FLUOR DANIEL GTI

ENVIRONMENTAL
PROTECTION
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PILOT TESTING REPORT
SEARS, ROEBUCK AND CO.
FORMER STORE NO. 1058
2633 TELEGRAPH AVENUE
OAKLAND, CALIFORNIA

May 22, 97

Fluor Daniel GTI Project 020200136

May 22, 1997

Prepared for:
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West Region

20200136.PTR

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1.0 INTRODUCTION

This report was prepared by Fluor Daniel GTI, Inc. (Fluor Daniel GTI), on behalf of Sears, Roebuck and Co. (Sears) to summarize the results of biotreatability and soil vapor extraction (SVE) pilot tests conducted at the former Sears facility located at 2633 Telegraph Avenue in Oakland, California. The Remedial Action Plan/Work Plan (RAP/WP) to conduct this work was submitted to the Alameda County Health Care Services Agency (ACHCSA) on September 8, 1995, and approved on January 30, 1996. The recommendations presented in this report provide a plan for final corrective actions at the site.

2.0 SITE BACKGROUND

The former Sears facility is located in the city of Oakland, Alameda County, California (figure 1). The surrounding area is predominantly commercial along Telegraph Avenue with residential properties located north, south, and east along 26th Street and 27th Street.

During the time Sears owned the property, several underground storage tank (UST) systems were in operation at the site. Six motor oil tanks were present northeast of the automotive repair building, two gasoline USTs were located in the northwest portion of the property and one used-oil tank was present between the gasoline USTs and the building (figure 2). Gasoline dispenser pumps were located due west of the gasoline USTs. The UST systems have been removed from the site.

A series of subsurface investigations has been conducted at the Sears Facility to define the lateral and vertical extent of petroleum impacts to soil and groundwater. The investigations included installing eight monitoring wells, four soil boreholes, and an off-site soil probe investigation consisting of three probe point locations. Results of these investigations indicated that petroleum hydrocarbons have been detected in the subsurface in three primary phases: adsorbed to the soils, dissolved in the groundwater, and separate-phase hydrocarbons (SPH) floating on the groundwater. A summary of the distribution of the hydrocarbons in these phases is discussed below in Section 3.0.

2.1 Geology/Hydrogeology

The subsurface material encountered during the previous investigations consisted primarily of unconsolidated silt and clay above the water table; and silty and sandy clay, gravely silt, sand, and gravel below the water table. Groundwater occurs beneath the site at elevations ranging from approximately 13 to 17 feet above mean sea level (10 to 14 feet below ground surface). The local groundwater gradient is approximately 0.02 foot per foot to the south. Figures 4 and 5 show a geologic cross-section of the site.

3.0 SITE CHARACTERIZATION

3.1 Adsorbed-Phase Hydrocarbons (Soil)

Adsorbed-phase hydrocarbons have been detected in soil samples collected from well borings MW-1, MW-2, MW-3, MW-4, MW-5 and from soil borings B-1 and B-2 (figure 3 and table 1). Adsorbed-phase hydrocarbons were also detected in the closure soil samples collected from the used-oil tank basin. A soil sample collected from boring B-2 located adjacent to the south wall of the building contained total petroleum hydrocarbons as gasoline (TPH-g) at 130 parts per million (ppm), and lower concentrations of benzene, toluene, ethylbenzene, and total xylenes (BTEX) (figure 3, table 1). It appears that downgradient migration of the hydrocarbons has occurred principally along the building foundation. This is supported by the nondetectable or low concentrations of hydrocarbons in boring B-1 (1.7 ppm TPH-g) and B-3 (below detection limits) which are located only several feet from the building foundation. An attempt to assess the condition of the basement of the building for cracks and seeps could not be conducted at the time of our pilot test because the current owner of the building could not locate the key.

The lateral extent of adsorbed-phase hydrocarbons around boring B-2 is defined by soil probe points B-3, B-4, and SB-5. The adsorbed-phase hydrocarbons are present both in the unsaturated and saturated zones but are primarily detected at the groundwater interface.

Inspection of the laboratory analytical results reported in table 1 shows that, where samples were analyzed for both total petroleum hydrocarbons (TPH) and TPH-g, the TPH concentration is much greater than the TPH-g concentration. The TPH analysis method, Environmental Protection Agency (EPA) Method 418.1, is used to measure the concentration of oil and grease in soil. The results of this analysis are indicative of high molecular weight (HMW) hydrocarbons. The calculation of the relative mass of TPH and TPH-g based on the laboratory analysis results for this site is included in appendix A. That calculation shows that the hydrocarbon mass in the vadose zone soil consists primarily of HMW hydrocarbons.

3.2 Dissolved-Phase Hydrocarbons (Groundwater)

The dissolved-phase plume is defined to the south by soil probe point SB-5, to the southwest by boring B-3, monitoring well MW-7 and soil probe SB-6, to the southeast by well MW-6, to the east by well MW-1, and to the north by well MW-5 (figure 6, table2). Laboratory analytical results indicate that the dissolved-phase plume consists predominantly of TPH-g and total petroleum hydrocarbons as motor oil (TPH-mo). TPH-mo is indicative of HMW hydrocarbons. As calculated in appendix A, the mass of hydrocarbons in the groundwater consists primarily of HMW hydrocarbons.

Quarterly groundwater monitoring and sampling for the last four years have reported that concentrations of BTEX in groundwater have been below the California maximum contaminant levels (MCLs) established by the California Department of Health Services (table 2). The highest dissolved-phase concentrations of TPH are present downgradient of the used oil and gasoline tank basins in monitoring wells MW-2, MW-3, and MW-4 (figure 6). The general groundwater gradient is to the south.

3.3 Separate-Phase Hydrocarbons

Measurable thicknesses of SPH have been detected in monitoring well MW-3. SPH was first detected in this well in September 1993 at a thickness of 0.04 feet. Thicknesses of SPH have ranged from 0.01 feet to 0.22 feet, except for the period from February through May 1994 when SPH was not present. Traces of SPH have also been periodically detected in monitoring well MW-2 (table 3). A sample of SPH from well MW-3 was analyzed on June 19, 1996 (appendix D). The laboratory analytical results from this product sample indicated that only petroleum hydrocarbons in the motor oil boiling point range were present in the SPH.

3.4 Mass Estimates

The analytical results for TPH and TPH-g (EPA Methods 3550/418.1 and 8015) in soil were used to estimate the total mass of adsorbed hydrocarbons in the subsurface. First, an average concentration of TPH and TPH-g at each boring location was estimated as explained in appendix A. From these averages, isoconcentration contours were developed as shown on figure 7.

The mass estimates were developed using the isoconcentration contours on figure 7 from the ground surface down to an average depth of 12 feet below grade surface (bgs). The volume of soil within each isoconcentration contour was calculated based on the measured areas multiplied by the thickness of the interval. The mass of petroleum hydrocarbon compounds in each soil interval was calculated using the average concentration present between the isoconcentration contours. An estimated 3,400 pounds of adsorbed-phase hydrocarbons are present in the unsaturated zone soils. The calculations used to obtain the mass estimate for hydrocarbons adsorbed in the soil are presented appendix A.

4.0 PILOT TESTING

Based on the results of initial screening of remedial technologies applicable to the geology/hydrogeology and contaminant types beneath the site, SVE and bioventing technologies were determined to have the best potential for the removal of hydrocarbons at this site. To assess the feasibility of SVE and bioventing, a pilot test was conducted on June 20, 1996. In addition, to aid in removal of separate-phase hydrocarbons and to assist with the pilot test, an extraction well (EW-1, figure 2) was installed on June 11, 1996. The following sections discuss the procedures used, the results obtained, and the evaluation of the pilot test results.

4.1 Extraction and Monitoring Well Installation

On June 11, 1996, Fluor Daniel GTI installed a 4-inch-diameter extraction well (EW-1, figure 2) to an approximate depth of 23 feet bgs. On September 9, 1996, one 2-inch-diameter monitoring well (MW-9, figure 2) was installed to an approximate depth of 20 feet bgs. Soil samples were not collected for laboratory analysis from this monitoring well.

Soil samples were collected at 3-foot intervals starting from approximately 3 feet bgs to the total depth of the boring for the extraction well. A modified California split-spoon sampler was used for sample collection. Soil samples were screened using a photoionization detector (PID) and results recorded on the boring log (appendix B).

The extraction well was constructed using 4-inch-diameter polyvinyl chloride (PVC) continuous wrapped well screen (0.020-inch slot size) and casing. The well casing extended from ground surface to 9.5 feet bgs and the well screen extended from 9.5 feet to 22.7 feet bgs. The monitoring well was constructed using 2-inch-diamter PVC well screen (0.020-inch slot size) and casing. The well casing extended from ground surface to 6.5 feet bgs and the well screen extended from 6.5 feet to 20 feet bgs.

For both the extraction well and the monitoring well, the annular space between the borehole and casing was backfilled with No. 3 sand from the well completion depth to approximately 2 feet above the well screen. A 2-foot seal of hydrated bentonite pellets was installed above the sand followed by cement grout to the surface. The well was finished with a watertight locking cap inside a traffic-rated street box. Well construction diagrams are presented on the drilling log (appendix B). Soil cuttings generated during the drilling activities were placed in 55-gallon steel drums and stored on-site pending off-site disposal. The approximate depth to groundwater in well RW-1 was 13 feet bgs and the approximately depth in well MW-9 is 12 feet bgs.

4.1.1 Extraction Well and Monitoring Well Development

The extraction well and monitoring well were developed on June 17 and October 11, 1996, respectively, to improve the hydraulic communication with the surrounding aquifer. Suspended sediment was removed from the well using a surge and bail technique until the extracted groundwater was relatively free of fine particles. Development water was placed in 55-gallon steel drums, and stored on-site pending off-site disposal.

4.2 Soil Vapor Extraction Test

The SVE test was conducted to meet the following objectives:

- quantify the vadose zone response to soil vapor extraction
- evaluate the feasibility of SVE as a remedial technology for the site
- provide the design basis for a remedial system based on results of the SVE test

4.2.1 Methodology

The SVE test was designed to extract soil vapor from the vadose zone using a V.R. Systems® internal combustion (IC) engine with a manifold vacuum extraction system. The IC engine produced a maximum vacuum of -100 inches of water column (in.WC). Soil vapor was withdrawn from the extraction well (EW-1) at a known vacuum and the resultant vapor flow rate was recorded. The vacuum applied to extraction well (EW-1) and the vacuum response induced in the subsurface was measured at the observation wells (observation points) and recorded for each of the extraction rates. The observation points were MW-1 through MW-8 (figure 2). The vacuum response at each observation point was measured using a Magnehelic® vacuum gauge to estimate an effective radius of influence for soil vapor extraction.

Carbon dioxide and oxygen concentrations were monitored (respirometry) in observation points before, during and after the SVE pilot test in order to determine the level of microbiological activity in the subsurface. The gas concentrations were measured using a GA-90 Landtec® Infrared gas analyzer.

Hydrocarbon, oxygen and carbon dioxide concentrations in the effluent air stream from the extraction well were analyzed throughout the SVE pilot test. The hydrocarbon discharge concentrations were measured using a Sensidyne® flame-ionization detector (FID). The vapor temperature, applied vacuum, and vapor flow rate were monitored at EW-1 during the pilot test. The flow and temperature were measured at the wellhead using a hot tip anemometer. The applied vacuum was measured using a Magnehelic® vacuum gauge.

One vapor sample was collected from EW-1 during the final stage of the pilot test for laboratory analysis. The results from the vapor sample collected from EW-1 were used to evaluate the initial hydrocarbon removal rate by a potential vapor extraction system.

4.2.2 Field Activities

The SVE test was conducted on June 20, 1996. The test was conducted at three stages of increasing vacuum. The soil vapor extraction vacuums were -30 inches of water column (in.WC), -60 in.WC, and -100 in.WC. The vapor extraction flow rate, applied vacuum, respirometry, and field FID measurements of the SVE system were recorded throughout the test (appendix C). The vacuum influence at wells MW-1 through MW-8 was monitored to determine influence in the subsurface to a depth of approximately 12 feet bgs.

During each stage of the pilot test, vapor samples were field analyzed with an FID and an infrared gas analyzer. During the final stage of the test a sample was collected in a Tedlar® sample bag at the influent of the treatment unit to determine the concentration of TPH in the vapor being extracted. After the pilot test was completed, a vapor sample was collected from well MW-4 because this monitoring point showed elevated levels of hydrocarbon vapor during the test. The samples were analyzed by a California-certified laboratory for BTEX and TPH-g using EPA Methods 8015/8020 (modified). The laboratory analytical results of the vapor samples are presented in table 4 and appendix D.

The extracted soil vapor was treated through the IC engine and catalytic oxidizer to remove hydrocarbons present in the soil vapor prior to discharge. The vapor emissions were monitored during the test using a FID to evaluate the vapor treatment system effectiveness.

4.2.3 Results

At an applied vacuum of -30 in.WC, vacuum influence was recorded 73 feet from well EW-1 in observation well MW-7. At an applied vacuum of -60 in.WC to -100 in.WC, vacuum influence was monitored approximately 118 feet from EW-1 in well MW-5. The field monitoring data collected during the SVE pilot test are presented in appendix C. At applied vacuums of -30 in.WC, -60 in.WC, and -100 in.WC, the maximum monitored vacuum influences were approximately -0.96 in.WC, -1.1 in.WC, and -3.4 in.WC, respectively. These data were measured in MW-3, approximately 4 feet from well RW-1.

Static carbon dioxide (CO_2) concentrations were measured in the observation points prior to starting the test. Static CO_2 concentrations in the monitoring wells (figure 8) were above atmospheric levels, as high as 5.4%. The normal atmospheric concentration of CO_2 at sea level is approximately 0.03%.

Static oxygen (O_2) levels measured in the observation points were near ambient atmospheric levels in the perimeter monitoring wells near the property boundary (figure 9). Observation points closer to the center of the hydrocarbon plume had O_2 concentrations as low as [illegible] percent. The normal concentration of atmospheric O_2 at sea level is approximately 20.9 percent. Elevated carbon dioxide levels and depleted oxygen measurements are indicators of biological activity. The static carbon dioxide and oxygen levels in the subsurface indicate that microbial activity is naturally occurring in the unsaturated zone soils and is most active in the subsurface areas with the greatest TPH levels (wells MW-3 and MW-4).

Carbon dioxide and oxygen levels were also monitored in EW-1 during the SVE pilot test (appendix C). Carbon dioxide levels in EW-1 decreased from 9.7 percent to 5.0 percent. Oxygen levels in EW-1 increased from 9.7 percent to 13.6 percent during the pilot test. These levels indicate that the unsaturated zone in the area of the vapor extraction well was being oxygenated in response to the SVE test.

The FID field analysis of the vapors extracted from EW-1 during the pilot study indicated hydrocarbon concentrations from 795 parts per million by volume (ppmv) to 1,511 ppmv (appendix C). The laboratory analytical results of the sample from EW-1 taken during the final stages of the test indicate a total BTEX concentration of 13 milligrams per cubic meter (mg/M^3) and a TPH-g concentration of 1,500 mg/M^3 (appendix D). The vapor sample from MW-4 contained a TPH-g concentration of 12,000 mg/M^3 (appendix D).

4.2.4 Analysis

To prepare a design for a SVE system, the effective radius of influence for a theoretical set of vapor extraction wells should be estimated using the data collected during the pilot test. The effective radius of influence is defined as the maximum distance from a vapor extraction well through which sufficient air is drawn to remove the required mass of contaminants in the desired time frame. The effective radius of influence is determined by performing a vapor extraction test on a single vapor extraction well (such as was performed at EW-1) and extrapolating the results to model a vapor extraction system of multiple wells. To model a full scale remediation system, Fluor Daniel GTI has developed a computerized design tool titled "Vent-ROI" (Vent-Radius of Influence).

Vent-ROI uses vacuum/flow response and vacuum dissipation data recorded during the vapor extraction test to prepare an analytical model of flow in the subsurface in response to an applied vacuum. A wide range of operating variables may be adjusted to design a cost-effective system. The variables considered by Vent-ROI include seven items: well depth, screen intervals, temperature, applied vacuum, air flow rate, cleanup time, and cleanup goals. By adjusting the variables, it is possible to determine SVE well spacing and blower size specifications for the final system design.

The induced vacuum measured in the observation points and other site specific data collected during the pilot test were input into the Vent-ROI model. The model assumptions, model description, and final results are included in appendix E.

The results of the model calculations indicated that an SVE system at this site could be expected to have an interwell effective radius of influence of 13 feet with a flow rate of 23.9 standard cubic feet per minute (scfm) per vapor extraction well at an applied vacuum of -100 in.WC (table 4). An interwell effective radius of influence is the radius achieved after considering the counter effects of multiple vapor extraction wells.

4.3 Biotreatability Test

4.3.1 Methodology

Fluor Daniel GTI's Remediation Technology Testing Facility (RTTF) performed a treatability study on soil and groundwater samples collected from the site to evaluate the overall feasibility of using bioremediaton at the site (appendix F). The study examined the chemical, physical, and microbial properties of the soil and evaluated the rate and extent of treatment achievable under aerobic and anaerobic denitrifying conditions.

During drilling of well EW-1, 2.5 kilograms of soil and 5 liters of groundwater were collected and shipped under chain-of-custody to the RTTF laboratory. A soil composite was generated by blending the soil samples. The groundwater and soil composite samples were then characterized for a series of chemical, physical, and microbiological parameters. An aerobic and anaerobic biodegradation study was conducted to assess the feasibility of bioremediation, following the initial characterization.

The aerobic study was performed on soil and groundwater in the slurry phase. The aerobic biodegradation evaluation was performed under three experimental conditions: 1) nutrified, 2) non-nutrified, and 3) poisoned. Each experimental condition consisted of a series of sealed reactors. Nitrogen and phosphorus nutrients were added to the nutrified systems and a chemical poison was added to the poisoned systems to minimize biological activity. The poisoned condition was studied to determine the effect of nonbiological degradation on the slurry sample. The reactor contents were shaken and incubated at room temperature for 60 days.

The anaerobic study was performed on the groundwater alone, under denitrifying conditions. Two anaerobic studies were performed: 1) anaerobic nitrified condition and 2) anaerobic poisoned condition. Each system consisted of a series of sealed reactors, each containing portions of the groundwater composite and amendments. To promote denitrification, the anaerobic reactors are filled completely with the site groundwater composite. The small amount of dissolved oxygen in the water is consumed rapidly, resulting in anoxic conditions. Nitrate and phosphorus were added to the nutrified systems and a chemical poison was added to the poisoned systems. The poisoned test was performed as a control to demonstrate the effect of nonbiologically active conditions. The reactors were inverted and incubated on a reciprocating shaker at room temperature for 83 days.

Reactors from the aerobic slurry test systems were analyzed for TPH by gas chromatography with flame ionization detection (GC/FID) at five time points over the course of the biotreatment study. The anaerobic systems were also analyzed for TPH by GC/FID at five time points over the course of the study. Motor oil-utilizing bacteria were enumerated in each system at the beginning and end of each study.

A bench-scale nutrient adsorption test was also performed to demonstrate the effectiveness of the native soil to adsorb nutrients. Successful application of an *in situ* bioremediation system relies on supplying adequate nutrients to the impacted areas to support the biodegradation. This test was designed to evaluate the capacity of the site soils to retain inorganic nutrients using several portions of soil composite in a standard nutrient solution. If the option of *in situ* biodegradation with nutrient amendments were considered feasible, the nutrient adsorption data would be utilized to plan the rate of application. The nutrient solution for this test contained potassium tri-polyphosphate and ammonium nitrate. The site soil/nutrient mixtures were shaken for 24 hours to facilitate nutrient contact with the soil and allow for any mass transfer to occur. The slurries were then filtered, and the supernatant analyzed for changes in nutrient concentration. The nutrients analyzed in this procedure were ammonia-nitrogen and total phosphate using colorimetric test kits by Hach Company for quantification.

4.3.2 Results

The pH and contaminant utilizing bacteria (CUB) enumeration results (table 5) indicate suitable site conditions for aerobic biodegradation. The soil nutrient tests, however, indicate that naturally occurring levels of nutrients are a limiting factor that will prevent optimum levels of biodegradation from occurring (appendix F).

The 60-day aerobic biodegradation test results (table 6) showed that degradation of TPH in nutrified soil was considerably better than non-nutrified or poisoned (nonbiologically active) soil. There was a 26 percent reduction in contaminant mass in the nutrified soil during the 60-day test as compared with a 31 percent increase in the contaminant mass in the non-nutrified soil.

As demonstrated by the bench-scale biotreatment test, a suitable soil remediation strategy for the oil-impacted soil at the Sears property could include biodegradation that is enhanced by nutrient amendments to the soil and oxygen addition by soil venting. This conclusion is supported by the aerobic CUB enumeration results (table 7) which show an increase of two orders of magnitude in the CUB count in the nutrified soil over the 60 day test, while there was very little change in the CUB count in the non-nutrified soil.

Under anaerobic conditions, a 24 percent increase in contaminant population was observed over the 83-day test in the nutrified system. The TAB population in the nutrified system declined by a factor of 20 during this same period.

The nutrient adsorption test indicated that site soil can adsorb up to approximately 9,000 mg/kg ammonia-nitrogen and 70,000 mg/kg total phosphate (appendix F).

4.3.3 Analysis

Because nutrients in the subsurface are limited, an infiltration system would be necessary to enhance nutrient concentrations. However, infiltration and proper distribution of nutrients is difficult and expensive to accomplish in silt/clay soil such as are present at this site. Clay soil will greatly limit the effectiveness of infiltration systems by impeding the flow of liquids through the shallow unsaturated soil. As a result, the option of enhanced in situ biodegradation is not feasible for this project.

5.0 CONCLUSIONS AND PROPOSED REMEDIATION APPROACH

This section describes the proposed remedial approach and how this approach differs from the approach proposed in the RAP/WP.

5.1 Remedial Action Plan Approach

Fluor Daniel GTI's RAP/WP of September 8, 1995, anticipated that the remedial approach for this site would consist of the following combination of technologies:

- Bioremediation of the used oil in the saturated and unsaturated zones
- Soil vapor extraction to remove volatile hydrocarbons and to provide oxygen to the unsaturated zone for bioremediation
- Groundwater pumping and SPH recovery for control of the dissolved-phase plume and for removal of SPH in monitoring well MW-3.

Pilot testing of these processes was performed in order to demonstrate their feasibility and obtain design conditions for their implementation. That testing indicated that bioremediation is not feasible.

5.2 Recent Developments

After approval of the RAP/WP, the 1995 Lawrence Livermore National Laboratory (LLNL) Report prepared for the California Regional Water Quality Control Board (RWQCB) was released. The LLNL Report, SB 1764 LUFT Advisory Committee and the January 1996 RWQCB memorandum on interim Guidance on Required Cleanup at Low-Risk Fuel Sites would classify this site as a low-risk case because of the low concentrations of BTEX in the subsurface and no drinking water wells nearby. Due to this classification, it is assumed that the HMW hydrocarbons adsorbed on the vadose zone soil will not need to be actively remediated. The SPH will require removal, however.

5.3 Conclusions

The following conclusions can be made following the pilot testing:

- Soil vapor extraction is feasible. An SVE system at this site could be expected to have an interwell effective radius of influence of 13 feet with a flow rate of 23.9 scfm per vapor extraction well at an applied vacuum of -100 in.WC.
- The petroleum hydrocarbons in the subsurface are primarily HMW hydrocarbons. They have very low volatility and would not be removed by SVE. Thus, SVE alone would remove only a small fraction of the petroleum hydrocarbons.
- The biotreatability testing has shown that nutrient and oxygen addition is required to achieve remediation of the soil hydrocarbons. Bioventing without nutrient addition has been ruled out because the addition of oxygen to the subsurface will be largely ineffective, due to the limiting factor of unavailable naturally occurring nutrients as indicated in the biotreatability tests results. Nutrient addition with infiltration systems would not be practical due to clay in the shallow soil.
- There is minimal SPH on the site. SPH has been observed in only one well, MW-3. The thickness has varied between zero and 0.42 feet.
- Laboratory analytical reports of quarterly groundwater monitoring and sampling for the last four years have indicated that concentrations of BTEX in groundwater have been below the California and Federal MCLs established by the California Department of Health Services and US Environmental Protection Agency. No MCLs have been established for other petroleum hydrocarbons.

5.4 Proposed Approach

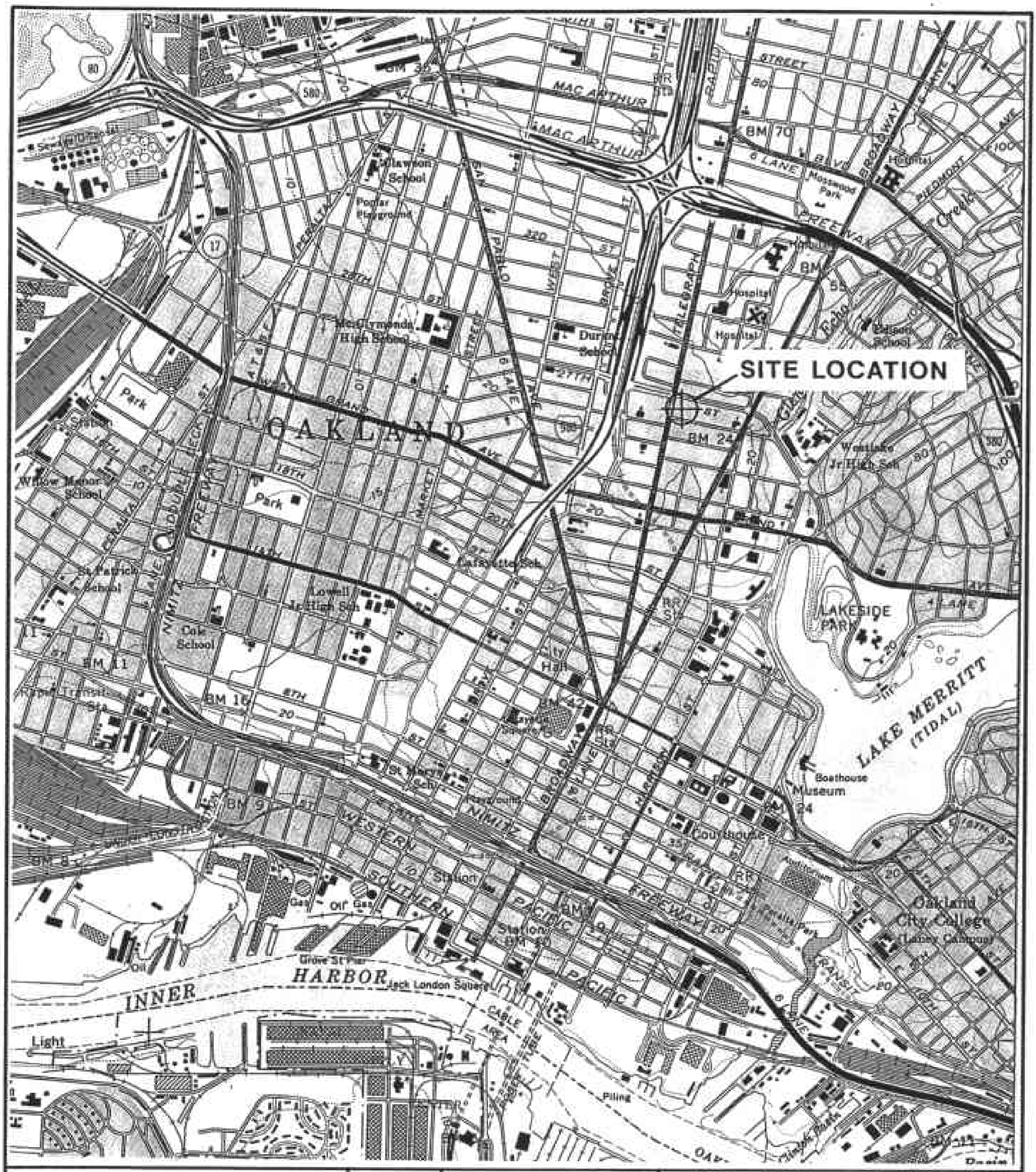
Based upon the preceding considerations, passive SPH skimming will be installed to address the SPH in monitoring well MW-3. The soil and groundwater investigations have determined that SPH has been collecting in and near monitoring well MW-3. The proposed remediation system will consist of an oil skimmer in monitoring well MW-3 to collect SPH. A fenced compound will be located on the former Sears property to house a 55-gallon Department of Transportation (DOT)-approved product holding drum. The skimmer will be manually emptied into the product drum on a regular basis. The SPH should continue to collect near monitoring well MW-3 due to the effect of the downgradient basement wall. When the SPH thickness decreases to the point where the passive skimmer is no longer effective, a SPH adsorbent system will be used to collect the final traces of SPH.

Permits or notifications required for this project include the following:

- City of Oakland Building and Fire Permits
- ACHCSA Work Plan Approval

Once all traces of SPH have been removed, a risk assessment, using the American Society of Testing and Materials (ASTM) standard methodology will be performed to determine if any additional remediation is required.

FIGURES


SITE LOCATION

GROUNDWATER TECHNOLOGY

4057 PORT CHICAGO HWY
CONCORD, CA 94520
(510) 671-2387

N

SCALE:
0 FEET 2000

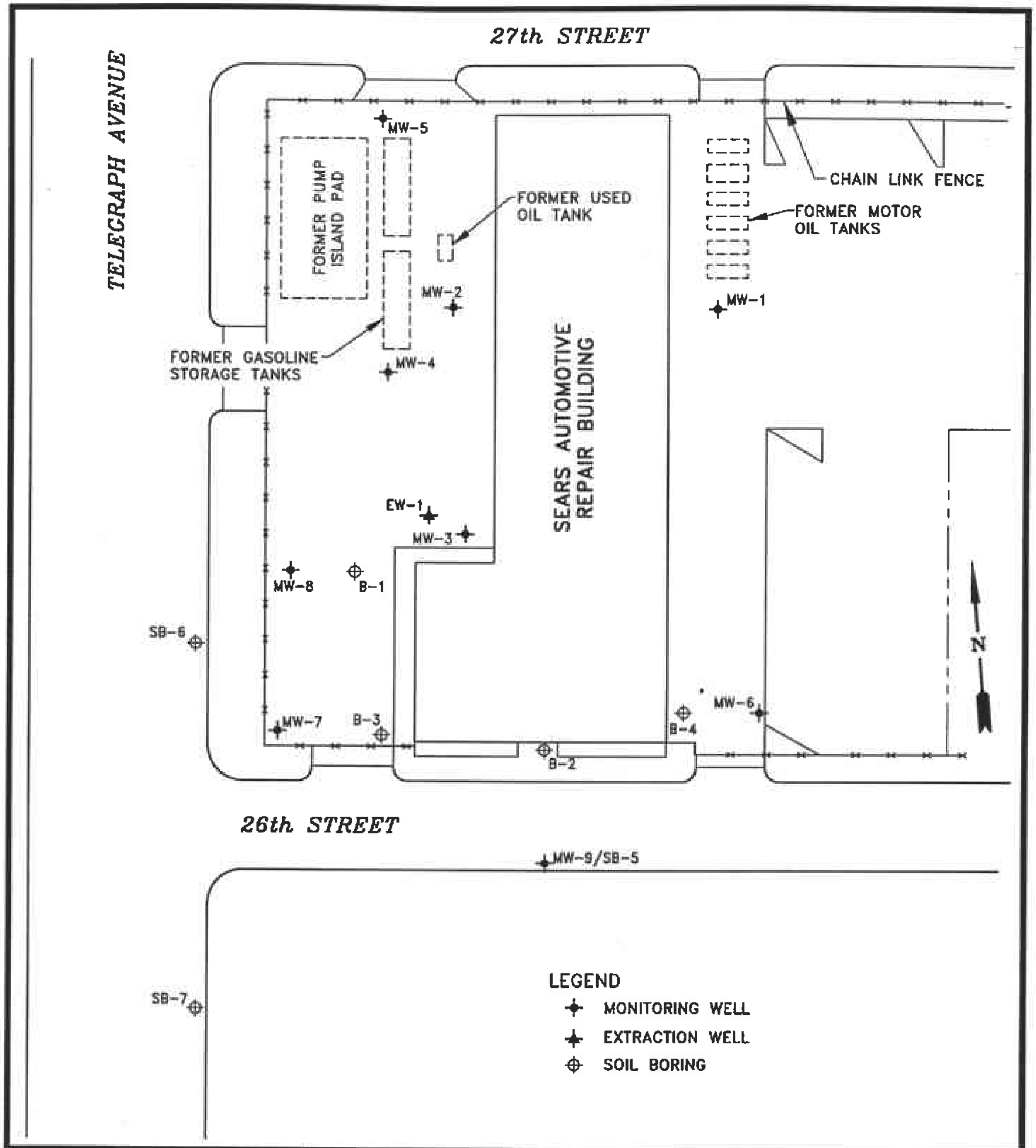
SITE LOCATION MAP

CLIENT:
SEARS, ROEBUCK AND CO.
SITE No. 1058

DATE:
8/18/92

LOCATION:
2633 TELEGRAPH AVE.
OAKLAND, CALIFORNIA

FIGURE:
1

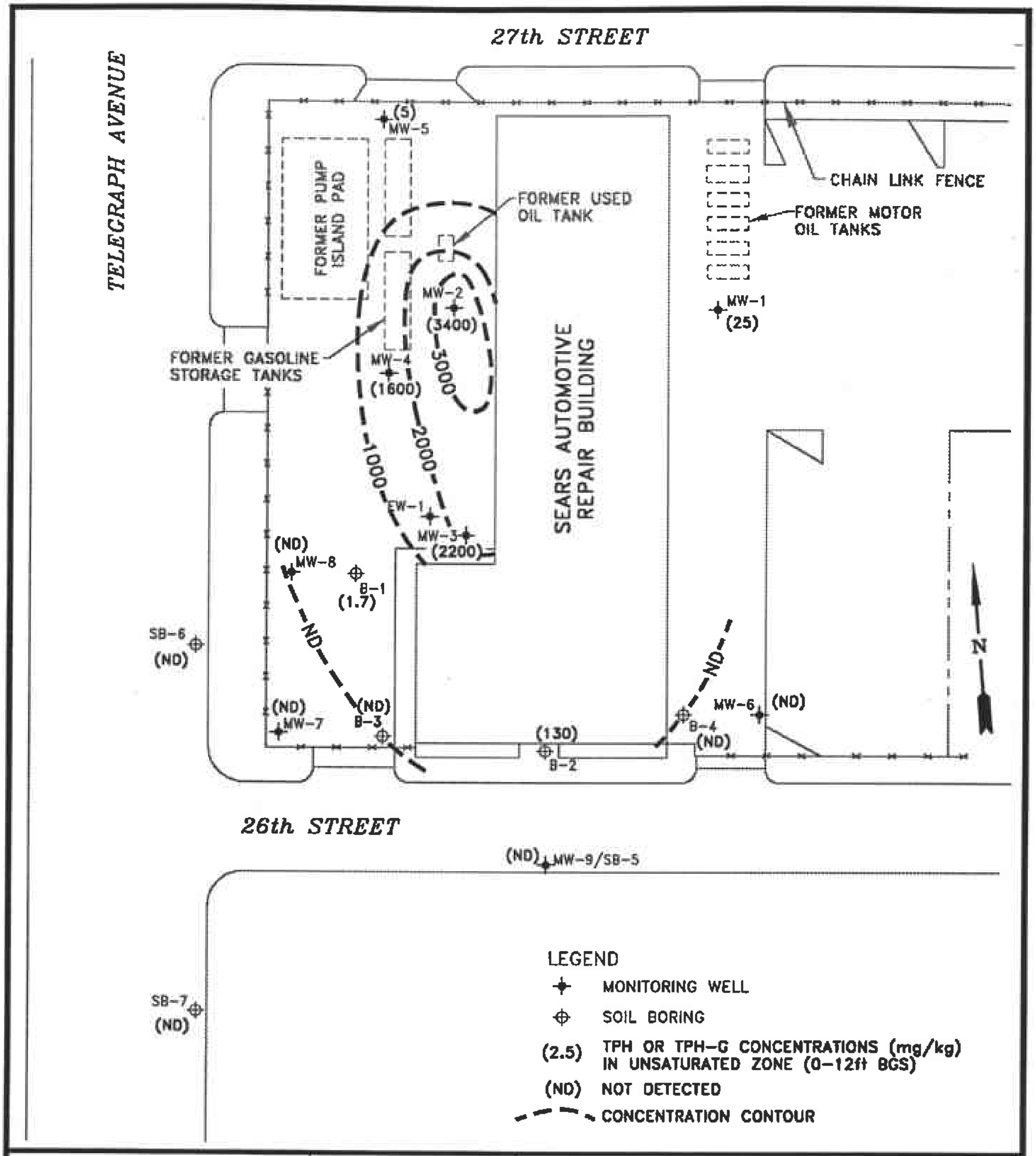


FLUOR DANIEL GTI

0 FEET 40
SCALE

SITE PLAN

CLIENT: SEARS, ROEBUCK AND CO. SITE No. 1058	FILE: SP796	PROJECT NO: 020200136	PM	RG/PE
LOCATION: 2633 TELEGRAPH AVENUE OAKLAND, CALIFORNIA	REV: 1 DES: BB DET: ML DATE: 7/17/95		FIGURE: 2	



FLUOR DANIEL GTI

0 FEET 40
SCALE

MAXIMUM TPH CONCENTRATIONS IN THE UNSATURATED ZONE

CLIENT:
SEARS, ROEBUCK AND CO.
SITE No. 1058

LOCATION: 2633 TELEGRAPH AVENUE
OAKLAND, CALIFORNIA

FILE: SLTPHVZ/SP796

PROJECT NO: 020200136

PM

RG/PE

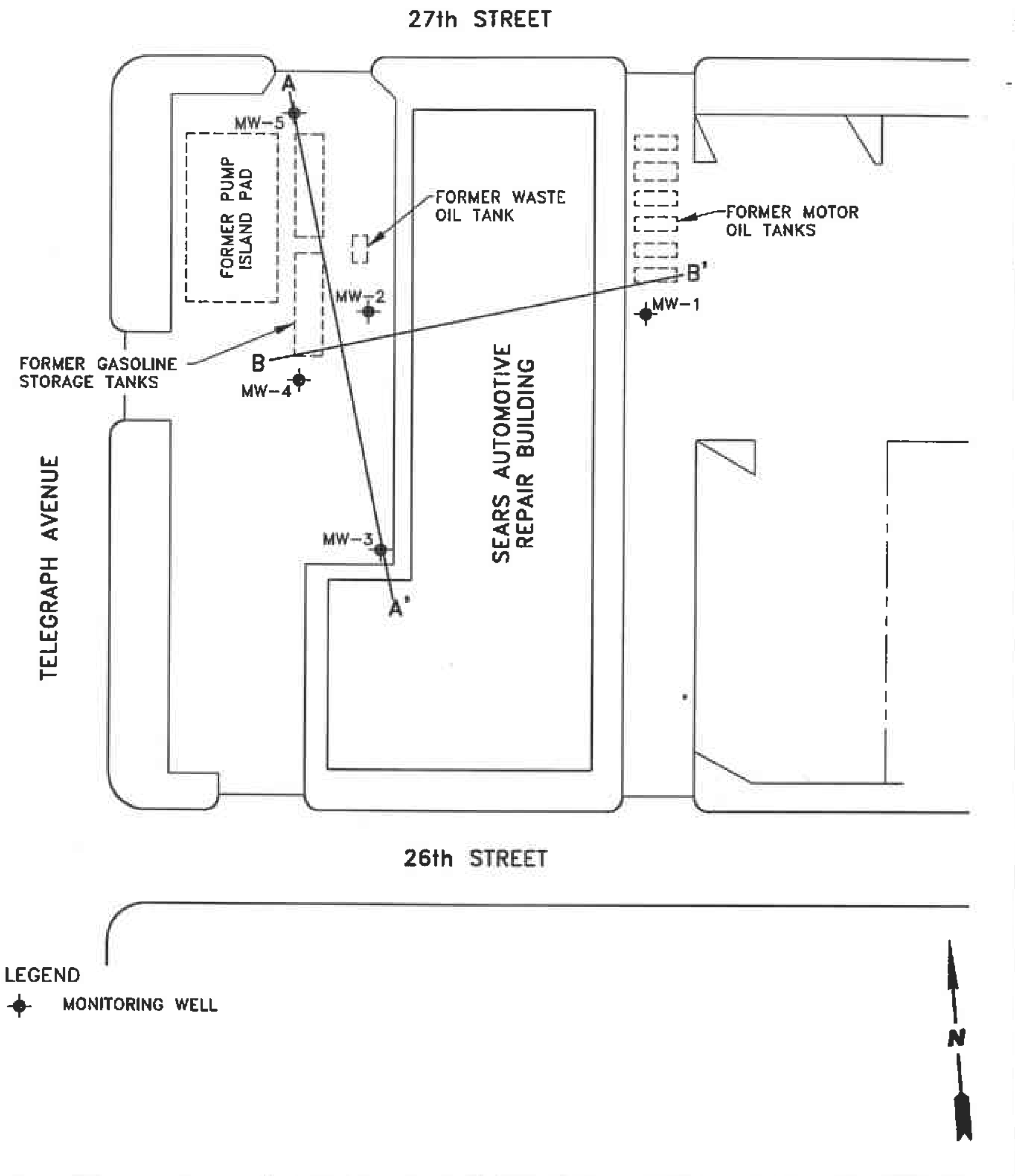
REV: 1

DES: GE

DET: ML

DATE: 10/1/96

FIGURE: 3

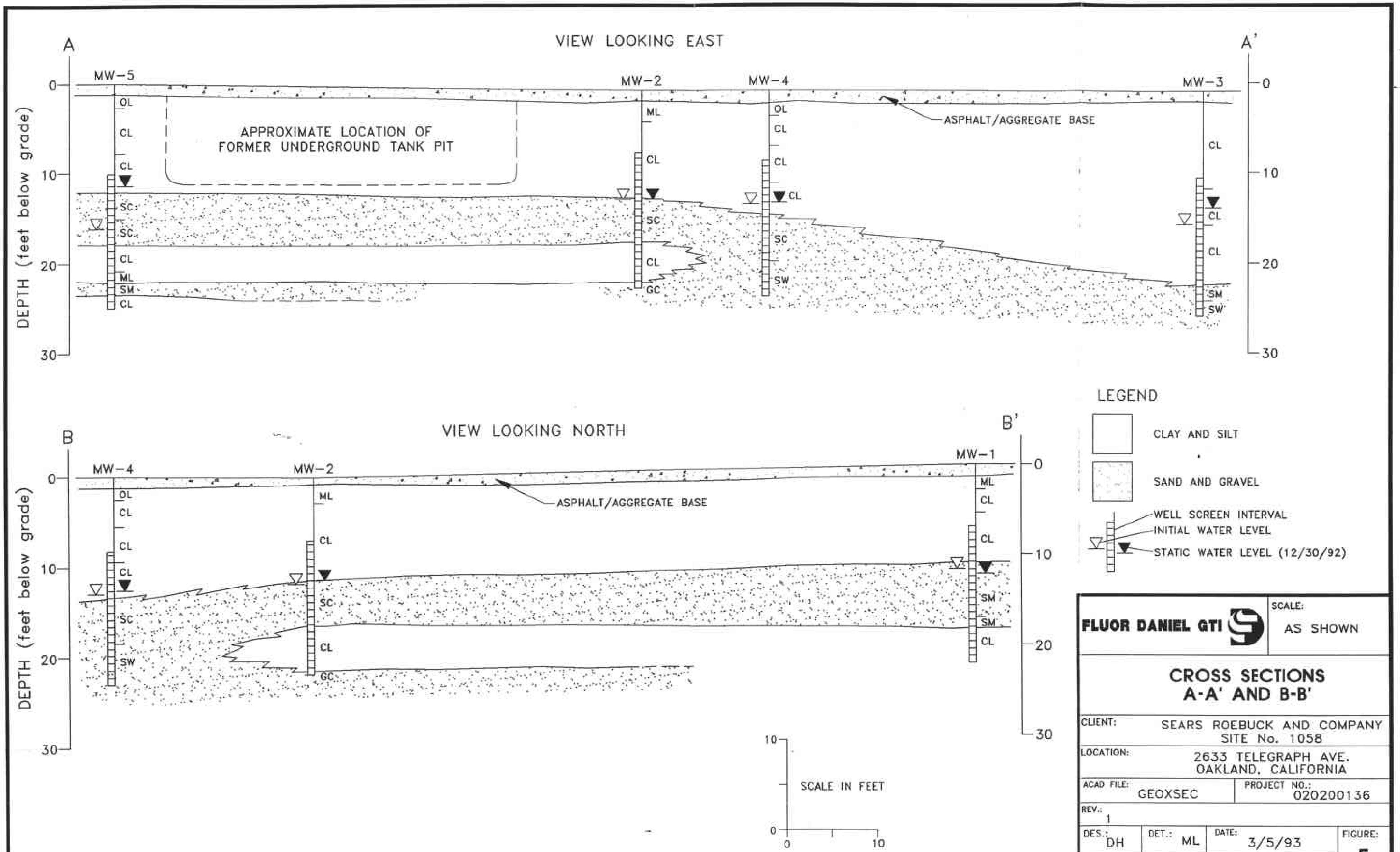


FLUOR DANIEL GTI

0 FEET 40
SCALE

CROSS SECTION LOCATION MAP

CLIENT: SEARS, ROEBUCK AND CO. SITE No. 1058	FILE: CSECLOC	PROJECT NO: 020200136	PM	RG/PE
	REV: 1			
LOCATION: 2633 TELEGRAPH AVENUE OAKLAND, CALIFORNIA	DES: DH	DET: ML	DATE: 3/5/93	FIGURE: 4



FLUOR DANIEL GTI

SCALE: AS SHOWN

CROSS SECTIONS A-A' AND B-B'

CLIENT: SEARS ROEBUCK AND COMPANY
SITE No. 1058

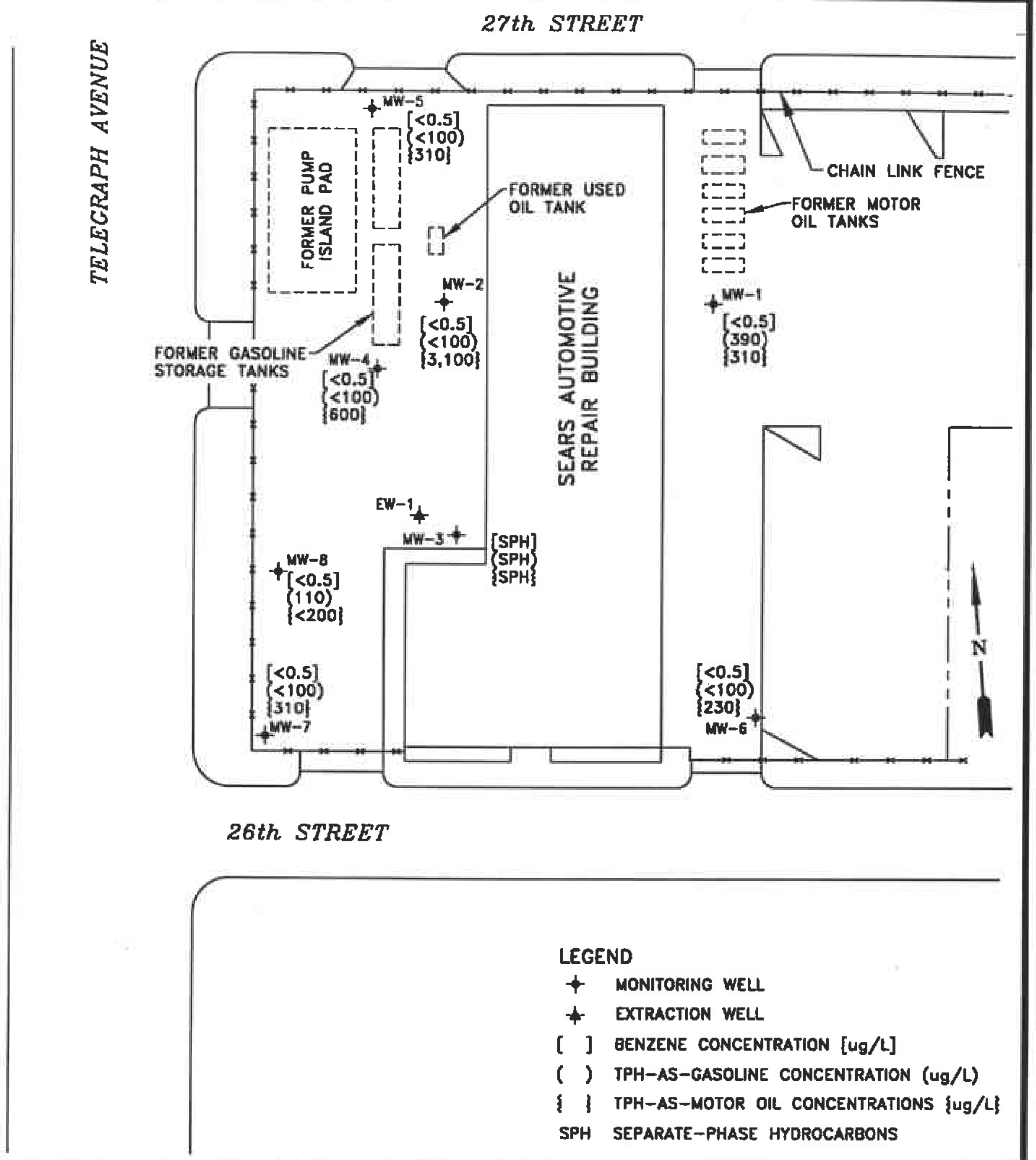
LOCATION: 2633 TELEGRAPH AVE.
OAKLAND, CALIFORNIA

ACAD FILE: GEOXSEC
PROJECT NO.: 020200136

REV.: 1

DES.: DH
DET.: ML
DATE: 3/5/93
FIGURE: 5

PM:
PE/RG:



LEGEND

✛	MONITORING WELL
✛	EXTRACTION WELL
[ ]	BENZENE CONCENTRATION [ug/L]
( )	TPH-AS-GASOLINE CONCENTRATION (ug/L)
{ }	TPH-AS-MOTOR OIL CONCENTRATIONS {ug/L}
SPH	SEPARATE-PHASE HYDROCARBONS

FLUOR DANIEL GTI

0 FEET 40
SCALE

CONCENTRATIONS OF BENZENE, TPH-AS-GASOLINE & TPH-AS-MOTOR OIL IN GROUNDWATER (9/4/96)

CLIENT: SEARS, ROEBUCK AND CO.
SITE No. 1058

LOCATION: 2633 TELEGRAPH AVENUE
OAKLAND, CALIFORNIA

FILE: BNZ9496/SP796

PROJECT NO: 020200136

PM

RG/PE

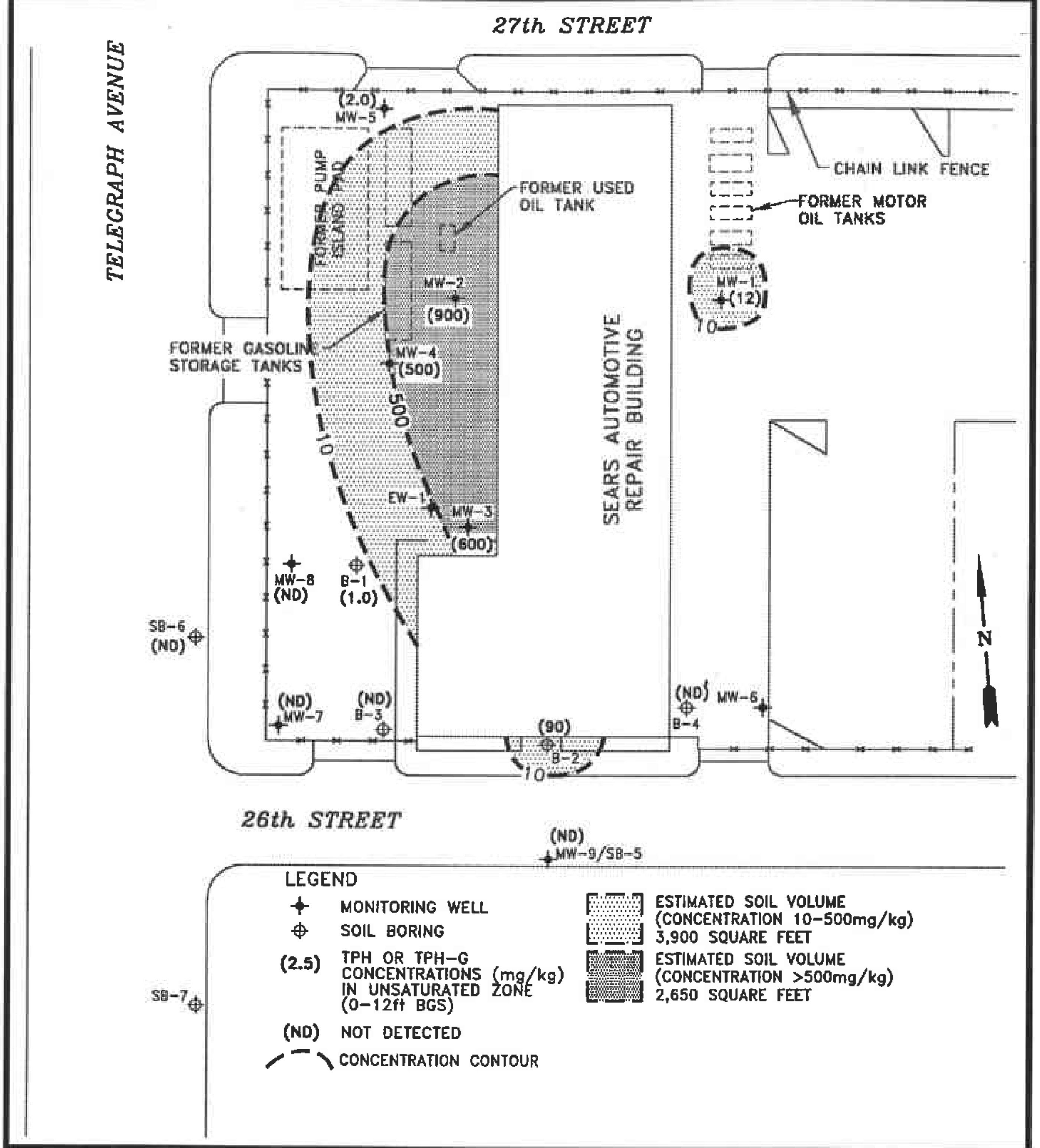
REV: 1

DES: BB

DET: ML

DATE: 11/12/96

FIGURE: 6



FLUOR DANIEL GTI

AREAL ESTIMATES (SQUARE FEET) OF TPH IMPACTED SOIL IN THE UNSATURATED ZONE

CLIENT: SEARS, ROEBUCK AND CO.
SITE No. 1058

LOCATION: 2633 TELEGRAPH AVENUE
OAKLAND, CALIFORNIA

FILE: SOILVOL/SP796

PROJECT NO: 020200136

PM

RG/PE

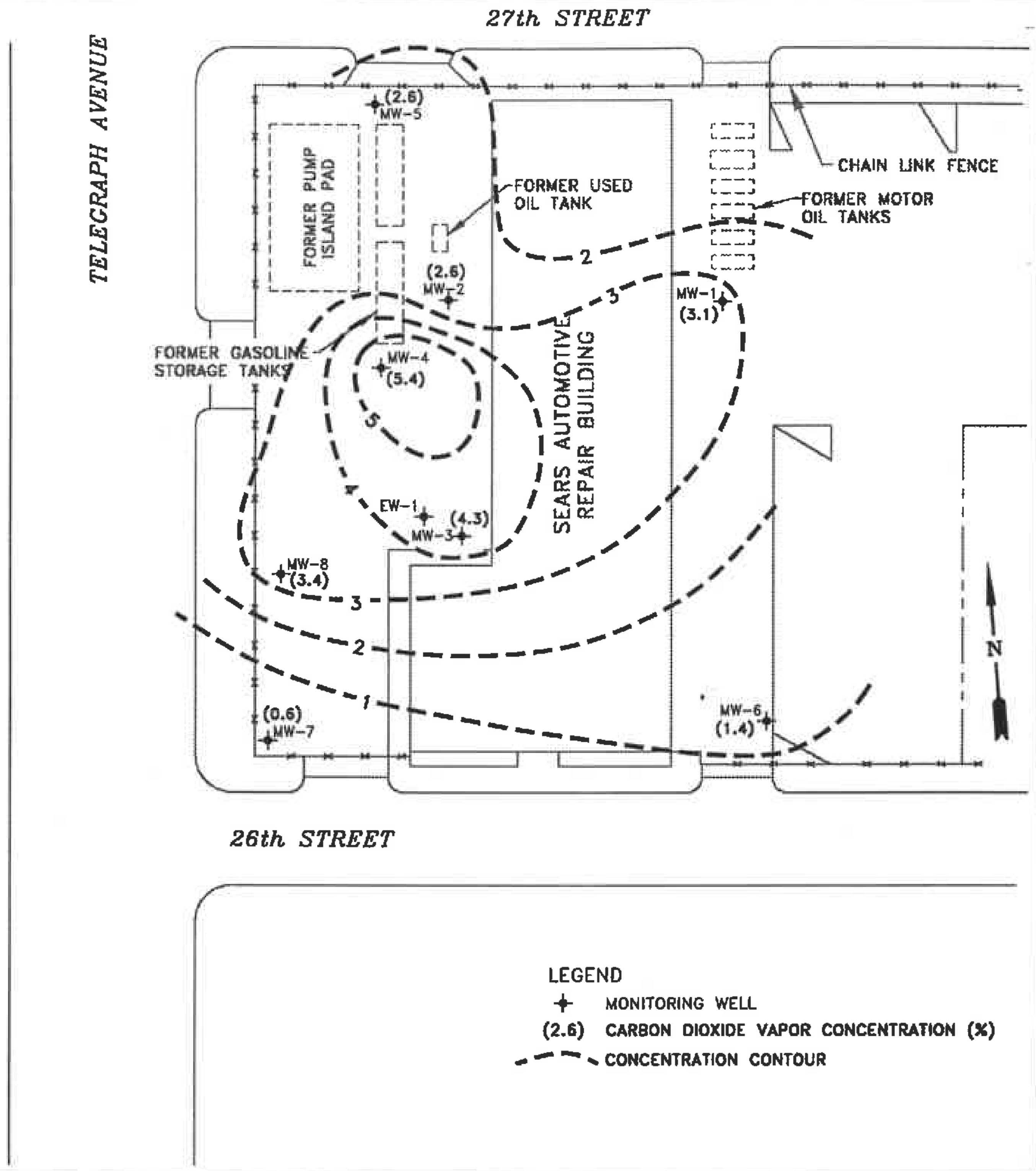
REV: 1

DES: GE

DET: ML

DATE: 10/1/96

FIGURE: 7

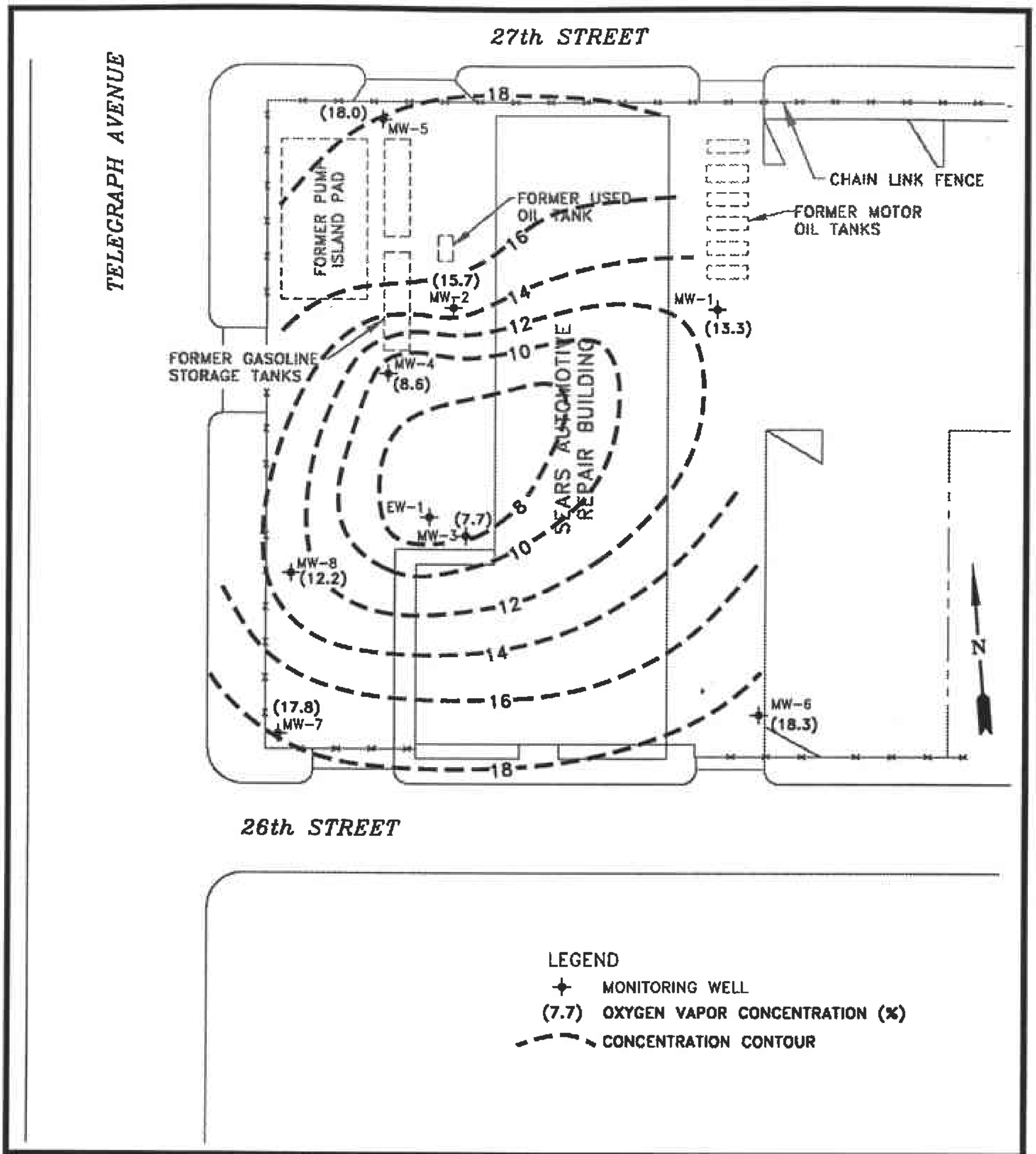


FLUOR DANIEL GTI

0 FEET 40
SCALE

STATIC CARBON DIOXIDE VAPOR DATA (6/20/96)

CLIENT: SEARS, ROEBUCK AND CO. SITE No. 1058	FILE: SCDVD696/SP796	PROJECT NO: 020200136	PM	RG/PE
LOCATION: 2633 TELEGRAPH AVENUE OAKLAND, CALIFORNIA	REV: 1		FIGURE: 8	
	DES: GE	DET: ML	DATE: 10/1/96	



FLUOR DANIEL GTI

0 FEET 40
SCALE

STATIC OXYGEN VAPOR DATA (6/20/96)

CLIENT: SEARS, ROEBUCK AND CO. SITE No. 1058	FILE: SO2VD696/SP796	PROJECT NO: 020200136	PM	RG/PE
	REV: 1		FIGURE: 9	
LOCATION: 2633 TELEGRAPH AVENUE OAKLAND, CALIFORNIA	DES: GE	DET: ML	DATE: 10/1/96	

TABLES

TABLE 1
ANALYTICAL RESULTS OF SOIL SAMPLES
(All results expressed in mg/kg unless otherwise noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Location	Date Sampled	Depth	B	T	E	X	TPH-G	TPH-D	VOCs	TPH	Metals				
											Pb	Cd	Cr	Ni	Zn
B1	12/13/93	10'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
	12/13/93	15'	<0.005	0.01	<0.005	<0.015	1.7	--	--	<5	--	--	--	--	--
	12/13/93	20'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
B2	12/13/93	10'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
	12/13/93	15'	0.14	0.44	3.5	8.1	130	--	--	92	--	--	--	--	--
	12/13/93	20'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
B3	12/13/93	10'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
	12/13/93	20'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
	12/13/93	22'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
B4	12/13/93	10'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
	12/13/93	20'	<0.005	<0.005	<0.005	<0.015	<1.0	--	--	<5	--	--	--	--	--
SB-5	1/11/95	5'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	10'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	16'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
SB-6	1/11/95	5'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	11'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	16'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
SB-7	1/11/95	5'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	10'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--
	1/11/95	13'	<0.005	<0.005	<0.005	<0.015	<10	--	--	--	--	--	--	--	--

TABLE 1
ANALYTICAL RESULTS OF SOIL SAMPLES
(All results expressed in mg/kg unless otherwise noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Location	Date Sampled	Depth	B	T	E	X	TPH-G	TPH-D	VOCs	TPH	Metals				
											Pb	Cd	Cr	Ni	Zn
MW1	12/8/92	5.5'	<0.005	<0.005	<0.005	<0.015	<1	<10	–	<5	–	–	–	–	–
	12/8/92	11'	<0.005	<0.005	<0.005	<0.015	<1	<10	–	<5	–	–	–	–	–
	12/8/92	12'	<0.005	<0.005	<0.005	<0.015	<1	<10	–	25	–	–	–	–	–
	12/8/92	21'	<0.005	<0.005	<0.005	<0.015	<1	<10	–	5	–	–	–	–	–
MW2	12/8/92	6'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	8	6.8	–	–	–	–
	12/8/92	11'	<0.005	<0.005	0.035	0.22	11	<10	N	3,400	9.9	–	–	–	–
	12/8/92	12'	<0.005	<0.005	<0.005	0.09	9	<10	N	560	8.1	–	–	–	–
	12/8/92	15.5"	<0.005	<0.005	<0.005	0.027	5	<10	N	–	7.5	–	–	–	–
MW3	12/7/92	11'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	2,200	8.9	–	–	–	–
	12/7/92	12'	<0.005	<0.005	<0.005	0.24	22	<10	N	1,900	9.0	–	–	–	–
	12/7/92	15'	<0.005	<0.005	<0.005	0.87	46	<10	N	86	4.8	–	–	–	–
	12/7/92	25'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	–	6.3	–	–	–	–
MW4	12/8/92	5.5'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	–	7.5	–	–	–	–
	12/8/92	10.5'	<0.005	<0.005	<0.005	0.33	41	<10	N	1,600	12	–	–	–	–
	12/8/92	12'	<0.005	<0.005	<0.005	0.15	27	<10	N	1,100	8.2	–	–	–	–
	12/8/92	20.5'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	12	6.8	–	–	–	–
MW5	12/7/92	11'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	5	3.7	6.4	31	46	56
	12/7/92	15.5'	<0.005	<0.005	<0.005	<0.015	<1	<10	N	<5	4.4	4.3	36	35	34
MW6	12/14/93	21.5'	<0.005	<0.005	<0.005	<0.015	<1	–	–	–	<5	–	–	–	–

TABLE 1
ANALYTICAL RESULTS OF SOIL SAMPLES
(All results expressed in mg/kg unless otherwise noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Location	Date Sampled	Depth	B	T	E	X	TPH-G	TPH-D	VOCs	TPH	Metals				
											Pb	Cd	Cr	Ni	Zn
MW7	12/14/93	16.5'	<0.005	<0.005	<0.005	<0.015	<1	--	--	--	<5	--	--	--	--
MW8	12/14/93	6.5'	<0.005	<0.005	<0.005	<0.015	<1	--	--	--	40	--	--	--	--
	12/14/93	16.5'	<0.005	<0.005	<0.005	<0.015	<1	--	--	--	<5	--	--	--	--

Notes:

N	Nondetectable (detection limits for each compound are listed in laboratory reports, *Soil and Groundwater Investigation*, appendix B, March 24, 1993)
--	Not analyzed
BTEX	Benzene, toluene, ethylbenzene, and total xylenes (EPA Method 8020)
TPH-g	Total Petroleum hydrocarbons as gasoline (Modified EPA Method 8015)
TPH-d	Total Petroleum hydrocarbons as diesel fuel (Modified EPA Methods 3550/8015)
VOCs	Volatile organic compounds (EPA Method 8010)
TPH	Total petroleum hydrocarbons by Infrared Spectrometry (Modified EPA Method 3550/EPA Method 418.1 (SM 5520 FC)

mg/kg	Milligrams per kilogram (parts per million)
Pb	Lead (EPA Method 7421)
Cd	Cadmium (EPA Method 6010)
Cr	Chromium (EPA Method 6010)
Ni	Nickel (EPA Method 6010)
Zn	Zinc (EPA Method 6010)

TABLE 2
Summary of Historical Groundwater Sample Analyses
(All results expressed in micrograms per liter, except as noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Date Sampled	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH as Gasoline	TPH as Motor Oil	TPH (mg/l)	Dissolved Metals	MTBE
MW-1	12/30/92	1	1	2	2	–	–	1	–	–
	03/24/93	0.4	1	0.3	10	–	–	1	–	–
	06/21/93	<0.3	1	2	6	–	**<100	–	–	–
	09/16/93	<0.3	0.7	<0.3	7	–	**<100	–	–	–
	12/01/93	0.4	1	2	7	–	–	–	–	–
	12/30/93	–	–	–	–	–	<100	–	–	–
	03/09/94	<0.3	<0.3	1	4.2	–	<100	–	–	–
	06/30/94	0.6	0.7	2.4	15	–	<100	–	–	–
	09/27/94	0.9	0.5	1.4	10	–	*<250	–	–	–
	12/01/94	0.4	0.4	<0.3	6.6	–	*<250	–	–	–
	03/08/95	<0.3	0.6	<0.3	2.7	–	*<250	–	–	–
	06/09/95	<0.3	1.4	4.7	5.6	–	*<250	–	–	–
	08/29/95	0.3	0.9	3.9	2.8	–	*<250	–	–	–
	11/15/95	<0.5	<0.5	<0.5	27	–	*<200	–	–	–
	03/05/96	<0.5	<1.0	<1.0	<2.0	–	*<200	–	–	–
	06/03/96	<0.5	<1.0	<1.0	3.4	340	*<200	-	–	–
	09/04/96	<0.5	<1.0	3.7	<2.0	390	310	–	–	<10
MW-2	12/30/92	0.7	<0.3	<0.3	3	190	–	1	[a]ND	–
	03/24/93	0.6	<0.3	<0.3	2	120	–	<1	[a]ND	–
	06/21/93	0.3	<0.3	<0.3	0.7	82	**<100	–	[c]ND	–
	09/16/93	<0.3	<0.3	<0.3	<0.5	28	**<100	–	[c]ND	–
	12/01/93	<0.3	<0.3	<0.3	1	68	–	–	[c]ND	–
	12/30/93	–	–	–	–	–	310	-	–	–
	03/09/94	<0.3	<0.3	<0.3	<0.5	47	<100	–	ND	–
	06/30/94	<0.3	<0.3	<0.3	<0.5	<10	100	–	ND	–
	09/27/94	<0.3	<0.3	<0.3	<0.5	<10	*<250	–	[d]15	–
	12/01/94	<0.3	<0.3	<0.3	<0.5	54	[f]1,300	–	[e]6	–
	03/08/95	<0.3	<0.3	<0.3	<0.5	<10	3,000	–	ND	–
	06/09/95	<0.3	<0.3	<0.3	<0.5	<50	2,000	–	ND	–
	08/29/95	<0.3	<0.3	<0.3	<0.5	<50	4,300	–	[h]20	–
	11/15/95	<0.5	<0.5	<0.5	<0.5	<50	6,100	–	ND	–
	03/05/96	<0.5	<1.0	<1.0	<2.0	<100	3,200	–	ND	–
	06/04/96	<0.5	<1.0	<1.0	<2.0	<100	3,800	–	ND	–
	09/04/96	<0.5	<1.0	<1.0	<2.0	<100	3,100		–	<10

TABLE 2
Summary of Historical Groundwater Sample Analyses
(All results expressed in micrograms per liter, except as noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Date Sampled	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH as Gasoline	TPH as Motor Oil	TPH (mg/l)	Dissolved Metals	MTBE
MW-3	12/30/92	11	0.9	<0.3	2	910	SPH	20	*ND	--
	03/24/93	28	0.7	1	8	3,300	SPH	28	**15	--
	06/21/93	21	5	2	19	**2,600	32,000	26	cd5	--
	09/16/93	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	12/01/93	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	03/09/94	2	1.4	4.5	13	2,000	**5,700	**63	*ND	--
	06/30/94	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	09/27/94	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	12/01/94	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	03/08/95	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	06/09/95	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	08/29/95	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	11/15/95	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	03/05/96	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	06/03/96	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	--
	09/04/96	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH	<10
	12/30/92	2	<0.3	1	<0.5	1,200	--	<1	*ND	--
MW-4	03/24/93	<0.3	<0.3	<0.3	<0.5	750	--	2	**7	--
	06/21/93	<0.3	2	<0.3	0.5	660	19,000	--	*ND	--
	09/16/93	0.3	<0.3	2	3	410	2,500	--	*ND	--
	12/01/93	<0.3	<0.3	<0.3	<0.5	150	390	--	*ND	--
	03/09/94	0.7	0.8	2	3.6	1,500	780	--	*ND	--
	06/30/94	<0.3	1.7	0.5	1.0	450	130	--	ND	--
	09/27/94	0.5	<0.3	<0.3	<0.5	110	1,100	--	ND	--
	12/01/94	0.6	0.5	0.3	0.8	290	580	--	*<5	--
	03/08/95	<0.3	<0.3	<0.3	<0.5	360	1,000	--	*<5	--
	06/09/95	<0.3	0.4	<0.3	<0.5	64	1,100	--	*<5	--
	08/29/95	<0.3	<0.3	<0.3	<0.5	<50	1,200	--	*<5	--
	11/15/95	<0.5	<0.5	<0.5	<0.5	<50	2,100	--	*ND	--
	03/05/96	<0.5	<1.0	<1.0	<2.0	<100	590	--	*ND	--
	06/03/96	<0.5	<1.0	<1.0	<2.0	<100	860	--	ND	--
	09/04/96	<0.5	<1.0	<1.0	<2.0	<100	600	--	--	<10
MW-5	12/30/92	<0.3	<0.3	<0.3	<0.5	37	--	<1	bc5	--
	03/24/93	<0.3	<0.3	<0.3	0.5	19	--	2	**341	--
	06/21/93	<0.3	<0.3	<0.3	<0.5	<10	<100	--	cND	--
	09/16/93	0.3	<0.3	<0.3	1	<10	<100	--	cND	--
	12/01/93	<0.3	<0.3	<0.3	1	17	--	--	cND	--
	12/30/93	--	--	--	--	--	<100	--	--	--
	03/09/94	<0.3	<0.3	<0.3	<0.5	22	<100	--	cND	--
	06/30/94	<0.3	<0.3	<0.3	<0.5	<10	<100	--	ND	--
	09/27/94	0.5	0.4	<0.3	<0.5	<10	560	--	ND	--
	12/01/94	<0.3	<0.3	<0.3	<0.5	<10	<250	--	ND	--
	03/08/95	<0.3	<0.3	<0.3	<0.5	<10	<250	--	ND	--
	06/09/95	<0.3	<0.3	<0.3	<0.5	<50	<250	--	c7	--
	08/29/95	<0.3	<0.3	<0.3	<0.5	<50	<250	--	b36	--
	11/15/95	<0.5	<0.5	<0.5	<0.5	<50	<200	--	ND	--
	03/05/96	<0.5	<1.0	<1.0	<2.0	<100	<200	--	ND	--
	06/03/96	NS	NS	NS	NS	NS	NS	NS	NS	--
	09/04/96	<0.5	<1.0	<1.0	<2.0	<100	310	--	--	<10

TABLE 2

Summary of Historical Groundwater Sample Analyses

(All results expressed in micrograms per liter, except as noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Date Sampled	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH as Gasoline	TPH as Motor Oil	TPH (mg/l)	Dissolved Metals	MTBE
MW-6	12/27/93	<0.3	<0.3	<0.3	<0.5	<10	<100	<1	^{a}70	–
	03/09/94	<0.3	<0.3	<0.3	<0.5	15	<100	–	^{c}ND	–
	06/30/94	<0.3	<0.3	<0.3	<0.5	<10	<100	–	ND	–
	09/27/94	<0.3	<0.3	<0.3	<0.5	<10	<250	–	^{d}8	–
	12/01/94	<0.3	<0.3	<0.3	<0.5	<10	<250	–	^{e}32	–
	03/08/95	<0.3	<0.3	<0.3	<0.5	<10	<250	–	ND	–
	06/09/95	<0.3	<0.3	<0.3	<0.5	<50	<250	–	ND	–
	08/29/95	<0.3	<0.3	<0.3	<0.5	<50	<250	–	^{h}24	–
	11/15/95	<0.5	<0.5	<0.5	<0.5	<50	<200	–	^{g}31	–
	03/05/96	<0.5	<1.0	<1.0	<2.0	<100	<200	–	ND	–
	06/03/96	NS	NS	NS	NS	NS	NS	NS	NS	–
	09/04/96	<0.5	<1.0	<1.0	<2.0	<100	230	–	–	<10
MW-7	12/27/93	<0.3	<0.3	1	2	140	<100	<1	^{a}40	–
	03/09/94	<0.3	<1.0	1.5	4.1<	620	<100	–	^{c}ND	–
	06/30/94	<0.3	<0.3	<0.3	0.5	33	<100	–	ND	–
	09/27/94	<0.3	<0.3	0.4	0.7	52	•<250	–	ND	–
	12/01/94	<0.3	<0.3	<0.3	1.1	<10	•<250	–	^{e}28	–
	03/08/95	<0.3	<0.3	<0.3	<0.5	<10	•<250	–	ND	–
	06/09/95	<0.3	<0.3	<0.3	<0.5	<50	<250	–	ND	–
	08/29/95	<0.3	<0.3	<0.3	<0.5	<50	<250	–	^{h}13	–
	11/15/95	<0.5	<0.5	<0.5	<0.5	<50	<200	–	ND	–
	03/05/96	<0.5	<1.0	<1.0	<2.0	<100	270	–	ND	–
	06/03/96	NS	NS	NS	NS	NS	NS	NS	NS	–
	09/04/96	<0.5	<1.0	<1.0	<2.0	<100	310	–	–	<10
MW-8	12/27/93	0.4	4	0.4	1	390	<100	<1	^{a}18	–
	03/09/94	0.6	0.8	0.5	1.5	420	<100	–	^{a}ND	–
	06/30/94	0.9	<0.3	<0.3	1.1	250	<100	–	ND	–
	09/27/94	<0.3	<0.3	<0.3	<0.5	210	•<250	–	^{d}9	–
	12/01/94	5.4	<0.3	0.7	1.3	230	•<250	–	^{c}ND	–
	03/08/95	<0.3	<0.3	<0.3	<0.5	230	•<250	–	ND	–
	06/09/95	<0.3	<0.3	<0.3	<0.5	<50	•<250	–	ND	–
	08/29/95	0.9	0.4	<0.3	0.8	200	•<250	–	^{h}15	–
	11/15/95	0.58	<0.5	<0.5	0.54	120	–	–	^{g}21	–
	12/11/95	–	–	–	–	–	•<200	–	–	–
	03/05/96	0.6	<1.0	<1.0	<2.0	<100	•<200	–	ND	–
	06/03/96	<0.5	<1.0	<1.0	<2.0	100	–	–	–	–
	09/04/96	<0.5	<1.0	<1.0	<2.0	110	<200	–	–	<10
SB-1	12/13/95	<0.3	0.5	<0.3	<0.5	11	N/A	–	–	–
SB-2	12/13/95	0.4	<0.3	5	12	140	N/A	–	–	–
SB-2	12/13/95	0.6	<0.3	7	16	160	N/A	–	–	–
SB-4	12/13/95	<0.3	<0.3	<0.3	0.8	29	N/A	–	–	–
SB-5	01/11/95	<0.5	<0.5	<0.5	<1.5	85	N/A	–	–	–

TABLE 2
Summary of Historical Groundwater Sample Analyses
(All results expressed in micrograms per liter, except as noted)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Date Sampled	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH as Gasoline	TPH as Motor Oil	TPH (mg/l)	Dissolved Metals	MTBE
SB-6	01/11/95	<0.5	<0.5	<0.5	<1.5	<50	N/A	--	--	--
SB-7	01/11/95	<0.5	<0.5	<0.5	<1.5	<50	N/A	--	--	--
EW-1	09/04/96	<0.5	<1.0	<1.0	<2.0	1100	1700	--	--	<10

Notes:

"--" indicates no datum for the cell, including "not analyzed for this constituent".

Values beginning with "<" indicate the compound was not detected above the indicated laboratory reporting limit.

TPH = Total petroleum hydrocarbons
mg/l = Milligrams per liter
MTBE = Methyl tert-butyl ether
ND = Non-detectable (detection limits for each metal are listed in laboratory reports, included in previous reports)
SPH = Separate phase hydrocarbon
NS = Not sampled
* = Water samples were not filtered, analytical results represent total metals present, not dissolved concentrations.
** = Uncategorized hydrocarbon compound not included in this hydrocarbon concentration.
[a] = Dissolved lead
[b] = Dissolved lead only analyte detected
[c] = Dissolved lead, cadmium, total chromium, nickel, and zinc.
[d] = Cadmium only analyte detected.
[e] = Hydrocarbon pattern not characteristic of motor oil.
[f] = Uncategorized compounds included in concentration
[g] = Zinc only analyte detected
[h] = Chromium only analyte detected

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-1	26.20	12/30/92	10.60	--	--	15.60
		02/26/93	10.14	--	--	16.06
		03/24/93	10.48	--	--	15.72
		04/27/93	11.30	--	--	14.90
		05/28/93	11.43	--	--	14.77
		06/21/93	11.71	--	--	14.49
		07/22/93	11.87	--	--	14.33
		08/13/93	11.94	--	--	14.26
		09/16/93	12.05	--	--	14.15
		10/22/93	12.00	--	--	14.20
		11/03/93	12.10	--	--	14.10
		11/24/93	11.97	--	--	14.23
		12/01/93	11.46	--	--	14.74
		12/27/93	11.58	--	--	14.62
		01/05/94	11.69	--	--	14.51
		02/08/94	11.87	--	--	14.33
		03/09/94	11.08	--	--	15.12
		04/01/94	11.47	--	--	14.73
		05/10/94	10.77	--	--	15.43
		06/30/94	11.82	--	--	14.38
		07/28/94	11.90	--	--	14.30
		08/31/94	11.94	--	--	14.26
		09/27/94	12.04	--	--	14.16
		10/28/94	12.06	--	--	14.14
		11/15/94	10.02	--	--	16.18
		12/01/94	10.61	--	--	15.59
		01/04/95	9.93	--	--	16.27
		02/01/95	9.56	--	--	16.64
		03/08/95	10.51	--	--	15.69
		04/03/95	NM	NM	NA	NA
		05/18/95	10.80	--	--	15.40
		06/09/95	11.18	--	--	15.02
		07/13/95	11.27	--	--	14.93
		08/03/95	11.48	--	--	14.72
		08/29/95	11.56	--	--	14.64
		09/15/95	11.71	--	--	14.49
		10/20/95	11.80	--	--	14.40
		11/15/95	11.61	--	--	14.59
		01/15/96	11.21	--	--	14.99
		03/05/96	9.35	--	-	16.85
		04/19/96	10.60	--	--	15.60
		05/10/96	11.18	--	--	15.02
		06/03/96	10.90	--	--	15.30
		09/04/96	11.31	--	--	14.89

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-2	26.50	12/30/92	10.65	--	Sheen	15.85
		02/26/93	10.56	--	--	15.94
		03/24/93	10.52	--	--	15.98
		04/27/93	11.17	--	--	15.33
		05/28/93	11.12	--	--	15.38
		06/21/93	11.41	--	--	15.09
		07/22/93	11.50	--	--	15.00
		08/13/93	11.54	--	--	14.96
		09/16/93	11.62	--	--	14.88
		10/22/93	11.57	--	--	14.93
		11/03/93	11.65	--	--	14.85
		11/24/93	11.52	--	--	14.98
		12/01/93	11.08	--	--	15.42
		12/27/93	11.27	--	--	15.23
		01/05/94	11.39	--	--	15.11
		02/08/94	11.49	--	--	15.01
		03/09/94	11.06	--	--	15.44
		04/01/94	11.25	--	--	15.25
		05/10/94	10.83	--	--	15.67
		06/30/94	11.44	--	--	15.06
		07/28/94	11.48	--	--	15.02
		08/31/94	11.56	--	--	14.94
		09/27/94	11.61	--	--	14.89
		10/28/94	11.65	--	--	14.85
		11/15/94	9.65	--	--	16.85
		12/01/94	10.71	--	--	15.79
		01/04/95	10.11	--	--	16.39
		02/01/95	10.38	--	--	16.12
		03/08/95	10.80	--	--	15.70
		04/03/95	10.61	--	--	15.89
		05/18/95	10.95	--	--	15.55
		06/09/95	11.13	--	--	15.37
		07/13/95	11.15	--	--	15.35
		08/03/95	11.26	--	--	15.24
		08/29/95	11.32	--	--	15.18
		09/15/95	11.42	--	--	15.08
		10/20/95	11.42	--	--	15.08
		11/15/95	11.37	--	--	15.13
		01/15/96	11.10	--	--	15.40
		03/05/96	10.24	--	--	16.26
		04/19/96	10.84	--	--	15.56
		05/10/96	11.13	--	--	15.37
		06/03/96	10.94	--	--	15.56
		09/04/96	11.24	--	--	15.26

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-3	26.34	12/30/92	12.43	--	Sheen	13.91
		02/26/93	12.21	--	--	14.13
		03/24/93	12.36	--	--	13.98
		04/27/93	12.70	--	--	13.64
		05/28/93	12.72	--	--	13.62
		06/21/93	12.87	--	--	13.47
		07/22/93	12.92	--	--	13.42
		08/13/93	12.96	--	--	13.38
		09/16/93	13.01	12.97	0.04	13.36
		10/22/93	NM	12.96	NA	NA
		11/03/93	13.13	13.02	0.11	13.30
		11/24/93	12.94	12.92	0.02	13.42
		12/01/93	12.71	12.69	0.02	13.65
		12/27/93	12.77	12.73	0.04	13.60
		01/05/94	12.85	12.83	0.02	13.51
		02/08/94	12.37	--	--	13.97
		03/09/94	12.53	--	--	13.81
		04/01/94	12.64	--	--	13.70
		05/10/94	12.32	--	--	14.02
		06/30/94	12.84	12.82	0.02	13.51
		07/28/94	12.93	12.89	0.04	13.44
		08/31/94	13.04	13.01	0.03	13.32
		09/27/94	13.13	13.02	0.11	13.30
		10/28/94	13.30	13.08	0.22	13.22
		11/15/94	11.05	11.02	0.03	15.31
		12/01/94	11.90	11.88	0.02	14.46
		01/04/95	11.80	11.76	0.01	14.55
		02/01/95	12.00	11.98	0.02	14.36
		03/08/95	12.35	12.30	0.05	14.03
		04/03/95	12.09	12.05	0.04	14.28
		05/18/95	12.43	12.40	0.03	13.93
		06/09/95	12.60	12.58	0.02	13.76
		07/13/95	12.55	12.46	0.09	13.87
		08/03/95	12.64	12.61	0.03	13.73
		08/29/95	12.65	12.62	0.03	13.71
		09/15/95	13.00	12.86	0.14	13.45*
		10/20/95	12.86	12.03	0.03	13.50*
		11/15/95	12.81	12.74	0.07	13.59*
		01/15/96	12.60	12.47	0.13	13.84*
		03/05/96	11.68	11.64	0.04	14.69
		04/19/96	12.36	12.34	0.02	14.00
		05/10/96	11.93	11.91	0.02	14.43
		06/03/96	12.93	12.50	0.43	13.75
		09/04/96	12.60	12.55	0.05	13.79

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-4	26.17	12/30/92	11.53	--	--	14.64
		02/26/93	11.35	--	--	14.82
		03/24/93	11.46	--	--	14.71
		04/27/93	11.74	--	--	14.43
		05/28/93	11.77	--	--	14.40
		06/21/93	11.92	--	--	14.25
		07/22/93	11.95	--	--	14.22
		08/13/93	12.01	--	--	14.16
		09/16/93	12.08	--	--	14.09
		10/22/93	12.03	--	--	14.14
		11/03/93	12.10	--	--	14.07
		11/24/93	12.02	--	--	14.15
		12/01/93	11.78	--	--	14.99
		12/27/93	11.80	--	--	14.97
		01/05/94	11.91	--	--	14.26
		02/08/94	11.85	--	--	14.32
		03/09/94	11.61	--	--	14.56
		04/01/94	11.73	--	--	14.44
		05/10/94	11.49	--	--	14.68
		06/30/94	11.90	--	--	14.20
		07/28/94	11.97	--	--	14.27
		08/31/94	12.06	--	--	14.11
		09/27/94	12.11	--	--	14.06
		10/28/94	12.18	--	--	13.99
		11/15/94	10.72	--	--	15.45
		12/01/94	11.37	--	--	14.80
		01/04/95	11.20	--	--	14.97
		02/01/95	11.16	--	--	15.01
		03/08/95	11.49	--	--	14.68
		04/03/95	11.35	--	--	14.82
		05/18/95	11.56	--	--	14.61
		06/09/95	11.72	--	--	14.45
		07/13/95	11.72	--	--	14.45
		08/03/95	11.81	--	--	14.36
		08/29/95	11.88	--	--	14.29
		09/15/95	11.99	--	--	14.18
		10/20/95	12.00	--	--	14.17
		11/15/95	11.96	--	--	14.21
		01/15/96	11.71	--	--	14.46
		03/05/96	11.02	--	--	15.15
		04/19/96	11.51	--	--	14.46
		05/10/96	11.74	--	--	14.43
		06/03/96	11.60	--	-	14.57
		09/04/96	11.85	--	--	14.32

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-5	26.98	12/30/92	10.50	--	--	16.48
		02/26/93	10.12	--	--	16.86
		03/24/93	10.31	--	--	16.67
		04/27/93	10.75	--	--	16.23
		05/28/93	10.80	--	--	16.18
		06/21/93	10.94	--	--	16.04
		07/22/93	11.01	--	--	15.97
		08/13/93	11.07	--	--	15.91
		09/16/93	11.18	--	--	15.60
		10/22/93	11.19	--	--	15.79
		11/03/93	11.23	--	--	15.75
		11/24/93	12.00	--	--	14.98
		12/01/93	10.84	--	--	16.14
		12/27/93	10.81	--	--	16.17
		01/05/94	10.96	--	--	16.02
		02/08/94	10.94	--	--	16.04
		03/09/94	10.54	--	--	16.44
		04/01/94	10.77	--	--	16.21
		05/10/94	10.44	--	--	16.54
		06/30/94	10.88	--	--	16.10
		07/28/94	10.98	--	--	16.00
		08/31/94	11.07	--	--	15.91
		09/27/94	11.12	--	--	15.86
		10/28/94	11.21	--	--	15.77
		11/15/94	10.05	--	--	16.93
		12/01/94	10.39	--	--	16.59
		01/04/95	10.18	--	--	16.80
		02/01/95	9.93	--	--	17.05
		03/08/95	10.35	--	--	16.63
		04/03/95	10.15	--	--	16.83
		05/18/95	10.43	--	--	16.55
		06/09/95	10.62	--	--	16.36
		07/13/95	10.76	--	--	16.22
		08/03/95	10.82	--	--	16.16
		08/29/95	10.91	--	--	16.07
		09/15/95	11.00	--	--	15.98
		10/20/95	11.02	--	--	15.96
		11/15/95	11.95	--	--	15.03
		01/15/96	10.57	--	--	16.41
		03/05/96	9.81	--	--	17.17
		04/19/96	10.32	--	--	16.66
		05/10/96	10.56	--	--	16.40
		06/03/96	10.46	--	--	16.52
		09/04/96	10.86	--	--	16.12

TABLE 3

Summary of Historical Groundwater Monitoring Data

(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-6	24.32	12/27/93	11.24	--	--	13.08
		01/05/94	11.39	--	--	12.93
		02/08/94	11.15	--	--	13.17
		03/09/94	10.97	--	--	13.35
		04/01/94	11.25	--	--	13.07
		05/10/94	10.78	--	--	13.54
		06/30/94	11.49	--	--	12.83
		07/28/94	11.59	--	--	12.73
		08/31/94	11.56	--	--	12.76
		09/27/94	11.65	--	--	12.67
		10/28/94	11.59	--	--	12.73
		11/15/94	10.24	--	--	14.08
		12/01/94	10.30	--	--	14.02
		01/04/95	9.81	--	--	14.51
		02/01/95	10.01	--	--	14.31
		03/08/95	10.64	--	--	13.68
		04/03/95	10.26	--	--	14.06
		05/18/95	10.81	--	--	13.51
		06/09/95	11.07	--	--	13.25
		07/13/95	10.91	--	--	13.41
		08/03/95	11.15	--	--	13.17
		08/29/95	11.09	--	--	13.23
		09/15/95	11.35	--	--	12.97
		10/20/95	11.32	--	--	13.00
		11/15/95	11.20	--	--	13.12
		01/15/96	10.83	--	--	13.49
		03/05/96	9.60	--	--	14.72
		04/19/96	10.71	--	--	13.61
		05/10/96	11.05	--	--	13.27
		06/03/96	10.91	--	--	13.41
		09/04/96	10.84	--	--	13.48

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-7	24.88	12/27/93	11.80	–	–	13.08
		01/05/94	11.53	–	–	13.35
		02/08/94	11.90	–	–	12.98
		03/09/94	11.23	–	–	13.65
		04/01/94	11.34	–	–	13.54
		05/10/94	11.02	–	–	13.86
		06/30/94	11.49	–	–	13.39
		07/28/94	11.58	–	–	13.30
		08/31/94	11.69	–	–	13.19
		09/27/94	11.73	–	–	13.15
		10/28/94	11.77	–	–	13.11
		11/15/94	10.29	–	–	14.59
		12/01/94	10.89	–	–	13.99
		01/04/95	10.77	–	–	14.11
		02/01/95	10.70	–	–	14.18
		03/08/95	11.05	–	–	13.83
		04/03/95	10.88	–	–	14.00
		05/18/95	11.12	–	–	13.76
		06/09/95	11.25	–	–	13.63
		07/13/95	11.15	–	–	13.73
		08/03/95	11.32	–	–	26.79
		08/29/95	11.53	–	–	13.35
		09/15/95	11.65	–	–	13.23
		10/20/95	11.64	–	–	13.24
		11/15/95	11.60	–	–	13.28
		01/15/96	11.07	–	–	13.81
		03/05/96	10.50	–	–	14.38
		04/19/96	12.02	–	–	12.86
		05/10/96	11.14	–	–	13.74
		06/03/96	11.10	–	–	13.78
		09/04/96	11.45	–	–	13.43

TABLE 3
Summary of Historical Groundwater Monitoring Data
(All measurements are in feet; all elevations are in feet above mean sea level)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well ID	Casing Elev.	Date	Depth to Water	Depth to Product	Product Thickness	Groundwater Elev.
MW-8	26.12	12/27/93	12.45	–	–	13.67
		01/05/94	12.57	–	–	13.55
		02/08/94	12.02	–	–	14.10
		03/09/94	12.22	–	–	13.90
		04/01/94	12.33	–	–	13.79
		05/10/94	12.00	–	–	14.12
		06/30/94	12.52	–	–	13.60
		07/28/94	12.61	–	–	13.51
		08/31/94	12.72	–	–	13.40
		09/27/94	12.80	–	–	13.32
		10/28/94	12.84	–	–	13.28
		11/15/94	11.72	–	–	14.40
		12/01/94	11.87	–	–	14.25
		01/04/95	11.75	–	–	14.37
		02/01/95	11.64	–	–	14.48
		03/08/95	12.04	–	–	14.08
		04/03/95	11.86	–	–	14.26
		05/18/95	12.11	–	–	14.01
		06/09/95	12.34	–	–	13.78
		07/13/95	12.37	–	–	13.75
		08/03/95	12.50	–	–	13.62
		08/29/95	12.55	–	–	13.57
		09/15/95	12.70	–	–	13.42
		10/20/95	12.69	–	–	13.43
		11/15/95	12.67	–	–	13.45
		12/11/95	11.80	–	–	14.32
		01/15/96	12.38	–	–	13.74
		03/05/96	11.44	–	–	14.68
		04/19/96	10.80	–	–	15.32
		05/10/96	12.40	–	–	13.72
		06/03/96	12.26	–	–	13.86
		09/04/96	12.51	–	–	13.61

Notes: "–" indicates no datum for the cell, including "product not detected"

NM = Not monitored

NA = Not Available

*Corrected elevations. Review of calculations for well MW-3 inidcated that previous elevations were incorrect.

TABLE 4
SVE TEST
(RUN 1)
VENT-ROI MODEL RESULTS

Parameter	Model Results
Flow Rate (Single Well)	23.9 SCFM
Applied Vacuum Required	-100 in. WC
Interwell Radius of Influence (Multiple Wells)	13 ft.
Radius of Influence (Single Well)	33 ft.
Screen Interval	5.5 ft. to 12 ft.
Borehole Diameter	10 in.
Maximum Benzene Concentration	6.8 mg/M^3
Maximum Total BTEX Concentration	42 mg/M^3
Maximum TPH-g Concentration	12,000 mg/M^3
Cleanup Time	2 yrs.
Removal Goal	99%

SCFM - Standard cubic feet per minute
in. WC - inches of water column
mg/M^3 - milligrams per cubic meter

TABLE 5
Initial Soil and Groundwater Characterization

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Analysis	Methodology	Results	
		Soil	Groundwater
Contaminant Screening (mg/kg[4] for soils and mg/L for groundwater)			
Total Organic Carbon (TOC)	CFA S:18.0	3,100	-
Total Petroleum Hydrocarbon (TPH) by GC/FID[1]	EPA 8015 (modified)	730	65
Other Chemical Properties			
pH	SM 4500-h+	7.9 pH units	7.3 pH units
Microbiological Screening (cfu x 10,000/g for soil and cfu x 10,000/ml for groundwater)[2]			
Total Heterotrophic Bacteria (THB)	SM 9215 C (modified)	$1.3X10^6$	$4.9X10^4$
Contaminant Utilizing Bacteria (CUB) [3]	SM 9215 C (modified)	$1.1X10^4$	$3.9X10^4$

Notes:
1 - GC/FID = Gas chromotography with flame ionization detection
2 - cfu = colony forming units, g - gram, ml - milliliter
3 - Contaminant utilized was motor oil
4 - All soil results reported on a dry weight basis
mg/kg - milligram per kilogram
mg/L - milligram per liter

TABLE 6

Aerobic Biodegradation
Total Petroleum Hydrocarbons by GC/FID (mg/kg)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

System	Day 0	Day 15	Day 30	Day 45	Day 60	% Removal
Nutrified	1,467 avg*	1,252 avg	1,534 avg	1,025 avg	1,091 avg	26
Non-nutrified	1,467 avg*	1,920 avg	1,821 avg	2,588 avg	1,921 avg	+0.31
Poisoned	1,467 avg*	1,624 avg	1,894 avg	2,319 avg	1,602 avg	+0.09

Notes:
* Average of all six "Day 0" analyses
GC/FID = Gas chromotography with flame ionization detection
mg/kg = milligram per kilogram

TABLE 7

Aerobic Utilizing Bacteria Enumeration
(Results Expressed in cfu/mL)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Total Hetrotrophic Bacteria (THB)		
Test System	Day 0	Day 60
Nutrified	$3.8X10^{5}$	$1.9X10^{6}$
Non-nutrified	$3.3X10^{5}$	$6.8X10^{5}$
Poisoned	<100	<100
Contaminant-Utilizing Bacteria (CUB) - Motor Oil		
Nutrified	$3.6X10^{4}$	$1.2X10^{6}$
Non-Nutrified	$3.0X10^{5}$	$3.1X10^{5}$
Poisoned	<100	<100

Notes:
cfu/ml = colony forming units per milliliter

TABLE 8

Anaerobic Biodegradation

Total Petroleum Hydrocarbons by GC/FID (mg/kg)

Former Sears Store 1058

2633 Telegraph Avenue, Oakland, California

System	Day 0*	Day 20	Day 45	Day 60	Day 83	% Removal
Nutrified	1,028 avg*	1,450 avg	1,293 avg	1,026 avg	1,272 avg	+0.24
Poisoned	1,028 avg*	1,739 avg	2,495 avg	2,057 avg	2,315 avg	+1.25

Notes:

* Average of all six "Day 0" analyses.

GC/FID = Gas chromotography with flame ionization detection

mg/kg = milligram per kilogram

TABLE 9
Anaerobic Utilizing Bacteria Enumeration
(Results Expressed in cfu/mL)

Former Sears Store 1058
2633 Telegraph Avenue, Oakland, California

System	Day 0	Day 83
Nutrified	$1.3X10^6$	$6.5X10^4$
Poisoned	<100	<100

Notes:
cfu/ml - colony forming units per milliliter

APPENDIXES

A. Soil TPH Mass Calculations
B. Well Permits and Drilling Logs
C. Soil Vapor Extraction Test Data
D. Laboratory Analyses Results
E. Soil Vapor Extraction Test Calculations, Vent-ROI Model Outputs, and Vent-ROI Model Description
F. Biotreatability Laboratory Test Report

APPENDIX A

SOIL TPH MASS CALCULATIONS

APPENDIX A
SOIL TPH MASS CALCULATION

PURPOSE: The purpose of this calculation is to estimate the quantity of petroleum hydrocarbons in the vadose zone soil. Only the soil with an estimated concentration of 10 milligrams per kilogram (mg/kg) total petroleum hydrocarbons (TPH) or greater will be considered.

ASSUMPTIONS:

1. Depth of impacted soil is 12 feet (ft) from the ground surface to water table.
2. Soil density is 100 pounds per cubic foot (lb/ft^3).
3. The concentration of TPH is zero at the ground surface.
4. Unless laboratory analysis of samples indicates otherwise, the concentration of TPH at 6 ft. below ground surface (bgs) is zero.

METHOD: The concentration of TPH and TPH as gasoline (TPH-g) from laboratory analysis of soil samples collected from each boring and monitoring well boring are added to develop weighted average soil concentrations (table A-1).

For example, in the boring for well MW-2, at 11 ft. bgs, the measured concentration of TPH-G is 11 milligrams per kilogram (mg/kg); the concentration of TPH is 3,400 mg/kg; the total is 3,411 mg/kg. The concentration of TPH at 6 ft. bgs is 8 mg/kg. The average of these two samples is 1,709.5 mg/kg. The average concentration for the interval is multiplied by the interval between the two samples (5 ft. in this case). The averages times intervals are summed and divided by the total interval, 12 ft.

Weighted average soil concentrations are plotted on a scaled site plan (figure 7). An estimate of the location of isoconcentration lines for 10 mg/kg and 500 mg/kg is made based on these concentrations. The area within each of these isoconcentration lines is estimated using a 4 ft. x 4 ft. = 16 ft^2 grid. These areas are multiplied by the depth (12 ft) and average concentration to yield the mass within each area. These are summed to yield the total mass.

CALCULATION:

Zone	Area (figure 7)	Average Concentration
10 - 500 mg/kg	3,900 sq ft	255 mg/kg
>500 mg/kg	2,650 sq ft	700 mg/kg

Typical calculation:

255 mg/kg x 10^{-6} kg/mg x 3,900 ft^2 x 12 ft x 100 lb/ft^3 = 1,200 lbs
700 mg/kg x 10^{-6} kg/mg x 2,650 ft^2 x 12 ft x 100 lb/ft^3 = 2,200 lbs

TOTAL = **3,400 lbs**

Table A-1
Average Vadose Zone Soil Concentration

Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Well Number	B-1		B-2		MW-1	
	Sample Depth,ft	TPH & TPHg Conc, mg/kg	Sample Depth,ft	TPH & TPHg Conc, mg/kg	Sample Depth,ft	TPH & TPHg Conc, mg/kg
	0	0	0	0	5.5	0
	10	0	10	0	11	0
	15	1.7	15	222	12	25
	20	0	20	0	21	5
Weighted Average Concentration, mg/kg		1		90		12

Well Number	MW-2		MW-3		MW-4	
	Sample Depth,ft	TPH & TPHg Conc, mg/kg	Sample Depth,ft	TPH & TPHg Conc, mg/kg	Sample Depth,ft	TPH & TPHg Conc, mg/kg
	0	0	0	0	0	0
	6	8	6	0	5.5	0
	11	3411	11	2200	10.5	1641
	12	569	12	1922	12	1127
Weighted Average Concentration, mg/kg		900		600		500

Well Number	MW-5	
	Sample Depth,ft	TPH & TPHg Conc, mg/kg
	0	0
	6	0
	11	5
	15.5	0
Weighted Average Concentration, mg/kg		2

Table A-2
Ratio of TPH to TPHg in Soil and Groundwater Samples

Sears Store 1058
2633 Telegraph Avenue, Oakland, California

Table 1 - Soil Samples
Assumptions:

Each sample is representative of 100 lbs (approx 1 cu ft) of soil.
TRPH is equivalent to TPH
"<" concentrations are treated as concentrations at the detection limit.

Sample ID	TPH mg/kg	TPHg mg/kg	TPH lbs	TPHg lbs
B2-15'	92	130	0.009	0.0130
MW1-12'	25	< 0.5	0.003	< 0.0001
MW2-11'	3,400	11	0.340	0.0011
MW2-12'	560	9	0.056	0.0009
MW3-11'	2,200	< 0.5	0.220	< 0.0001
MW3-12'	1,900	22	0.190	0.0022
MW3-15'	86	46	0.009	0.0046
MW4-10.5'	1,600	41	0.160	0.0041
MW4-12'	1,100	26	0.110	0.0026
SUM			1.10	< 0.029
Percentage			97%	3%

Table 2 - Groundwater Samples
Assumptions:

Each sample is representative of 1000 lbs (approx 120 gal.) of groundwater.
TPH is equivalent to TPH as motor oil
Most recent sample results are used.
"<" concentrations are treated as concentrations at the detection limit.

Sample ID	TPH mg/kg	TPHg mg/kg	TPH lbs	TPHg lbs
MW-1	310	390	0.00031	0.00039
MW-2	3,100	< 100	0.00310	< 0.00010
MW-4	600	< 100	0.00060	< 0.00010
MW-5	310	< 100	0.00031	< 0.00010
MW-6	230	< 100	0.00023	< 0.00010
MW-7	310	< 100	0.00031	< 0.00010
MW-8	< 200	110	< 0.00020	0.00011
SUM			< 0.0051	< 0.0010
Percentage			83%	17%

APPENDIX B

WELL PERMITS AND DRILLING LOGS

FLUOR DANIEL GTI

Drilling Log

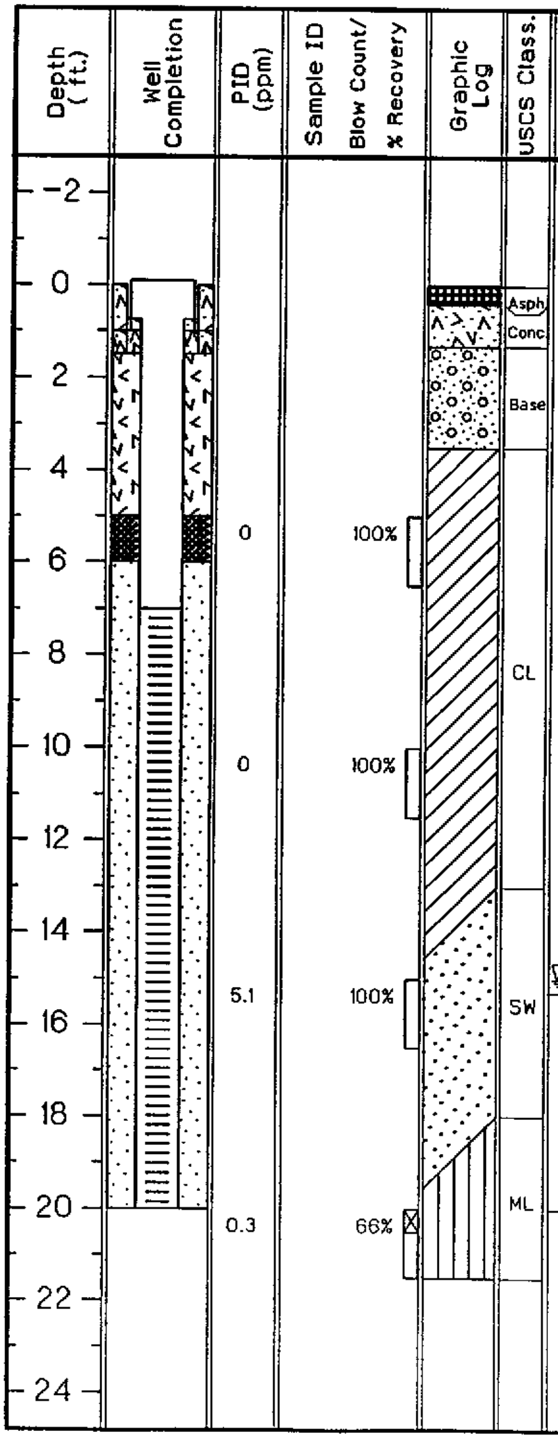
Monitoring Well **MW-9**

Project *Sears - Telegraph* Owner *Sears Roebuck and Company*
Location *2633 Telegraph Aveune, Oakland, CA* Proj. No. *020200136*
Surface Elev. ______ Total Hole Depth *20 ft.* Diameter *8 in.*
Top of Casing ______ Water Level Initial *15 ft.* Static ______
Screen: Dia *2 in.* Length *13 ft.* Type/Size *0.020 in.*
Casing: Dia *2 in.* Length *7 ft.* Type *PVC Riser*
Fill Material *Lonestar #3* Rig/Core *M5T Rhino*
Drill Co. *Gregg Drilling* Method *Hollow Stem Auger*
Driller *Rich Messinger* Log By *Bob Fehr* Date *10/09/96* Permit # ______
Checked By *Dennis Maslonkowski* License No. *RG #*

See Site Map For Boring Location

COMMENTS:

Soil cuttings stored on-site in a 55-gallon steel drum pending proper disposal.



Depth (ft.)	PID (ppm)	Blow Count/ % Recovery	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
0			Asph Conc	Approximately 4 inches of asphalt over 8 inches of concrete
2			Base	Base Course (Slight odor while hand augering
6	0	100%	CL	Clay with silt, trace root casts, medium brown, medium stiff, plastic, moist, no odor
10	0	100%		Grades to no root casts
16	5.1	100%	SW	*Encountered water at 0822* Grades to SAND, poorly sorted with trace fine gravel and isolated medium gravel, little or no fines, dark gray, loose, saturated, no odor
20	0.3	66%	ML	Grades to SILT, medium brown, medium stiff, no plasticity, wet, no odor End of boring at 20 feet, split-spoon to 21.5. Installed monitoring well

Drilling Log

FLUOR DANIEL GTI

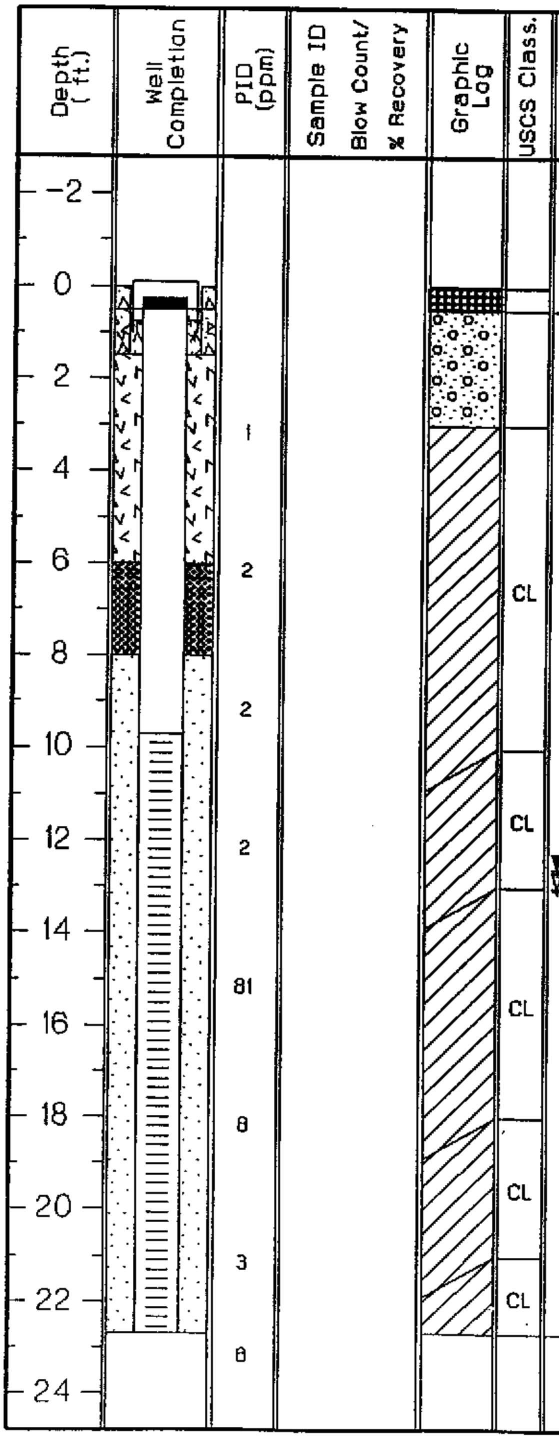
Extract. / Inject. Well **EW-1**

Project *Sears Telegraph* Owner *Sears*
Location *2600 Telegraph, Oakland CA* Proj. No. *020200136*
Surface Elev. *-- ft.* Total Hole Depth *22.7 ft.* Diameter *10 in.*
Top of Casing *-- ft.* Water Level Initial *13 ft.* Static *12.59 ft.*
Screen: Dia *4 in.* Length *13 ft.* Type/Size *.020 in.*
Casing: Dia *4 in.* Length *9.5 ft.* Type *PVC*
Fill Material *Monterey #3 Sand* Rig/Core *Mobile B-56*
Drill Co. *Exploration Geoservices* Method *Hollow Stem Auger*
Driller *Dave* Log By *Terry James* Date *6/11/96* Permit # *96399*
Checked By *Ken Johnson* License No. *R.G. 6254*

See Site Map
For Boring Location

COMMENTS:

This extraction well was installed 4 ft. west of MW-3 The well head was set in a Emco-Wheaton streetbox. Separate phase was detected in the saturated zone. Samples and litological descriptions were taken from cuttings at 3 ft. intervals.



Description

(Color, Texture, Structure)
Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%

Asphalt

Base course.

CLAY: with little silt, dark reddish brown, slightly stiff to stiff, moist, no hydrocarbon odor.

Silty CLAY: light brown, soft, plastic, damp, no hydrocarbon odor.

Groundwater encountered during drilling, June 11, 1996.

Sandy CLAY: with trace medium gravel, greenish gray, soft, plastic, sand is fine, wet, strong hydrocarbon odor.

Silty CLAY: with trace fine sand, olive, plastic, moist.

(Grades very stiff.)

Sandy CLAY: with little medium gravel, yellowish brown, soft, wet, gravel is angular.

End of boring, installed extraction well.

APPENDIX C

SOIL VAPOR EXTRACTION TEST DATA

Page 1 of 1

Sears Roebuck and Co.
2633 Telegraph Avenue
Oakland, California
Site No. 1058

Date- June 20, 1996
Weather - Warm and Dry

	Distance From Venting Point RW1 (ft)	Methane (%)	Carbon Dioxide (%)	Oxygen (%)	FID Total VOCs (PPMv)	Vacuum (in.WC)
		STATIC SITE DATA				
MW1	100	-----	3.1	13.3	-----	0
MW2	63	-----	2.6	15.7	-----	0
MW3	4	-----	4.3	7.7	-----	-0.05
MW4	47	-----	5.4	8.6	-----	0
MW5	118	-----	2.6	18	-----	0
MW6	110	-----	1.4	18.3	-----	0
MW7	73	-----	0.6	17.8	-----	0
MW8	49	-----	3.4	12.2	-----	0
Pilot Test Vapor Data (long term vent from RW1/short-term venting from individual wells)						
MW1/14:55	100	0	6.1	12.1	36	-55"/16.8cfm
MW2/13:50	63	0	3.5	12.1	32	-48"/59.8cfm
MW3	4	---	---	---	---	NA
MW4/13:30	47	26.4	18.2	0.6	10,690	-70"/21.6cfm
MW5	118	---	---	---	---	
MW6	110	---	---	---	---	NA
						NA
MW7/14:15	73	0	4.6	14.8	12	-80"/22.1cfm
MW8/14:00	49	0.2	8.9	6.0	286	-60"/24.8cfm
RW1/10:00	NA	0.4	5.6	12.5	1511	-30"/13cfm
RW1/10:45	NA	0.3	5.1	13.3	795	-60"/15.8cfm
RW1/11:15	NA	1.1	5.1	13.2	1420	-100"/30cfm
RW1/12:20	NA	0.8	5.0	13.6	1262	-100"/30cfm

Remarks:

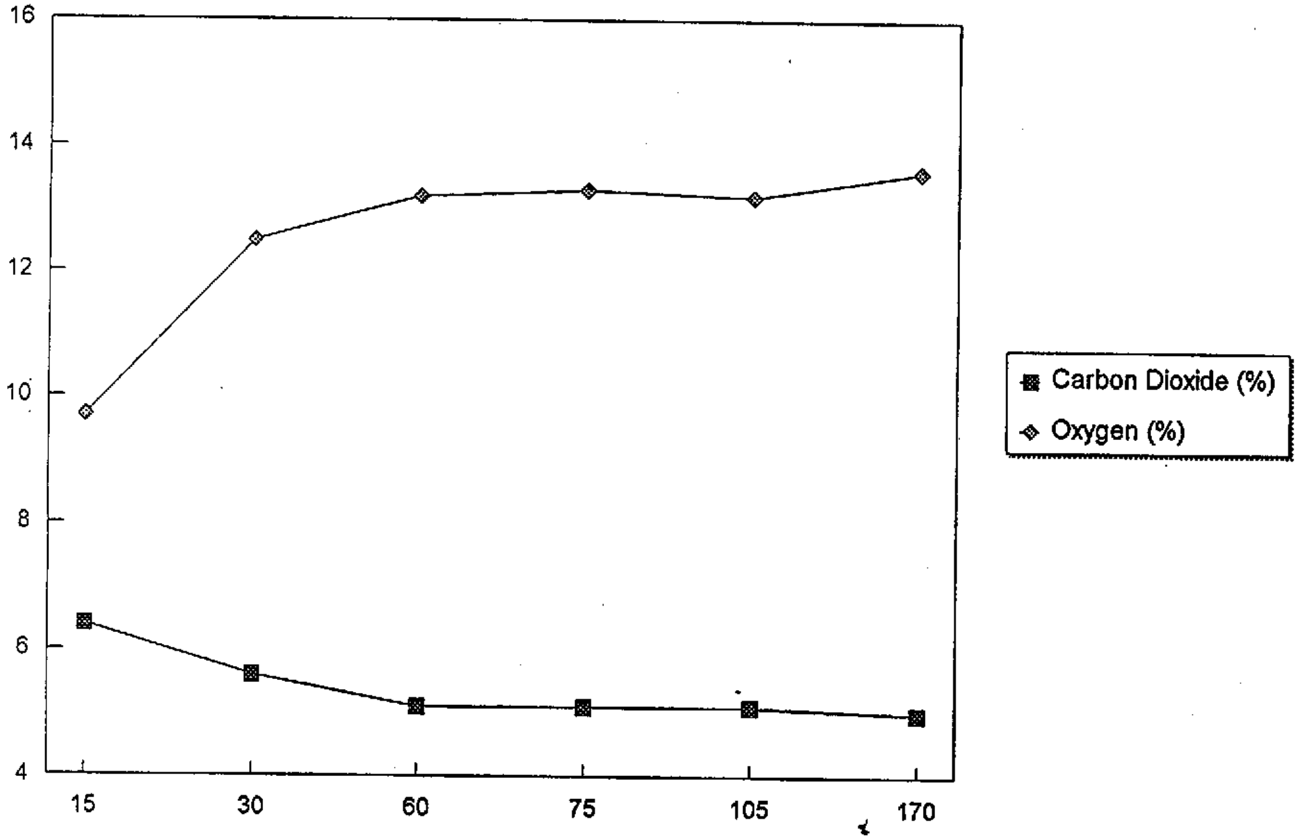
Venting test at RW1 stopped at 12:26

Each short-term vent test (MW1, MW2, MW4, MW7, and MW8) ran for approximately 10 minutes after the long-term test on RW1.

c:\seroakvap

Sears and Roebuck Co Site No. 1058 SVE Test

Respirometry Data During Venting RW1



6/20/96

Sears/Oakland (1058) Soil Vapor Extraction Test
Weather: warm , dry , partly cloudy

RW1-Soil Vapor Extraction Flow
RW1-Soil Vapor Extraction Vacuum

Phase One
13 cfm (625 fpm)
-30 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
09:30	0											
09:35	5	0	-0.02	-0.29	-0.1	0	0	0	-0.04			
09:45	15	0	-0.02	-0.95	-0.1	0	0	-0.02	-0.04			
09:57	27	0	-0.02	-0.96	-0.1	0	0	-0.02	-0.05			

Sears/Oakland Soil Vapor Extraction Test
RW1-Soil Vapor Extraction Flow
RW1-Soil Vapor Extraction Vacuum

Phase Two
15.8 cfm (725 fpm)
-60 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
10:00	0											
10:05	5	-0.02	-0.025	-0.35	-0.10	-0.01	-0.03	-0.06	-0.085			
10:20	20	-0.02	-0.025	-1.10	—	-0.035	-0.03	-0.06	-0.11			
10:30	30	0.02	-0.025	-1.10	--	-0.05	-0.01	-0.06	-0.12			
10:40	40	-0.01	-0.02	-1.10	+0.05	-0.03	-0.01	-0.06	-0.11			
10:45	45	-0.01	-0.02	-1.10	+0.03	-0.03	-0.01	-0.06	-0.11			

Sears/Oakland Soil Vapor Extraction Test
RW1-Soil Vapor Extraction Flow
RW1-Soil Vapor Extraction Vacuum

Phase Three
30 cfm (1380 fpm)
-100 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
11:10	0											
11:15	5	-0.01	-0.03	-3.4	-0.2	0	-0.01	-0.06	-0.14			
11:25	15	0	-0.03	-2.9	-0.27	-0.02	0	-0.06	-0.14			
11:35	25	0	-0.03	-3.0	-0.26	-0.02	0	-0.06	-0.14			
11:48	38	0	-0.03	-3.4	-0.26	-0.02	0	-0.06	-0.14			
12:15	65	0	-0.03	-3.4	-0.26	-0.02	0	-0.06	-0.14			

Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			

Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			

6/20/96

Sears/Oakland (1058) Soil Vapor Extraction Test
Weather: warm , dry , partly cloudy

Phase One
RW1-Soil Vapor Extraction Flow: 13 cfm (625 fpm)
RW1-Soil Vapor Extraction Vacuum: -30 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
09:30	0											
09:35	5	0	-0.02	-0.29	-0.1	0	0	0	-0.04			
09:45	15	0	-0.02	-0.95	-0.1	0	0	-0.02	-0.04			
09:57	27	0	-0.02	-0.96	-0.1	0	0	-0.02	-0.05			

Sears/Oakland Soil Vapor Extraction Test

Phase Two
RW1-Soil Vapor Extraction Flow: 15.8 cfm (725 fpm)
RW1-Soil Vapor Extraction Vacuum: -60 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
10:00	0											
10:05	5	-0.02	-0.025	-0.35	-0.10	-0.01	-0.03	-0.06	-0.085			
10:20	20	-0.02	-0.025	-1.10	--	-0.035	-0.03	-0.06	-0.11			
10:30	30	0.02	-0.025	-1.10	--	-0.05	-0.01	-0.06	-0.12			
10:40	40	-0.01	-0.02	-1.10	+0.05	-0.03	-0.01	-0.06	-0.11			
10:45	45	-0.01	-0.02	-1.10	+0.03	-0.03	-0.01	-0.06	-0.11			

Sears/Oakland Soil Vapor Extraction Test

Phase Three
RW1-Soil Vapor Extraction Flow: 30 cfm (1380 fpm)
RW1-Soil Vapor,Extraction Vacuum: -100 in WC

		Influence Vacuum (in WC)										
Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			
11:10	0											
11:15	5	-0.01	-0.03	-3.4	-0.2	0	-0.01	-0.06	-0.14			
11:25	15	0	-0.03	-2.9	-0.27	-0.02	0	-0.06	-0.14			
11:35	25	0	-0.03	-3.0	-0.26	-0.02	0	-0.06	-0.14			
11:48	38	0	-0.03	-3.4	-0.26	-0.02	0	-0.06	-0.14			
12:15	65	0	-0.03	-3.4	-0.26	-0.02	0	-0.06	-0.14			

Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			

Clock Time	Elapsed Time	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8			

APPENDIX D

LABORATORY ANALYSES RESULTS

NEI/GTEL
ENVIRONMENTAL
LABORATORIES, INC.

Midwest Region
4211 May Avenue
Wichita, KS 67209
(316) 945-2624
(800) 633-7936
(316) 945-0506 (FAX)

June 19, 1996

Mike Wray
Fluor Daniel GTI
757 Arnold Drive Suite D
Martinez, CA 94555

RE: GTEL Client ID:	020200136
Login Number:	W6060055
Project ID (number):	020200136
Project ID (name):	Sears/1058/2633 Telegraph Ave./Oakland/CA

Dear Mike Wray:

Enclosed please find the analytical results for the samples received by GTEL Environmental Laboratories, Inc. on 06/05/96 under Chain-of-Custody Number(s) 40592.

A formal Quality Assurance/Quality Control (QA/QC) program is maintained by GTEL, which is designed to meet or exceed the EPA requirements. Analytical work for this project met QA/QC criteria unless otherwise stated in the footnotes. This report is to be reproduced only in full.

NEI/GTEL is certified by the California Department of Health Service under Certification Number 1845.

If you have any questions regarding this analysis, or if we can be of further assistance, please call our Customer Service Representative.

Sincerely,
GTEL Environmental Laboratories, Inc.

Customer Service Manager

Terry R. Loucks
Laboratory Director

Project ID (Number): 020200136
Project ID (Name): Sears #1058
2633 Telegraph Ave.
Oakland, CA
Work Order Number: W6-06-0055
Date Reported: 06-19-96

ANALYTICAL RESULTS

Hydrocarbon Screen in Water
GC/FID[a]

GTEL Sample Number		06			
Client Identification		MW-3			
Date Sampled		06-03-96			
Date Extracted		06-18-96[d]			
Date Analyzed		06-19-96			
Analyte	Reporting Limit ug/L	Concentration, ug/L			
TPH as Gasoline[b]	50	<5000			
TPH as Mineral Spirits	50	<5000			
TPH as Diesel Fuel	50	<5000			
TPH as Lubricating Oil[c]	200	320000			
Dilution Multiplier		100			

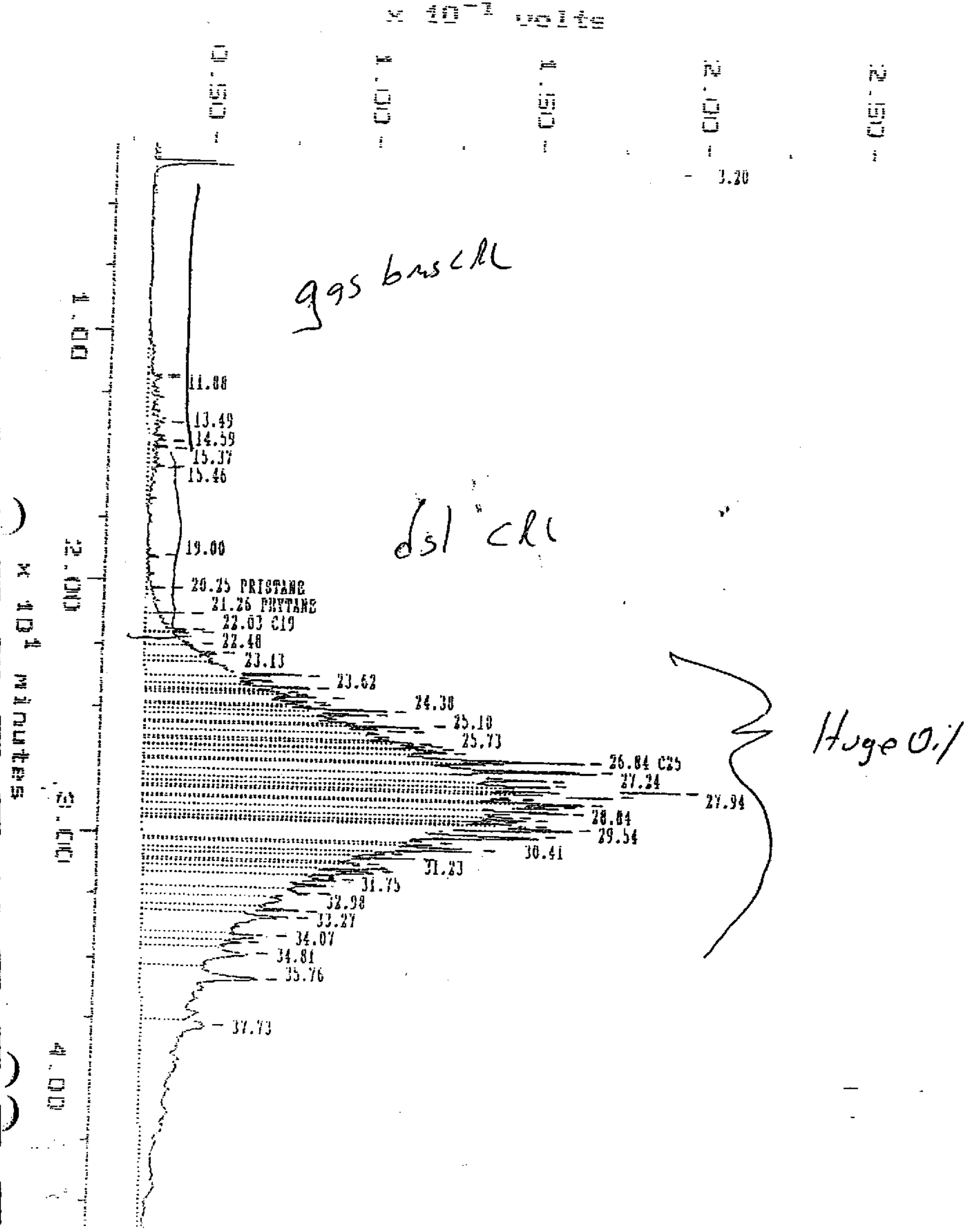
a ASTM Method D3328 (modified) is used for qualitative identification of fuel patterns. The method has been modified to include quantitation by applying calibration and quality assurance guidelines outlined in EPA's publication, Test Methods for Evaluating Solid Waste, SW846, Third Edition, Revision 0, November 1986. Extraction per EPA 3510. This method is equivalent to the California LUFT manual DHS method for diesel fuel.

b Due to potential loss of volatile components during sample extraction and concentration, quantitation of gasoline by this method should be treated as an estimate. For the most accurate gasoline analysis, a purge-and-trap procedure is recommended.

c Lubricating oil can not be qualitatively identified by type of oil because of chromatogrpahic likeness of different oil types. Due to non-volatility of certain oils, much of the oil present may never be quantified by this gas chromatographic method. Quantitation obtained for lubricating oil by this method should, therefore, be treated as an estimate. This method quantifies lubricating oil against 10-W-40 standards. For the most accurate analysis of lubricating oil, an infrared method is recommended.

d This sample was extracted outside of the method recommended holding time.

Sample: 06005506 X20[5] Channel: GC13B-SIG B Filename: 13B16563
Acquired: 19-JUN-96 6:32 Method: J:\GCDATA\GC13\TPHACQU2 Operator: HAC
Dilution: 1 : 100.000 Amount: 1.000



gas brsckt

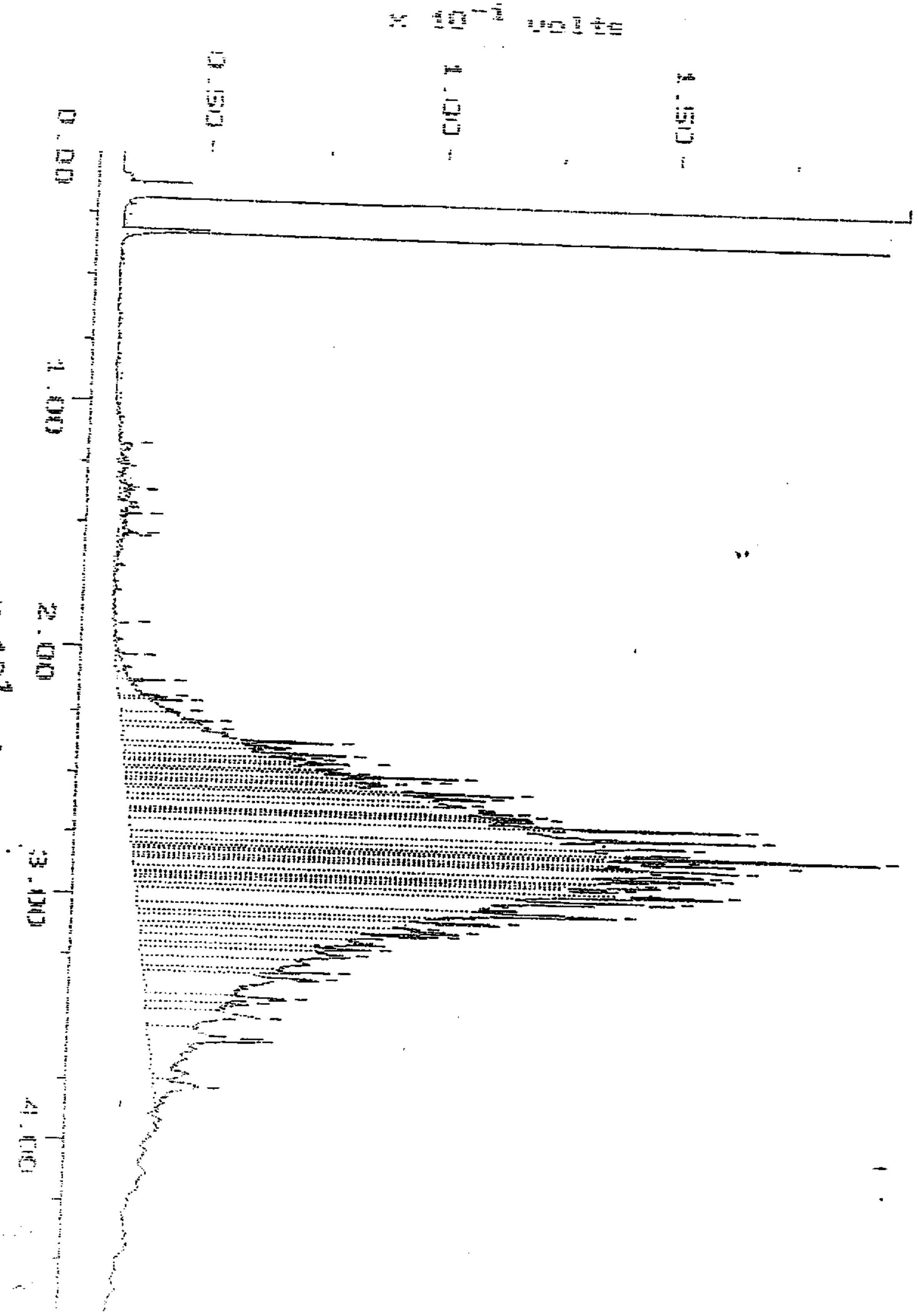
dsl ckl

Huge Oil

Sample: 06005506 X20[5]
Acquired: 19-JUN-96 6:32
Dilution: 1 : 100.000

Channel: GC13B-SIG B
Method: J:\GCDATA\GC13\TPHACQ02
Amount: 1.000

Filename: 13B16563
Operator: NAC



NEI/GTEL
ENVIRONMENTAL
LABORATORIES, INC.

Midwest Region
4211 May Avenue
Wichita, KS 67209
(316) 945-2624
(800) 633-7936
(316) 945-0506 (FAX)

June 25, 1996

Mike Wray
Fluor Daniel GTI
757 Arnold Drive Suite D
Martinez, CA 94555

RE: GTEL Client ID: 020200136
Login Number: W6060381
Project ID (number): 020200136
Project ID (name): Sears/1058/2633 Telegraph Ave./Oakland/CA

Dear Mike Wray:

Enclosed please find the analytical results for the samples received by GTEL Environmental Laboratories, Inc. on 06/22/96 under Chain-of-Custody Number(s) 35145.

A formal Quality Assurance/Quality Control (QA/QC) program is maintained by GTEL, which is designed to meet or exceed the EPA requirements. Analytical work for this project met QA/QC criteria unless otherwise stated in the footnotes. This report is to be reproduced only in full.

NEI/GTEL is certified by the California Department of Health Service under Certification Number 1845.

If you have any questions regarding this analysis, or if we can be of further assistance, please call our Customer Service Representative.

Sincerely,
GTEL Environmental Laboratories, Inc.

Customer Service Manager for

Terry R. Loucks
Laboratory Director

ANALYTICAL RESULTS
Volatile Organics

GTEL Client ID: 020200136
Login Number: W6060381
Project ID (number): 020200136
Project ID (name): Sears/1058/2633 Telegraph Ave./Oakland/CA

Method: MOD 8015/8020
Matrix: Air

		GTEL Sample Number	W6060381-01	W6060381-02	--	--
		Client ID	RW1	MW4	--	--
		Date Sampled	06/20/96	06/20/96	--	--
		Date Analyzed	06/22/96	06/22/96	--	--
		Dilution Factor	1.00	5.00	--	--
Analyte	**Reporting Limit**	**Units**	**Concentration:**			
Benzene	0.5	ug/L	6.8	< 2.5	--	--
Toluene	0.5	ug/L	3.3	< 2.5	--	--
Ethylbenzene	0.5	ug/L	1.0	27.	--	--
Xylenes (total)	0.5	ug/L	2.0	15.	--	--
BTEX (total)	--	ug/L	13.	42.	--	--
TPH as Gasoline	50	ug/L	1500	12000	--	--

Notes:

Dilution Factor:

Dilution factor indicates the adjustments made for sample dilution.

MOD 8015/8020:

Note: This method for air analysis is not an EPA approved method and all results should be treated as estimates. All quality assurance procedures are based on aqueous standards and may not be reflective of the gaseous matrix of the samples. "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", SW-846, Third Edition including promulgated Update II.

GTEL
ENVIRONMENTAL LABORATORIES, INC

4080 PIKE LANE, SUITE C
CONCORD, CA 94520
(510) 685-7852
(800) 423-7143

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

35145

Company Name: Fluor Daniel- GTI

Phone #: 510 370-3990

FAX #:

Company Address: 757 Arnold Martinez CA

Site Location: 6033 Telegraph Rd Oakland CA

Project Manager: Mike Wong

Client Project ID: (#) 020200136-040663

(NAME) SEARS

I attest that the proper field sampling procedures were used during the collection of these samples.

Sampler Name (Print): Gordon Erickson

			Matrix						Method Preserved						Sampling		ANALYSIS REQUEST																					OTHER			
Field Sample ID	GTEL Lab # (Lab Use only)	# CONTAINERS	WATER	SOIL	AIR	SLUDGE	PRODUCT	OTHER	HCl	HNO_3	H_2SO_4	ICE	UNPRESERVED	OTHER (Specify)	1996 DATE	TIME	BTEX 602 ☐ 8020 ☐ with MTBE ☐	BTEX/Gas Hydrocarbons PID/FID ☒ with MTBE ☐	Hydrocarbons GC/FID Gas ☐ Diesel ☐ Screen ☐	Hydrocarbon Profile (SIMDIS) ☐	Oil and Grease 413.1 ☐ 413.2 ☐ SM-503 ☐	TPH/IR 418.1 ☐ SM 503 ☐	EDB by 504 ☐ DBCP by 504 ☐	EPA 503.1 ☐ EPA 502.2 ☐	EPA 601 ☐ EPA 8010 ☐	EPA 602 ☐ EPA 8020 ☐	EPA 608 ☐ 8080 ☐ PCB only ☐	EPA 624/PPL ☐ 8240/TAL ☐ NBS (+15) ☐	EPA 625/PPL ☐ 8270/TAL ☐ NBS (+25) ☐	EPA 610 ☐ 8310 ☐	EP TOX Metals ☐ Pesticides ☐ Herbicides ☐	TCLP Metals ☐ VOA ☐ Semi-VOA ☐ Pest ☐ Herb ☐	EPA Metals - Priority Pollutant ☐ TAL ☐ RCRA ☐	CAM Metals TTLC ☐ STLC ☐	Lead 239.2 ☐ 200.7 ☐ 7420 ☐ 7421 ☐ 6010 ☐	Organic Lead ☐	Corrosivity ☐ Flash Point ☐ Reactivity ☐				
RW1		1			X								X		6-20	12:20		X																							
MW4	W606354	1			X								X		6-20	13:15																						HOLD			

TAT
Priority (24 hr) ☐
Expedited (48 hr) ☐
7 Business Days ☐
Other_____
Business Days ☐

Special Handling
GTEL Contact ____________
Quote/Contract # ____________
Confirmation # ____________
P.O. # ____________

QA/QC Level
Blue ☐ CLP ☐ Other ☐ ____________

SPECIAL DETECTION LIMITS

SPECIAL REPORTING REQUIREMENTS

FAX ☐

REMARKS:
SRS - OAK

Lab Use Only Lot #: 10C

Storage Location

Work Order #: No Seals

CUSTODY RECORD

Relinquished by Sampler:	Date 6-21-96	Time 11:00	Received by: Welber
Relinquished by: Welber	Date 6-21-96	Time 16:45	Received by: DS
Relinquished by:	Date 6/22/96	Time 8:30	Received by Laboratory: Waybill # Dean Smith

APPENDIX E

SOIL VAPOR EXTRACTION TEST CALCULATIONS, VENT-ROI MODEL OUTPUTS AND VENT-ROI MODEL DESCRIPTIONS

```
                    RESULTS OF VENT-ROI ANALYSIS

  EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

Sears Roebuck and Company site in Oakland, CA


    Weathered Gasoline/JP-4 (contaminant mixture, volatile and biodegradable)
         log10(MW P*)                                = 1.41 - 3.19 δm
         Temperature Constant                        = 1904 deg K
         Liquid Density                              = .7 g/cc
         Zero Order Bioremediation Rate Constant     = 6.1 ppm/day
         Initial Total Soil Contaminant Concentration = 3400 ppm
         Residual (Non-degradable) Soil Concentration = 1 ppm

     Vertical wells in 10 inch boreholes, extending to groundwater,
         screened from 9.5 to 12 feet

    Thickness of Vented Soil Interval                = 12 feet
    Slope of log10(P) vs Distance from Pilot Test    = .024 per ft
    Soil Gas Temperature                             = 55 deg F
    Applied Vacuum                                   = 100 in. water column
    Air Flow Rate per Vapor Extraction Well          = 23.9 scfm
    Desired Time to Cleanup                          = 730 days
    Cleanup Goal                                     = 99 % removal

VOLATILIZATION:  SINGLE WELL EFFECTIVE RADIUS    = 6.7 FEET
                 INSUFFICIENT SURFACE INFILTRATION FOR MULTIPLE WELL SYSTEM

BIODEGRADATION:  SINGLE WELL RADIUS OF INFLUENCE = 33.09 FEET
                 INTERWELL RADIUS OF INFLUENCE   = 13.25 FEET

VOL. PLUS BIO.:  SINGLE WELL EFFECTIVE RADIUS    = 33.09 FEET
                 INTERWELL EFFECTIVE RADIUS      = 13.25 FEET
```

OBSERVED AND PREDICTED FLOW RESPONSE TO APPLIED VACUUM

	Applied Vacuum (inches w.c.)	Observed Flow Response (scfm)	Predicted Flow Response (scfm)	Relative Percent Difference
1.	30	11	7.86	-33.3 %
2.	60	11.7	15.11	25.5 %
3.	100	19.7	23.85	19.1 %

Mean Value of Relative Percent Difference:	3.7 %
Mean Absolute Value of Relative Percent Difference:	26 %
Standard Deviation of Prediction:	4.4 scfm
Soil Permeability in Horizontal Direction (sq cm):	9.7E-08
Standard Deviation of Soil Permeability Estimation (sq cm):	3.4E-08
Ratio of Horizontal to Vertical Permeability:	8.2

```
                    RESULTS OF VENT-ROI ANALYSIS

    EXTENT OF REMEDIATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

Sears Roebuck and Company site in Oakland, CA


     Weathered Gasoline/JP-4 (contaminant mixture, volatile and biodegradable)
          log10(MW P*)                                = 1.41 - 3.19 ðm
          Temperature Constant                        = 1904 deg K
          Liquid Density                              = .7 g/cc
          Zero Order Bioremediation Rate Constant     = 6.1 ppm/day
          Initial Total Soil Contaminant Concentration = 3400 ppm
          Residual (Non-degradable) Soil Concentration = 1 ppm

      Vertical wells in 10 inch boreholes, extending to groundwater,
          screened from 9.5 to 12 feet

     Thickness of Vented Soil Interval                = 12 feet
     Slope of log10(P) vs Distance from Pilot Test    = .024 per ft
     Soil Gas Temperature                             = 55 deg F
     Applied Vacuum                                   = 100 in. water column
     Air Flow Rate per Vapor Extraction Well          = 23.6 scfm
     Desired Time to Cleanup                          = 730 days
     Distance from Vapor Extraction Well              = 35.5 feet

   IF CONTAMINATION PLUME ENDS 35.5 FEET AWAY FROM VAPOR EXTRACTION WELL:
        PERCENT REMOVAL AT 28.4 TO 35.5 FEET          = 99.9 %
```

```
                    RESULTS OF VENT-ROI ANALYSIS

    SOIL GAS EXTRACTION RATE FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

Sears Roebuck and Company site in Oakland, CA


    Weathered Gasoline/JP-4 (contaminant mixture, volatile and biodegradable)
         log10(MW P*)                                    = 1.41 - 3.19 δm
         Temperature Constant                            = 1904 deg K
         Liquid Density                                  = .7 g/cc
         Zero Order Bioremediation Rate Constant         = 6.1 ppm/day
         Initial Total Soil Contaminant Concentration    = 3400 ppm
         Residual (Non-degradable) Soil Concentration    = 1 ppm

     Vertical wells in 10 inch boreholes, extending to groundwater,
         screened from 9.5 to 12 feet
         100 by 160 foot plume requires 7 wells, operated simultaneously,

    Thickness of Vented Soil Interval                    = 12 feet
    Slope of log10(P) vs Distance from Pilot Test        = .024 per ft
    Soil Gas Temperature                                 = 55 deg F
    Interwell Effective Radius                           = 16.9 feet
    Single Well Effective Radius                         = 35.5 feet
    Desired Time to Cleanup                              = 730 days
    Cleanup Goal                                         = 99 % removal

 LOW REQUIRED FOR SINGLE WELL AT THESE CONDITIONS        = 29.2 scfm
    APPLIED VACUUM REQUIRED TO ACHIEVE THIS FLOW         = 128.8 in. water column

 OTAL FLOW REQUIRED FOR MULTIWELL SYSTEM                 = 89.58 scfm
```

ANALYSIS OF VACUUM DISSIPATION DATA FROM PILOT TEST

30 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MW2	63	.02	-1.699
MW3	4	.96	-.018
MW4	47	.1	-1
* MW5	118	0	
MW7	73	.02	-1.699
MW8	49	.05	-1.301

* = outlier, not considered in analysis
Additional data point based on applied vacuum:
3 inches of water column at 0 feet from SVE well

Slope = -.029 per foot
Intercept = 1.895 inches of water column
R squared = .965

60 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MW2	63	.02	-1.699
MW3	4	1.1	.041
MW4	47	.1	-1
MW5	118	.03	-1.523
MW7	73	.06	-1.222
MW8	49	.11	-.959

Additional data point based on applied vacuum:
6 inches of water column at 0 feet from SVE well

Slope = -.019 per foot
Intercept = 1.43 inches of water column
R squared = .74

100 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MW2	63	.03	-1.523
MW3	4	3.4	.531
MW4	47	.26	-.585
MW5	118	.02	-1.699
MW7	73	.06	-1.222
MW8	49	.14	-.854

Additional data point based on applied vacuum:
10 inches of water column at 0 feet from SVE well

Slope = -.023 per foot
Intercept = 3.648 inches of water column
R squared = .858

Average slope from tests at 3 applied vacuums = -.024 per foot.

ANALYSIS AND SCALEUP OF SOIL VAPOR EXTRACTION PILOT TEST DATA

David H. Bass, Sc.D., CHMM
Manager of Technology Development
Groundwater Technology, Inc.
3 Edgewater Drive
Norwood, MA 02062

ABSTRACT

A set of equations has been developed which can facilitate design of effective SVE systems using data routinely obtained from conventional SVE pilot tests. The design tool can be used to estimate the effective cleanup radius, (defined as "the maximum distance from a vapor extraction point through which sufficient air is drawn to remove the required fraction of contamination in the desired time") for soil vapor extraction (SVE) systems. This provides an understanding of the contaminant recovery rate as a function of distance from each vapor extraction well and allows SVE systems to be designed so that cleanup goals can be achieved within a specified time frame.

The design tool can also facilitate the design of multiple-well SVE systems based on a single-well pilot test by accounting for the competition for air which occurs between vapor extraction wells in multiple-well SVE systems. Equations useful in designing horizontal SVE systems based on pilot tests performed on vertical wells are also developed by modifying and adapting the standard transport equations for a buried vertical rod and horizontal cable to represent vertical and horizontal SVE systems respectively. This approach facilitates more accurate estimates of blower sizing, offgas treatment selection, and well spacing requirements.

The design tool is based on simple models and uses analytical rather than numerical methods. It is simpler, faster, more versatile, and more robust then more sophisticated, multi-dimensional models. Although accuracy and resolution are somewhat reduced, the use of this model instead of more complicated approaches is generally justified given the limited site characterization data ordinarily available and the subsurface anisotropies commonly encountered at most small SVE sites.

Although widely applicable, the design tool should be used with some caution when the vadose zone is highly stratified or when venting contaminated soil greater than 30 feet below grade. This approach has been implemented in a proprietary computer program, VENT-ROI, which Groundwater Technology, Inc. has been using routinely since 1992 for rapid and effective design of SVE systems.

ANALYSIS AND SCALEUP OF SOIL VAPOR EXTRACTION PILOT TEST DATA

David H. Bass, Sc.D., CHMM

BACKGROUND

Soil vapor extraction (SVE) is a widely used *in situ* remediation technique for treatment of contaminated vadose zone soil. SVE removes volatile organic compounds (VOCs) from vadose zone soils by inducing air flow through contaminated areas. SVE is typically performed by applying a vacuum to either vertical or horizontal vapor extraction wells or to gravel-filled trenches. The resulting pressure gradient causes the soil gas to migrate through the soil pores toward the vacuum source. VOCs are volatilized and transported out of the subsurface by the migrating soil gas. In addition, SVE increases oxygen flow to contaminated areas, thus stimulating natural biodegradation of aerobically degradable contaminants.

SVE is applicable to most compounds with a vapor pressure greater than about 1 mm Hg at ambient temperature. This includes a wide variety of common contaminants, such as benzene, toluene, ethylbenzene, xylenes, gasoline hydrocarbons, mineral spirits, methyl t-butyl ether, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane. Since vapor pressure increases with temperature, SVE also can be applied to semi-volatile compounds by heating the vadose zone with steam or hot air.

The efficacy of a SVE system is determined by its ability to draw sufficient air through the contaminated portion of the vadose zone. Pilot tests are routinely performed to determine well spacing and to size components for full scale SVE systems, based on the attainable soil gas recovery rate and the attenuation of soil vacuum with distance from the vapor extraction well. Tests are typically performed on vertical, often pre-existing wells (see Figure 1); however the final system design may be modified in several ways so as to enhance the flow of air throughout the contamination zone:

- The system usually employs multiple wells, which compete with each other for air, resulting in a lower total soil gas recovery rate per vapor extraction well.

- The system may employ vertical wells screened over different intervals than the test well, in an effort to more closely match the vertical extent of soil contamination.

- Horizontally drilled wells may be used. These are usually installed near the bottom of the contaminated vadose zone, as depicted in Figure 2;

- Vented gravel-filled trenches (Figure 3), which typically extend downward to the bottom of the contaminated vadose zone, may be used. The gravel-filled portion of the trench is generally designed to match the vertical extent of contamination.

- Ambient air may be forced or allowed to be drawn through wells screened at the level of the vadose zone contamination.

- An engineered surface seal may be applied by paving or covering an unpaved surface with polyethylene film to prevent surface infiltration of air and water.

Historically, pilot test data were interpreted by defining the vapor extraction "radius of influence" as the distance from the vapor extraction well where an arbitrary vacuum level (usually 0.01 to 1 inch of water column) could be measured in the soil. Such rules of thumb yield no information on the quantity of air moving through the vadose zone, and so cannot provide an assessment of remediation time or design information specific to the contaminant (a system designed to remove benzene will be less effective on the less volatile xylene, for example). Furthermore, this approach provides no mechanism for scaling up from pilot test results for a single, vertical well to any of the above modifications which the final system design may employ. Without a theoretically-based method for assessing such scaleup issues, significant errors in well spacing, component sizing, and anticipated system performance can occur.

One approach to characterizing the subsurface in such a way as to facilitate the prediction of SVE system performance as a function of system geometry and orientation is the use of multi-dimensional analytical or numerical modeling of vacuum and soil gas flow fields in the vadose zone. Baehr, Marley, Falta, Lingineni, and others have employed such solutions for systems with unsealed or partially sealed surfaces.[1-4] Joss and Baehr have recently adapted MODFLOW, a groundwater numerical modeling program, to SVE applications.[5]

It is not always feasible to apply these sophisticated models, however. The data available at many small sites where SVE is considered, such as retail gasoline stations and dry cleaning facilities, are often sparse, and budgets rarely exist for gathering the more extensive data required for multi-dimensional models. Most of these sites have been repeatedly excavated and refilled, creating subsurface anisotropies which confound the limited data. Multi-dimensional models typically require substantial time and training to input variables and to run, making the design process tedious and costly. Therefore, the need exists for a design tool which can provide rapid order-of-magnitude assessments of SVE system performance, based on the limited data typically obtained from a routine SVE pilot study.

DESIGN TOOL DEVELOPMENT

The extent and rapidity of remediation in SVE systems is determined principally by the rate at which air which can be moved through the contaminated subsurface. Evaluation of the subsurface distribution of soil gas flow in response to an applied vacuum at the vapor extraction well is therefore the principal objective of SVE pilot test data analysis. The vacuum/flow response is a function of

1. factors affecting the permeability of the soil to air flow, including:
    - the resistance to flow provided by the soil matrix;
    - the resistance to air infiltration provided by the soil surface;
2. the geometric aspects of the vapor extraction well, such as:
    - screen length (in vertical and horizontal wells) or length of trench;
    - position of the screen or vented trench interval relative to ground surface;
    - horizontal vs vertical orientation;
    - well diameter or trench width; and
3. the number, spacing, and placement pattern of vapor extraction wells.

When a pilot test is performed, the geometric and placement aspects of the extraction well(s) are known. The only two variables left unspecified are the resistance to flow through the soil and the resistance to air infiltration through the ground surface. Therefore, only two parameters which are independent functions of these two variables need to be measured in order to describe air flow in the subsurface. In a conventional SVE pilot test, these parameters are (1) the soil gas recovery rate in response to an applied vacuum at the vapor extraction well and (2) the dissipation of vacuum with distance from the vapor extraction well(s).

With flow in the subsurface described, a conventional pilot test performed on a single, vertical well can be (1) sized so that the required extent of remediation is achieved in the desired time frame, (2) scaled up to multiple-well systems, and (3) scaled up to systems with differing extraction well geometries and/or orientations. The design tool described below has been derived to provide these capabilities. It assumes that the subsurface is homogeneous and isotropic within each vented stratum, and that the nature of surface does not change with distance from the vapor extraction well.

Ensuring the Required Extent of Remediation is Achieved in the Desired Time

In a single-well SVE system, the maximum distance from the vapor extraction well through which sufficient air is drawn to remove the required fraction of contamination in the desired time is the effective radius, R_E. This differs from the radius of influence, which is the distance from the vapor extraction well that vacuum can be detected. The effective radius is based on site-specific conditions and SVE system parameters, and it is specific to the contaminant, cleanup goals, and cleanup time frame.

The effective radius in a single-well SVE system will extend to the edge of the contaminant plume. All air entering the contamination zone is initially uncontaminated. As the air flows through the soil, contaminants rapidly equilibrate between soil and air phases.[6] This equilibration is determined by the contaminant soil concentration, vapor pressure, and water solubility, and by the moisture and organic content of the soil. Of these parameters, only the contaminant soil concentration changes dramatically during the course of the remediation, and so for a given site and contaminant, the equilibrium gas concentration can be expressed generally as a function only of soil concentration:

$$C_g = f(C_s) \tag{1}$$

where C_g = contaminant concentration in the gas
C_s = contaminant concentration in the soil

The rate at which contaminant mass is lost from soil must equal the rate at which the soil gas flowing through the soil carries the contamination away:

$$\frac{dM_s}{dt} = \frac{d(V_s C_s)}{dt} = C_g q = f(C_s) q \tag{2}$$

where M_s = mass rate of contaminant removal from soil
t = time
V_s = volume of soil (control volume)
q = flow rate of gas through control volume

The contaminated zone is represented as a uniform cylinder of radius R_E and height h, as indicated in Figure 4. Remediation will occur from the outside of the plume inward (due to lateral introduction of uncontaminated air into the contamination zone) and from the top down (due to vertical infiltration of air). Although the outermost portion of the contamination zone will be treated first, the rate of treatment at this location will be the slowest since the air flux decreases rapidly with distance from the vapor extraction well. The control volume is therefore taken as a fraction of the contamination zone furthest from the vapor extraction well, i.e. an annulus of outer radius R_E and inner radius εR_E. The value for parameter ε, typically 0.7 to 0.9, is selected such that vertical infiltration at distances less than εR_E from the vapor extraction well provides a rate of remediation roughly comparable to the remediation rate within the control volume due to lateral and vertical introduction of clean air. The control volume is then

$$V_s = \pi(R_E^2 - (\epsilon R_E)^2)h = (1 - \epsilon^2)\pi R_E^2 h \tag{3}$$

The gas flow through the control volume, q, is calculated by assuming that the driving force for infiltration of atmospheric air through the soil surface is the difference between the squares of the subsurface and atmospheric pressures.[2,6] At any distance r from the vapor extraction well, this driving force acts through an area of ground surface represented by an annulus of differential thickness:

$$d\dot{Q}_v = k_v(P_a^2 - P_r^2)dA = k_v(P_a^2 - P_r^2)2\pi r dr \tag{4}$$

where Q_v = vertical infiltration of atmospheric air
r = distance from the vapor extraction well
P_a = absolute atmospheric pressure
P_r = absolute pressure at distance r from the vapor extraction well
k_v = constant
A = area of ground surface

The term $k_v(P_a^2 - P_r^2)$ comes from Darcy's Law for flow of a compressible fluid. The constant k_v is a lumped parameter related to the permeability of the soil to vertical gas infiltration, as well as to the gas viscosity, density, travel distance, and atmospheric pressure.

Since all the air collected at the SVE well must come ultimately from the atmosphere through the ground surface, the integral of equation (4) from the well radius to the radius of influence yields the rate of total soil gas recovery, Q°:

$$\int_{r_w}^{R_I} dQ_v = 2\pi k_v \int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr = Q^\circ \tag{5}$$

where r_w = radius of vapor extraction well
R_I = radius of influence

Rearranging equation (5) provides an expression for k_v. Substituting this into equation (4) and integrating from the well radius to the inner edge of the control volume gives:

$$\frac{Q_v}{Q^\circ} = \frac{\int_{r_w}^{\epsilon R_E} (P_a^2 - P_r^2)\, r\, dr}{\int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr} \quad . \tag{6}$$

The gas passing through the control volume is the total gas flow collected less the vertical infiltration which occurs closer to the SVE well:

$$q = Q^\circ - Q_v = Q^\circ \frac{\int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr - \int_{r_w}^{\epsilon R_E} (P_a^2 - P_r^2)\, r\, dr}{\int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr} \tag{7}$$

Combining equations (2), (3), and (7) and integrating yields:

$$\int_{C_s}^{C_s^\circ} \frac{dC_s}{f(C_s)} = \frac{\int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr - \int_{r_w}^{\epsilon R_E} (P_a^2 - P_r^2)\, r\, dr}{(1 - \epsilon^2)\pi R_E^2 \int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr} \; \frac{Q^\circ t}{h} \tag{8}$$

where C_s° = initial contaminant concentration in the soil

Whenever $dC_s/f(C_s)$ and $P_r^2 rdr$ are analytically integrable, equation (8) provides a vehicle for relating the effective radius (R_E) to soil concentration in the control volume (C_s), soil gas recovery rate ($Q°$), and remediation time (t) without the use of cumbersome numerical methods. Generally, r is assumed to be proportional either to $\log(P_r)$ or to $\exp\{P^2\}$.[6,7] At lower soil concentrations, it is proper to assume ideal partitioning between soil and gas ($f(C_s) = K_{gs}C_s$), while above a compound-specific threshold soil concentration, vapor concentration reaches the contaminant saturated vapor density, and $f(C_s)$ is constant.[8] When the contaminant is a diverse mixture of compounds, such as gasoline, $f(C_s)$ decreases exponentially with decreasing C_s over the course of the remediation.

Scaling Up to Multiple-Well Systems

When two or more vapor extraction wells are operated simultaneously, the subsurface air flow between the wells is decreased as the wells compete for air infiltrating from the surface. This reduces the effective radius between wells, as well as the flow per well in response to an applied vacuum.

The interwell effective radius, R_{EI}, is the distance from two vapor extraction wells to an equidistant point between them through which just enough air is drawn to remove the required fraction of contamination in the desired time. R_{EI} defines the remediation extent between vapor extraction wells and is always less than R_E, which defines the extent of remediation for a single-well system and for the area external to an array of vapor extraction wells. Quantifying R_{EI} requires only minor modifications to the equations from which R_E was derived above. The differential surface infiltration between two adjacent wells is given by equation (4). At a point located a distance R_{EI} from both wells, the differential volume through which this passes is $2\pi h R_{EI} dr$ (from equation (3)). Substituting these expressions for q and V_s in equation (2), and obtaining an expression for k_v from equation (5) yields

$$\int_{C_s^*}^{C_s} \frac{dC_s}{f(C_s)} = \frac{P_a^2 - P_r^2}{2\pi \int_{r_w}^{R_I} (P_a^2 - P_r^2)\, r\, dr} \frac{Q° t}{h} \qquad (9)$$

The approach to modeling total flow in multiple-well systems is developed below and is specific to hexagonal-arrays. However, this approach can be extended readily to any conceivable well placement pattern. Relating multiple-well flow to pilot study results involves comparing the equations for the multiple-well system with the corresponding equation for single-well flow ($Q°$) given in equation (4).

In SVE systems with three or more vapor extraction wells, the wells are usually placed so that the lines connecting the well form approximately equilateral triangles, as shown in Figure 5. In this case, the capture zone for each well is bounded by two to six lines representing the locus of points equidistant from each pair of adjacent wells. These lines intersect at 120° angles (Figure 5), and when sufficient wells are present, form an array of regular hexagons (Figure 6).

To model the system depicted in Figure 5 which has three equally spaced wells, assume that air infiltrating the ground surface migrates to the vapor extraction well nearest the point of infiltration. As shown at the top of Figure 5, infiltration will be the same for each well as for the single-well system, so long as $r \leq R$ (where R is half the well spacing). When $R < r < 2R/\sqrt{3}$, the area available for surface infiltration is reduced by the fraction $2\Theta_r/\pi$, as depicted in the lower right of Figure 5. The lower left of Figure 5 shows that when $r \geq 2R/\sqrt{3}$, the area available for surface infiltration is reduced by the fraction $1/6 + \Theta_r/\pi$. The relative flow per well for a three-well and single-well system, assuming identical well construction and applied vacuum, is then:

$$\frac{Q_{3,array}}{Q^{\circ}} = \frac{\int_{r_w}^{R}(P_r^2-P_a^2)r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} + \frac{\int_{R}^{2R/\sqrt{3}}(P_r^2-P_a^2)(1-\frac{2\Theta_r}{\pi})r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} + \frac{\int_{2R/\sqrt{3}}^{R_I}(P_r^2-P_a^2)(\frac{5}{6}-\frac{\Theta_r}{\pi})r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} \qquad (10)$$

where $Q_{3,array}$ = flow per well from a three-well triangular system

Extending this analysis to a hexagonal array of n vapor extraction wells spaced 2R feet apart requires classification of vapor extraction wells as either interior or exterior. Interior wells are adjacent to six other wells, exterior wells are adjacent to fewer than six (the seven-well array in Figure 6 has one interior and six exterior vapor extraction wells). The distinction is important because interior wells are assumed to have no influence beyond a distance of $2R/\sqrt{3}$. The general expression for the relative flow per well for a hexagonal array of n wells and a single-well system is:

$$\frac{Q_{n,array}}{Q^{\circ}} = \frac{\int_{r_w}^{R}(P_r^2-P_a^2)r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} + \frac{\int_{R}^{2R/\sqrt{3}}(P_r^2-P_a^2)(1-\frac{(6n-2n_e-6)\Theta_r}{n\pi})r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} + \frac{\frac{n_e}{n}\int_{2R/\sqrt{3}}^{R_I}(P_r^2-P_a^2)(\frac{n_e+2}{2n_e}-\frac{\Theta_r}{\pi})r\,dr}{\int_{r_w}^{R_I}(P_r^2-P_a^2)r\,dr} \qquad (11)$$

where $Q_{n,array}$ = flow per well from an n-well array of vapor extraction wells
n_e = number of exterior vapor extraction wells

Equation (11) has been validated by comparing the observed performance of 13 operating multiple-well SVE systems with the predicted performance, based on single-well pilot tests.[9] The observed and predicted results generally agreed, although substantial scatter was observed.

Scaling Up to Systems with Differing Geometries and Orientations

Equations describing the flux resulting from a potential applied to buried objects in heat transfer applications are available in standard transport texts. The potential in the case of heat transfer is the temperature difference between the buried object (generally assumed to be of uniform temperature) and the ground surface; the resultant flow is the net heat transferred to or from the buried object. The potential in SVE applications is the difference between the square of the pressures at the vapor extraction well/trench and the ground surface (atmospheric);[2,6] the resultant flow is the soil gas extraction rate. Note that this approach implies that the pressure within the vapor extraction well/trench is uniform. This is ordinarily a good assumption, however substantial pressure drop can occur over long lengths of perforated pipe, especially at higher air flow rates and smaller pipe diameters. A method for estimating vacuum distribution along perforated pipes in soil vapor extraction applications was presented in an earlier publication.[10]

The equation for transport to/from a thin vertical rod buried from the ground surface to a depth N is represented by the following equation:[11]

$$Q_v = \frac{2\pi k N \phi}{\ln(4N/D)} \tag{12}$$

where Q_v = resultant flow (soil gas recovery rate)
ϕ = applied potential ($P_{SVE}^2 - P_{atm}^2$)
D = diameter of the rod

The transport to/from a thin vertical rod buried from a depth N_1 to a depth N_2 can be found by subtracting the transport to/from a rod buried from the surface to N_1 from the transport to/from a rod buried from the surface to N_2:

$$Q_v = 2\pi k \phi \left(\frac{N_2 \ln(4N_1/D) - N_1 \ln(4N_2/D)}{\ln(4N_2/D)\ \ln(4N_1/D)} \right) \tag{13}$$

The transport (neglecting end effects) to/from a horizontal rod of length L buried at a depth N from the ground surface can be determined from:[11]

$$Q_h = \frac{2\pi k L \phi}{\ln[(2N/D) + \sqrt{(2N/D)^2 - 1}]} \tag{14}$$

Equation (13) provides the flow response to a vacuum applied to a vertical vapor extraction well of diameter D screened from depth N_1 to depth N_2; equation (14) provides the flow response to a vacuum applied to a horizontal well of screen length L and diameter D installed at a depth N below the surface. A vented trench which is much deeper than it is wide can be represented by the equation for transport to/from a buried vertical sheet. In practice, however, the width and depth of vented trenches are almost always similar (since trenches are used almost exclusively for shallow SVE applications), and equation (14) can be used to represent the trench with D taken to be the effective diameter of the trench, D_{eff}:

$$D_{eff} = 2\sqrt{wh/\pi} \tag{15}$$

where w = width of the trench
h = thickness of gravel-filled portion of the trench

If a conventional pilot test has been performed, equations (13) and (14) can be used to predict the vacuum/flow response for SVE systems of geometries which differ from the pilot test well/trench. For example, by dividing equation (14) by equation (13), the results of a pilot test performed on a vertical well (diameter D_v, screened from N_{v1} to N_{v2} below grade) can be extrapolated to a horizontal well (diameter D_h, length L, installed at a depth N_h below the surface):

$$\frac{Q_h}{Q_v} = \frac{\phi_h}{\phi_v}\left(\frac{\ln(4N_{v2}/D_v)\ \ln(4N_{v1}/D_v)}{N_v\ln(4N_{v1}/D_v) - N_{v1}\ln(4N_{v2}/D_v)}\right)\left(\frac{L}{\ln[(2N_h/D_h) + \sqrt{(2N_h/D_h)^2 - 1}]}\right) \tag{16}$$

where Q_h = soil gas flow collected by horizontal well
Q_v = soil gas flow collected by vertical well in the pilot test
ϕ_h = vacuum applied to horizontal well
ϕ_v = vacuum applied to vertical well in the pilot test

Similarly, the performance of vertical and horizontal wells of various diameters and screened intervals also can be assessed. The validity of equation (16) has been demonstrated in case studies in which conventional vertical pilot tests were scaled up to horizontally drilled wells and to vented trenches.[12]

This approach assumes that the horizontal and vertical air permeability of the soil matrix are comparable, a condition which is not always met in stratified formations. If the ratio of the horizontal and vertical permeabilities, k_h/k_v, is known, compensating for differing horizontal and vertical permeabilities requires multiplying all values for depth below grade by this ratio. For example, equation (16) would become

$$\frac{Q_h}{Q_v} = \frac{\phi_h}{\phi_v}\left(\frac{\ln(4kN_{v2}/D_v)\ \ln(4kN_{v1}/D_v)}{kN_{v2}\ln(4kN_{v1}/D_v) - kN_{v1}\ln(4kN_{v2}/D_v)}\right)\left(\frac{L}{\ln[(2kN_h/D_h) + \sqrt{(2kN_h/D_h)^2 - 1}]}\right) \tag{17}$$

where $k = k_h/k_v$

DISCUSSION

The equations derived above provide a basis for design of effective SVE systems based on data routinely obtained from conventional SVE pilot tests. Examination of these equations lead to some conclusions regarding SVE design which are not immediately obvious.

Equations (8) and (9) indicate that for a fixed cleanup level, changes in vapor extraction rate (Q°), cleanup time (t), and depth of the vented interval (h) will not effect the effective radius so long as $Q^{\circ}t/h$ remains constant. In other words, the same system performance can be obtained in half the time by doubling the vapor extraction rate or halving the depth of the vented interval.

Figure 7 shows an example of how single-well effective radius varies with $Q^{\circ}t/h$ for a variety of common volatile soil contaminants (where cleanup is defined as 90% removal; ideal soil-vapor partitioning and an unsealed surface are assumed). The conditions in this example are typical for SVE systems, and the resulting effective radius varies from a few feet to as much as 70 feet. Effective radius is most sensitive to the volatility of the contaminant; the effective radius for weathered gasoline is 3 to 10 times less than for 1,1,1-trichloroethane under the same conditions. Large changes in $Q^{\circ}t/h$ are required to substantially affect effective radius, especially for the more volatile contaminants; doubling the effective radius generally requires increasing $Q^{\circ}t/h$ by a factor of 10 to 50.

The above derivation distinguishes between the single-well effective radius, R_E, and the interwell effective radius, R_{EI}. Since R_{EI} is always less than R_E, an optimum SVE system design often will place vapor extraction wells closer to each other than to the edge of the plume. In other words, bunching vapor extraction wells in the middle of the site often provides more uniform remediation than distributing well evenly throughout the site. In extreme cases where horizontal permeability greatly exceeds vertical permeability, timely remediation between wells is not possible without air injection, regardless of well spacing.

Equation (11) indicates that, for a given applied vacuum and vapor extraction well construction, the flow per well in a multiple-well system is always less than flow in a single-well system. This difference can be dramatic, depending on the well spacing and relative horizontal-to-vertical permeability. Neglecting the competition for air between wells in multiple-well systems will therefore result in unnecessary costs due to oversized vapor extraction blowers and offgas treatment technology.

LIMITATIONS

While the above discussion provides the basis for a useful design tool, it is not applicable to all SVE situations without qualification. The simplifying assumptions which provide the ease of calculation also contribute to the uncertainty in the result. For example, the actual resistance to air flow provided by the soil matrix may be non-uniform due to subsurface anisotropies and anthropogenic structures (sewers, foundations, etc.). Unfortunately, site data are often inadequate to characterize fully such features. This design tool may be useful as a basis for design, but SVE installations must be executed with sufficient flexibility to enable compensation for such unidentified features.

This derivation is applicable to SVE systems with any well construction, number of wells, or well orientation. While it presumes an unsealed surface, it can be readily extended to sites with an engineered surface seal. However, because it assumes the vadose zone conditions to be uniform with depth, caution should be exercised when applying this model to SVE systems venting strata greater than about 30 feet below grade. In addition, this design tool is not appropriate when vertical infiltration of air through the ground surface is virtually non-existent. Such a situation would arise during venting of a high permeability stratum underlying an extensive, substantial, and continuous stratum of much lower permeability. Fortunately, such situations occur only rarely, and they can be modeled effectively using the sealed surface approach taken by Johnson, et al.[6,13]

CONCLUSIONS

A set of equations has been developed which can facilitate design of effective SVE systems using data routinely obtained from conventional SVE pilot tests. This approach can be used to (1) estimate the effective cleanup radius; (2) design multiple-well SVE systems based on a single-well pilot test; and (3) design horizontal SVE systems based on pilot tests performed on vertical wells. The design tool facilitates more accurate estimates of blower sizing, offgas treatment selection, and well spacing requirements.

The design tool is based on a simple model which uses analytical rather than numerical methods, and so is simpler, faster, more versatile, and more robust then more sophisticated, multi-dimensional models. Although accuracy and resolution are somewhat reduced, the use of this model instead of more complicated approaches is generally justified given the limited site characterization data ordinarily available and the subsurface anisotropies commonly encountered at most small SVE sites.

Although widely applicable, the design tool should be used with some caution when the vadose zone is highly stratified or when venting contaminated soil greater than 30 feet below grade. This approach has been implemented in a proprietary computer program, VENT-ROI, which Groundwater Technology, Inc. has been using routinely since 1992 for rapid and effective design of SVE systems.

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FIGURE 1

TYPICAL VERTICAL IN-SITU SOIL VAPOR EXTRACTION DESIGN

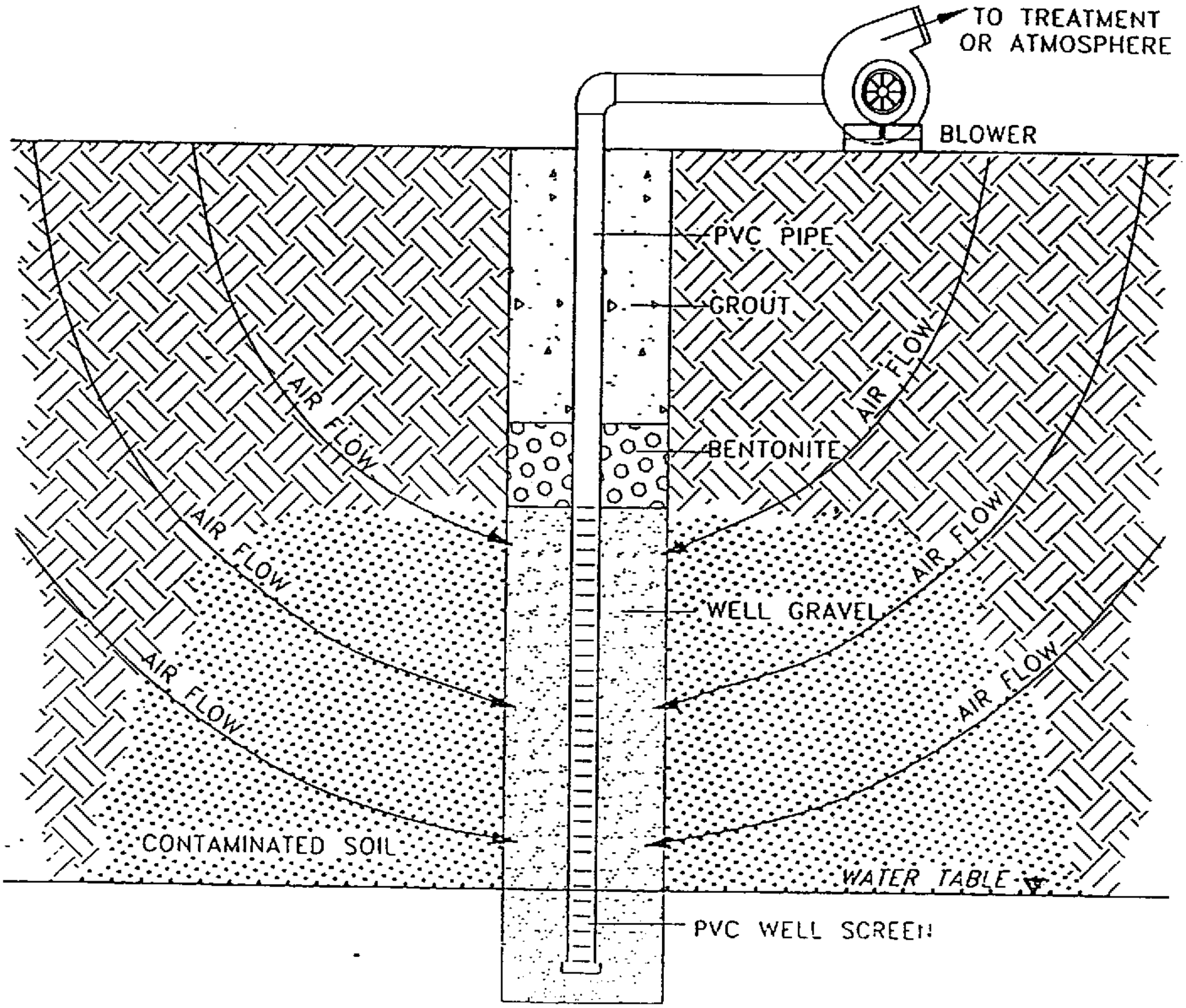


FIGURE 2

TYPICAL HORIZONTALLY DRILLED SOIL VAPOR EXTRACTION WELL

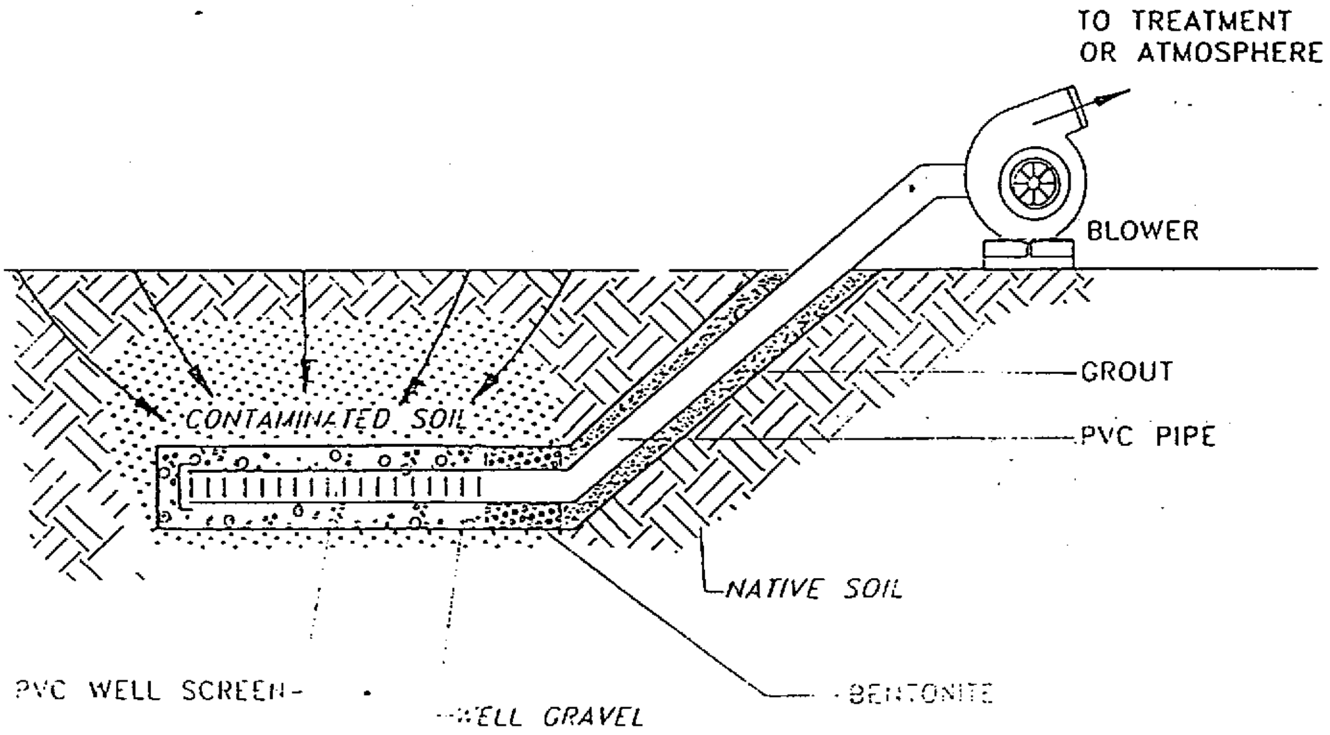
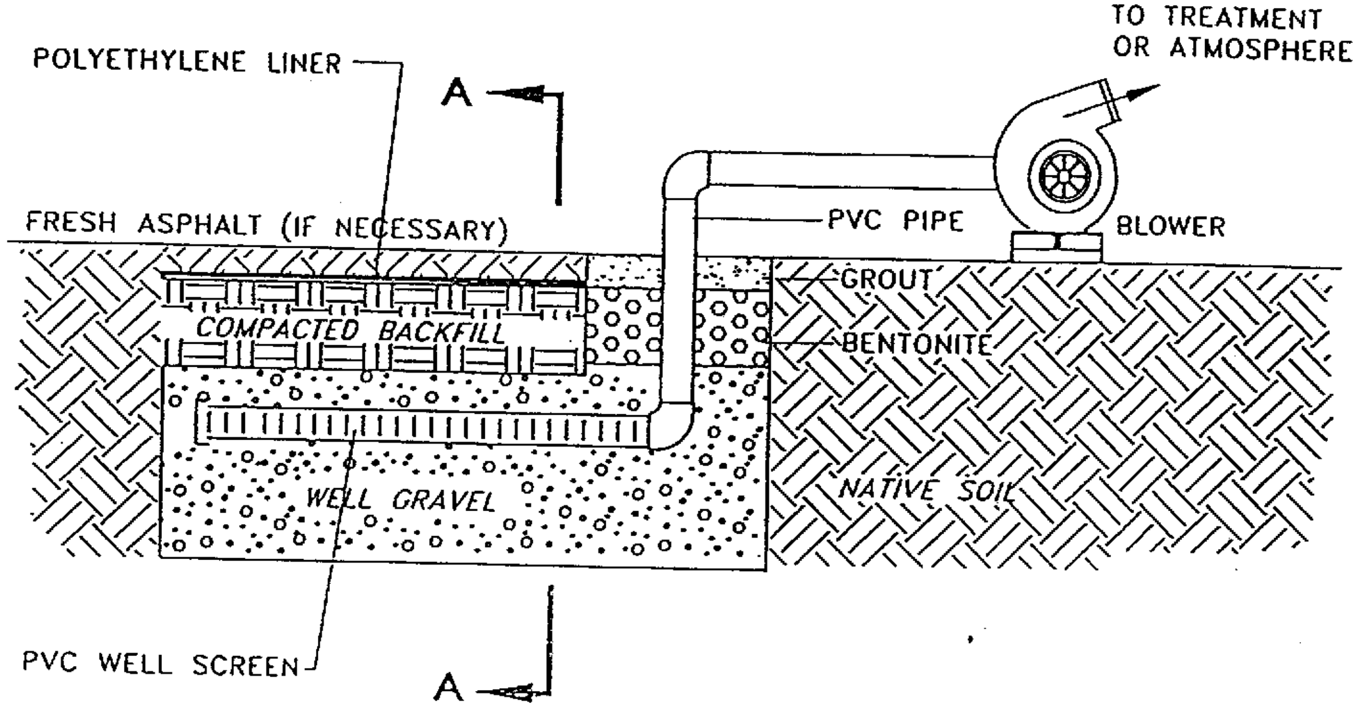
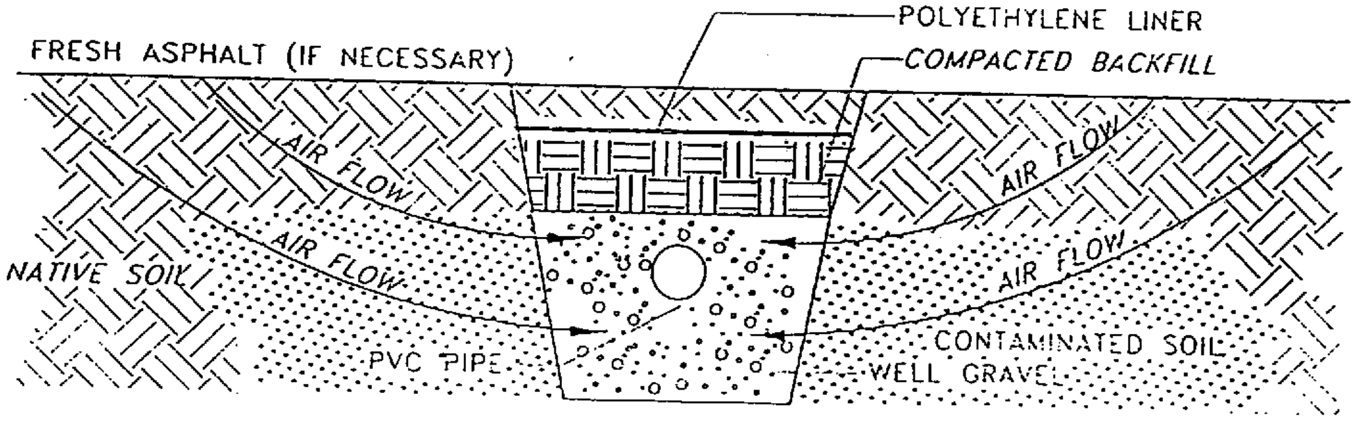


FIGURE 3

TYPICAL HORIZONTAL IN-SITU SOIL VAPOR EXTRACTION DESIGN





TRENCH CROSS-SECTION A-A

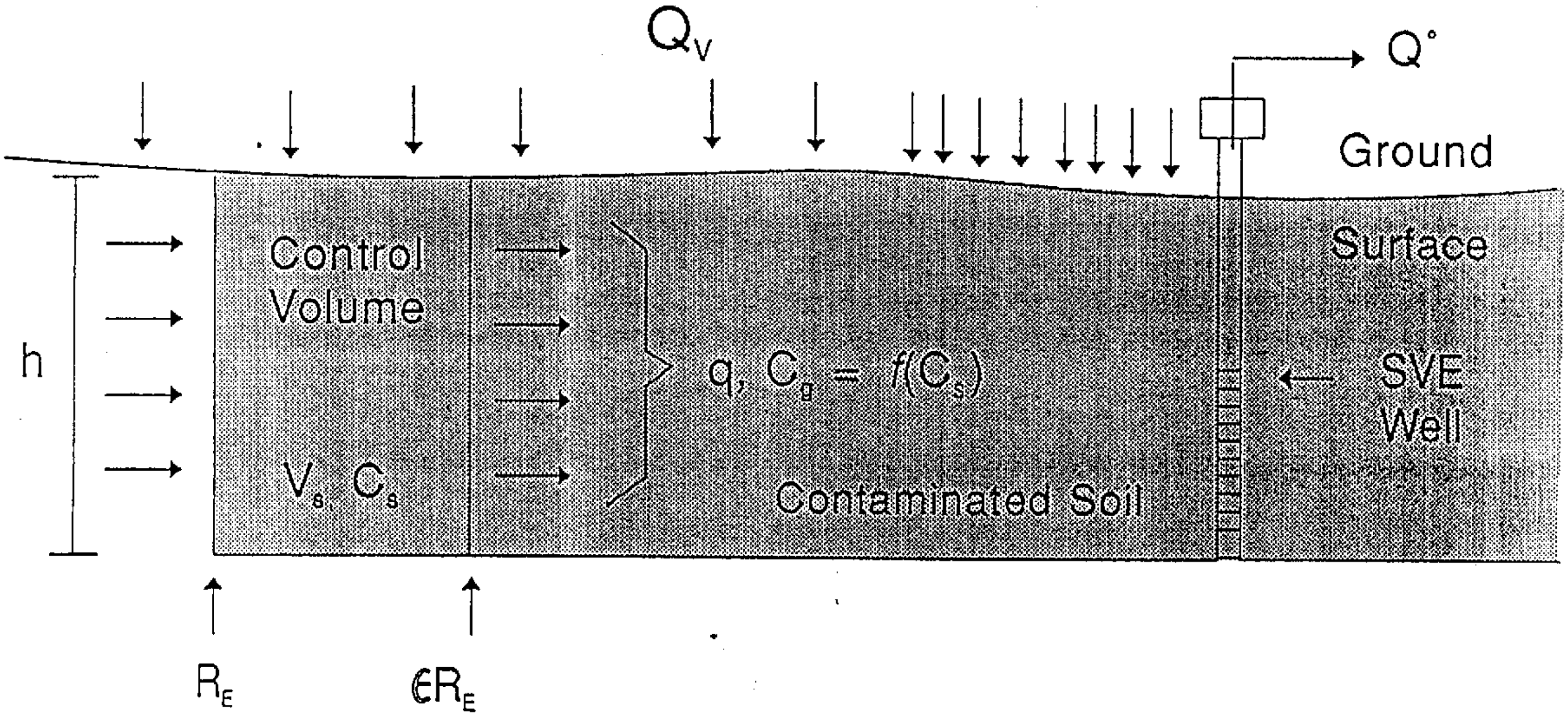
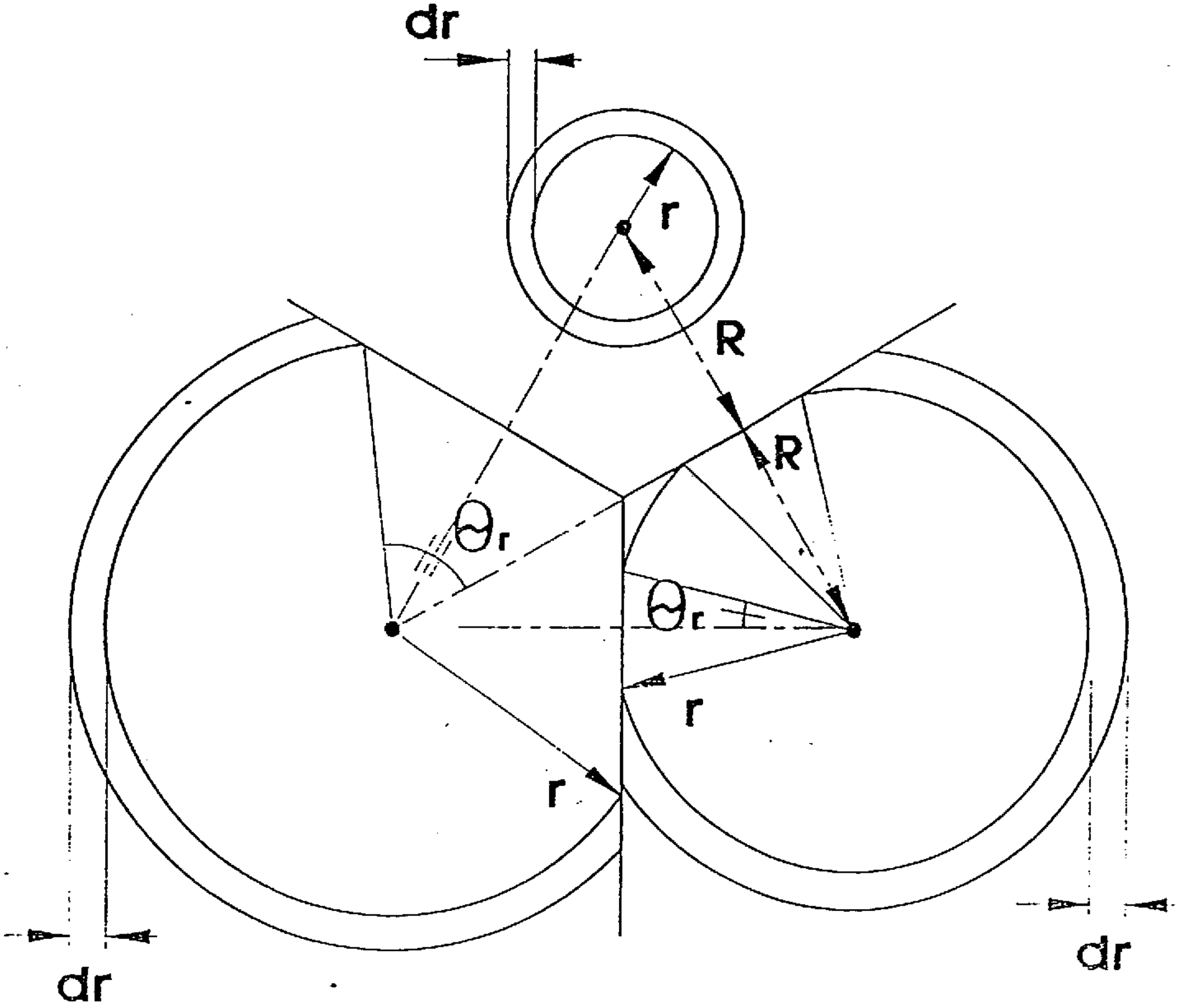


Figure 4: Conceptualization of the model. The system is to be designed such that the effective radius, R_E, corresponds to the extent of contamination. Clean air enters the contaminated zone by horizontal movement through the soil and by vertical infiltration through the ground surface. The overall cleanup time is dominated by the remediation rate for the contaminated soil between $\in R_E$ and R_E ("control volume"), which is determined by the air flow rate, q, through this portion of the contaminated zone.

P:\WENSKEVI\HGDATA\BASS\AIRFLOW3

FIGURE 5

Modeling competition for air infiltrating the ground surface between three vapor extraction wells (.), placed in an equilateral triangle with spacing 2R. The capture zone for each well is bounded by the locus of points equidistant from each pair of adjacent wells.

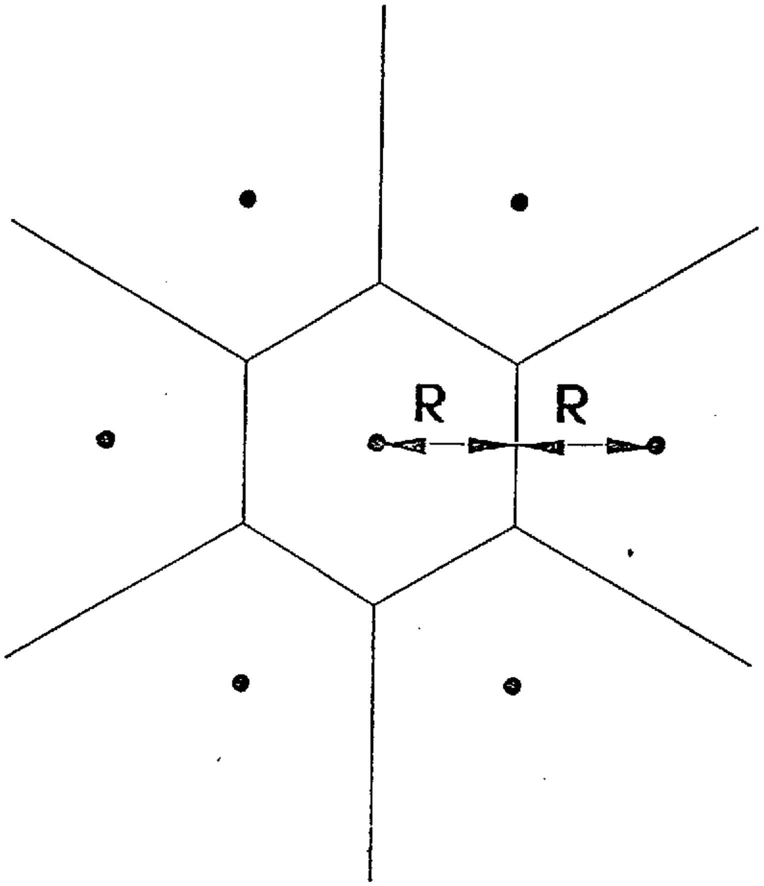


KEY

● – VAPOR EXTRACTION WELL

FIGURE 6

A Hexagonal Array of Seven Vapor Extraction Wells



KEY

● – VAPOR EXTRACTION WELL

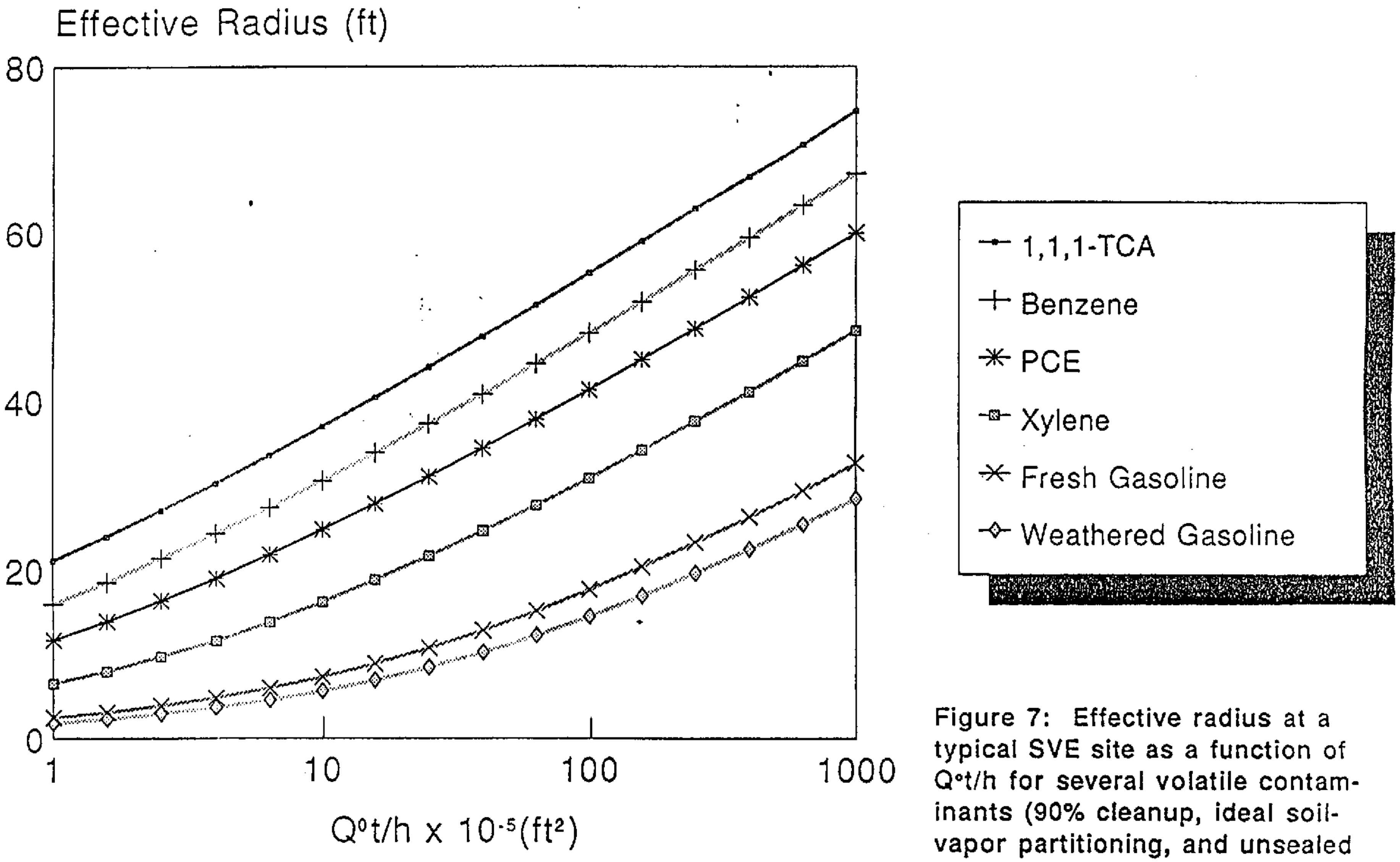


Figure 7: Effective radius at a typical SVE site as a function of $Q^{o}t/h$ for several volatile contaminants (90% cleanup, ideal soil-vapor partitioning, and unsealed surface assumed).

P:\WENSKEVI\HGDATA\BASS\FIG4A

APPENDIX F

BIOTREATABILITY LABORATORY TEST REPORT

FLUOR DANIEL GTI

April 4, 1997

Mr. Mike Wray
Fluor Daniel GTI, Inc.
757 #D Arnold Drive
Martinez, CA 94553

Re: Sears Store 1058 - Oakland, CA
RTTF Project - 001000068

Dear Mr. Wray:

This report presents the findings of the bench-scale treatability studies performed by the Fluor Daniel GTI Remediation Technology Testing Facility (RTTF) on soil and groundwater samples received from the Sears Store 1058 site in Oakland, California. The site previously contained underground tanks in which motor oil, gasoline and used motor oil were stored. Vadose and saturated soils as well as groundwater were found to be impacted with these petroleum products.

As part of evaluating suitable remediation technologies for the site, the RTTF was contracted to conduct a laboratory bench-scale study to evaluate the overall feasibility of using bioremediation under both aerobic and anaerobic (denitrifying) conditions. Aerobic conditions are expected to be present in the site vadose zone, especially in areas when soil vapor extraction is also occurring. Anoxic or anaerobic conditions are frequently found in the saturated zone of sites containing readily biodegradable materials.

The Scope of Work to be performed by the RTTF included: (1) an initial chemical and biological characterization of composited site soil and groundwater; (2) an aerobic biodegradation test; (3) an anaerobic biodegradation test; and (4) a nutrient adsorption test. Descriptions of the tests performed, results and conclusions appear in the sections below.

INITIAL CHARACTERIZATION OF SITE SOILS AND GROUNDWATER

Five liters of site groundwater and eight 8-ounce containers of site soil samples were received at the RTTF on June 18, 1996 under Chain of Custody numbers 35108 and 35118. A copy of the Chain of Custody forms is included in Appendix A.

Initial characterization testing is used to ensure that the contaminants and concentrations to be used in the bench-scale tests are representative of known field conditions. Total petroleum hydrocarbons (TPH) as motor oil was chosen as the target contaminant for monitoring during the aerobic and anaerobic biodegradation tests.

The soil samples were composited upon receipt prior to testing, and visually appeared to be a dark brown clay soil. The clay content of the soil sample made it very difficult to blend thoroughly. Composited soil samples were analyzed for total organic carbon (TOC), total petroleum hydrocarbons (TPH) as motor oil, ammonia-nitrogen, nitrate-nitrogen, orthophosphate-phosphorus, total phosphorus, pH, total heterotrophic bacteria (THB), and contaminant-utilizing bacteria (CUB) using motor oil as the sole carbon source. A copy of the Chain of Custody form for contracted analytical work is included in Appendix A, and a copy of the laboratory report is included in Appendix B. All initial characterization results are presented in Table 1.

A composited groundwater sample was analyzed for total petroleum hydrocarbons (TPH) as motor oil, ammonia-nitrogen, nitrate-nitrogen, orthophosphate-phosphorus, total phosphorus, pH, total heterotrophic bacteria (THB), and contaminant-utilizing bacteria (CUB) using motor oil as carbon source. A copy of the Chain of Custody form for contracted analytical work is included in Appendix A, and a copy of the laboratory report is included in Appendix B. All initial characterization results are presented in Table 1.

Site soils contained a concentration of heterotrophic bacteria (1.3 x 10^5 CFU/g) within the range typically observed with soils (1 x 10^4 to 1 x 10^7); approximately 10% of this population had the ability to use motor oil as a sole source of carbon and energy. The soils had a pH of 7.9, also within the range typically favorable for microbial growth (6 to 8). Inorganic nutrient levels were low for ammonia (below the detection limit of 5 mg/Kg). Adequate amounts of soluble nitrate-nitrogen (27 mg/Kg), total phosphorus (82 mg/Kg) and soluble orthophosphate (7.5 mg/Kg) were also observed. The TOC and TPH values of the soil (3,100 and an average of 730 mg/kg, respectively) are sufficiently high enough to provide carbon sources for microbial growth.

Site groundwater contained a concentration of heterotrophic bacteria (1.1 x 10^4) within the range typically observed with groundwater (1 x 10^3 to 1 x 10^5); approximately 80% of this population had the ability to use motor oil as a sole source of carbon and energy. The soils had a pH of 7.3, also within the range typically favorable for microbial growth (6 to 8). Inorganic nutrient levels were low for both forms of nitrogen (ammonia at less than 0.3 mg/L and nitrate at 0.09 mg/L), as well as total phosphorus (0.31 mg/L) and orthophosphate (0.25 mg/L). The average (of two analyses) TPH concentration of the groundwater was 65 mg/L, again sufficiently high to serve as a carbon source for microbial growth.

In general, the site soils and groundwater had TPH concentrations high enough to serve as food sources but below levels typically causing microbial inhibition and/or toxicity. An increase in nutrient levels (ammonia for aerobic treatment and nitrate for anaerobic treatment) may be required in order to generate a significant increase in beneficial biological activity.

The contaminant concentrations observed in the site samples were deemed to be representative of site conditions, and the biotreatability studies were begun. The available volume of site groundwater was reduced performing the initial characterization tests, and a total working volume of eight liters was desired for set-up of the aerobic and anaerobic tests. To overcome this limitation, four liters of site groundwater were mixed with four liters of deionized water to make a working liquid volume of eight liters of water.

AEROBIC BIODEGRADATION TEST

Aerobic biodegradation can be limited by the concentration of nutrients, oxygen and contaminants present as well as the chemical structure of the contaminants. To account for these factors, biotreatability experiments are frequently designed to determine whether biodegradation can occur under different sets of environmental conditions. Three such conditions were tested in this experiment: (1) nutrified conditions, in which supplemental inorganic nutrients were added; (2) unamended conditions, in which supplemental nutrients were not added; and (3) poisoned conditions, in which a microbial poison is added as a control in order to differentiate between biotic and abiotic losses occurring during the study.

Biodegradation progress during the aerobic biodegradation study was monitored by following changes in the concentration of TPH present, using motor oil as the reference standard. TPH concentrations were expected to show moderate to high variability due to difficulties in initially uniformly homogenizing the clay soils as well as extracting the soil/water slurries. For example, the composited soil used in the initial characterization was analyzed in triplicate, and gave concentrations of 1,038, 494 and 652 mg/Kg. The groundwater showed much less variability, with the two initial characterization analyses having concentrations of 61 and 69 mg/L.

Set-up: The aerobic microcosms for each of the three test conditions were created by adding five grams of soil to 50 ml of diluted groundwater in 165 mL glass bottles. The remaining 115 mL volume consisted of room air in order to supply oxygen to the slurry. Microcosms with supplemental nutrients received aliquotes of a concentrated stock nutrient solution, resulting in a final ammonia-nitrogen concentration of 25 mg/L and a final orthophosphate-phosphorus concentration of 22 mg/L per bottle. Poisoned bottles received mercuric chloride to a final concentration of 0.3%. Each bottle was sealed using a rubber septa and aluminum crimp cap. To ensure constant soil/water contact the slurry bottles were maintained on a platform shaker throughout the study. Bottles were incubated at room temperature (approximately 20°C).

Monitoring: Individual microcosm bottles were sacrificed in duplicate for TPH analysis on days 0, 15, 30, 45, and 60. The concentration of contaminant-utilizing bacteria (CUB) and total heterotrophic bacteria (THB) were also determined on days 0 and 60. All of these analyses were performed in-house by RTTF staff.

Results and Conclusions of the Aerobic Biodegradation Study: In reviewing biotreatability data it is important to directly review not only the concentrations of target compounds over time but supporting information such as changes in microbial numbers. It is also important to keep in mind the type and concentration of target compounds used in the test. Higher molecular weight petroleum compounds such as motor oils tend to biodegrade slower that lighter petroleum products such as BTEX. For slow to degrade compounds, the time needed for reduction trends to become evident may require four to six months or more.

Table 2 presents the TPH analytical results generated during the aerobic biotreatability study. As expected based on the results on the initial characterization TPH tests, their analysis exhibited significant concentration variability. For example, the six bottles analyzed on Day 0 were expected to yield similar

TPH concentrations. Instead, the six concentrations ranged from a low of 913 mg/Kg to a high of 2,170 mg/Kg, with an average concentration of 1,467 mg/Kg. TPH concentrations ranged from these test conditions ranged from a low of 593 mg/Kg to a high of 2,415 mg/Kg over the next 60 days of the test.

Because of this variability, the data obtained was initially reviewed for major trends. Average TPH concentrations decreased in the nutrified system and increased in the unamended and poisoned systems. It is not uncommon to observe a transient increase in hydrocarbon concentrations during biodegradation tests due to the biological production of surfactants which solubilize TPH from soils and thereby increase their extraction and quantitation efficiency. As the microbial population increases, biological activity then reduces the concentration of hydrocarbons. Thus the nutrified condition showed a decrease in TPH concentration over the 60 days of the test, but TPH concentration variability makes it difficult to draw specific conclusions as to what percent reduction was actually obtained.

In order to reduce the significance of the analytical variability, another approach was used to evaluate the data. Rather than evaluating the average concentration of TPH occurring for each condition per time point, all eight analyses per condition (days 15, 30, 45 and 60) were averaged and compared to the Day 0 average concentration. Using this evaluation method, the nutrified condition concentrations decreased from 1,467 mg/Kg to 1,226 mg/Kg, the unamended condition concentrations increased from 1,467 mg/Kg to 2,063 mg/Kg, and the poisoned condition concentrations increased from 1,467 mg/Kg to 1,860 mg/Kg. This data interpretation again supports the benefits of additional inorganic nutrients.

While trends in TPH concentrations were difficult to discern, the supporting bacterial plate count numbers from the beginning and end of the test did show obvious trends. Table 3 presents the THB and CUB results. Over the 60 day test period, the concentration of total heterotrophic bacteria in the nutrified microcosms increased five-fold, compared to a two-fold increase in the unamended system and no noticeable increase in the poisoned controls. The CUB results were even more striking in that the nutrified colony counts increased 33-fold compared to no change in the unamended and poisoned systems. The plate count results support the previous findings that enhanced biological activity was occurring under nutrient amended conditions, while to a lesser extent biological activity was also occurring in the unamended test conditions. The poisoned control flasks also responded as expected, showing significant decreases in viable microbial numbers and subsequently little to no reduction in TPH concentrations.

Because of the limited solubility of motor oil components as well as their typically lower biodegradation rates, extending the study for an additional few months may have made any underlying trends in contaminant reduction easier to observe. Since this was not possible, it is reasonable to conclude that under the aerobic test conditions used nutrient addition did have a beneficial influence on biological activity. The exact amount of biodegradation occurring is difficult to ascertain because of the variability in the TPH concentrations, but a reduction of 10 to 30% would be a conservative estimate. THB and CUB data also support the conclusion that biological activity is enhanced in the nutrified systems.

ANAEROBIC BIODEGRADATION TEST

A second bioremediation option at the site is to use anoxic or anaerobic biological activity to destroy specific contaminants present. This option was evaluated in the laboratory by constructing microcosms with low initial oxygen concentrations. As incubation continued, any aerobic biological activity occurring was expected to quickly deplete the limited supply of free oxygen and create anaerobic conditions. In this anaerobic condition, nitrate could be used as a terminal electron acceptor instead of the oxygen used under aerobic conditions.

Set-up: The anaerobic microcosms were created by adding five grams of soil to 165 mL glass bottles. The remaining volume of each bottle was then filled with the diluted groundwater. Only two different environmental conditions were tested: nutrified and poisoned. Microcosms with supplemental nutrients received aliquotes of a concentrated stock nutrient solution, resulting in a final ammonia-nitrogen concentration of 25 mg/L and a final orthophosphate-phosphorus concentration of 22 mg/L per bottle. Poisoned bottles received mercuric chloride to a final concentration of 0.3%. Each bottle was sealed using a rubber septa and aluminum crimp cap. Bottles were inverted and incubated in the dark at room temperature (approximately 20°C) without shaking.

Monitoring: Individual microcosm bottles were sacrificed in duplicate for TPH analysis on days 0, 20, 45, 60 and 83. The concentration of total aerobic heterotrophic bacteria (THB) were also determined on days 0 and 83. All of these analyses were performed in-house by RTTF staff.

Results and Conclusions of the Anaerobic Biodegradation Study: Because of the reduced amount of energy available per unit of substrate consumed under anaerobic conditions compared to aerobic conditions, anaerobic biodegradation tends to be a slower process. For this and the TPH analytical variability issues already discussed, trends in the anaerobic study were expected to be more difficult to observe in spite of the fact that the anaerobic experiment lasted a total of 83 days.

Table 4 presents the TPH analytical results generated during the anaerobic biotreatability study. TPH monitoring results continued to exhibit significant concentration variability. The four supposedly identical concentration bottles analyzed on Day 0 exhibited TPH concentrations ranging from a low of 485 mg/Kg to a high of 1,650 mg/Kg, with an average concentration of 1,028 mg/Kg. TPH concentrations ranged from a low of 780 mg/Kg to a high of 2,794 mg/Kg over the next 83 days of the test.

The data obtained was initially reviewed for major trends. Lower TPH concentrations were more frequently observed in the nutrified microcosms, but no clear-cut trend over time was seen with either the nutrified or poisoned systems.

In order to reduce the significance of the analytical variability, another approach was used to evaluate the data. Rather than evaluating the average concentration of TPH occurring in each condition per time point, all eight analyses per condition (days 0, 20, 45, 60 and 83) were averaged and compared to the Day 0 average concentration. Using this evaluation method, the nutrified condition concentrations increased from 1,028 mg/Kg to 1,264 mg/Kg, while the average poisoned condition concentrations increased from

1,028 mg/Kg to 2,157 mg/Kg. While the addition of nutrients appears to be favorable, the ambiguity in TPH results cautions against concluding that anaerobic biological activity is occurring to any great extent.

The supporting aerobic THB plate count numbers shown in Table 5 from the beginning and end of the anaerobic test demonstrate again that the mercuric chloride added to the poisoned microcosms was effective in reducing viable microbial activity. The nutrified plate counts show an approximately 20-fold reduction in viable colony forming units over the 83 day test. One explanation of this result is that under strict anaerobic conditions many of the microorganisms originally present in the site soil and groundwater were unable to survive and flourish. Initially selecting for microorganisms able to grow under anoxic/anaerobic conditions, then plating these organisms under aerobic conditions may also under-represent the number of viable microorganisms present. The plate count results alone are inconclusive as to whether significant anaerobic biological activity is occurring.

Because of the limited solubility of motor oil components as well as their typically lower biodegradation rates under anaerobic conditions, extending the study for an additional few months may have made any underlying trends in contaminant reduction more obvious. Based on the results obtained, the benefit of using anaerobic bioprocesses to treat motor oil is inconclusive.

NUTRIENT ADSORPTION TEST

Since the addition of nutrients to the aerobic microcosms appears to aid in stimulating biodegradation, it is reasonable to assume that inorganic nutrients may be used in any full-scale bioremediation project. Ammonia-nitrogen and orthophosphate-phosphorus are not only removed in the saturated and vadose zones due to biological activity, they may also adsorb to soil particles as the nutrients move through the subsurface. If high amounts of nutrients are adsorbed, larger initial amounts of the chemicals will need to be used to ensure that nitrogen and phosphorus are available to microorganisms throughout the site.

The Nutrient Adsorption Test is designed to quickly assess the amount of ammonia-nitrogen and orthophosphate capable of being adsorbed to site soils. The test brings different masses of wet-weight soil in contact with distilled water containing known concentrations of ammonia-nitrogen and total phosphate for 24 hours. The soil is then removed from solution by centrifugation, and the supernatent tested to determine the ammonia-nitrogen and total orthophosphate concentrations remaining.

Results from the test are shown in Table 6. The last column presents the milligrams of nutrient adsorbed per dry kilogram of site soils. The highest number from the table for each nutrient represents the worst-case scenario for nutrient adsorption. For ammonia-nitrogen, the maximum concentration of adsorbed nutrients lies between 6,000 and 9,250 mg/Kg. For total phosphate, the maximum concentration of adsorbed nutrients lies between 37,620 and 70,250 mg/Kg.

CONCLUSIONS

Site soils and groundwater submitted to the RTTF were used in biotreatability and nutrient adsorption tests. Biodegradation effectiveness was monitored directly by following changes in TPH concentrations using motor oil as the reference standard. While the hydrocarbons collectively making up motor oil are believed to be biodegradable, their low solubility in water and relatively low biodegradation rates may limit their disappearance from treatability studies of relatively short duration.

While TPH measurements as motor oil showed significant variability in both the aerobic and anaerobic biodegradation tests, decreasing overall average TPH levels and increasing microbial plate counts from nutrified aerobic microcosms suggest that the addition of inorganic nutrients in the field would significantly improve the potential for aerobic biodegradation. Anaerobic microcosms, also nutrified and compared to poisoned controls, did not demonstrate clear effectiveness, and results from these tests are best considered inconclusive. Additional testing time may be required before unambiguous trends are observed.

The nutrient adsorption test confirmed that the site soils do not already contain high levels of soluble ammonia-nitrogen and total phosphorus. The site soils have the ability to adsorb up to 9,250 mg/Kg of ammonia-nitrogen and 70,250 mg/Kg total phosphate under idealized conditions. The amount of ammonia-nitrogen and total phosphate adsorbed under field conditions is expected to be less than that obtained with this laboratory test.

If you have any questions or need additional information, please do not hesitate to contact me at 609-587-0300.

Sincerely,
Fluor Daniel GTI, Inc.

Geo J. Skladany
George J. Skladany
Director, RTTF

Table 1
Initial Soil and Groundwater Characterization

Analysis	Methodology	Results	
		Soil	Groundwater
Contaminant Screening (mg/Kg for soils and mg/L for water)			
Total Organic Carbon (TOC)	CFA S:18.0	3,100	Not Analyzed
Total Petroleum Hydrocarbons (TPH)[1]	EPA 8015 modified	730 (average of three)	65 (average of two)
Background Nutrient Concentrations (mg/Kg for soil and mg/L for water)			
Ammonia-Nitrogen	EPA 350.1	<15	<0.3
Soluble Nitrate-Nitrogen	EPA 353.1	27	0.09
Total Phosphorus	EPA 365.4	82	0.31
Soluble Orthophosphate	EPA 365.3	7.5	0.25
Other Chemical Properties			
pH	SM 4500-H$^+$	7.9 pH units	7.3 pH units
Microbiological Screening (CFU x 10,000/g for soil and CFU x 10,000/ml for water)[2]			
Total Heterotrophic Bacteria (THB)	SM 9215 C (modified)	13	4.9
Contaminant Utilizing Bacteria (CUB)[3]	SM 9215 C (modified)	1.1	3.9

1 - Gas chromotography by flame ionization detection
2 - CFU = colony forming units
3 - Motor oil used as carbon source

Table 2
Aerobic Biodegradation Study:
Total Petroleum Hydrocarbon by GC/FID (mg/Kg)

System	Day 0	Day 15	Day 30	Day 45	Day 60
Nutrified	2170	823	653	593	832
	1665	1680	2415	1456	1350
	*1467 ave.**	*1252 ave.*	*1534 ave.*	*1025 ave.*	*1091 ave.*
Unamended	1050	2280	1785	3038	1693
	1815	1560	1856	2138	2149
	*1467 ave.**	*1920 ave.*	*1821 ave.*	*2588 ave.*	*1921 ave.*
Poisoned	913	1530	1695	2574	923
	1184	1718	2093	2063	2280
	*1467 ave.**	*1624 ave.*	*1894 ave.*	*2319 ave.*	*1602 ave.*

* Average of all six "Day 0" analyses.

Table 3
Aerobic Biodegradation Study:
Bacteria Enumeration

System	Day 0	Day 60
Total Heterotrophic Bacteria (THB) (CFU x 10,000/mL of slurry)		
Nutrified	38	190
Unamended	33	68
Poisoned	<0.01	<0.01
Contaminant Utilizing Bacteria (CUB) - Motor Oil (CFU x 10,000/ml of slurry)		
Nutrified	3.6	120
Unamended	30	31
Poisoned	<0.01	<0.01

Table 4
Anaerobic Biodegradation Study:
Total Petroleum Hydrocarbon by GC/FID (mg/Kg)

System	Day 0	Day 20	Day 45	Day 60	Day 83
Nutrified	1226	905	1470	1300	1058
	773	1995	1116	780	1485
	*1028 ave.**	*1450 ave.*	*1293 ave.*	*1026 ave.*	*1272 ave.*
Poisoned	485	1290	2195	2090	2156
	1650	2188	2794	2023	2473
	*1028 ave.**	*1739 ave.*	*2495 ave.*	*2057 ave.*	*2,315 ave.*

* Average of all six "Day 0" analyses.

Table 5
Anaerobic Biodegrdation Study:
Bacteria Enumeration

System	Day 0	Day 83
Total Heterotrophic Bacteria* (CFU x 10,000/ml of slurry)		
Nutrified	130	6.5
Poisoned	<0.01	<0.01

* All plates were incubated aerobically.

Table 6
Nutrient Adsorption Test

Sample	Ammonia-nitrogen (mg adsorbed per Kg)	Total Phosphate (mg adsorbed per Kg)
0.5 g Soil + N and P	6,000	70,250
1.0 g Soil + N and P	9,250	37,620
2.0 g Soil + N and P	4,625	18,810
5.0 g Soil + N and P	2,100	8,000
10 g Soil + N and P	1,050	4,000
20 g Soil + N and P	619	2,000

GTEL RTL
ENVIRONMENTAL LABORATORIES, INC.

408[redacted]E LA[redacted]UIT[redacted]
CONCORD, CA 94520
(510) 685-7852
(800) 423-7143

RTL

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

35108

Company Name: Fluor Daniels GTI
Phone #: (510) 370 3990
FAX #: (510) 370 3991
Company Address: 757-D Arnold Dr. Martinez CA
Site Location: 2600 Telegraph OAKLAND CA
Project Manager: Mike Wray
Client Project ID: (#) 020200136
(NAME) SEARS Telegraph
I attest that the proper field sampling procedures were used during the collection of these samples.
Sampler Name (Print): Terry JAMES

Field Sample ID	GTEL Lab # (Lab Use only)	# CONTAINERS	Matrix: WATER	Matrix: SOIL	Matrix: AIR	Matrix: SLUDGE	Matrix: PRODUCT	Matrix: OTHER	Method Preserved: HCl	Method Preserved: HNO₃	Method Preserved: H₂SO₄	Method Preserved: ICE	Method Preserved: UNPRESERVED	Method Preserved: OTHER (Specify)	Sampling: DATE	Sampling: TIME
3	T7506-1	1		X								X	X		6/11	805
6	T7506-2															845
9	-3															850
12	-4															855
15 high OVM	-5															900
18 high OVM	-6															1000
21 ✓	-7															1020
23 high OVM	T7506-8															1040
~~comp~~																~~1020~~

ANALYSIS REQUEST / OTHER

Field Sample ID	BTEX 602 ☐ 8020 ☐ with MTBE ☐	BTEX/Gas Hydrocarbons PID/FID ☐ with MTBE ☐	Hydrocarbons GC/FID Gas ☐ Diesel ☐ Screen ☐	Hydrocarbon Profile (SIMDIS) ☐	Oil and Grease 413.1 ☐ 413.2 ☐ SM-503 ☐	TPH/IR 418.1 ☐ SM 503 ☐	EDB by 504 ☐ DBCP by 504 ☐	EPA 503.1 ☐ EPA 502.2 ☐	EPA 601 ☐ EPA 8010 ☐	EPA 602 ☐ EPA 8020 ☐	EPA 608 ☐ 8080 ☐ PCB only ☐	EPA 624/PPL ☐ 8240/TAL ☐ NBS (+15) ☐	EPA 625/PPL ☐ 8270/TAL ☐ NBS (+25) ☐	EPA 610 ☐ 8310 ☐	EP TOX Metals ☐ Pesticides ☐ Herbicides ☐	TCLP Metals ☐ VOA ☐ Semi-VOA ☐ Pest ☐ Herb ☐	EPA Metals - Priority Pollutant ☐ TAL ☐ RCRA ☐	CAM Metals TTLC ☐ STLC ☐	Lead 239.2 ☐ 200.7 ☐ 7420 ☐ 7421 ☐ 6010 ☐	Organic Lead ☐	Corrosivity ☐ Flash Point ☐ Reactivity ☐	OTHER			
3																									
6																									
9																									
12																									
15 high OVM																									
18 high OVM																									
21 ✓																									
23 high OVM																									
~~comp~~																									

TAT
Priority (24 hr) ☐
Expedited (48 hr) ☐
7 Business Days ☐
Other____
Business Days ☐

Special Handling
GTEL Contact ____
Quote/Contract # ____
Confirmation # ____
P.O. # ____

QA/QC Level
Blue ☐ CLP ☐ Other ☐ ____

SPECIAL DETECTION LIMITS

SPECIAL REPORTING REQUIREMENTS

FAX ☐

REMARKS: See David C. for analysis

Lab Use Only Lot #:
Storage Location
Work Order #:

CUSTODY RECORD

Relinquished by Sampler: Terry James	Date 6/11/96	Time 13:05	Received by: ~~John Weber~~ Bridget Baxter
Relinquished by: Bridget Baxter	Date 6/18/96	Time 11:10	Received by: John Weber
Relinquished by: John Weber	Date 6/ /96	Time	Received by Laboratory: Waybill #

GTEL ENVIRONMENTAL LABORATORIES, INC.

4080 PIKE LANE, SUITE C
CONCORD, CA 94520
(510) 685-7852
(800) 423-7143

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

35118

Company Name: FLUOR DANIEL GTI

Phone #: (510) 370-3990

FAX #: (510) 370-3991

Company Address: 757 ARNOLD DR #D MARTINEZ CA 94553

Site Location: 2033 TELEGRAPH, OAKLAND CA

Project Manager: MIKE WRAY

Client Project ID: (#) 020200136

(NAME) SEARS OAKLAND #1

I attest that the proper field sampling procedures were used during the collection of these samples.

Sampler Name (Print): STEVEN STREM

			Matrix						Method Preserved						Sampling		ANALYSIS REQUEST																					OTHER			
Field Sample ID	GTEL Lab # (Lab Use only)	# CONTAINERS	WATER	SOIL	AIR	SLUDGE	PRODUCT	OTHER	HCl	HNO₃	H₂SO₄	ICE	UNPRESERVED	OTHER (Specify)	DATE	TIME	BTEX 602 ☐ 8020 ☐ with MTBE ☐	BTEX/Gas Hydrocarbons PID/FID ☐ with MTBE ☐	Hydrocarbons GC/FID Gas ☐ Diesel ☐ Screen ☐	Hydrocarbon Profile (SIMDIS) ☐	Oil and Grease 413.1 ☐ 413.2 ☐ SM-503 ☐	TPH/IR 418.1 ☐ SM 503 ☐	EDB by 504 ☐ DBCP by 504 ☐	EPA 503.1 ☐ EPA 502.2 ☐	EPA 601 ☐ EPA 8010 ☐	EPA 602 ☐ EPA 8020 ☐	EPA 608 ☐ 8080 ☐ PCB only ☐	EPA 624/PPL ☐ 8240/TAL ☐ NBS (+15) ☐	EPA 625/PPL ☐ 8270/TAL ☐ NBS (+25) ☐	EPA 610 ☐ 8310 ☐	EP TOX Metals ☐ Pesticides ☐ Herbicides ☐	TCLP Metals ☐ VOA ☐ Semi-VOA ☐ Pest ☐ Herb ☐	EPA Metals - Priority Pollutant ☐ TAL ☐ RCRA ☐	CAM Metals TTLC ☐ STLC ☐	Lead 239.2 ☐ 200.7 ☐ 7420 ☐ 7421 ☐ 6010 ☐	Organic Lead ☐	Corrosivity ☐ Flash Point ☐ Reactivity ☐				
EW-1	T7506-9	5	X									X	X		6-17	1250																								

TAT
Priority (24 hr) ☐
Expedited (48 hr) ☐
7 Business Days ☐
Other______ Business Days ☐

Special Handling
GTEL Contact ________
Quote/Contract # ________
Confirmation # ________
P.O. # ________

QA/QC Level
Blue ☐ CLP ☐ Other ☐ ________

SPECIAL DETECTION LIMITS

SPECIAL REPORTING REQUIREMENTS

FAX ☐

REMARKS: See David C. for analysis

Lab Use Only Lot #:

Storage Location

Work Order #:

CUSTODY RECORD

Relinquished by Sampler:	Date 6-18-96	Time 11:00	Received by:
Relinquished by:	Date 6-18-96	Time	Received by:
Relinquished by:	Date	Time	Received by Laboratory: Waybill #

GTEL ENVIRONMENTAL LABORATORIES, INC

4080 PIKE LANE, SUITE C
CONCORD, CA 94520
(510) 685-7852
(800) 423-7143

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

36455

Company Name: Fluor Daniel GTI
Phone #: (510) 671-2116
FAX #: (510) 687-0843
Company Address: 1050 Pike Lane, suite A Concord, CA 94520
Site Location: 2600 Telegraph
Project Manager: David Cacciatore
Client Project ID: (#) T 7506
(NAME) Sears Telegraph
I attest that the proper field sampling procedures were used during the collection of these samples.
Sampler Name (Print): Beatriz Athanasios

			Matrix						Method Preserved						Sampling		ANALYSIS REQUEST																				OTHER			
Field Sample ID	GTEL Lab # (Lab Use only)	# CONTAINERS	WATER	SOIL	AIR	SLUDGE	PRODUCT	OTHER	HCl	HNO₃	H₂SO₄	ICE	UNPRESERVED	OTHER (Specify)	DATE	TIME	BTEX 602 ☐ 8020 ☐ with MTBE ☐	BTEX/Gas Hydrocarbons PID/FID ☐ with MTBE ☐	Hydrocarbons GC/FID Gas ☐ Diesel ☐ Screen ☐	Hydrocarbon Profile (SIMDIS) ☐	Oil and Grease 413.1 ☐ 413.2 ☐ SM-503 ☐	TPH/IR 418.1 ☐ SM 503 ☐	EDB by 504 ☐ DBCP by 504 ☐	EPA 503.1 ☐ EPA 502.2 ☐	EPA 601 ☐ EPA 8010 ☐	EPA 602 ☐ EPA 8020 ☐	EPA 608 ☐ 8080 ☐ PCB only ☐	EPA 624/PPL ☐ 8240/TAL ☐ NBS (+15) ☐	EPA 625/PPL ☐ 8270/TAL ☐ NBS (+25) ☐	EPA 610 ☐ 8310 ☐	EP TOX Metals ☐ Pesticides ☐ Herbicides ☐	TCLP Metals ☐ VOA ☐ Semi-VOA ☐ Pest ☐ Herb ☐	EPA Metals - Priority Pollutant ☐ TAL ☐ RCRA ☐	CAM Metals TTLC ☐ STLC ☐	Lead 239.2 ☐ 200.7 ☐ 7420 ☐ 7421 ☐ 6010 ☐	Organic Lead ☐	Corrosivity ☐ Flash Point ☐ Reactivity ☐	NH3	NO3	O. phosphate	T. phosphate
Sears H2O comp	9607038	1	✓												[illegible]	[illegible]																						X	X	X	
Sears Soil Comp		1		X																																		X	X	X	

TAT
Priority (24 hr) ☐
Expedited (48 hr) ☐
7 Business Days ☒
Other_____ Business Days ☐

Special Handling
GTEL Contact ______
Quote/Contract # QUK60176
Confirmation # ______
P.O. # 5156

QA/QC Level
Blue ☐ CLP ☐ Other ☐ ______

SPECIAL DETECTION LIMITS

SPECIAL REPORTING REQUIREMENTS
FAX ☐

REMARKS: 250 ml of H2O FOR: NH3, NO3 and if you have extra H2O O. phosphate RUN T. phosphate. As per conversation

Lab Use Only Lot #: No Seals 1°C
Storage Location with Justin 7-8

Work Order #:

CUSTODY RECORD

Relinquished by Sampler: Beatriz Athanasios	Date 7-9-96	Time 11:00	Received by: John Weller
Relinquished by: John Weller	Date 7-9-96	Time 16:10	Received by:
Relinquished by:	Date 7.[illegible]96	Time 08:35	Received by Laboratory: Waybill #

NEI/GTEL
ENVIRONMENTAL
LABORATORIES, INC.

Midwest Region
4211 May Avenue
Wichita, KS 67209
(316) 945-2624
(800) 633-7936
(316) 945-0506 (FAX)

July 18, 1996

David Cacciatore
Remediation Technology, Labs
4080 Pike Lane
Concord, CA 94520

RE: GTEL Client ID: RTL01RTL01
Login Number: W6070138
Project ID (number): T 7506
Project ID (name): SEARS/2600 TELEGRAPH/CONCORD/CA

Dear David Cacciatore:

Enclosed please find the analytical results for the samples received by GTEL Environmental Laboratories, Inc. on 07/10/96 under Chain-of-Custody Number(s) 36455.

A formal Quality Assurance/Quality Control (QA/QC) program is maintained by GTEL, which is designed to meet or exceed the EPA requirements. Analytical work for this project met QA/QC criteria unless otherwise stated in the footnotes. This report is to be reproduced only in full.

NEI/GTEL is certified by the California Department of Health Service under Certification Number 1845.

If you have any questions regarding this analysis, or if we can be of further assistance, please call our Customer Service Representative.

Sincerely,
GTEL Environmental Laboratories, Inc.

Customer Service Manager

Terry R. Loucks
Laboratory Director

Project ID (Number): T 7506
Project ID (Name): Sears
2600 Telegraph
Concord, CA
Work Order Number: W6-07-0138
Date Reported: 07-18-96

ANALYTICAL RESULTS

Inorganics in Water

		GTEL Sample Number	01			
		Client Identification	Sears H_2O			
		Date Sampled	07-09-96			
		Date Analyzed	07-10 to 07-15-96			
Analyte	Method	QL *& Units	Concentration			
Ammonia-N	EPA 350.1[a]	0.3 mg/L	<0.3			
Nitrate-N	EPA 353.1	0.05 mg/L	**0.09**			
Orthophosphate	EPA 365.3	0.05 mg/L	**0.25**			
Total Phosphorus	EPA 365.4	0.2 mg/L	**0.31**			

a Distillation by EPA 350.2

* Quantitation Limit

NA Not applicable

Project ID (Number): T 7506
Project ID (Name): Sears
2600 Telegraph
Concord, CA
Work Order Number: W6-07-0138
Date Reported: 07-18-96

ANALYTICAL RESULTS

Inorganics in Soil

		GTEL Sample Number	02			
		Client Identification	Sears Soil			
		Date Sampled	07-09-96			
		Date Analyzed	07-11 to 07-18-96			
Analyte	Method	QL* & Units	Concentration			
Ammonia-N	EPA 350.1[a]	15 mg/Kg	<15			
Soluble Nitrate-N	EPA 353.1	2.5 mg/Kg	27			
Soluble Orthophosphate	EPA 365.3	2.5 mg/Kg	7.5			
Total Phosphorus	EPA 365.4	4.0 mg/Kg	82			
Percent Solids			77.9			

a Distillation by EPA 350.2

* Quantitation Limit.

NA Not applicable