels, leaving most of the contaminants in the vadose zone. Should the drought end and groundwater levels rise through artificial or natural recharge, this alternative not be implementable. It is also dependent on permitting requirements.

Cost

H^+GCL estimates the present worth cost of Alternative 3 is to be $262,410. Capital costs are estimated to be $130,560 and include the costs of the vapor-extraction system. O&M costs are anticipated to be $29,500 per year over 2 years plus $18,000 per year for 5 years of groundwater monitoring.

3.4.4 *Alternative No. 4 - Air Sparging and Vapor-Extraction with Carbon Adsorption of Extracted Vapors*

Description

Under this alternative, the same vapor-extraction system would be installed as described in Alternative 2. In addition, an air injection point would be installed within the radius of influence of each vapor-extraction well. Compressed air bubbling into the aquifer would strip PCE from the water and the vapor-extraction system would subsequently remove these released vapors through the soil. Extracted vapors would be captured by carbon adsorption (Alternative 2).

Continued groundwater monitoring would be undertaken to assess the effectiveness of the systems in reducing contaminant levels and preventing the migration of contamination to the deeper aquifer. Although this enhanced vapor-extraction system would collect PCE from groundwater, groundwater monitoring would be required to supplement this alternative until the lead regulatory agency verifies its success. Monitoring for 5 years was used for cost calculations, but the actual monitoring requirements may be less.

Effectiveness

This alternative should be very effective in reducing contaminants in both contaminated soil and groundwater and in preventing human exposure. Because this alternative removes volatile contaminants from both the saturated and unsaturated zones, it would be effective in reducing the total loading of contaminants in both the soil and groundwater, regardless of groundwater level. Case studies show over a 90 percent reduction of VOCs in groundwater in a relatively short time frame (within a few months) The effectiveness of this system will remain high even if groundwater levels rise due to natural or artificial recharge, with a greater zone of contamination surrounded by shallow groundwater. Additional air injection points can easily be added as required to cover expanded zones of contamination. This alternative would be expected to remove PCE in both the groundwater and the soil located in the treatment zone in less than one year. Currently the SVE system pilot test shows a radius of influence of about 75 feet and PCE removal rate at 0.42 pounds per day without sparging.

Implementability

This alternative can be implemented quite easily, especially if Alternative 2 is already in place. An air blower or compressor could be added to the vapor-extraction system with little difficulty. Air injection points could consist of monitor wells that are screened below the water table or could simply be small diameter pipes driven through the ground into the aquifer. They must be sealed to maintain air pressure for successful operation. Existing probes installed in connection with the pilot-scale vapor-extraction test can be utilized for the initial system.

The addition of air sparging to an already effective vapor-extraction system provides very rapid remediation of both soil and groundwater. Alternative 4 appears to provide the best potential for rapid and economical cleanup. Implementation of Alternative 4 would follow installation and testing of either Alternative 2.

Cost

The present worth cost of Alternative 4 is estimated to be $282,480. Capital costs are estimated to be $161,280 and include the costs of a soil-vapor-extraction system and a vapor-phase carbon treatment facility. O&M costs are anticipated to be $43,100 per year for one year of system operation plus $18,000 per year for the 5-year groundwater monitoring program.

3.4.5 *Alternative No. 5 - Air Sparging and Vapor-Extraction with Direct Discharge to Ambient Air*

Description

This alternative is the same as Alternative 4, but without control of vapors with carbon adsorption.

Effectiveness

This alternative is potentially as effective as Alternative 4, but is limited to reduced contaminant removal rates to comply with BAAQMD emission requirements.

Implementability

Again, this alternative can be implemented just as Alternative 4. An air blower or compressor could be added to the vapor-extraction system with little difficulty. Air injection points could consist of monitor wells that are screened below the water table or could simply be small diameter pipes driven through the ground into the aquifer. They must be sealed to maintain air pressure for successful operation. Existing probes installed in connection with the pilot-scale vapor-extraction test can be utilized for the initial system.

The addition of air sparging to an already effective vapor-extraction system provides very rapid remediation of both soil and groundwater. Implementation of Alternative 5 would follow installation and testing of Alternative 3.

Cost

The present worth cost of Alternative 4 is estimated to be $267,100. Capital costs are estimated to be $157,440 and include the costs of a soil-vapor-extraction system and vapor-phase carbon treatment facility. O&M costs are anticipated to be $31,560 per year for one year of system operation plus $18,000 per year for the 5-year groundwater monitoring program.

3.4.6 *Alternative No. 6 - Groundwater Extraction with Air Stripping or Liquid-Phase Carbon Adsorption, and Disposal to POTW*

Description

Under this alternative, a groundwater extraction system would be installed using existing monitor wells as extraction wells. Extracted groundwater would be treated through air stripping or liquid phase carbon adsorption, and then discharged to the local POTW.

Continued long term groundwater monitoring would be required to assess the effectiveness of the system in reducing contaminant levels and preventing the migration of contamination to the deeper aquifer.

Effectiveness

This alternative would likely be effective in reducing contaminants and preventing human exposure to contaminated groundwater. However, given the low present groundwater levels, Alternative 6 would not be as effective as Alternatives 2, 3, 4 or 5 in reducing the total loading of contaminants in the soil, soil vapors and groundwater, since it would only address a relatively small portion of the contamination. If groundwater levels rise due to natural or artificial recharge, and a greater zone of contamination is surrounded by shallow groundwater, the relative effectiveness of this alternative would increase.

Either air stripping or carbon adsorption would be effective in treating the contaminant levels at the site, at similar costs for this size project. Air stripping may require treatment of vapors while carbon adsorption would require disposal of spent carbon. Permitting requirements will affect the selection of treatment type in this case. Because of the inefficiency of groundwater extraction systems, this alternative is expected to remove no more than 50 percent of PCE in the groundwater of the treatment zone and virtually none of the PCE in the vadose zone soil. Based on calculations using pump test data, it may take six years or more to achieve a significant reduction of PCE in the groundwater.

Implementability

This alternative could be readily implemented. For the initial system, the remediation contractor can use existing wells installed in connection with the site assessment.

Since groundwater extraction systems are typically inefficient and do not treat vadose zone contamination, this approach will likely take more time than Alternatives 2, 3, 4 or 5 to address the problem at the site. It may take six years or more to achieve a significant reduction of PCE in the groundwater.

As a practical matter, effective implementation of Alternative 6 is dependent upon groundwater levels returning to historic levels. Under the present conditions, this alternative in not considered practical at this site.

Cost

The present worth cost of Alternative 6 is estimated to be $507,970. Capital costs are estimated to be $172,800 and include the costs of the groundwater extraction system and above ground treatment facilities. O&M costs are anticipated to be $50,160 per year over 6 years plus $18,000 per year for the 5-year groundwater monitoring program.

3.4.7 Alternative No. 7- Groundwater Extraction with Direct Disposal to POTW

Description

Under this alternative, a groundwater extraction system would be installed using existing monitor wells as extraction wells. The system would be similar to that of Alternative 6 except the extracted groundwater would not be treated before being discharged to the local POTW.

Continued long term groundwater monitoring would be undertaken to assess the effectiveness of the system in reducing contaminant levels and preventing the migration of contamination to the deeper aquifer.

Effectiveness

This alternative likely would be effective in reducing contaminants and preventing human exposure to contaminated groundwater. However, given the low present groundwater levels, Alternative 7 would not be as effective as Alternatives 2, 3, 4 or 5 in reducing the total loading of contaminants in the soil, soil vapors and groundwater, since it would only address a relatively small portion of the contamination. If groundwater levels rise due to natural or artificial recharge, and a greater zone of contamination is surrounded by shallow groundwater, the relative effectiveness of this alternative would increase. Because of the inefficiency of groundwater extraction systems, this alternative is expected to remove no more than 50 percent of PCE in the groundwater of the treatment zone and virtually none of the PCE in the vadose zone soil.

Implementability

This alternative could be readily implemented. Existing wells installed in connection with site assessment can be utilized for the initial system.

Since groundwater extraction systems are typically inefficient and do not treat vadose zone soil, this approach will likely take more time than Alternatives 2, 3, 4 or 5 to address the problem at the site. It may take six years or more to achieve a significant reduction of PCE in the groundwater.
As a practical matter, effective implementation of Alternative 7 is dependent upon groundwater levels returning to historic levels, as well as acceptance by the POTW operating authority to discharge directly to their sewer. The City of Livermore does not allow direct discharge. Under the present conditions, this alternative is not considered practical at this site.

Cost

The present worth cost of Alternative 7 is estimated to be $349,510. Capital costs are estimated to be $88,320 and include the costs of the groundwater extraction system. O&M costs are anticipated to be $35,760 per year over 6 years plus $18,000 per year for the 5-year groundwater monitoring program.

3.4.8 Alternative No. 8- Subsurface Bioremediation

Description

Under this alternative, a groundwater extraction system would be installed using existing monitor wells as extraction wells similar to Alternatives 6 and 7. Extracted groundwater would be treated in an above ground bioreactor before being injected back into the aquifer through two newly installed injection wells.

Two bioremediation cells would be established to treat the vadose zone soil, the wetted soil and the groundwater in the treatment zone. For practical purposes, however, the entire groundwater plume would not be included in the bioremediation cell. The remainder of the plume outside the cell would be expected to degrade naturally at an acceptable rate.

As with the other alternatives, continued long term groundwater monitoring would be required to assess the effectiveness of the system in reducing contaminant levels and preventing the migration of contamination to the deeper aquifer.

Effectiveness

This alternative would likely be effective in reducing contaminants and preventing human exposure to contaminated groundwater. However, given the low present groundwater levels, this alternative would not be as effective as Alternatives 2, 3, 4 or 5 in reducing the total loading of contaminants in the soil, soil vapors and groundwater, since it would require the controlled movement of groundwater. If groundwater levels rise due to natural or artificial recharge and the levels of groundwater contamination increase, the relative effectiveness of this alternative would increase. If properly implemented, this alternative could be expected to remove greater than 90 percent of PCE from both soil and groundwater within the treatment zone in less than two years of operation.

Implementability

This alternative would be implemented with considerable difficulty. Although existing wells installed in connection with site assessment could be utilized for the initial extraction system, new injection wells would be required as well as bioreactors. A treatability study would be required prior to system design, and much attention would be required for proper operation. Since groundwater extraction systems are typically inefficient, this approach would likely take more time than Alternatives 2, 3, 4 or 5 to address the problem at the site. Once the bioremediation cell becomes active, however, the rate of remediation would be expected to increase rapidly.

Because of the high initial expense of a bioremediation system and the difficulty of implementation, this alternative is not considered practical at this site.

Cost

The present worth cost of Alternative 7 is estimated to be $435,110. Capital costs are estimated to be $282,240 and include the costs of the groundwater extraction system and above-ground treatment facilities. O&M costs are anticipated to be $41,040 per year over 2 years plus $18,000 per year for the 5-year groundwater monitoring program.

3.5 Summary

Generally speaking, all the alternatives are feasible at the Livermore Arcade PCE site under certain conditions, but not all are practical. The no action alternative is feasible only if it can be assured by strict monitoring that the contamination in both the soil and groundwater will remain isolated and confined to its present location, while natural biodegradation eventually reduces it to acceptable levels. Alternatives 2, 3, 4 and 5 would provide the quickest results and the highest level of protection, at the least cost of the alternatives studied. Alternatives 6 and 7, which require extraction of groundwater, will not be further considered because of the limited amount of shallow groundwater that can be extracted, because of the typical inefficiency of pump-and-treat systems, and because of their high present value costs. Due to the high cost of Alternative No. 8, its difficulty of implementation, and its lack of advantage over other alternatives, it will no longer be considered. The remaining five alternatives will be evaluated in detail in Section 4.0.

4.0 DETAILED ANALYSIS OF SELECTED REMEDIAL ACTION ALTERNATIVES

4.1 General

The final phase in the FS process is the detailed analysis of alternatives passing the initial screening. The detailed analysis provides decision makers with sufficient information to use as a basis for selecting alternatives that are protective of human health and the environment and meet the objectives of the EPA, state, and local agencies, and the community, to the maximum extent practicable.

The detailed analysis consists of the following components:

- Development of additional information for each alternative with respect to the volumes or areas of contaminated media to be addressed, the technologies to be used, and any performance requirements associated with those technologies.

- An assessment and a summary of each alternative against the nine evaluation criteria, with respect to each subunit, is discussed in the following section.

- A comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion.

The alternatives remaining for further consideration are:

- Alternative No. 1 - No Action.

- Alternative No. 2 - Vapor-extraction with carbon adsorption of extracted vapors

- Alternative No. 3 - Vapor-extraction with direct discharge to ambient air

- Alternative No. 4 - Air sparging and vapor-extraction with carbon adsorption of extracted vapors

- Alternative No. 5 - Air sparging and vapor-extraction with direct discharge to ambient air

Groundwater monitoring will be implemented for each alternative when the effect of the remedial action is no longer significant (with the exception of No. 1). Monitoring for the no action is estimated to be 30 years for cost estimation purposes. This monitoring requirement is based on recommended long-term monitoring requirements at RCRA sites and the estimated time for natural biodegradation to reduce PCE concentrations to 5 ppb throughout the Arcade site. The other alternatives have the potential to achieve the ARARs in a relatively shorter time frame. For each of the other alternatives, monitoring was limited to 5 years beyond the expected cleanup periods. This could actually be less, depending on the success of the remediation process.

4.2 Criteria for Detailed Analysis

The detailed analysis includes an analysis of the nine criteria presented below which encompass technical, cost, and institutional considerations; compliance with specific statutory requirements; and state/local agency and community acceptance.

- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Implementability
- Cost
- Compliance with ARARs
- Overall protectiveness
- State and local agency acceptance
- Community acceptance

Evaluation of the nine criteria is consistent with the latest EPA guidance under CERCLA.

For state law purposes as part of the remedial action plan, the following criteria will be considered to the extent consistent with the NCP, as provided in Health and Safety Code Section 25356.1:

- The health and safety risks at the site;
- The effect of contamination on present, future, and probable beneficial uses of the threatened resources;
- The effect of alternative remedial action measures on the reasonable availability of groundwater for present, future, and probable beneficial uses;
- The site-specific characteristics;
- The cost effectiveness of the alternative remedial action measures, including the potential for rapidly escalating costs if action is deferred; and
- The potential environmental impacts of the alternative remedial action measures.

Each NCP criterion is described in the following subsections.

4.2.1 Short-Term Effectiveness

The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation period until response objectives have been met. In particular, this criterion examines the remedial activities associated with each alternative that may result in increased risks from ingestion or inhalation of PCE. This evaluation is limited to a qualitative analysis based on assumed activities. Worker safety is also considered. The National Contingency Plan states the requirement as follows:

> Short-term effectiveness. The short-term impacts of alternatives shall be assessed considering the following: (1) Short-term risks that might be posed to the community during implementation of an alternative; (2) Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures; (3) Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and (4) Time until protection is achieved.

4.2.2 *Long-Term Effectiveness and Performance*

The assessment of alternatives against this criterion evaluates the long term effectiveness of alternatives in protecting human health and the environment from the time the response objectives have been met until the end of the design life and beyond. The adequacy and reliability of long-term maintenance and controls are considered. The assessment of the magnitude of remaining risk is limited in this study to a qualitative analysis. The National Contingency Plan states the requirement as follows:

> Long-term effectiveness and permanence. Alternatives shall be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered, as appropriate, include the following: (1) Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate. (2) Adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste. This factor addresses in particular the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

4.2.3 *Reduction of Toxicity, Mobility, or Volume (TMV)*

Reduction of TMV is achieved through treatment of wastes. Reduction of mobility is defined as the containment of PCE in order to reduce, minimize, or eliminate the potential for airborne PCE (i.e., inhalation pathway) and direct human contact (i.e., ingestion pathway). The National Contingency Plan states the requirement as follows:

> Reduction of toxicity, mobility, or volume through treatment. The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the site. Factors that shall be considered, as appropriate, include the following: (1) The treatment or recycling

> processes the alternatives employ and materials they will treat; (2) The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled; (3) The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring; (4) The degree to which the treatment is irreversible; (5) The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents; and (6) The degree to which treatment reduces the inherent hazards posed by principal threats at the site.

4.2.4 *Implementability*

This criterion evaluates the technical and administrative feasibility of constructing and operating the alternative. In particular, this criterion evaluates administrative feasibility, technical feasibility including physical ability to implement and construction methods, and availability of services and materials, including experienced personnel. The National Contingency Plan states the requirement as follows:

> Implementability. The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors as appropriate: (1) Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy. (2) Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions); (3) Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies.

4.2.5 *Cost*

This criterion evaluates the capital, operations and maintenance (O&M), and present worth costs of each alternative. Capital costs include direct (construction) and indirect (nonconstruction and overhead) costs. Direct capital costs would include cost of materials, labor, equipment, land and site development, buildings, services, utilities, transport and disposal. Indirect capital costs may include engineering design, startup and shakedown costs, contingency allowances, legal fees and administrative costs. O&M are the yearly costs to ensure the continued effectiveness of a remedial action. These may include maintenance, labor, services, and periodic site reviews. Present worth costs are presented, by discounting all future costs to the current, or base, year. The costs represent an accuracy of +50/-30 percent based on available information. Detailed costs are presented in Appendix D. The National Contingency Plan states the requirement as follows:

> Cost. The types of costs that shall be assessed include the following: (1) Capital costs, including both direct and indirect costs; (2) Annual operation and maintenance costs; and (3) Net present value of capital and O&M costs.

4.2.6 Compliance with ARARs

The assessment against this criterion describes how the alternative complies with ARARs. The assessment includes information from advisories, criteria, and guidance that the lead and support agencies have agreed is necessary and appropriate. The National Contingency Plan states the requirement as follows:

> Compliance with ARARs. The alternatives shall be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws or provide grounds for invoking one of the waivers under paragraph (f)(1)(ii)(C) of this section.

Waivers, however, are not available for private party cleanups without government participation.

4.2.7 Overall Protection

This criterion evaluates the ability of the alternative to protect and maintain protection of human health and the environment. The analysis indicates how each source of contamination is eliminated, reduced, or controlled for each alternative. This criterion is, in effect, a summary of the first three criteria. The National Contingency Plan states the requirement as follows:

> Overall protection of human health and the environment. Alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both

the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals consistent with § 300.430(e)(2)(i). Overall protection of human health and the environment draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

4.2.8 State and Local Agency Acceptance

This criterion evaluates potential comments or concerns from state and local agencies. Since actual comments or concerns will be unknown until after the public comment period, this criterion will be addressed in general terms only. Comments/concerns received during the public comment period will be responded to in the Responsiveness Summary. The National Contingency Plan states the requirement as follows:

> State acceptance. Assessment of state concerns may not be completed until comments on the RI/FS are received but may be discussed, to the extent possible, in the proposed plan issued for public comment. The state concerns that shall be assessed include the following: (1) The state's position and key concerns related to the preferred alternative and other alternatives; and (2) State comments on ARARs or the proposed use of waivers.

4.2.9 Community Acceptance

This criterion evaluates the community's comments or concerns. Like the preceding criterion, however, actual community comments/concerns will not be known until after the public comment period, so the discussion will be presented in general terms. Comments/concerns received from the community during the public comment period will be responded to in the Responsiveness Summary. The National Contingency Plan states the requirement as follows:

> Community acceptance. This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received.

It should be noted that during the comment period on the remedial investigation report no moments were received from the general public, and only certain responsible parties responded.

4.3 Individual Analysis of Alternatives

Each alternative is analyzed below according to the previously discussed criteria. This analysis is also summarized in Table 4.1.

4.3.1 Alternative No. 1 - No action

Description

This alternative would not involve remedial action. No Action means that the site would remain in its current condition. Risks from ingestion of PCE would remain at the levels described in Section 1.3.4, Risk Assessment. Long term groundwater monitoring would be required to make sure that this alternative was the correct selection, and a contingency plan would be required if contamination were found to be spreading.

Short-Term Effectiveness

Since no remedial activity would occur under No Action, no short-term effectiveness or reduction in risk would be achieved.

Long-Term Effectiveness and Permanence

The No Action alternative is included as a baseline for comparison of other remedial alternatives. Under No Action, the existing site risks would be reduced only as a result of biodegradation, volatilization and dilution. Long-term effectiveness and permanence would be achieved when contamination concentrations naturally reach acceptable levels. Long term monitoring would be required to assess the rate of natural biodegradation. Areas with low concentrations of contaminants (<100 ppb, assuming a half-life of 1 year) could naturally remediate within 5 years to below 5 ppb. High concentration areas near Mike's Cleaners would take considerably longer. The source area would remain to recontaminate downgradient locations.

Reduction of Toxicity, Mobility or Volume

No Action would slowly reduce toxicity, mobility and volume.

Implementability

Since no actions would be undertaken, implementability does not apply. Long term monitoring would be implemented.

Cost

The present worth cost of the no action alternative is estimated to be $322,900. These costs assume groundwater sampling for 30 years, along with regular re-evaluation of the existing risk assessment. The costs are presented in Appendix D, and include an estimated $18,000 annual cost. Groundwater monitoring could be required for 30 years because no remedial action would occur. Groundwater monitoring would cease after cleanup levels are attained and the regulatory agency is convinced of success. Costs would increase if the affected water resources had to be replaced at a future date.

Compliance with ARARs

The No Action alternative would not initially attain ARARs but is expected to do so in areas of low concentration (<100 ppb) within 5 years.

The area in the vicinity of Mike's Cleaners could take considerably longer (up to 30 years).

Overall Protectiveness

The No Action alternative would provide limited protectiveness and risk reduction. Initial risks would remain similar to the levels estimated in the Risk Assessment, or $1 X 10^{-3}$, but is expected to decrease with time. Monitoring results will determine if protection is increased over time.

State & Local Agency Acceptance

State and local agency acceptance will not be known until after the public comment period, but it is anticipated that this option would not be acceptable.

will initially be used and can be easily connected. Additional vapor extraction wells will be constructed and connected as required. Piping is expected to be above-ground, but if any excavation is required, it will not intrude into contaminated soil. Additional vapor-extraction wells will be installed by qualified contractors.

The short-term effectiveness for Alternative No. 2 would be high. Based upon the removal rates observed in the pilot test, it is conservatively estimated that adequate removal to eliminate loading of PCE in the vadose zone could be accomplished within two years.

Long-Term Effectiveness and Permanence

Under this alternative, the existing site risks discussed in Section 1.3.4. would be reduced and the remedial action objectives discussed in Section 2.3 would be met. With the use of activated carbon treatment of the emitted vapors and with proper operation and maintenance procedures, there will be little chance of human exposure to the contamination. The carbon canisters will be professionally serviced by the carbon supplier who will remove them from the site and replace them with new canisters as needed. Final disposal of the carbon will be done under controlled conditions with little risk to humans or the environment.

Vapor-extraction is effective in removing soil contaminants and will provide a permanent solution when the target levels have been reached. The long-term effectiveness for Alternative No. 2 would be high.

Reduction of Toxicity, Mobility or Volume

Vapor-extraction with carbon adsorption will reduce the mobility of PCE in the soil by removing it from the soil. The influence of the vacuum blower and extraction unit will prevent further migration of vadose zone vapors away from the site. Toxicity will be reduced by removing the PCE from the vapor stream in the carbon units, and the volume of PCE in the soil will be reduced by the soil-vapor-extraction process. The removal of PCE from the soil in the vadose zone will encourage the transfer of PCE from groundwater into the vacated pores of the soil, where these newly transferred vapors will be removed by the vapor-extraction system. The effectiveness of this transfer will be determined by the monitoring program that will be in effect.

Community Acceptance

Community acceptance will not be known until after the public comment period.

4.3.2 Alternative No. 2 - Vapor-Extraction with Activated Carbon Treatment

Description

The pilot test was performed by attaching a 5 horsepower regenerative blower (with vapor phase carbon treatment) to monitor well MW 17. Piezometers were placed at 5, 10, 25, 35, 50, and 75 feet from MW 17. Monitor well MW 7 was used as a piezometer to measure the pressure response at 15 feet. With the blower on, the vacuum pressure was measured in the piezometers at different times starting at 1 minute up to 1170 minutes. The velocity of the air exiting the blower was measured and the flow rate was calculated. The pressure at the well head was measured as well.

Using a mathematical model developed by Johnson et. al, soil permeability to air flow was calculated at 0.28 Darcy and the radius of influence was determined to be 40 feet. Recent data shows a radius of influence of 75 feet. The data and calculations are presented in Appendix C. Additional testing and sampling shows that the rate of PCE remediation, with the SVE system used for the pilot test 0.4 pounds per day.

The pilot test unit, which is already on-site, will be suitable for use as the long term treatment unit. It consists of a 5 hp vacuum blower and two 200 pound activated carbon cannisters. The system is constructed with explosion-proof wiring and is housed in an attractive enclosed trailer. In order to remediate within the 100 ppb isopleth, the portable SVE unit will be employed at various extraction well locations throughout the site. Eight additional wells may need to be installed to provide adequate locations for extraction points.

Short-Term Effectiveness

Construction workers involved in the remediation would be protected by complying with current OSHA regulations. These include preparation of a site health and safety plan to which all workers must comply, monitoring with appropriate instruments during any intrusive work into potentially contaminated zones and protection from other hazards such as traffic and electricity. Existing wells

The vapor-extraction system would be applied only to the zone where PCE concentrations in groundwater exceed 100 ppb. Previous studies discussed in Section 1.3.5 show that natural biodegradation and volatilization processes are effective in reducing PCE concentrations in groundwater to acceptable levels over time. However, these field studies involve sites where relatively low concentrations of PCE are observed (e.g. less than 100 ppb). Thus, this alternative provides for remediation of groundwater within the 100 ppb isopleth and natural remediation for the remainder of the plume. Assuming that the half-life of PCE in groundwater at the Livermore Arcade site is similar to the 0.6 year half-life observed in the study of Roberts and others (1985), a period of 3 years is required to reduce groundwater concentrations from 100 ppb to within acceptable limits. A period of groundwater monitoring for 5 years is employed for cost estimation purposes. For the purposes of this FS a half-life for PCE of 1.0 year is used giving a reduction in PCE concentrations from 100 ppb to less than 5 ppb in 5 years.

Implementability

Vapor-extraction with carbon treatment is easily implemented. The existing pilot scale treatment unit can be adapted for long term use in a full scale system. Existing monitor wells can be used for the vapor-extraction unit and the treatment unit can be moved to alternate locations if required to provide complete coverage. Additional extraction wells can be easily added if they are found to be necessary.

Results from the pilot scale study indicate that soil remediation by vapor-extraction will proceed rapidly when implemented on a full scale. It appears that it will be most practical to utilize one vapor-extraction unit that will successively be moved to various extraction wells located in the zone to be treated. Considering the size of the contaminated zone and the levels of contamination to be removed, the pilot scale system appears to be of the appropriate size to be utilized as the full scale unit as well.

Cost

The present worth cost of Alternative No. 2 is estimated to be $284,270. Capital cost is estimated to be $134,400. Yearly maintenance cost is estimated to be $41,040 for 2 years plus a yearly groundwater monitoring cost of $18,000 for 5 years. Costs are presented in Appendix D.

Compliance with ARARs

The ARARs pertaining to this alternative are BAAQMD Regulation 8, Rule 47, which limits the amount of emission of PCE and other listed compounds and the Safe Drinking Water Act Maximum Contaminant Level for PCE of 5 ppb. It is anticipated that the soil-vapor-extraction system will not only remove vapors from the vadose zone but will also create a difference in vapor pressure that will transfer PCE from the groundwater to the air in the vadose zone. If after sufficient operation, it is determined that the groundwater ARAR will not be attained, then air sparging should be considered, as described under Alternative No.4.

Overall Protection

Alternative No. 2 represents a proven technology that can remove PCE vapors from the soil with little risk of exposure to humans or the environment. It will provide a permanent solution when completed. Its overall protectiveness will be high.

State and Local Agency Acceptance

State and local agency acceptance of this alternative will not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. Similar systems have been accepted by the regulatory authorities.

Community Acceptance

Actual community acceptance would not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. The system would be quiet in operation and fully enclosed from view, and many communities have accepted similar systems. No complaints were received during the pilot test program.

4.3.3 *Alternative No. 3 - Vapor-Extraction with Direct Discharge to Ambient Air*

Description

Alternative No. 3 involves the installation of a vapor-extraction unit connected to a high power vacuum blower that will remove PCE vapors from the soil. This alternative is similar to Alternative

No. 2 except that the vapors are discharged directly to the ambient air instead of being passed through activated carbon. The initial system would use existing monitor wells, which are screened above the water table, as soil vapor-extraction locations. A pilot test was conducted at the site using monitor well MW-17 and recent results show the radius of influence to be 75 feet from the extraction well. This indicates that soil vapor-extraction is a suitable technology for this site.

The pilot test unit, which is already on-site, will be suitable for use as the long term treatment unit. It consists of a 5 hp vacuum blower and two 200-lb activated carbon canisters. For this alternative, the carbon canisters would be by-passed. The portable system is constructed with explosion-proof wiring and is housed in an attractive enclosed trailer. Eight additional extraction wells may be installed to provide necessary extraction locations.

Short-Term Effectiveness

Construction workers involved in the remediation would be protected by complying with current OSHA regulations. These include preparation of a site health and safety plan to which all workers must comply, monitoring with appropriate instruments during any intrusive work into potentially contaminated zones and protection from other hazards such as traffic and electricity. Existing wells will initially be used and can be easily connected. Piping is expected to be above-ground, but if any excavation is required, it will not intrude into contaminated soil. Additional wells will be installed by qualified contractors.

The short-term effectiveness for Alternative No. 3 would be medium. It is expected that sufficient removal of PCE vapors from the vadose zone could be accomplished within two years, although BAAQMD requirements may limit the rate of PCE removal (i.e. lbs/day)..

Long-Term Effectiveness and Permanence

Under this alternative, the existing site risks discussed in Section 1.3.4. would be reduced and the remedial action objectives discussed in Section 2.3 would be met. Vapor-extraction is effective in removing soil contaminants and will provide a permanent solution when the target levels have been reached. The long-term effectiveness for Alternative No. 3 would be high.

Reduction of Toxicity, Mobility or Volume

Vapor-extraction will reduce the mobility of PCE in the soil by removing it from the soil. The influence of the vacuum blower and the extraction unit will prevent further migration of vadose zone vapors away from the site. Toxicity will be reduced by removing the PCE from the vapors from the soil, and the volume of PCE in the soil will be reduced by the vapor-extraction process. The removal of PCE from the soil in the vadose zone will encourage the transfer of PCE from groundwater into the vacated pores of the soil, where these newly transferred vapors will be removed by the vapor-extraction system. The effectiveness of this transfer will be determined by the monitoring program that will be in effect.

The vapor-extraction system would be applied only to the zone within the identified 100 ppb isopleth (figure 4), with the assumption that removing the PCE source in the soil will allow for an increased rate of natural biodegradation of the groundwater plume. Because the entire plume will not be under treatment, it will be necessary to continue long term groundwater monitoring to assess the overall rate of remediation. Because of this, a 5-year groundwater monitoring period is used for cost estimation purposes.

Implementability

Vapor-extraction is easily implemented. The existing pilot scale treatment unit is adaptable for long term use in a full scale system. Existing monitor wells can be used for the vapor-extraction unit and the treatment unit can be moved to alternate locations as required to provide complete coverage. Additional extraction wells can be easily added.

Results from the pilot scale study indicate that soil remediation by vapor-extraction will proceed rapidly when implemented on a full scale. It appears that it will be most practical to utilize one vapor-extraction unit that will successively be moved to various extraction wells located in the zone to be treated. Considering the size of the contaminated zone and the levels of contamination to be removed, the pilot scale system appears to be of the appropriate size to be utilized as the full scale unit as well. The unit will be set up near Mike's Cleaners initially. It will operate more time in this area than in the down gradient areas. The amount of time spent at each location would be proportional to the level of PCE concentrations at each location.

Cost

The present worth cost of Alternative No. 3 is estimated to be $262,410. Capital cost is estimated to be $130,560. Yearly maintenance cost is estimated to be $29,500 for 2 years plus a yearly groundwater monitoring cost of $18,000 for 5 years. Costs are presented in Appendix D.

Compliance with ARARs

The ARARs pertaining to this alternative are BAAQMD Regulation 8, Rule 47, which limits the emission of PCE vapors and other listed compounds and the Safe Drinking Water Act Maximum Contaminant Level for PCE of 5 ppb. It is anticipated that the soil-vapor-extraction system will not only remove vapors from the vadose zone but will also create a difference in vapor pressure that will transfer PCE from the groundwater to the air in the vadose zone. Given enough time, Alternative No. 3 is expected to attain all ARARs, both for air and water quality. If, after sufficient operation, it is determined that the groundwater ARAR will not be attained, then air sparging should be added, as described under Alternative No. 4.

Overall Protection

Alternative No. 3 represents a proven technology that can remove PCE vapors from the soil with little risk of exposure to humans or the environment. It will provide a permanent solution when completed. Its overall protectiveness will be high.

State and Local Agency Acceptance

State and local agency acceptance of this alternative will not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. Similar systems have been accepted by the regulatory authorities.

Community Acceptance

Actual community acceptance would not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. The system would be quiet in operation and fully enclosed from view, and many communities have accepted similar systems.

4.3.4 Alternative No. 4 - Air Sparging and Vapor-Extraction with Carbon Adsorption

Description

Alternative No. 4 involves the addition of air sparging to the vapor-extraction system of Alternative No. 2. Air sparging provides in situ air stripping without the need to remove water from the ground. Compressed air, injected into the contaminated aquifer, strips volatile contaminants from the water and carries them into the vadose zone where the vapor-extraction system collects them for treatment by activated carbon. This alternative was selected over pump-and-treat technologies because of its simplicity and demonstrated effectiveness on similar projects and because of the limited amount of shallow groundwater that is accessible.

Air injection points, which would be small diameter pipes driven into the ground, would be used to inject air under pressure into the aquifer. Pilot-scale tests would be conducted to determine the zone of influence of the injection points and to assure that all injected air will be collected under the influence of the vapor-extraction system.

Alternative No. 4 should be considered as a contingency for Alternatives No. 2 and No. 3. If vapor-extraction alone is insufficient to provide adequate treatment of the groundwater, then air sparging should be added at the appropriate time. Air sparging should be included as an addition to the vapor-extraction pilot study.

Short-Term Effectiveness

Construction workers involved in the remediation would be protected by complying with current OSHA regulations. These include preparation of a site health and safety plan to which all workers must comply, monitoring with appropriate instruments during any intrusive work into potentially contaminated zones and protection from other hazards such as traffic and electricity. Existing wells will initially be used and air injection points can be easily installed. Piping is expected to be above-ground, but if any excavation is required, it will not intrude into contaminated soil. Additional vapor-extraction wells and the injection points will be installed by qualified contractors.

The short-term effectiveness for Alternative No. 4 would be high. Because of the rapid treatment rate often observed with this type of system, it is expected that adequate removal of PCE from the vadose zone, from the wetted soils in the treatment zone and from the groundwater in the treatment zone could be accomplished within one year.

Long-Term Effectiveness and Permanence

Under this alternative, the existing site risks discussed in Section 1.3.4. would be reduced and the remedial action objectives discussed in Section 2.3 would be met.

Vapor-extraction is effective in removing soil contaminants and air sparging is effective in transferring volatile contaminants from groundwater to the soil. Alternative No. 4 will provide a permanent solution when the target levels have been reached. The long-term effectiveness for Alternative No. 4 would be high.

Reduction of Toxicity, Mobility or Volume

Air sparging will enhance the effect of vapor-extraction in reducing mobility of PCE in the soil by adding additional air to the system that will provide a flushing effect in removing the vapors from the soil. In addition, air sparging will remove PCE from the groundwater and further reduce its mobility. The influence of the combined system will prevent further migration of both vadose zone vapors and groundwater contamination away from the site. Toxicity will be reduced by removing the PCE from the soil and groundwater, and the volume of PCE will be reduced in both media. Air sparging will be equally effective if combined with either Alternatives No. 2 or No. 3.

One portable air sparging/vapor-extraction system would be applied to the treatment zone, with the assumption that removing the PCE in the soil and groundwater to low levels will allow for an increased rate of natural biodegradation of the groundwater plume. Because the entire plume will not be under treatment, it will be necessary to continue long term groundwater monitoring to assess the overall rate of remediation. A 5-year groundwater monitoring period is used for cost estimation purposes. The anticipated success of this alternative is expected to allow for a shorter groundwater monitoring period.

Implementability

Air sparging with vapor-extraction is easily implemented. The existing pilot scale vapor-extraction unit can be modified for long-term use in the full scale system. Existing monitor wells can be used for the vapor-extraction unit and the treatment unit can be moved to alternate locations as required to provide complete coverage. Additional extraction wells can be easily added.

A 3-hp positive displacement blower can be easily installed inside the treatment unit to operate the air sparging system. Installation of the air injection points will be an easy operation and the system can be connected and put in operation in a very short time. The rapid response that is expected from air sparging is expected to result in accelerated remediation that will tend to offset the increased cost of the additional equipment, particularly if a shorter monitoring period is then required.

Cost

Experience has indicated that air sparging often provides effective remediation in a matter of weeks. Further testing would be required to determine the actual remediation time that could be expected at the Livermore Arcade site, and it is possible that considerable savings could be realized beyond the estimated cost, which is based on one year of operation and a 5 year monitoring program.

The present worth cost of Alternative No. 4 is estimated to be $282,480. Capital cost is estimated to be $161,280. Yearly maintenance cost is estimated to be $43,100 for one year plus a yearly cost for groundwater monitoring of $18,000 for 5 years. These estimates are based on combining air sparging with Alternative No. 2, using carbon adsorption of the vapors.

Compliance with ARARs

The ARARs pertaining to this alternative are BAAQMD Regulation 8, Rule 47, which limits the emission of combined PCE, TCE, benzene and methylene chloride vapors to 1.0 pound per day and the Safe Drinking Water Act Maximum Contaminant Level for PCE of 5 ppb. The vapor-extraction system will attain ARARs for air quality and the air sparging system will attain ARAR for water quality. Alternative No. 4 is expected to attain all ARARs, both for air and water quality in the shortest time.

Under Alternative 4, the ultimate cleanup goal of 5 ppb in groundwater at all points of potential human contact will be met through five basic processes: (1) natural biodegradation, (2) dilution in the shallow groundwater, (3) dilution in transit to the deeper aquifer below the clay aquitard, (4) vapor-extraction and (5) air sparging. The effects of these five processes generally are cumulative. Information concerning these processes is available both from available published research, as well as from the results to date of the pilot test program. The mechanisms and predicted effectiveness of each of these processes are discussed below, focusing on their combined ability to achieve the ultimate cleanup goal.

As discussed previously in Section 1.3., natural biotransformation of 100 ppb PCE has been estimated to have a half-life in groundwater of approximately 1 year (half-life range in literature 0.1 to 2 years). At this rate, it is expected that groundwater with current concentrations of 100 ppb would be reduced through natural remediation to be less than 5 ppb over a period of approximately 5 years (5 half lives).

Although measurements at the site began only in 1990, and the effects of dilution, groundwater movement and recontamination cannot be separated from the measured values, measurements of concentrations in the shallow aquifer bear out the assumption that natural remediation will occur. For example, PCE values measured at MW-14 dropped 80% from 5 ppb to 1 ppb between September 24, 1990 and March 5, 1991, remaining at that level in the July 25, 1992 samples. (RI Report, Table 4). Values at MW-10 similarly dropped from 35 ppb to 22 ppb between August, 1990 and July, 1991. Id. Although groundwater concentrations at some of the wells closer to the contamination source actually increased during the study period, this appears to reflect the competing process of recontamination from PCE in the vadose zone.

The second mechanism, dilution of the contaminated shallow aquifer, would occur if and when shallow groundwater levels rise. This dilution can be approximated by comparing the thickness of the current shallow aquifer to its potential thickness if groundwater levels rise. Currently, only an average of approximately 15 feet of groundwater is present above the clay aquitard in the contaminated area. Above this is an average of approximately 30 feet in the low permeability vadose zone below the more permeable zone near ground level. Therefore, existing contaminated groundwater would be diluted by a factor of approximately (30/15) before it reached the height at which significant new migration would occur.

The mechanics and degree of dilution of the contaminated shallow aquifer in transit to the deeper aquifer are more speculative because the transit mechanisms are at this point hypothetical. Again, however, comparing the thickness of the shallow aquifer (15 feet) to the thickness of the deeper aquifer mechanics of this dilution are unknown. As a conservative assumption a dilution factor of 10 can be applied. The calculations below do not include this additional dilution, resulting in a substantial margin of safety in the proposed cleanup approach.

Combining the first two factors, through dilution and natural biodegradation those areas with groundwater concentrations presently at or below 100 ppb could be expected to naturally remediate to less than the 5 ppb level in less than 5 years, assuming that the recent drought ends and groundwater levels rise. Even without dilution, natural biodegradation alone would be expected to produce a reduction from 100 ppb to 5 ppb over a 5 year period. Since direct use of the groundwater at the site is expected to be prevented by current uses and ownership for at least that long, this natural remediation time frame is considered acceptable.

Soil vapor-extraction can be expected to significantly reduce PCE concentrations in the shallow soils within the zone of influence from current concentrations of up to 2,300 micrograms ug/kg (RI Report, Table 3) to less than 100 ug/kg over an average period of approximately 8 weeks in each well zone. This would effectively eliminate recontamination from soils as a threat to groundwater.

Air sparging combined with SVE has been shown in case studies (Kaback, et al, 1990) to reduce PCE concentrations in groundwater to 10 ppb. This is well below the 100 ppb threshold, below which natural remediation can be expected ultimately to achieve the ARAR of 5 ppb.

Using these assumptions, the following cleanup scenario is presented. Subject to further refinement during the remedial design and remedial action phases, vapor-extraction wells with associated air sparging injector pipes would be installed (as needed to supplement the current wells) on not more than 150 foot centers (twice the radius of influence shown through the pilot test program) within the area of the 100 ppb contour of PCE in groundwater. This zone would include approximately 12 extraction points, and would include all of the areas with contaminated soils. The SVE/air sparging system would be operated at different locations until groundwater concentrations of less than 100 ppb were reached at each location, which is anticipated to occur over a period of two weeks to two months at each well, with longer time periods required in those areas having higher starting concentrations and soil loadings of PCE. Therefore, within approximately 6 months to 2 years (1 year for cost analysis), it is expected that all locations in the site groundwater would be cleaned to a less than 100 ppb level, with PCE laden soils effectively eliminated as a source of recontamination. From that point, natural remediation could be expected to produce 5 ppb or lower concentrations throughout the shallower aquifer over a 5 year time period. Natural biodegradation may take longer if the actual half-life for PCE is longer than 1 year.

Following the initial cleanup period, and given the time scale of natural biodegradation, annual groundwater monitoring is proposed to verify the pace of biodegradation and dilution during the following few years. If natural remediation is proceeding as anticipated during that period, monitoring would occur thereafter at less frequent intervals to ensure continuing improvements.

In conclusion, the pilot test program has demonstrated the effectiveness of soil vapor-extraction at the site, and a combination of pilot test results and experience at similar sites indicates that the proposed cleanup, with the addition of air sparging, will achieve the 5 ppb ARAR within an acceptable time frame.

Overall Protection

Alternative No. 4 represents proven technologies that can remove PCE from both soil and groundwater with little risk of exposure to humans or the environment. It will provide a permanent solution when completed. Its overall protectiveness would be high.

State and Local Agency Acceptance

State and local agency acceptance of this alternative will not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. Similar systems have been accepted by regulatory authorities.

Community Acceptance

Actual community acceptance would not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. The system would be quiet in operation and fully enclosed from view, and many communities have accepted similar systems.

Alternative 4 would also produce the greatest degree of compliance with state criteria under Health and Safety Code Section 25356.1. The alternative reduces the health and safety risks at the site more than other alternatives, protects beneficial uses and usable quantities of groundwater, takes into account site specific characteristics, avoids rapidly escalating costs that would result from rising groundwater levels or potential contamination of the lower aquifer, and has the fewest overall environmental impacts from the remedial action measure.

4.3.5 *Alternative No. 5 - Air Sparging and Vapor-Extraction with Direct Discharge to Ambient Air*

Description

Alternative No. 5 involves the addition of air sparging to the vapor-extraction system of Alternative No. 3. Air sparging provides in situ air stripping without the need to remove water from the ground. Compressed air, injected into the contaminated aquifer, strips volatile contaminants from the water and carries them into the vadose zone where the vapor-extraction system collects them for discharge to ambient air. This alternative was selected over pump-and-treat technologies because of its simplicity and demonstrated effectiveness on similar projects and because of the limited amount of shallow groundwater that is accessible.

Air injection points, which would be small diameter pipes driven into the ground, would be used to inject air under pressure into the aquifer. Pilot-scale tests would be conducted to determine the zone of influence of the injection points and to assure that all injected air will be collected under the influence of the vapor-extraction system.

Alternative 5 should be considered as a contingency for Alternative 3. If vapor-extraction alone is insufficient to provide adequate treatment of the groundwater, then air sparging should be added at the appropriate time. Air sparging should be added to the current SVE system in order to determine the level of increased efficiency of the system in reducing PCE in the groundwater.

Short-Term Effectiveness

Construction workers involved in the remediation would be protected by complying with current OSHA regulations. These include preparation of a site health and safety plan to which all workers must comply, monitoring with appropriate instruments during any intrusive work into potentially contaminated zones and protection from other hazards such as traffic and electricity. Existing wells will initially be used and air injection points can be easily installed. Piping is expected to be above-ground, but if any excavation is required, it will not intrude into contaminated soil. Additional vapor-extraction wells or horizontal collectors, if required, and the injection points, will be installed by qualified contractors.

The short-term effectiveness for Alternative No. 5 is potentially high. Because of the rapid treatment rate often observed with this type of system, it is expected that adequate removal of PCE from the vadose zone, from the wetted soils in the treatment zone and from the groundwater in the treatment zone could be accomplished. However, air permit requirements will inhibit the speed of contaminant removal compared to Alternative 4.

Long-Term Effectiveness and Permanence

Under this alternative, the existing site risks discussed in Section 1.3.4. would be reduced and the remedial action objectives discussed in Section 2.3 would be met.

Vapor-extraction is effective in removing soil contaminants and air sparging is effective in transferring volatile contaminants from groundwater to the soil. Alternative No. 4 will provide a permanent solution when the target levels have been reached. The long-term effectiveness for Alternative No. 4 would be high.

Reduction of Toxicity, Mobility or Volume

Air sparging will enhance the effect of vapor-extraction in reducing mobility of PCE in the soil by adding additional air to the system that will provide a flushing effect in removing the vapors from the soil. In addition, air sparging will remove PCE from the groundwater and further reduce its mobility. The influence of the combined system will prevent further migration of both vadose zone vapors and groundwater contamination away from the site. Toxicity will be reduced by removing the PCE from the soil and groundwater, and the volume of PCE will be reduced in both media.

The air sparging/vapor-extraction system would be applied to the treatment zone with the assumption that removing the PCE in the soil and groundwater to low levels will allow for an increased rate of natural biodegradation of the groundwater plume. Because the entire plume will not be under treatment, it will be necessary to continue long term groundwater monitoring to assess the overall rate of remediation. Because of this, a 5-year groundwater monitoring period is used for cost estimation purposes. With rapid success of the air sparging system, groundwater monitoring requirements should be reduced.

Implementability

Air sparging with vapor-extraction is easily implemented. The existing pilot scale vapor-extraction unit can be modified for long-term use in the full scale system. Existing monitor wells can be used for vapor-extraction and the treatment unit can be moved to alternate locations as required to provide complete coverage. Additional extraction wells could be easily added.

A 3-hp positive displacement blower can be easily installed inside the treatment unit to operate the air sparging system. Installation of the air injection points will be an easy operation and the system can be connected and put in operation in a very short time. The rapid response that is expected from air sparging is expected to result in accelerated remediation that will tend to offset the increased cost of the additional equipment.

Cost

Experience has indicated that air sparging often provides effective remediation in a matter of weeks. Further testing would be required to determine the actual remediation time that could be expected at the Livermore Arcade site, and it is possible that considerable savings could be realized beyond the estimated cost, which is based on one year of operation.

The present worth cost of Alternative No. 5 is estimated to be $267,100. Capital cost is estimated to be $157,440. Yearly maintenance cost is estimated to be $31,560 for one year plus a yearly cost for groundwater monitoring of $18,000 for 5 years. These estimates are based on combining air sparging and Alternative No. 3, (SVE with direct discharge to the ambient air). Costs are presented in Appendix D.

Compliance with ARARs

The ARARs pertaining to this alternative are BAAQMD Regulation 8, Rule 47, which limits the emission of PCE and other listed compounds to 1.0 pound per day and the Safe Drinking Water Act Maximum Contaminant Level for PCE of 5 ppb. The vapor-extraction system must be restricted in operation to attain ARARs for air quality and the air sparging system will attain ARAR for water quality. Alternative No. 5 can attain all ARARs, both for air and water quality, but in the areas where petroleum hydrocarbons are present in high concentrations, the efficiency of Alternative 5 will be significantly reduced.

Overall Protection

Alternative No. 4 represents proven technologies that can remove PCE from both soil and groundwater with little risk of exposure to humans or the environment. It will provide a permanent solution when completed. Its overall protectiveness would be high but stringent air monitoring would be required.

State and Local Agency Acceptance

State and local agency acceptance of this alternative will not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. Similar systems have been accepted by regulatory authorities.

Community Acceptance

Actual community acceptance would not be known until after the public comment period. Comments and concerns received during that period will be incorporated in the Responsiveness Summary. The system would be quiet in operation and fully enclosed from view, and many communities have accepted similar systems.

4.4 Comparative Analysis of Alternatives

Table 4.2 lists the five alternatives considered to be acceptable at this site along with their estimated present worth costs. These alternatives are (1) No action, (2) Vapor-extraction with carbon adsorption, (3) Vapor-extraction with direct discharge to ambient air, (4) Air sparging and vapor-extraction with carbon adsorption, and (5) Air sparging and vapor-extraction with direct discharge to ambient air. All of the alternatives would include a groundwater monitoring program that would continue until cleanup objectives are met.

Although the no action alternative does not remove the contamination, it may be acceptable if it can be shown that the contamination will remain isolated until it naturally degrades. This will require long term groundwater monitoring (30 years was selected as an estimate) based on range of biodegradation half-lifes, literature, and the recommended monitoring requirements at RCRA sites. Based on the estimated cost presented in Appendix D, this would be the highest cost of the five final alternatives, at a present worth cost of $322,900. The obligation of long term monitoring with the possibility of remedial action required at a later date, along with the higher present value cost, makes the no action alternative less attractive than other alternatives that provide accelerated remediation. The probability of having to replace the contaminated natural resource adds a potential future increase in the cost of this alternative that is not reflected in the above estimated cost.

Vapor-extraction has been demonstrated to be effective in remediating contaminated soil over a relatively short time period, and the on-site pilot test indicated that a high level of effectiveness can be expected. Therefore, a time period of 2 years was conservatively selected for the expected cleanup period with long term monitoring continuing for 5 years. The vapor-extraction with activated carbon treatment alternative would meet all cleanup objectives. It would be an effective method of removing the source of PCE that is retained in the vadose zone soil. It is also a fast acting method that can be expected to reach soil cleanup levels in a relatively short period. The estimated present worth cost for a two-year cleanup effort with 5 years of groundwater monitoring is $284,270. Results of the pilot test conducted at the site indicate that this alternative will be effective and that relatively rapid results can be expected. A disadvantage of this option, however, would be the transfer of PCE from the soil to activated carbon that could present handling, disposal and possible permitting problems.

Vapor-extraction with direct discharge to the ambient air would provide all of the features described above, without the use of activated carbon for treatment of the vapors. Cost would be lower without the need to replenish the carbon and dispose of the spent carbon. The estimated present worth cost for a two-year cleanup period with 5 years of groundwater monitoring is $262,410. By limiting the concentration of emitted PCE vapors, this alternative can provide safe, effective treatment at a reasonable cost. The disadvantage of this alternative is the estimated efficiency of clean-up will be inhibited by reduced, daily operating time due to BAAQMD discharge restrictions.

The air sparging alternative should be implemented if conditions arise that would inhibit the effectiveness of vapor-extraction alone. If the groundwater level should rise into the zone of soil contamination so that direct evaporation is not possible, then adding air to the groundwater through air sparging will be a required system modification. Also, if the levels of PCE throughout the groundwater contamination plume do not satisfactorily diminish through natural degradation, then air sparging should be added at specific locations to allow sufficient removal of PCE from the groundwater. The effect of air sparging would be to increase the rate of remediation and decrease the length of time required to meet remediation objectives. It is expected that this alternative could sufficiently remove PCE from the treatment zone within a one year period. The estimated present worth cost for a one year cleanup effort with 5 years of groundwater monitoring is $282,480 for air sparging/vapor extraction with carbon adsorption.

Alternative 4 will provide the ability to conduct aggressive remedial action on the contaminated soil and groundwater at the site. Using carbon adsorption will allow the vapor-extraction system to operate at peak efficiency. With peak operating efficiency the clean-up objectives may be achieved in less than one year and the actual cost for this alternative may be less than what was estimated

Alternative 5, which has the potential to perform similar to Alternative 4, will be less efficient at removing contaminants because the BAAQMD will allow only 1 pound per day of PCE, TCE, benzene and methylene chloride combined, and no more than 15 pounds per day TOC. The estimated present worth of Alternative 5 is $267,100 for a one year clean-up with 5 years of groundwater monitoring. Because of restricted operating time, the actual cost for this alternative may be more than what was estimated.

Table 4.1
Comparison of Alternatives
Livermore Arcade PCE Site

	Alternative 1 No Action w/ Groundwater Monitoring	Alternative 2 Vapor Extraction w/ Carbon Treatment	Alternative 3 Vapor Extraction w/ Direct Discharge	Alternative 4 Air Sparging/VE w/ Carbon Treatment	Alternative 5 Air Sparging/VE w/ Direct Discharge
1) Short-term effectiveness					
Community protection	No additional risks	Little additional risk. Existing wells to be used. Carbon adsorption drums will be monitored to determine breakthrough.	Little additional risk. Existing wells would be used. Vapors would be emitted to the air, but the loading of PCE in the discharged vapors would be limited to allowable standards.	Air injected into aquifer could cause vapors to migrate to occupied areas but supplemental vapor extraction will prevent this from occurring. Loading in carbon adsorption drums will be monitored.	Vapor extraction will prevent air injected into aquifer to cause vapors to migrate into occupied areas. Extracted vapors will be limited to allowable limits.
Worker protection	No worker risk	Workers would be protected from risk.	Workers would be protected from risk.	Workers would be protected from risk.	Workers would be protected from risk.
Environmental impacts	Plume would remain isolated until natural degradation eventually reduces contamination to acceptable levels.	The source of PCE in the vadose zone would be removed rapidly. Disposal of spent carbon. Treatment of ground-water not aggressive.	The source of PCE in the vadose zone would be removed rapidly. Untreated but limited vapors would be exhausted to the atmosphere. Treatment of groundwater not aggressive.	A highly effective combination that would treat both soil and groundwater at the PCE source. Disposal of spent carbon.	A highly effective combination that would treat both soil and groundwater at the PCE source. Disposal of spent carbon. Extracted vapors are exhausted to atmosphere.
Time to complete action	No action. At least 30 years for natural remediation.	2 years to remove vadose zone vapors and at least 5 years for natural degradation of residual plume.	At least 2 years to remove vadose zone vapors because of limited operation due to BAAQMD restrictions and at least 5 years for natural degradation of residual plume.	1 year to remove PCE from soil and groundwater in the treatment zone, and 5 years for natural degradation of residual plume.	More than one year to remove PCE from soil and groundwater because of limited operation due to BAAQMD restrictions.

Table 4.1
Comparison of Alternatives
Livermore Arcade PCE Site

	Alternative 1 No Action w/ Groundwater Monitoring	Alternative 2 Vapor Extraction w/ Carbon Treatment	Alternative 3 Vapor Extraction w/ Direct Discharge	Alternative 4 Air Sparging/VE w/ Carbon Treatment	Alternative 5 Air Sparging/VE w/ Direct Discharge
2) Long-term effectiveness					
Magnitude of residual risk	Risks would remain unchanged for many years. Potential impact to CWS wells.	Source of PCE in soil would be removed. Risk concerned with groundwater contamination would diminish with removal of the source in the soil.	Source of PCE in soil would be removed. Risk concerned with groundwater contamination would diminish with removal of the source in the soil.	Source of PCE in both soil would be removed. Risk associated with residual groundwater contamination would be minimized .	Source of PCE in both soil would be removed. Risk associated with residual groundwater contamination would be minimized .
Adequacy and reliability of controls	No controls would be in effect, but the monitoring would continually assess the adequacy of this alternative.	No controls required. Groundwater monitoring would assess the existence of residual groundwater contamination.	No controls required. Groundwater monitoring would assess the existence of residual groundwater contamination.	No controls required. Groundwater monitoring would assess the existence of residual groundwater contamination.	No controls required. Groundwater monitoring would assess the existence of residual groundwater contamination.
3) Reduction of toxicity, mobility and volume					
Treatment used	None	Carbon adsorption of vapors.	None	Air sparging-air injected into the aquifer and carbon adsorption.	Air sparging-air injected into the aquifer and carbon adsorption.
Amount treated	None	Removal of more than 90% of vadose zone PCE vapors.	Removal of more than 90% of vadose zone PCE vapors.	Removal of more than 90% of PCE in both the soil and groundwater in the treatment zone.	Removal of more than 90% of PCE in both the soil and groundwater in the treatment zone.

Table 4.1
Comparison of Alternatives
Livermore Arcade PCE Site

	Alternative 1 No Action w/ Groundwater Monitoring	Alternative 2 Vapor Extraction w/ Carbon Treatment	Alternative 3 Vapor Extraction w/ Direct Discharge	Alternative 4 Air Sparging/VE w/ Carbon Treatment	Alternative 5 Air Sparging/VE w/ Direct Discharge
Reduction of toxicity, mobility or volume	None	PCE vadose zone would be greatly reduced in toxicity, mobility and volume.	PCE vadose zone would be greatly reduced in toxicity, mobility and volume.	PCE in the soil and groundwater would be greatly reduced in toxicity, mobility and volume.	PCE in the soil and groundwater would be greatly reduced in toxicity, mobility and volume.
Irreversibility of treatment	Not applicable	Irreversible	Irreversible	Irreversible	Irreversible
Type and quantity of treatment residuals	None	Approximately 24 drums of spent carbon would require proper disposal.	None	Approximately 24 drums of spent carbon would require proper disposal	None
4) Implementability					
Technical feasibility	Not applicable	Technically feasible. Pilot scale test was successful.	Technically feasible. Pilot scale test was successful.	Technically feasible. Air sparging can be readily added to a vapor extraction system.	Technically feasible. Air sparging can be readily added to a vapor extraction system.
Administrative feasibility	Not applicable	Treatment permit may be required	Air discharge permit required.	Treatment permit may be required.	Air discharge permit required.
5) Cost					
Capital	$0	$134,400	$130,560	$161,280	$157,440
Annual O&M	$0	$41,040 per year for 2 years	$29,500 per year for 2 years	$43,100 per year for 1 year	$31,560 for 1 year
Groundwater monitoring	$18,000 per year for 30 years	$18,000 per year for 5 years	$18,000 per year for 5 years	$18,000 per year for 5 years	$18,000 per year for 5 years
Total present worth	$322,900	$284,270	$262,410	$282,480	$267,100

Table 4.1
Comparison of Alternatives
Livermore Arcade PCE Site

	Alternative 1 No Action w/ Groundwater Monitoring	Alternative 2 Vapor Extraction w/ Carbon Treatment	Alternative 3 Vapor Extraction w/ Direct Discharge	Alternative 4 Air Sparging/VE w/ Carbon Treatment	Alternative 5 Air Sparging/VE w/ Direct Discharge
6) Compliance with ARARs					
Chemical specific	Estimated to require more than 30 years to achieve MCL for PCE in groundwater over entire site.	Would rapidly achieve target levels of PCE in the vadose zone soils but not in the wetted soil or groundwater, except by natural remediation	Would rapidly achieve target levels of PCE in the vadose zone soils but not in the wetted soil or groundwater, except by natural remediation	Would rapidly achieve target levels of PCE in the soil and groundwater in the treatment zone, but would rely on natural remediation in the down-gradient residual ground-water plume.	Would rapidly achieve target levels of PCE in the soil and groundwater in the treatment zone, but would rely on natural remediation in the down-gradient residual ground-water plume.
Location specific	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Action specific	No action	Would comply with air emission regulations and treatment permit, if required.	Would comply with air emission regulations and treatment permit, if required.	Would comply with air emission regulations and treatment permit, if required. RCRA permit may be required.	Would comply with air emission regulations and treatment permit, if required.
7) Overall protection					
Human health	No immediate threat human health but does not protect from the potential future use of contaminated groundwater or spread of contamination during the 30 year natural remediation period..	Protective of current and future human health by eliminating the source of PCE contamination in the vadose zone.	Protective of current and future human health by eliminating the source of PCE contamination in the vadose zone.	Protective of current and future human health by eliminating the source of PCE contamination in both the soil and groundwater in most of the contaminated zone.	Protective of current and future human health by eliminating the source of PCE contamination in both the soil and groundwater in most of the contaminated zone.

Table 4.1
Comparison of Alternatives
Livermore Arcade PCE Site

	Alternative 1 No Action w/ Groundwater Monitoring	Alternative 2 Vapor Extraction w/ Carbon Treatment	Alternative 3 Vapor Extraction w/ Direct Discharge	Alternative 4 Air Sparging/VE w/ Carbon Treatment	Alternative 5 Air Sparging/VE w/ Direct Discharge
Environment	Little impact on the environment is expected since contamination is isolated in localized soil and ground-water plume. Risk of recontamination if groundwater levels rise.	Protective of the environment by removing the source of PCE in the vadose zone. PCE will remain in groundwater, but is expected to remain isolated and move no further, unless groundwater rises.	Protective of the environment by removing the source of PCE in the vadose zone. PCE will remain in ground-water, but is expected to remain isolated and move no further, unless ground-water rises.	Protective of the environment by removing the source of PCE in the environment. PCE will remain in downgradient groundwater in low concentrations that are expected to remain isolated and naturally degrade.	Protective of the environment by removing the source of PCE in the environment. PCE will remain in downgradient groundwater in low concentrations that are expected to remain isolated and naturally degrade.
Considerations	Risk of future remedial action at escalating costs.	Does not aggressively remove PCE from groundwater. Natural remediation may take longer than estimated increasing time of long-term monitoring.	Does not aggressively remove PCE from groundwater. Natural remediation may take longer than estimated increasing time of long-term monitoring. Efficiency will be reduced to comply with BAAQMD restrictions.	System will remove PCE from soil and groundwater to low levels. Length of ground-water monitoring might be less than time estimated in cost analysis.	System will remove PCE from soil and groundwater to low levels. Length of ground-water monitoring might be less than time estimated in cost analysis. Efficiency will be reduced to comply with BAAQMD restrictions.

Table 4.2

PRESENT VALUE COST OF SELECTED ALTERNATIVES

No.	Description	Capital Cost	O&M ($/years)	GW Monitoring ($/years)	Total Present Value
1	No Action	$0	$0	$18,000/30	$332,900
2	Vapor-extraction w/carbon	$134,400	$41,040/2	$18,000/5	$284,270
3	Vapor-extraction w/ direct discharge	$130,560	$29,500/2	$18,000/5	$262,410
4	Air sparging/VE w/carbon	$161,280	$43,100/1	$18,000/5	$282,480
5	Air sparging/VE w/ direct discharge	$157,440	$31,560/1	$18,000/5	$267,100

PV = Present Value (@ 8% discount rate, 4.5 % inflation rate)

VE = Vapor-extraction

5.0 RECOMMENDED ACTION

Present worth analysis of each of the five final alternatives indicates that the final costs are equivalent within the range of estimating accuracy, with the possible exception of Alternative No. 1, the no action alternative. The remediation efficiency of each alternative and permitting requirements present the most significant criteria for selection.

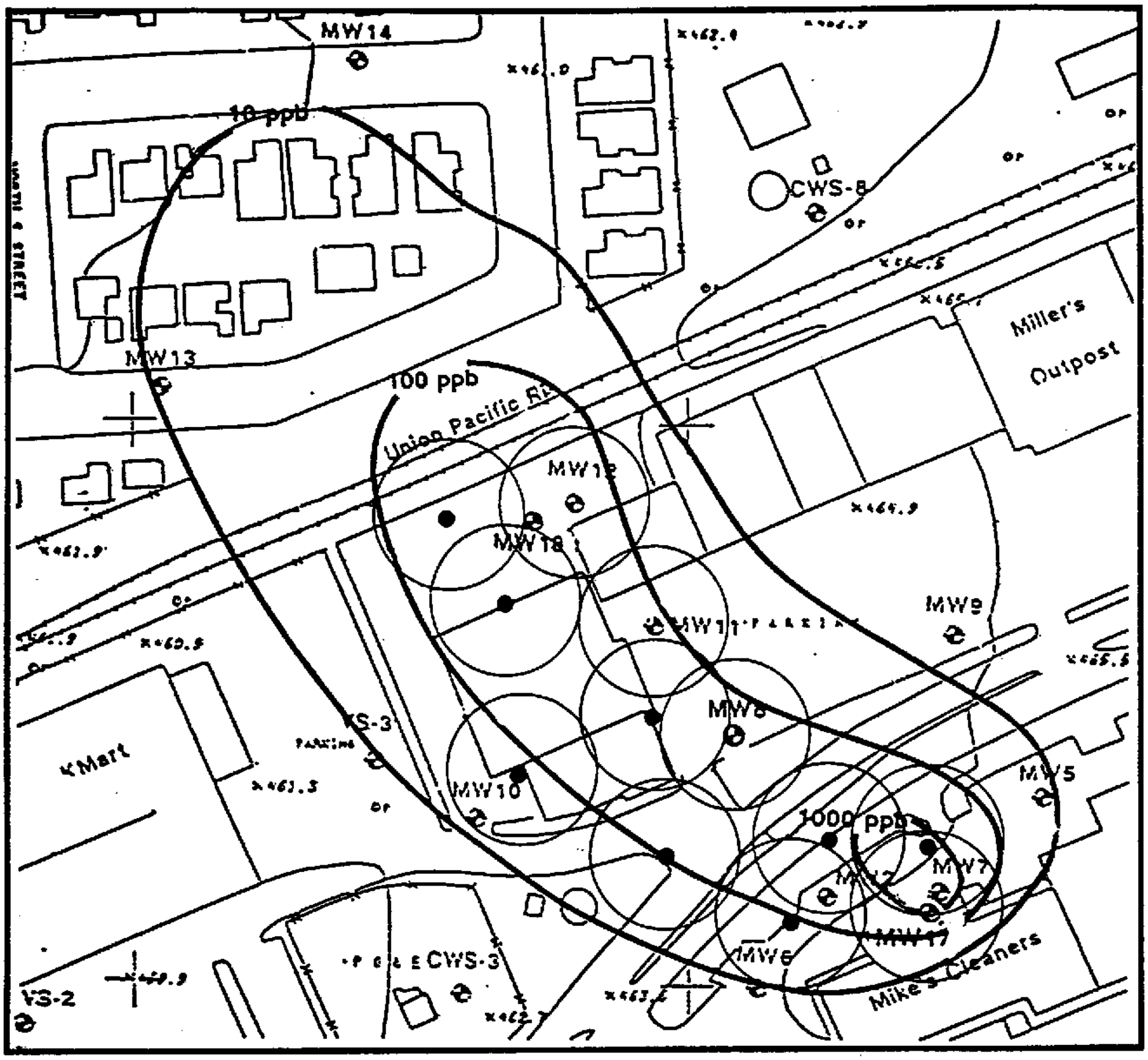
Soil vapor-extraction with discharge to the atmosphere (Alternative 3) will provide efficient remediation of the vadose zone. The remedial effect upon the groundwater will be determined as groundwater analysis data becomes available. This alternative would be recommended contingent upon the groundwater analysis data demonstrating significant reductions in solvent concentrations. H^+GCL considers this scenario plausible but unlikely. Also, the presence of petroleum hydrocarbons in the vicinity of Mike's Cleaners will restrict the efficiency of this alternative inhibiting its potential success.

Vapor treatment by the addition of carbon adsorption cannisters to the system can be easily implemented (Alternative 2). Higher removal rates can be achieved with this system, however, a lengthy RCRA permitting process may need to be undertaken, which will defeat the primary goal of treating vadose zone soils prior to the rise of the groundwater table. A meeting with the representatives of the BAAQMD, the California Department of Toxic Substances Control, and Grubb & Ellis is recommended. The purpose of the meeting would be to discuss potential RCRA treatment permitting procedures with regards to the use of carbon adsorption. If carbon adsorption can be implemented immediately, vapor-extraction rates can be maximized while complying with the BAAQMD emission control requirements.

If the groundwater contamination levels are not reduced with Alternative 2 or 3, air sparging of the groundwater is recommended (Alternative 4 or 5). The combined air sparging and vapor-extraction will provide the most efficient and rapid site remediation scenario. H^+GCL recommends the immediate addition of air injection points to the pilot-scale SVE system to evaluate the effectiveness of air sparging at the site.

With favorable results from the addition of air sparging to the pilot-scale SVE system, H^+GCL recommends that one air sparging/SVE system be employed at the Arcade site to operate at various extraction well locations. The portable unit will move from well to well within the area delineated by the 100 ppb isopleth (Figure 5). Additional extraction wells will need to be installed to provide

Figure 5: Proposed Vapor Extraction Locations



Legend

MW-10 — H+GCL Monitoring Well

VS-1 — Versar Monitoring Well

CWS-3 — California Water Service Well

10 ppb — PCE Concentrations in Groundwater 1990-1991 (parts per billion)

MW-10 — Proposed Vapor Extraction Well (with 75' Radius of Influence)

Scale: 0 100 feet 200 feet

N

necessary extraction locations. The application of this air sparging system at the site will insure a rapid reduction of PCE, and other VOCs, identified in the groundwater. A PCE concentration reduction to 100 ppb provides a conservative clean-up objective. PCE concentrations below 100 ppb are expected to naturally degrade to below 5 ppb within an estimated 5 year period. Periodic groundwater monitoring, following the reduction of PCE to 100 ppb, will provide evidence that natural biotransformation and volatilization are occurring as expected. The anticipated success of this approach may allow for a more limited monitoring program than the 5 year monitoring used for cost analysis.

6.0 NON-BINDING PRELIMINARY ALLOCATION OF LIABILITY

California Health and Safety Code Section 25356.1 provides that where a remedial action plan is being submitted to the water board for approval, it should include a non-binding preliminary allocation of responsibility among all identifiable potentially responsible parties at a site. The demand letter issued by Grubb & Ellis on January 31, 1992 addresses the known responsible parties at the site, and suggests an allocation of cleanup cost responsibilities. Specifically, the demand letter recommends that Catellus Development Corporation and Stark Investment Company (both of which are previous owners of the site) bear cleanup costs in proportion to the period of ownership of the property while the Neelys were operating Mike's Cleaners.

Under Federal Law (42 U.S.C. § 9607), any person who owned or operated a facility at the time of disposal of hazardous waste is a "responsible party" (RP) liable for contaminated site cleanup costs. RPs are all jointly, severally, and strictly liable for cleanup costs. Joint and several liability allow any of the responsible parties to be assessed the entire cost of the cleanup.

The costs that may be recovered from a responsible party could include all necessary costs of response incurred by any other person consistent with the National Contingency Plan (42 U.S.C. § 9607 (a)(4)). These costs include testing, monitoring, administrative, planning, and costs of the direct physical cleanup.

6.1 Responsible Parties

Several RPs have been determined to be liable for cleanup of the soil and groundwater contamination at the Livermore Arcade. The RPs have been identified as a result of research and investigation conducted prior to, as part of, and subsequent to the Remedial Investigation (RI).

6.1.1 Michael Neely and Perry Neely

As determined in the RI, the source of the PCE contamination was Mike's One Hour Dry Cleaners during the tenancy of the Neelys. The Neelys operated Mike's Cleaners from late 1981 to 1987. During that time, PCE was disposed to the sanitary sewer and released to the groundwater through faulty plumbing. This practice appears to have been continuous through the period of their operation. It has been reported that the original dry cleaning equipment used by the Neelys had significant leaks of solvent and was replaced by the Neelys during their first year of operation. It is likely that both the leaking solvent and the normal waste solvent were discharged to the sewer line during the Neelys' first year of operations. Only the normal waste solvent was discharged by the Neelys in later years of operation. As a result of their practice of discharging waste to the sewer, the Neelys are clearly RPs as both the "operator" of the facility and as "generator" of the waste.

6.1.2 Stark Investment Company

Stark Investment Company, a California General Partnership, owned the property from December 1982 to December 30, 1988. This represents about five years during the operation of Mike's Cleaners by the Neelys. As an owner of the facility at the time of disposal, Stark is a responsible party.

6.1.3. Catellus Development Corporation

Southern Pacific Land Company, a California Corporation, predecessor to Catellus Development Corporation, owned the property from February through December 1982, during which time Mike's Cleaners was being operated by the Neelys. This nine month period is also the period when the Neelys' dry cleaning equipment was leaking. The rate of PCE discharge during this period likely exceeds that which occurred after the leaking equipment was replaced.

The continuity of disposal is confirmed both by the failure of the Neelys to manifest any of the solvent generated at the facility during their ownership. As a result, Catellus is a RP.

6.1.4 Grubb & Ellis Realty Income Trust

Grubb & Ellis Realty Income Trust (Grubb & Ellis) has owned the property since December 31, 1988. Under Section 107 of the Superfund law, current owners and operators are also potentially responsible parties. The Superfund law, however, contains an affirmative defense to responsible party liability known as the "third party" defense.

Grubb & Ellis currently has no liability for cleanup costs in this instance because of the "third party" defense set out in the Superfund law. Grubb & Ellis is eligible for this defense because it can show the following:

(1) the release of hazardous substances was caused solely by a third party,

(2) the third party was not in a "contractual relationship with the RP",

(3) the responsible party exercised due care regarding the hazardous substance,

(4) the RP took precautions against the third party's acts (42 U.S.C § 9607 (B) (3)).

(5) due diligence was exercised at the time of purchase

6.1.5 Steven Song

Steven Song has operated the facility from 1987 to the present and includes all of the period that the Arcade has been owned by Grubb & Ellis. Mr. Song has provided all appropriate manifests for the disposal of his waste solvent since the beginning of his operation of Mikes' Cleaners. Based upon his claimed lawful operation of the facility, Mr. Song would appear not to be a responsible party.

6.2 Preliminary Allocation of Cleanup Costs

As determined through investigation, the RPs for the Livermore Arcade cleanup are the Neelys, Stark Investment, and Catellus.

6.2.1 Allocation to the Neelys

Action by the Neelys resulted in the generation of the soil and ground water plume originating from Mike's Cleaners. As operator of Mike's Cleaners, generator, and discharger of the solvent waste, the Neelys should be assigned as high a share (up to 100%) of the cleanup costs as possible.

6.2.2 Allocation to Other Responsible Parties

In the event that the Neelys are unable to pay for the entire cleanup at the Livermore Arcade, an allocation of liability has been prepared for the remaining responsible parties.

Based upon the amount of discharge which has been estimated to have occurred during their periods of ownership, the following allocations are calculated:

Catellus	15% - 50%
Stark Investment Company	50% - 85%

This allocation is proposed as the preliminary non-binding allocation of liability for state law purposes. It can be defined further if a more precise release history becomes available from the Neelys.

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APPENDIX B – GLOSSARY OF TERMS

ARAR - Applicable or Relevant and Appropriate Requirements.

ATSDR - Agency for Toxic Substance and Disease Registry: A branch of the Center for Disease Control that is responsible for preparing health assessments at sites.

BAAQMD - Bay Area Air Quality Management District.

Bench Scale - Treatability tests performed on a small scale, usually in a laboratory, to better define parameters of a treatment technology.

CAA - Clean Air Act.

Cal-OSHA - California Occupational Health and Safety Administration.

CEQA - California Environmental Quality Act.

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also known as Superfund: Amended in 1986 by the Superfund Amendments and Re-authorization Act (SARA).

CFR - Code of Federal Regulations.

CLP - Contract Laboratory Program.

CWA - Clean Water Act.

DHS - California Department of Health and Safety.

EIS - Environmental Impact Statement.

ERA - Expedited Response Action.

Excess lifetime cancer risk - The potential for carcinogenic effects from exposure to one or more chemicals.

FS - Feasibility Study.

General response action - General types of actions, such as containment, that may be taken to achieve exposure limits specified by remedial action objectives.

Health assessment - Assessment of existing risk to human health posed by NPL sites, prepared by the ATSDR.

Innovative technologies - Technologies that are fully developed but lack sufficient cost or performance data for routine use at CERCLA sites.

Lead agency - The agency, either the EPA, Federal agency, or appropriate State agency having primary responsibility-and authority for planning and executing the remediation at a site.

MCL - Maximum Contaminant Level: Established under the Safe Drinking Water Act.

MCLG - Maximum Contaminant Level Goal.

NCP - National Oil and Hazardous Substances Contingency Plan.

NIOSH - National Institute for Occupational Safety and Health.

NPDES - National Pollutant Discharge Elimination System.

NPL - National Priorities List: A list of sites identified for remediation under CERCLA.

O&M - Operation and maintenance.

OSHA - Occupational Safety and Health Administration.

OSWER - Office of Solid Waste and Emergency Response.

PEL - Permissible Exposure Limit.

PRP - Potentially Responsible Party.

Pilot Scale - Treatability tests performed on a large scale to simulate the physical, as well as chemical, parameters of a process.

Present Worth Analysis - A summary of costs to be incurred over a period of time, discounted to the present.

q_1^* - Cancer Potency Factor: The lifetime cancer risk for each additional mg/kg of body weight per day of exposure.

QA/QC - Quality assurance/quality control.

RCRA - Resource Conservation and Recovery Act.

RI/FS - Remedial Investigation/Feasibility Study.

ROD - Record of Decision: Documents selection of cost-effective Superfund-financed remedy.

Reference Dose (RfD) - For non-carcinogenic effects, the amount of a chemical that can be taken into the body each day over a lifetime without causing adverse effects.

Remedial Action Alternative - A potential approach to preventing or mitigating site-specific contamination problems, defined in terms of a remedial action technology option or combination of options and the volumes or areas of media to which the option or options will be applied.

Remedial Action Objective - A description of remedial goals for each medium of concern at a site; expressed in terms of the contamination of concern exposure route(s) and receptor(s), and maximum acceptable exposure level(s).

Remedial Action Technology Type (or technology type) - A general category encompassing a number of remedial action technology options that address a similar problem (e.g., capping, containment barriers, chemical treatment).

Remedial Action Technology Process Option (or process option) - A specific process, system, or action that may be used to clean up or mitigate contaminant problems (e.g., clay cap, slurry wall, neutralization).

SARA - Superfund Amendments and Re-authorization Act of 1986 (see CERCLA).

SWDA - Solid Waste Disposal Act.

Sensitivity Analysis - A test of a procedure to determine the overall changes that will result from any small change in one or more procedural elements.

TSD - Treatment, Storage, and Disposal.

TSCA - Toxic Substances Control Act.

TTLC - Total Threshold Limit Concentration.

Technology Process Option - See remedial action technology process.

Technology Type - See remedial action technology type.

Treatability Studies - Studies, usually performed after the FS Phase I, to better define the physical and chemical parameters of technology process options being evaluated for use at CERCLA sites.

USC - United States Code.

APPENDIX C

SOIL-VAPOR-EXTRACTION PILOT TEST RESULTS

Introduction

Soil vapor-extraction (SVE) is one of the treatment methods that has been proposed for the removal of the volatile organic compounds (VOCs) in the soil at the Arcade Shopping Center on First and South P Street in Livermore, California. This soil treatment method removes VOCs by extraction of the vapors containing VOCs. To determine the applicability of SVE to the Arcade Shopping Center, a pilot test was performed. From the results of this pilot test, calculations were made to determine the soils permeability to air flow and the radial extent of the air flow achieved during the pilot test.

Theory

Soil vapor-extraction removes VOCs from the soil by drawing vapor, primarily air through the contaminated soil volatilizing the VOCs. The air is drawn through the soil by applying a vacuum at a well with a vacuum blower. The pressure difference created by the vacuum draws air from the ground surface or from adjacent wells open to the atmosphere through the contaminated area. The vapor being drawn through the soil creates a concentration difference between the relatively clean air flow and the contamination. This concentration difference allows the contaminants in the soil to be transferred by volatilization into the air and ultimately extracted through the vent well.

The extent of the pressure difference, and thus the radial extent of the air flow is different with different soil types and soil conditions. In order to determine this extent, the soils permeability to air flow needs to be determined. To determine this factor a pilot test is performed by creating a vacuum at a well and measuring the pressure in the soil over time at different radial distances from the extraction well. Using a model presented by Johnson et.al. (REF.), the soils permeability to air flow (k) and the radial extent of influence can be determined. The model Johnson presents, takes into account the continuity equation, Darcy's Law and the ideal gas law.

Materials and Methods

The vacuum blower used for the pilot test was a 5 hp Rotron regenerative blower which was attached to monitoring well (MW 17). Vapor phase granular activated carbon treatment was attached to the effluent vapor side of the blower to remove the PCE from the extracted air. The blower was powered by a 3-phase diesel generator. Piezometers were installed at 5.25, 10.17, 25.42, 36.5, 50, and 75 feet radial distances from MW 17. The piezometers were constructed of 2-inch schedule 40 PVC with 5-feet of screen. Each piezometer was completed to a depth of 42 feet. The annulus of the piezometer bore hole was packed with pea gravel in a screened zone to a depth of 37.9 feet. A 2-foot deep annular seal was placed in the bore hole to a depth of 35.9 feet. Above the annular seal, native material was packed to a depth of 3 feet and bentonite pellets were packed from 3 feet to the surface (refer to completion diagram figure 1). Monitoring well 7 (MW 7) which is 15.58 feet from MW 17 was used as the piezometer at the 15-foot radial distance. For convenience, the piezometers at 5.25, 10, 17, 14.58, 25.42, 36.5, 50, and 75 feet were named P5, P10, P15, P25, P35, P50, and P75 respectively. Vacuum measurements were obtained with Dwyer manometers.

The pilot test was performed by creating a vacuum in the soil with the vacuum blower attached to MW 17 and obtaining measurements from the piezometers of the vacuum created in the soil at different time intervals. Vapor samples were collected each week to test the effectiveness of the system. The system is equipped with two vapor-phase carbon adsorption drums connected in series (a scrubber and a polisher). Measurements of the vacuum pressure at MW 17 and velocity measurements of the air flow exiting the system were obtained. The blower was run for a total of 1170 minutes (19.5 hours) with 17 measurements being taken from P5, P10, P15, P25, and P35 feet. No response was seen in P50 and P75 thus, measurements were discontinued in these piezometers after 8 hours.

Discussion

The results in Table 1 show the pressures obtained from each piezometer at different measurement times. To determine the permeability of the soil to air flow from the results shown in Table 1 the best fit straight line of pressure versus the natural log of the measurement time for each piezometer was determined using linear regression. As can be seen in Table 1, the pressure readings at times 1, 15, and 30 minutes for P25 were not used due to the drop to 0.01 in H_20 at the 45 minute pressure reading. From the pressure readings from P35 the readings at times 1, 15, 30, 45 and 60 minutes were not used, again due to the drop in pressure at the 30 minute and 120 minute pressure readings. These erroneous readings are thought to be due to the operator. The readings from P50 and P75 were all 0.00 in H_20 up to 540 minutes into the test when readings from these piezometers were discontinued.

Table 2 shows the slope, intercept and the square of the correlation coefficient obtained by linear regression for each piezometer. The calculated values of the soils permeability to air flow (k) for each piezometer are also shown in Table 2.

TABLE 1

RESULTS OF PIEZOMETER MEASUREMENTS

TIME		PIEZOMETER VACUUM PRESSURE (Inches of H_2O)						
Actual	Min.	P-5	P-10	P-15	P-25	P-35	P-50	P-75
10:08	1	0.07	0.06	0.03	0.02*	0.01*	0.00	0.00
10:23	15	0.11	0.05	0.03	0.03*	0.01*	0.01	0.00
10:38	30	0.012	0.05	0.03	0.02*	0.00*	0.00	0.00
11:53	45	0.12	0.08	0.02	0.01	0.00*	0.00	0.00
11:08	60	0.15	0.09	0.03	0.02	0.01*	0.00	0.00
12:08	120	0.05	0.05	0.02	0.02	0.00*	0.00	0.00
12:08	180	0.06	0.06	0.05	0.06	0.01	0.00	0.00
14:08	240	0.09	0.08	0.06	0.04	0.04	0.00	0.00
15:08	300	0.13	0.12	0.03	0.05	0.02	0.00	0.00
16:08	360	0.17	0.13	0.06	0.03	0.01	0.00	0.00
17:08	430	0.17	0.14	0.06	0.04	0.02	0.00	0.00
18:08	480	0.18	0.12	0.05	0.06	0.04	0.00	0.00
19:08	540	0.24	0.15	0.04	0.04	0.02	NM	NM
20:08	600	0.24	0.13	0.04	0.06	0.03	NM	NM
21:08	660	0.24	0.15	0.03	0.05	0.03	NM	NM
22:08	720	0.24	0.13	0.06	0.04	0.03	NM	NM
5:30	1170	0.24	0.15	0.05	0.04	0.02	NM	NM
9:45	1425	0.17	0.10	0.04	0.04	0.01	NM	NM

Piezometer Distances from vacuum well:

P-5 = Piezometer at 5.25 feet
P-10 = Piezometer at 10.17 feet
P-15 = Piezometer at 14.58 feet
P-25 = Piezometer at 25.42 feet
P-35 = Piezometer at 36.5 feet

P-50 = Piezometer at 50 feet
P-75 = Piezometer at 75 feet
NM = Not Measured
* = Discarded Reading

TABLE 2

LINEAR REGRESSION RESULTS AND CALCULATED K VALUES FOR PIEZOMETERS P5 THROUGH P35

Piezometer	Slope of Line	Y Intercept	R2	k (Darcy)
P5	0.0234	-0.07836	0.4502	0.17
P10	0.0166	-0.0495	0.5881	0.27
P15	0.0042	0.002021	0.2776	1.05
P25	0.0107	-0.06502	0.4207	0.41
P35	0.0090	-0.06857	0.2234	0.49

Comparing the k values and the square of the correlation coefficient in Table 2, it is shown that the square of the correlation coefficient for P15 and P35 are much lower than for P5, P10, and P25. It is assumed that the piezometers P15 and P35 did not have a complete seal which resulted in short circuiting air from the atmosphere to the subsurface resulting in fluctuating pressure readings and an erroneous indication of a more permeable soil. The results from P15 and P35 were discarded due to this error. Averaging the k values from P5, P10 and P25 an average k value of 0.28 Darcy results.

With a soil permeability to air flow of 0.28 Darcy a radius of influence is calculated to be 43 feet. To check the calculated radius of influence the straight line plot of the natural log of distance versus the pressure in the piezometers at the last readings(1170) minutes) is extrapolated to a pressure of 0.00 in H_20. From the equation of the line the distance from MW 17 to the radial extent of a pressure of 0.00 in H_20 is calculated to be 41.7 ft.

The differential vacuum pressure at MW 17 was 2.35 psi and the air flow velocity was approximately 250 feet per minute from the vacuum blower.

The effectiveness of the SVE unit was determined from mass balance calculations using analytical data obtained during the pilot study. Analytical results from the most recent sampling event on June 11, 1992, revealed the highest concentrations of the various compounds removed from the vadose zone by the SVE system. The removal rate of each compound, in pounds per day (lbs/day), was calculated using the measured flow rate of 159.3 liters/minute, the analytical results from the June 25, 1992, sampling event (Table 3), and the current daily operating time of 14 hours/24 hours. The SVE removal rates are as follows:

PCE = 0.42 lbs/day

Combined (Benzene, TCE, cis 1,2 DCE) = 0.01 lbs/day

TPH - gasoline = 44 lbs/day

Trichloroethene (TCE), benzene, and cis 1,2, dichloroethene (DCE) have also been detected in the samples at concentrations several orders of magnitude lower than PCE concentrations. In addition, petroleum hydrocarbon compounds characteristic of gasoline were detected in the extracted vapors from MW-17. The latest total petroleum hydrocarbon (TPH) concentration detected was 3882 ppm (Table 3). TPH is therefore a significant presence in addition to the PCE. Results from vapor and groundwater analysis are presented in Table 3 and Table 4, respectively.

TABLE 3

SVE PILOT TEST-VOLATILE ORGANICS ANALYSIS RESULTS

COMPOUNDS	CONCENTRATIONS (ppm)			
	May 19, 1992	June 1, 1992	June 11, 1992	June 25, 1992
Benzene	NA	NA	1.00	1.70
cis-1,2,DCE	0.590	2.17	3.43	5.52
PCE	142	177	194	196
TCE	0.850	1.69	1.72	2.46
1,2 DCA	ND	ND	---	0.77
1,2-dichloropropane	0.060	0.42	1.10*	---
2,2,3 Trimethylpentane	NA	---	262	479
Methylcyclohexane	NA	---	241	422
2,3 Dimethylhexane	NA	NA	156	---
Cyclohexane	NA	NA	142	276
2 Methylpentene	NA	NA	137	545
2 Methylhexane	NA	NA	130	246
3 Methylhexane	NA	NA	122	---
Hexane	NA	NA	117	252
2 Methylpentane	NA	NA	---	545
Methylpentane	NA	NA	104	243
2 Methylbutane	NA	NA	90.1	260
Total C3-C10 Range Hydrocarbons	134	1123	2774	3882

NA: Not Analyzed

ND: None Detected

* Potential interference from co-eluding non-target compound

— : not identified

TABLE 4

GROUNDWATER ANALYSIS

	SAMPLE LOCATIONS				
	MW-7	MW-17	MW-18	CWS-3	CWS-8
COMPOUNDS	CONCENTRATIONS (ppb)				
Bromochloromethane	ND	ND	ND	0.2	ND
Bromodichloromethane	ND	ND	ND	20	ND
Benzene	1000	870	ND	ND	ND
Bromoform	ND	ND	1	1.4	ND
Chloroform	ND	ND	ND	21	0.4
Dibromochloromethane	ND	ND	ND	12	ND
Ethylbenzene	93	56	ND	ND	ND
Tetrachloroethene	120	1300	170	ND	ND
Trichloroethene	110	150	1	ND	ND
Toluene	29	40	ND	ND	0.3
Total Xylene Isomers	92	71	ND	ND	ND
cis-1,2 - Dichloroethene	630	600	ND	ND	ND
Semi Quantified C5-C13 Hydrocarbon Matrix	10,000	6,000	ND	NA	NA

ND: None Detected

NA: Not Analyzed

CWS: California Water Service Well

MW: H+GCL Monitor Well

CONCLUSION

The pilot test on MW 17 with a 5 hp blower powered by a 3-phase generator created an air flow in the soil that was calculated using a model presented in Johnson, et. al. to be 43 feet in radius. The air permeability of the soil was calculated to be 0.28 Darcy which lends the soil to be conducive to soil vapor-extraction.

It is apparent from the vapor sampling results that the SVE system is effectively removing VOCs from the vadose zone.

Groundwater samples were recently collected from MW-7, MW-17 and MW-18. The results do not show an effect of the SVE system on reducing PCE concentrations in groundwater. More monitoring over time is required.

Appendix D

Cost Analysis of Alternatives
Livermore Arcade

***Alternative 1* - No Action w/GW Monitoring**		
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	$ 11,000	
Labor	4000	
Total Direct Annual O&M	15,000	
Indirect Annual O&M (20%)	3000	
Total Annual O&M	18,000	
O&M Present Worth (30 years, 8% discount, 4.5% inflation)		322,900
Total No Action w/GW Monitoring - Present Worth		**$322,900**
***Alternative 2* - Soil-Vapor Extraction w/Carbon Treatment**		
System Costs		
(1) Portable Soil-Vapor Extraction System	$ 20,000	
(6-8) Additional Wells	20,000	
Electrical Connections	5,000	
Activated Carbon System	2,000	
Installation	5,000	
Labor	18,000	
Total Direct Cost	70,000	
Indirect Costs (20%)	14,000	
Total Capital Cost	84,000	
Mobilization (25%)	21,000	
Contingency (20/%)	16,800	
Engineering (15%)	12,600	
Total Soil-Vapor Extr. w/Treatment - System Cost		134,400
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Air Sampling (Monthly)	2,400	
Electricity	1,800	
Carbon Replacement	12,000	
Total Direct Annual O&M	34,200	
Indirect Annual O&M (20%)	6840	
Total Annual O&M	41,040	
O&M Present Worth (2 years, 8% discount, 4.5% inflation)		74,770
GW Monitoring Present Worth (5 yrs., 8% discount, 4.5% inflation)		78,100
Total Soil-Vapor Extr. w/Treatment - Present Worth		**$284,270**

Appendix D

Cost Analysis of Alternatives
Livermore Arcade

Alternative 3 - **Soil-Vapor Extraction Without Treatment**

System Costs		
Portable Soil-Vapor Extraction System	$ 20,000	
(6-8) Additional Wells	20,000	
Electrical Connections	5,000	
Installation	5,000	
Labor	18,000	
Total Direct Cost	68,000	
Indirect Costs (20%)	13,600	
Total Capital Cost	81,600	
Mobilization (25%)	20,400	
Contingency (20%)	16,320	
Engineering (15%)	12,240	
Total Soil-Vapor Extr. w/o Treatment - System Cost		130,560
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Air Sampling (Monthly)	4,800	
Electricity	1,800	
Total Direct Annual O&M	24,600	
Indirect Annual O&M (20%)	4,900	
Total Annual O&M	29,500	
O&M Present Worth (2 years8% discount, 4.5% inflation)		53,750
GW Monitoring Present Worth (5 yrs., 8% discount, 4.5% inflation)		78,100
Total Soil-Vapor Extr. w/o Treatment - Present Worth		**$262,410**

Alternative 4 - **Air Sparging/Soil-Vapor Extraction and Treatment**

System Costs		
Portable Air Sparging/Soil-Vapor System	$ 25,000	
(6-8) Additional Wells	20,000	
Electrical Connections	5,000	
Activated Carbon System	2,000	
Installation	6,000	
Injection Points (2)	2,000	
Labor	24,000	
Total Direct Cost	84,000	
Indirect Costs (20%)	16,800	
Total Capital Cost	100,800	
Mobilization (25%)	25,200	
Contingency (20/%)	20,160	
Engineering (15%)	15,120	
Total Air Sparging/Vapor Extr. w/Carbon - System Cost		161,280

Cost Analysis of Alternatives
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Alternative 4 (cont'd)

Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Air Sampling (Monthly)	2,400	
Electricity	3,500	
Carbon Replacement	12,000	
Total Direct Annual O&M	35,900	
Indirect Annual O&M (20%)	7,200	
Total Annual O&M	43,100	
O&M Present Worth (1 year, current dollars)		43,100
GW monitoring Present Worth (5 years, 8% discount, 4.5% inflation)		78,100
Total Air Sparg/Vapor Extr. w/Carbon - Present Worth		**$282,480**

Alternative 5 - **Air Sparging/Soil-Vapor Extraction without Treatment**

System Costs		
Portable Air Sparging/Soil-Vapor System	$ 25,000	
(6-8) Additional Wells	20,000	
Electrical Connections	5,000	
Installation	6,000	
Injection Points (2)	2,000	
Labor	24,000	
Total Direct Cost	82,000	
Indirect Costs (20%)	16,400	
Total Capital Cost	98,400	
Mobilization (25%)	24,600	
Contingency (20/%)	19,680	
Engineering (15%)	14,760	
Total Air Sparging/Vapor Extr. without Treatment		157,440
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Air Sampling (Monthly)	4,800	
Electricity	3,500	
Total Direct Annual O&M	26,300	
Indirect Annual O&M (20%)	5,260	
Total Annual O&M	31,560	
O&M Present Worth (1 year, current dollars)		31,560
GW monitoring Present Worth (5 years, 8% discount, 4.5% inflation)		78,100
Total Air Sparg/Vapor Extr. w/Carbon - Present Worth		**$267,100**

Appendix D

Cost Analysis of Alternatives
Livermore Arcade

Alternative 6 - Groundwater Extraction and Treatment System

System Costs		
(2) Air Strippers	40,000	
Enclosures	4,000	
Electrical Connections	5,000	
Pumps and Controls	3,000	
(2) Activated Carbon Systems	4,000	
Installation	10,000	
Labor	24,000	
Total Direct Cost	90,000	
Indirect Costs (20%)	18,000	
Total Capital Cost	108,000	
Mobilization (25%)	27,000	
Contingency (20/%)	21,600	
Engineering (15%)	16,200	
Total GW Extraction and Treatment - System Cost		172,800
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Effluent Sampling (Monthly)	10,000	
Electricity	1,800	
Carbon Replacement	12,000	
Total Direct Annual O&M	41,800	
Indirect Annual O&M (20%)	8,360	
Total Annual O&M	50,160	
O&M Present Worth (6 years, 8% discount, 4.5% inflation)		257,070
GW Monitoring Present Worth (5 years, 8% discount, 4.5% inflation)		78,100
Total GW Extra. and Treatment - Present Worth		**$507,970**

Alternative 7 - Groundwater Extraction without Treatment

System Costs		
Enclosure for Controls	$ 4,000	
Electrical Connections	5,000	
Pumps and Controls	3,000	
Installation	10,000	
Labor	24,000	
Total Direct Cost	46,000	
Indirect Costs (20%)	9,200	
Total Capital Cost	55,200	
Mobilization (25%)	13,800	
Contingency (20/%)	11,040	
Engineering (15%)	8280	
Total GW Extr. w/o Treatment - System Cost		88,320

Cost Analysis of Alternatives
Livermore Arcade

Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Effluent Sampling (Monthly)	10,000	
Electricity	1,800	
Total Direct Annual O&M	29,800	
Indirect Annual O&M (20%)	5,960	
Total Annual O&M	35,960	
O&M Present Worth (6 years, 8% discount, 4.5% inflation)		183,090
GW Monitoring Present Worth (5 years, 8% discount, 4.5% inflation)		78,100
Total GW Extraction w/o Treatment - Present Worth		**$349,510**

***Alternative 8* - Subsurface Bioremediation**

Treatability Test	$ 2,000	
(2)Bioreactor Unit	100,000	
Enclosures	4,000	
Electrical Connections	5,000	
Pumps and Controls	3,000	
Installation	6,000	
Injection Well	3,000	
Labor	24,000	
Total Direct Cost	147,000	
Indirect Costs (20%)	29,500	
Total Capital Cost	176,400	
Mobilization (25%)	44,100	
Contingency (20%)	35,280	
Engineering 15%))	26,460	
Total Bioremediation - System Cost		282,240
Operation and Maintenance (Annual)		
GW Sampling (Quarterly)	18,000	
Bio Sampling (Monthly)	14,400	
Electricity	1,800	
Total Direct Annual O&M	34,200	
Indirect Annual O&M (20%)	6,840	
Total Annual O&M	41,040	
O&M Present Worth (2 years, 8% discount, 4.5% inflation)		74,770
GW Monitoring Present Worth (5 years, 8% discount, 4.5% inflation)		78,100
Total Bioremediation - Present Worth		**$435,110**