July 26, 1994

Chevron U.S.A. Products Company
2410 Camino Ramon
San Ramon, CA 94583
P.O. Box 5004
San Ramon, CA 94583-0804

Marketing Department
Phone 510 842 9500

Ms. Juliet Shin
Alameda County Health Care Services
Department of Environmental Health
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94501

Re: Former Chevron Service Station #9-1153
3126 Fernside Boulevard, Alameda, CA

Dear Ms. Shin:

Enclosed is a copy of the Risk Assessment report dated August, 1987, prepared by our consultant EA Engineering, Science, and Technology, Inc. for the above referenced site.

As we discussed on July 18, 1994, the main focus of the risk assessment is on fate and transport of hydrocarbons in ground water, however the report does contain a discussion on exposure assessment.

If you have any questions or comments, please do not hesitate to contact me at (510) 842-8134.

Sincerely,
CHEVRON U.S.A. PRODUCTS COMPANY

Mark A. Miller
Site Assessment and Remediation Engineer

Enclosure

File: 9-1153 HRA1

RISK ASSESSMENT, VICINITY OF FORMER
CHEVRON SERVICE STATION 9-1153
FERNSIDE AND GIBBONS, ALAMEDA, CA

Prepared for

Chevron U.S.A. Inc.
San Ramon, California

Prepared by

EA Engineering, Science, and Technology, Inc.
Lafayette, California

Carol A. Presley

Carol A. Presley
Chemist

19 August 1987
Date

Roger Greensfelder

Roger Greensfelder, Ph.D., P.G.
Geologist #003011

_8-19-87_
Date

Robert E. Hinchee, Ph.D., P.E.
Civil Engineer #C 039606

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CONTENTS

1. INTRODUCTION

This report summarizes and interprets previous investigations and a soil vapor contaminant assessment (SVCA) conducted by EA Engineering, Science, and Technology, Inc. (EA) on 21 July 1987 in the vicinity of former Chevron Service Station 9-1153. It combines the results of all investigations to date to develop a risk assessment of hydrocarbon contamination on and near the site.

1.1 SITE SETTING

Former Chevron SS 9-1153 is located at the northwest corner of the intersection of Fernside Boulevard and Gibbons Drive in Alameda, California (Figure 1). The site is located on essentially flat terrain of the east bay plain at an elevation of about five feet msl (from a Chevron site map). The nearest significant drainage appears to be the tidal Ship Canal, about 600 feet to the east. Land use in the site vicinity (Figure 2) is primarily residential, but also includes commercial establishments.

Hydrogeology

The site is situated on a thick accumulation of Pliocene-to-Quaternary alluvial sediments deposited in the structural geological depression occupied principally by the Bay Plain, which includes San Francisco Bay and the marginal flatlands. These sediments are at least 600 feet thick locally. Although the deposits range from clays to gravels, the shallower section is sometimes referred to as the Bay Muds. This appellation reflects the fact that the younger deposits are dominated by fine-grained components, mainly clay. According to local nomenclature, these sediments belong to the northern margin of the San Leandro

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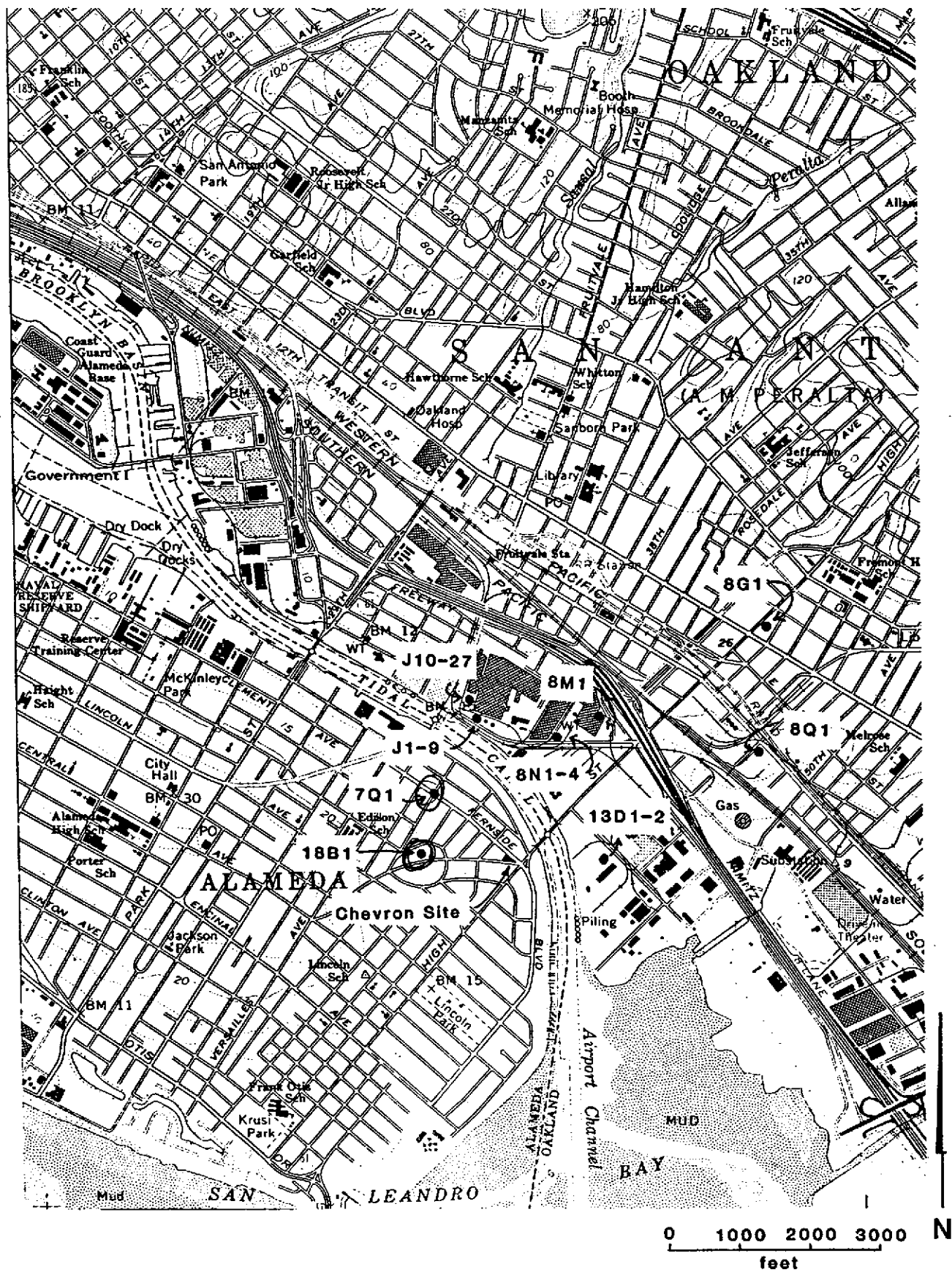
Figure 1.   Topography near Chevron SS 9-1153, Alameda, CA,
with wells within one-half mile.

Residential

Tidal Shore

High
Street
Bridge

High Street
Bridge Center

Fernside Boulevard

Residential

Marina
Convalescent
Hospital

Chevron Site

Residential

Gibbons Drive

Foreign Car
Repair

High Street

Residential

N

Not to Scale

Residential

Figure 2. Land use in the vicinity of Chevron SS 9-1153, Alameda, CA.

Figure 3. Regional geological cross-section illustrating aquifers south of Chevron SS 9-1153, Alameda, CA.

alluvial cone or to the south end of the Berkeley alluvial plain (CDWR 1964).
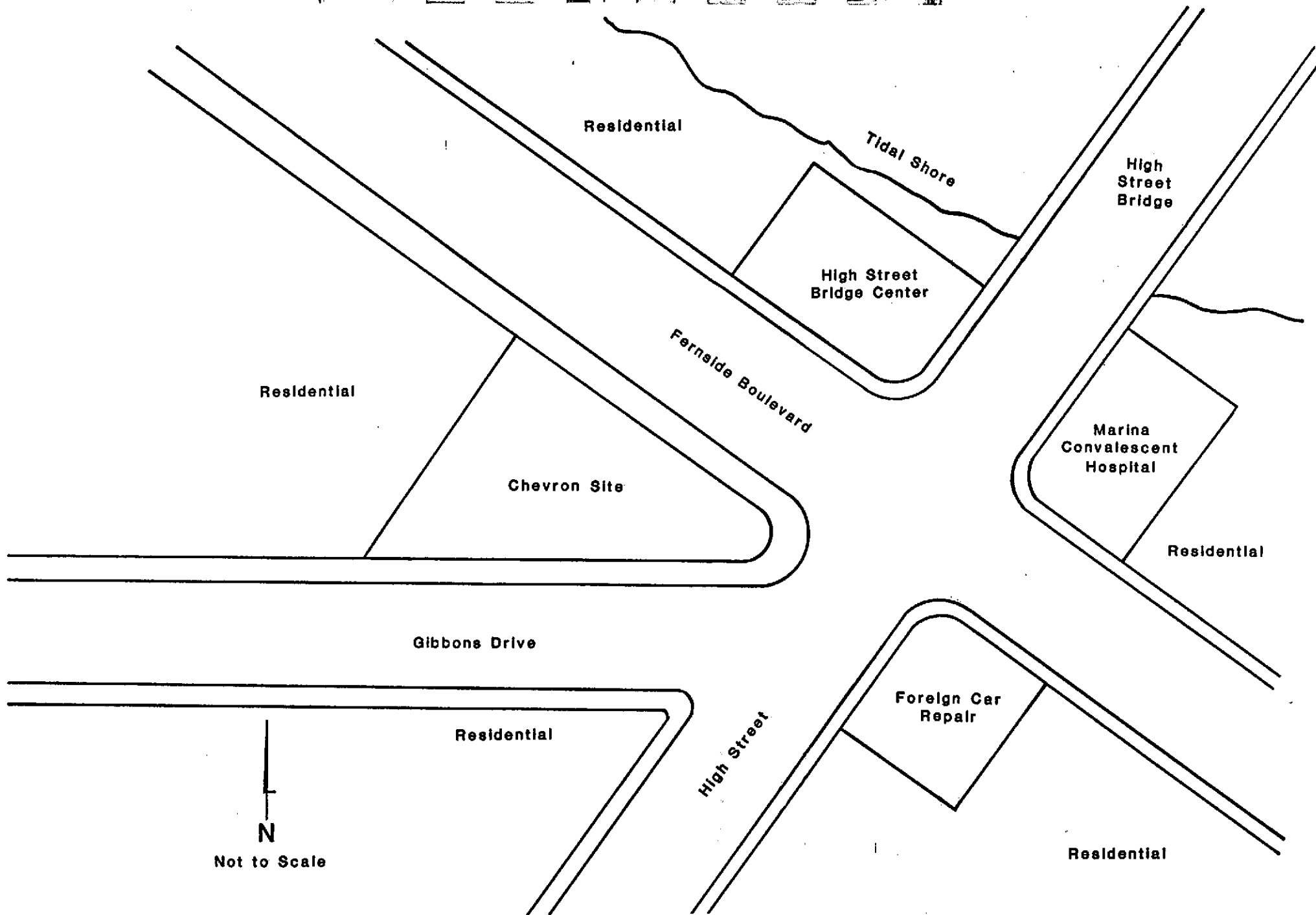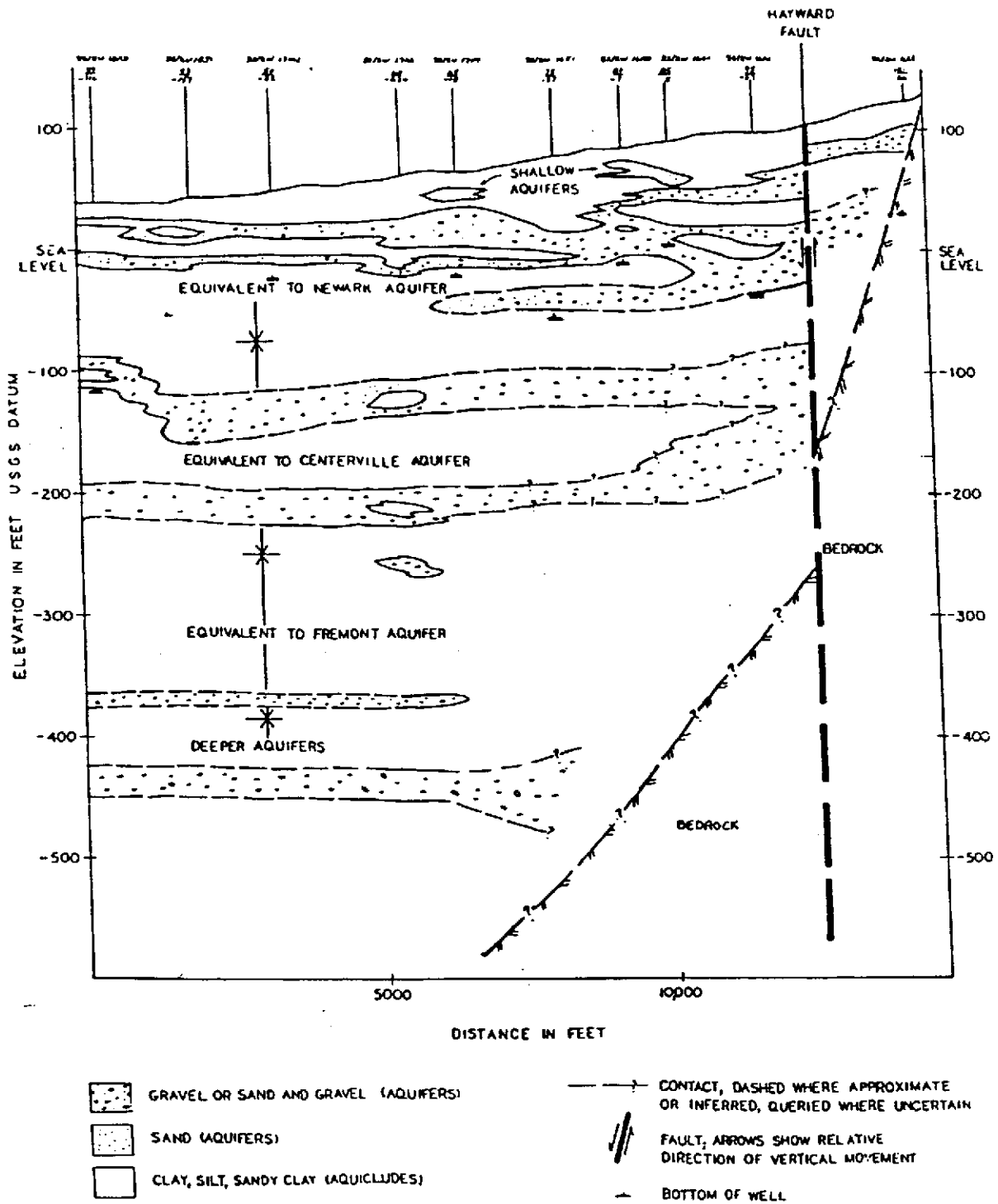
The hydrogeology of the immediate site area is not well known, but may be extrapolated from the southeast margin of San Francisco Bay (southwestern Alameda County), a well-studied area (Maslonkowski 1984). As far north as San Lorenzo, seven miles southeast of the site, four main aquifer zones, reaching depths of 500 feet, have been identified. These are sand-and-gravel beds, not more than 35 feet in thickness, sandwiched between thick, clay-rich aquicludes. Figure 3 presents a generalized geologic section of the San Leandro alluvial cone, about 7 miles southeast of the site.

Deep hydrogeologic information for the immediate site vicinity is limited to a driller's log for a 610-foot industrial well located on High Street about 1 mile northeast of the site (well 8, Figure 1). These data were provided by the Alameda County Department of Public Works (ACDPW unpublished). The log indicates two major water-bearing zones: (1) a gravel-dominated horizon from 182 to 250 feet, and (2) a sand-and-gravel layer from 510 to 560 feet. The first zone corresponds to the Centerville aquifer, as shown in Figure 3. The well log indicates the presence above this aquifer of two clay layers, each about 18 feet thick, and a clay-with-gravel layer about 70 feet thick.

Except for those used for cathodic protection, all wells in the inventory of the ACDPW and lying within one-half mile of the site are shown in Figure 1. These include more than 30 monitoring wells, most of which occur in clusters shown as one point (e.g., 7J 10-27). Only two wells serve a beneficial use, and these are for irrigation: they are 7Q1 and 18B1. The latter well, 1,200 feet west of the site, has a depth of 55 feet, a diameter of four inches, and a reported depth to water of ten feet. Water table depth varies both tidally and seasonally near the site, and only average depths can be compared from well to well.

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Reported depths to first ground water, based primarily on data from monitoring wells, average four feet at the site (EMCON 1986) and from 5 to 20 feet within a one-half mile radius. The variability of these reported depths, probably caused by local hydrogeologic factors, including tidal influence, is such that they cannot be used to estimate the ground-water gradient. The gradient may be assumed to approximately parallel that of the topography, which has an easterly direction; its magnitude may be about 0.003. No wells making beneficial use of ground water are located downgradient from the site.

1.2 PRINCIPLES OF SOIL VAPOR CONTAMINANT ASSESSMENT

The soil vapor survey, or SVCA, technique takes advantage of the behavior of hydrocarbon mixtures and the physicochemical properties of the individual components in the subsurface. Following a subsurface gasoline release, free product will migrate downwards towards the ground water, some of the gasoline will volatilize, and some will adsorb to the soils. In the event of a spill of sufficient volume to exceed the soil binding capacity, free liquid will reach ground water, at which point it will float and may begin to vaporize and solubilize. It may be noted that maximum gasoline concentration in product-saturated soil is about 100,000 mg/kg (Hoag and Marley 1986); gasoline-saturated water may contain total benzene, toluene, and xylenes in excess of 28 mg/L (API 1985).

Like most hydrocarbon liquids, gasoline is a complex mixture of many compounds, each with its own physicochemical properties. The contaminants found in ground water located beneath a layer of floating hydrocarbon are generally less hydrophobic and are generally found in concentrations proportional to the hydrocarbon/water partition coefficient (i.e., the relative solubility of a given compound in the bulk hydrocarbon to its solubility in water) and to their percent composition in the gasoline. Hydrocarbons will also volatilize into the air- or gas-filled soil

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interstices. Volatilization is largely a function of vapor pressure. The natures of the contaminant mixtures, in terms of specific component mixtures, in either the aqueous or vapor phase, are distinctly different from each other and from the gasoline. That is, the more hydrophilic hydrocarbons will be more likely to move into ground water, while the more volatile compounds are more likely to move into the vapor phase, and the compounds that are both less volatile and more hydrophobic are more likely to remain in the free product or be adsorbed to soils (Hinchee and Reisinger 1987).

Hydrocarbons not remaining in the free product will partition into either ground water or soil vapor and migrate as the result of a variety of interacting forces. In ground water, contaminants will migrate with the ground-water flow, interacting with the rock or soil geological medium. As the contaminants pass through a medium, organic constituents in the medium interact with the contaminants, and some are adsorbed or bound to particle surfaces (Bruell and Hoag 1986). The result is a net retardation in the velocity of movement of those compounds relative to that of the ground water in which they are dissolved. The process is analogous to laboratory chromatography. The compound with the least affinity for the porous medium is least retarded and there-fore moves most rapidly. This compound, then, is present at the leading edge of a contaminant plume.

The affinity of a compound for the soil porous medium is partly a function of the compound's hydrophobicity--that is, the more hydrophobic a compound the more likely it is to adsorb to the solid medium. Aqueous solubility is a good indicator of hydro-phobicity: the more soluble a compound is, the less hydrophobic and more hydrophilic it is, and vice versa. Vapor pressure is a good indicator of volatility; compounds with higher vapor pressures are more volatile.

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In determining the environmental fate of various hydrocarbon compounds in a hydrocarbon mixture such as gasoline, those which have a high vapor pressure are more likely to move into the vapor phase, or evaporate. Compounds with high solubility are more likely to move into ground water from the free product and, once in ground water, tend to move more rapidly. Compounds of low vapor pressure and low solubility tend to remain in the free product or be adsorbed to the solid matrix and remain relatively immobile.

Dissolved compounds will tend to volatilize from the aqueous phase. The Henry's Law constant is the equilibrium ratio of a compound's concentration in the vapor phase to its concentration in the aqueous phase. The higher a compound's Henry's Law constant, the greater its tendency to volatilize from water into air.

Figure 4 shows the vapor pressure, aqueous solubility, and Henry's Law constants for selected hydrocarbons typically found in gasoline. The Henry's Law constant is approximated here as the ratio of vapor pressure to solubility.

Compounds with Henry's Law constants greater than 0.001 (atm · m^3/mole) volatilize from water into air very rapidly (Lyman et al. 1982); those with Henry's Law constants greater than 0.01 (atm · m^3/mole) are generally volatilized so rapidly that they are seldom found in gasoline-contaminated ground water. It may be observed (Figure 4) that tetraethyl lead (TEL) has an extremely low solubility and a relatively low vapor pressure. As a result, this constituent would not be expected to solubilize and migrate in ground water, and although its low vapor pressure would indicate slow volatilization, its Henry's Law constant indicates that it may be more rapidly volatilized than solubilized. The fate of TEL would be expected to be long-term binding to the soil.

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H = Henry's Law Coefficient
(atm•M³/mole)

Vapor Pressure (Atmospheres)

100

10 — propylene

isobutane
n-butane

Increasing Tendancy to Volatilize from Water

1.0 — H = 100 — l-pentene

n-pentane
cyclopentane
1,2-dimethylbutane

Increasingly Volatile

0.1 — H = 10 — n-hexane
dimethylpentanes   methylcyclopentane
methylhexanes
trimethylpentanes

isopropylether
benzene
1,2-dichloroethane

H = 1

toluene   t-butylmethylether

Increasing Tendancy to Bind to Soils   ethylbenzene

0.01 — methyloctanes   1,2-dibromoethane
xylenes

H = 0.1

Increasingly Mobile in Ground Water

0.001 — H = 0.01   H = 0.001   H = 0.0001

tetraethyllead

0.001   0.01   0.1   1.0   10   100   1,000

Aqueous Solubility (m mole/l)

Figure 4. Vapor pressures, solubilities, and corresponding Henry's Law constants for major constituents of gasoline.

On the basis of these properties it can be seen that associated with any ground water, soil, or free-product contamination is vapor phase contamination. The SVCA technique takes advantage of this, and the collection and analysis of soil vapor permits a rapid, cost-effective delineation of the extent of contamination.

1.3 PRINCIPLES OF RISK ASSESSMENT

Risk assessment, simply stated, is the process of quantification of the risk to human health and the environment resulting from some occurrence. The procedure is not new, and it has been widely applied in the fields of transportation safety, new product evaluations, structural engineering, insurance, and nuclear power. In recent years the risk assessment procedure has been applied to contaminated sites as part of the remedial inves- tigation/feasibility study (RI/FS) process to quantify the degree to which human health and the environment are at risk as a result of the contamination. Data generated in these risk assessments are subsequently used to determine the need for and the degree of remediation. Risk assessment is a tool that can be applied to sites contaminated with fuels. The process has not been widely applied to fuel contaminated sites, perhaps because these are not addressed under CERCLA. In its absence, the need for and levels for cleanup have often been established arbi- trarily, with little or no technical rationale. A risk assess- ment can remove some of the ambiguity in the decision making process and permit prudent, technically founded decisions about cleanup that will result in protection of human health and the environment in a more technically based and perhaps more cost- effective manner.

Application of the risk assessment process to a fuel-contaminated site serves two purposes. First, it documents that risk to human health and the environment have been evaluated and given con- sideration in determining the appropriate response; second, it

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provides a rational approach to determining the appropriate level
of effort for investigation and remediation of the site.

The necessity for application of risk assessment is to ensure
that resources are applied to the sites of greatest need of
remediation. Following a subsurface fuel spill, the cost of the
investigation phase alone may range from less than $2,500 for a
few soil borings or a soil vapor survey, to more than $1,000,000
for a major remedial investigation. Remediation costs may vary
from $10,000 for simple free product recovery into the millions
of dollars for dissolved phase and soil clean up. The total
potential costs for investigation and remediation of fuel spills
nationwide is staggering. Although precise estimates are
difficult to obtain, utilizing the EPA (1986) figure of 189,000
as the number of leaking underground storage tanks in the United
States, and the California Commission for Economic Development's
(1986) per site figures for the ultimate cost of investigation
and remediation at leaking underground storage tank sites of
$100,000, $1,000,000, and $10,000,000 at 80%, 10%, and 10% of all
sites, respectively, a total cost to investigate and remediate
the identified sites in the United States would be approximately
210 billion dollars. This is on the order of the United States
defense budget and exceeds the gross national product of many
countries. It should be pointed out that these figures include
only non-farm underground fuel storage tank leaks and not pipe-
line leakage, above ground spillage, or nonfuel contamination.
Additionally, this figure is only an estimate of currently
leaking tanks and does not include abandoned tanks, past leaks,
or future leaks. Although the precise figures utilized to obtain
this estimate are certainly disputable, even 10 per cent of this
figure represents an enormous sum.

Guidelines for application of the risk assessment process in
California are outlined in the California Department of Health
Services Site Mitigation Tree (DHS 1985, 1986) and the California
Water Resources Control Board's Interim Guidance for Hazardous

Substance Site Clean-up (SWRCB 1985). Application of the process to fuel-contaminated sites is described by Hinchee et al. (1986).

2. FIELD INVESTIGATIONS

2.1 PREVIOUS INVESTIGATIONS

Previous studies of the site consist of the analysis of 12 soil samples and one water sample from the excavations tank pit and from removed backfill (Blaine Technical Services [BTS] 1986) and of three soil borings converted to monitoring wells (EMCON 1986), from each of which one water sample was analyzed. These sample points and wells are shown in Figure 5. The results of chemical analysis are presented in Table 1.

The soil samples taken by BTS were analyzed for total petroleum hydrocarbons (TPH), with a detection limit of 1 mg/kg. None of the soil samples showed detectable TPH; the one water sample, from near the center of the tank pit, showed 130 mg/L of TPH. However, removed backfill registered TPH levels from 33 to 1,400 mg/kg.

The three soil borings (EMCON 1986) indicated an average litho-logic section, to a depth of 22 feet, as follows: sandy fill (symbol SW) to about 2 feet; poorly graded sand (SP) or silty sand (SM) to about 6-9 feet; clayey sand (SC) to about 12-14 feet; and poorly graded sand (SP) to about 21-22 feet. Static water level was 4.1 feet below the surface in all wells on 18 August 1986. Product odor was strong in borings C1 and C2 within the shallow SP/SM horizon (2 to 9 feet deep), but faint or absent at greater depths. Apparently, the presence of clay (SC) and water prevented penetration of product to depths exceeding about 10 feet. In boring C3, faint product odor was noted in the shallow fill, but not beneath it.

Water samples indicated minor-to-moderate concentrations of gaso-line constituents: TPH ranged from 0.05 to 15 mg/L and benzene from 0.003 to 0.76 mg/L. Well C1 had the highest, and well C3
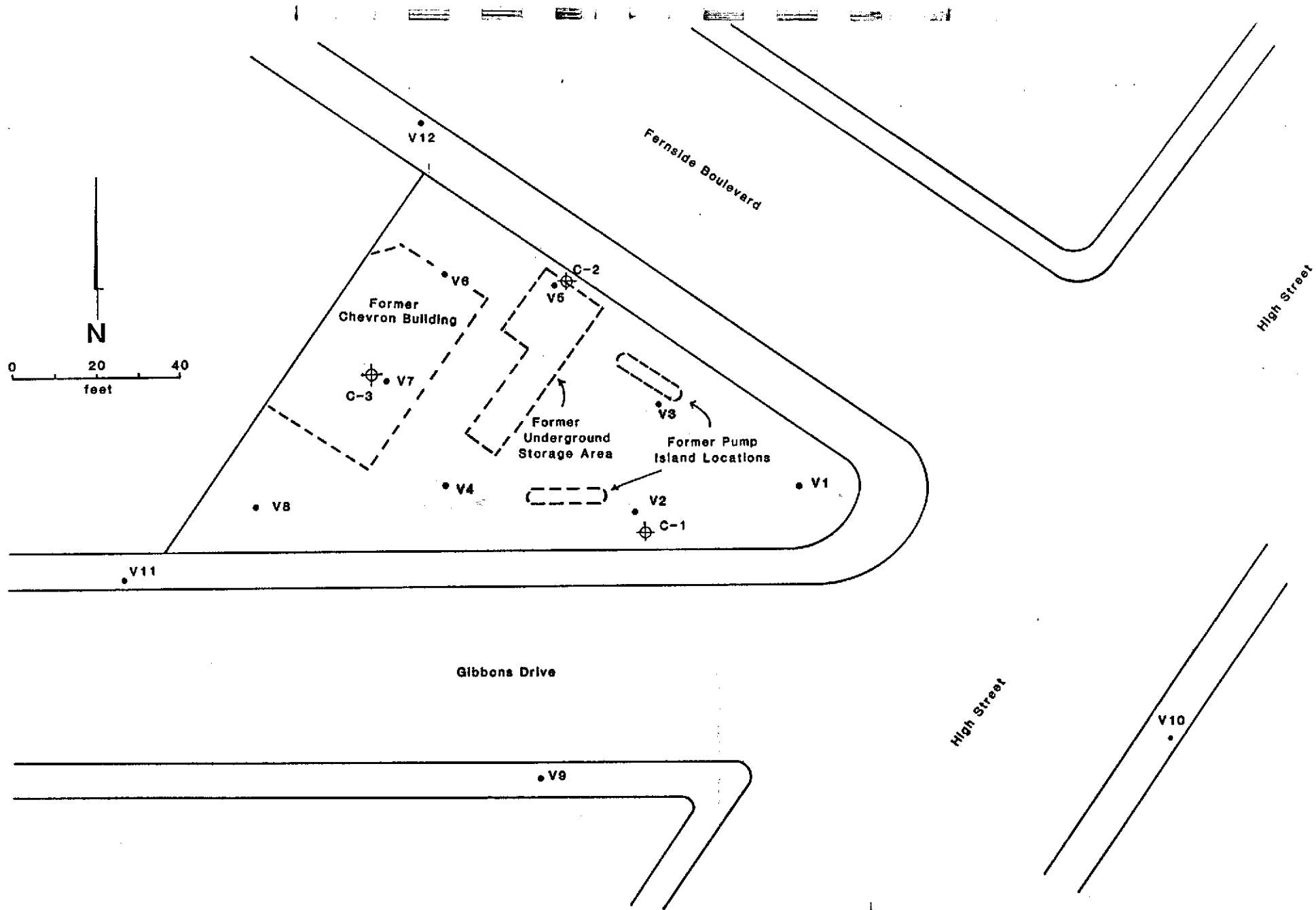
Figure 5. Locations of soil samples and monitoring wells, Chevron SS 9-1153, Alameda, CA.

TABLE 1 SOIL AND GROUND-WATER ANALYSES FOR CHEVRON SERVICE STATION 9-1153, FERNSIDE BLVD. AND GIBBONS DR., ALAMEDA, CA (mg/L and mg/kg)

Sample[b]	Depth/Date	Benzene	Toluene	Xylenes	Ethyl-benzene	Total Petroleum Hydrocarbons[8]
MW C1[1]						
Soil		−	−	−	−	−
Groundwater	09/04/86	.76	.82	1.5[2]		15.[3]
MW C2[4]						
Soil		−	−	−	−	−
Groundwater	09/04/86	.049	.018	.084[2]		1.1[3]
MW C3[5]						
Soil		−	−	−	−	−
Groundwater	09/04/86	.0032	.0054	.0058[2]		.050[3]
Soil Samples (collected from tank excavation spils)						
#1	11'	−	−	−	−	<1
#2[a]	12'	−	−	−	−	<1
#3[a]	10'	−	−	−	−	<1
#4[a]	10.5'	−	−	−	−	<1
#6[a]	8'	−	−	−	−	<11[7]
#7[a]	18"[9]	−	−	−	−	1400
#8[a]	20"[10]	−	−	−	−	530
#9[a]	12"[11]	−	−	−	−	150
#10[a]	10'	−	−	−	−	<1
#11[a]	12'	−	−	−	−	<1
#12[a]	10'	−	−	−	−	<11
#13[a]	12-18"[12]	−	−	−	−	33
#1[c]		−	−	−	−	<1[14]
#2[c]		−	−	−	−	<1[14]
Water Sample[a] (collected from the tank pit)						
#5[13]	06/04/86	−	−	−	−	130[8]

1. Designated in report as "CO1".

2. Combined figure for xylenes and etheylbenzene.

3. Combined as "Volatile Hydrocarbons due to Gasoline".

4. Designated in report as "CO2".

5. Designated in report as "CO3".

7. Waste oil by extraction.

8. Reported as gasoline unless otherwise noted.

9. Soil from stockpile 18" below surface.

10. Soil from stockpile 20" below surface.

11. Soil from stockpile 12" below surface.

12. Soil from stockpile 12-18" below surface.

13. Subsurface water sample.

14. Designated as total hydrocarbon-response-gasoline.

a. Flay, R. Report from Thermo Analytical, Inc. to Chevron U.S.A. No. date.

b. Murphy, P. 1986. Report from Emcon Associates to Gettler-Ryan, Inc., 15 September 1986.

c. Flay, R. 1986. Letter from Thermo Analytical Inc. to Vicki Hobbs, Chevron U.S.A., 8 July 1986.

the lowest, concentrations. No free product was observed in any
of the wells; it is noted here that none of the analyzed soil
samples had measurable TPH, and that none of the borings
encountered product-saturated soils. BTX can be as high as 28
mg/L in water (API 1985), but it was only 3.08 mg/L in well C1.

Measurements in wells C1, C2, and C3 on 18 August 1986 indicated
depths to ground water of 4.1 feet, or a water table elevation of
about 0.7 to 0.9 feet msl. Assuming that local ground water
moves toward the tidal canal, about 400 feet to the east, the
hydraulic gradient would be 0.002.

2.2 SOIL VAPOR CONTAMINANT ASSESSMENT

On 21 July 1987, EA conducted an SVCA in the vicinity of former
Chevron SS 9-1153. Soil vapor samples were collected from twelve
vapor points (see Figure 5) hand-driven to a depth of three feet.
The data are presented in Table 2. **Vapor points V1, V2, V3, and
V4 showed significant concentrations (70-11,000 ppm) of benzene,
toluene, and compounds with lower boiling points than benzene;** of
the remaining eight points (V5-V12), only three (V5, V6, and V8)
had detectable (>1 ppm) vapor concentrations.

Prior to collection of each sample, a vacuum pump was used to
purge previously collected vapor from the probes to ensure that
soil vapor samples collected were not contaminated. The vacuum
pressure reading on the purging apparatus was recorded. This
vacuum pressure is related to the soil's gas permeability and is
useful in data interpretation. The samples were collected
through a septum with a microsyringe and injected into a gas
chromatograph for analysis.

The Photovac 10S50 is a portable programmable integrating gas
chromatograph with a photoionization detector (PID). The PID is
a nondestructive flow-through detector that uses high energy
ultraviolet radiation as its ionization source. The high energy

TABLE 2 SVCA RESULTS, CHEVRON SS 9-1153, FERNSIDE BLVD AND GIBBONS DRIVE, ALAMEDA, CA, 21 JULY 1987

Sample Location	Depth (ft)	Peaks Prior to Benzene (VS)	Benzene (ppm)	Toluene (ppm)	Peaks Not Otherwise Identified (VS)
V1	3	1,800	110	30	100
V2	3	11,000	1,900	500	1,800
V3	3	5,000	120	50	90
V4	3	660	70	180	180
V5	3	<5	<1	<1	<1
V6	3	20	10	10	10
V7	3	<1	<1	<1	<1
V8	3	5	5	5	10
V9	3	<1	<1	<1	<1
V10	3	<1	<1	<1	<1
V11	3	<1	<1	<1	<1
V12	3	<1	<1	<1	<1

BLANK DATA

Test Time	Peaks Prior to Benzene (VS)	Benzene (ppm)	Toluene (ppm)	Peaks Not Otherwise Identified (VS)
1001	<0.1	<0.1	1.5	<0.1
1250	0.3	0.5	0.8	<0.1

PERCENTAGE OF STANDARD RECOVERED

Test Time	Standard	
	Benzene	Toluene
1446	85	84

radiation ionizes compounds, generating an energy increase in the detector which appears as an electrical signal. The signal is amplified, integrated, and recorded as a chromatographic peak. Vapor samples are injected into the chromatograph, separated on an analytical column, sensed by the detector, integrated, and reported as individual compounds on chromatograms. The device is operated in backflush mode to prevent contamination of the analytical column with high concentrations of interfering compounds. The chromatograph was standardized with 10 ppm each of benzene and toluene vapor. Compound retention time and response data are stored in the instrument integrator and subsequently used to make identifications and to quantify unknowns in samples. Blanks were run to ensure that the system was free of contamination. As necessary, the instrument was re-calibrated by injecting standards and by running ambient air blanks approximately every two hours through the day. This re-calibration ensured that the system was operating consistently and that parametric changes caused by temperature changes through the day were accounted for. These data, along with multiple standard runs, ensure system reproducibility.

2.3 DISCUSSION OF RESULTS

Figures 6, 7, 8, and 9 are contour maps of the concentrations in soil vapor of benzene, of toluene, and of hydrocarbons eluting before and after benzene. The first two are given in parts per million (ppm), and the last two are shown in volt-seconds (VS). One VS may be considered to very roughly equal 1 ppm. All of the contour plots indicate moderate levels (exceeding 1,000 ppm) of hydrocarbon vapors beneath the east end of the site and beneath adjacent streets. In all cases, maximum measured soil vapor concentrations occur at point V2, adjacent to monitoring well C1 and about 35 feet from the former tank pit.

The site of maximum concentration in Figures 5 through 8 is located approximately 10 feet east of the eastern end of a former
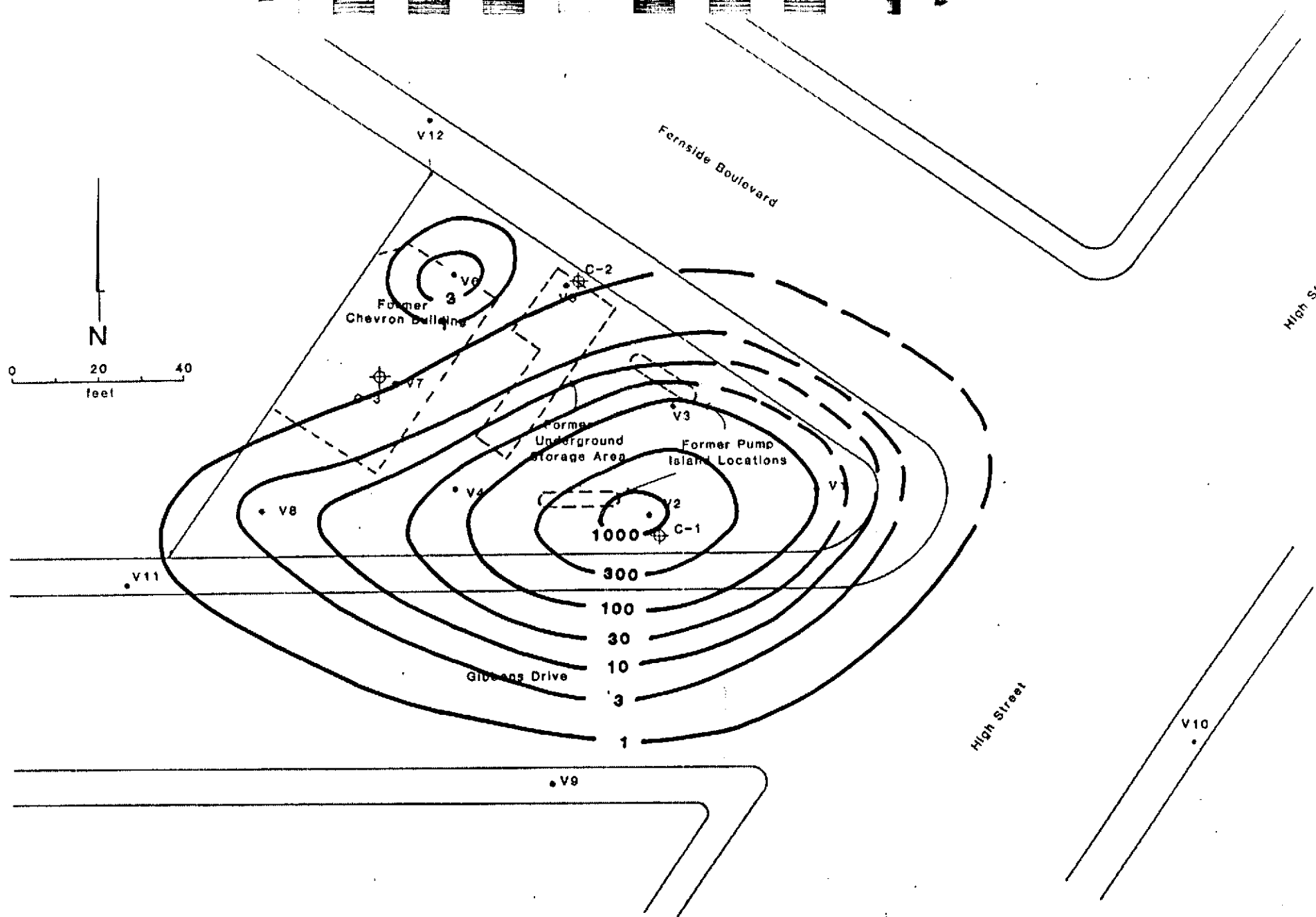
11

Figure 6. Isoconcentrations (ppm, log-scaled) of benzene in the vicinity of Chevron SS 9-1153, Alameda, CA.
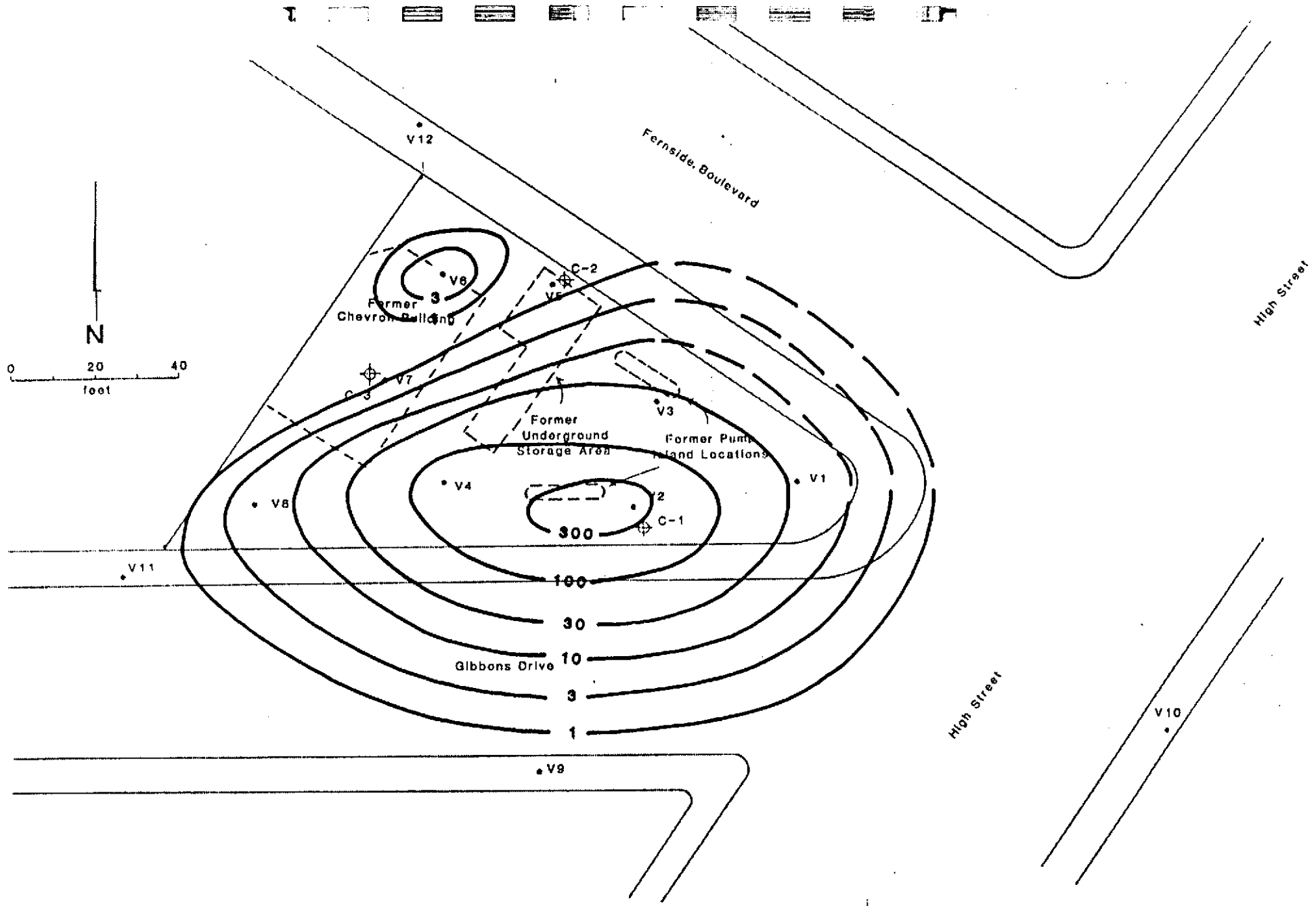
Figure 7. Isoconcentrations (ppm, log-scaled) of toluene in the vicinity of Chevron SS 9-1153, Alameda, CA.
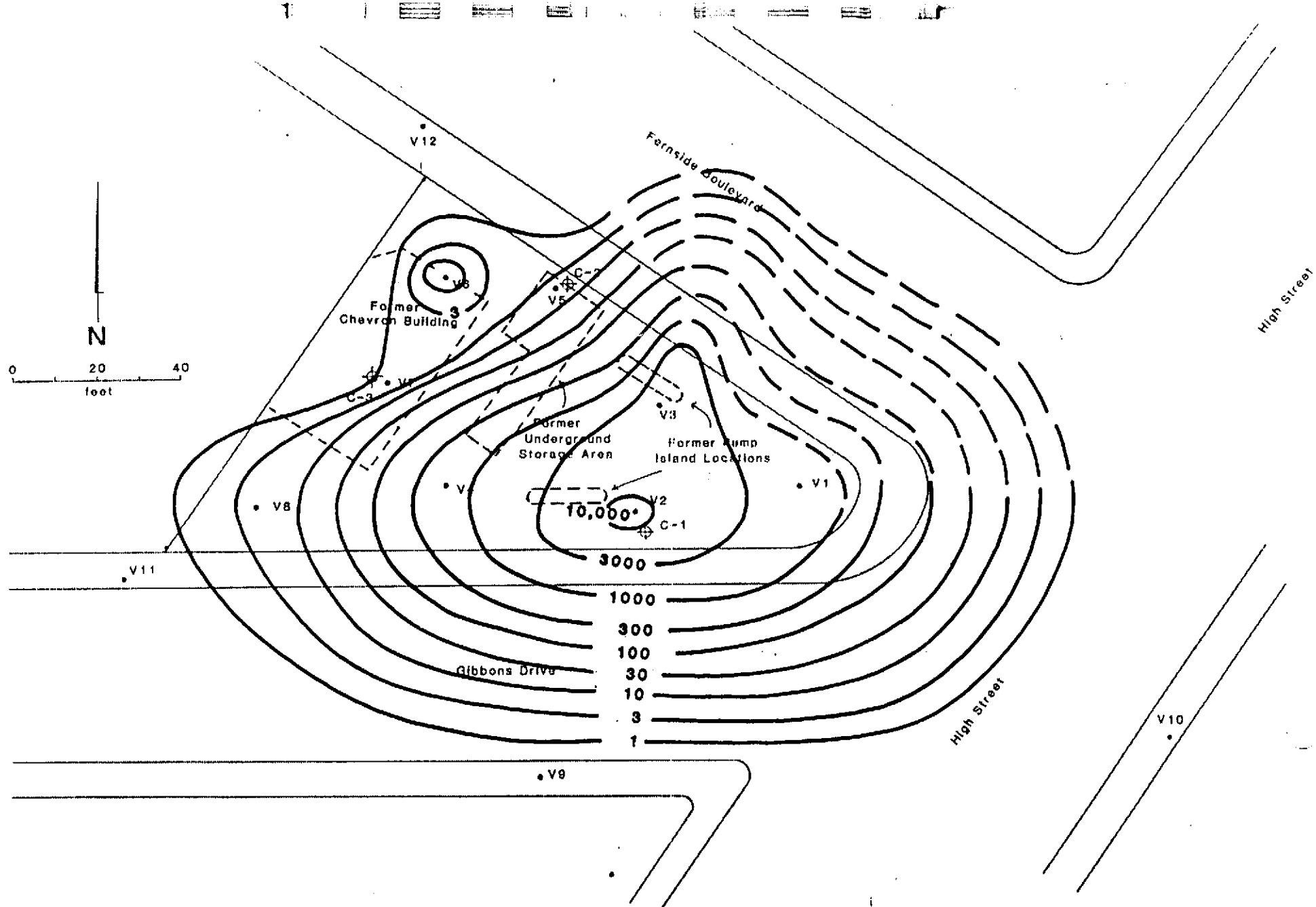
Figure 8. Isoconcentrations (VS, log-scaled) of constituents eluting prior to benzene in the vicinity of Chevron SS 9-1153, Alameda, CA.
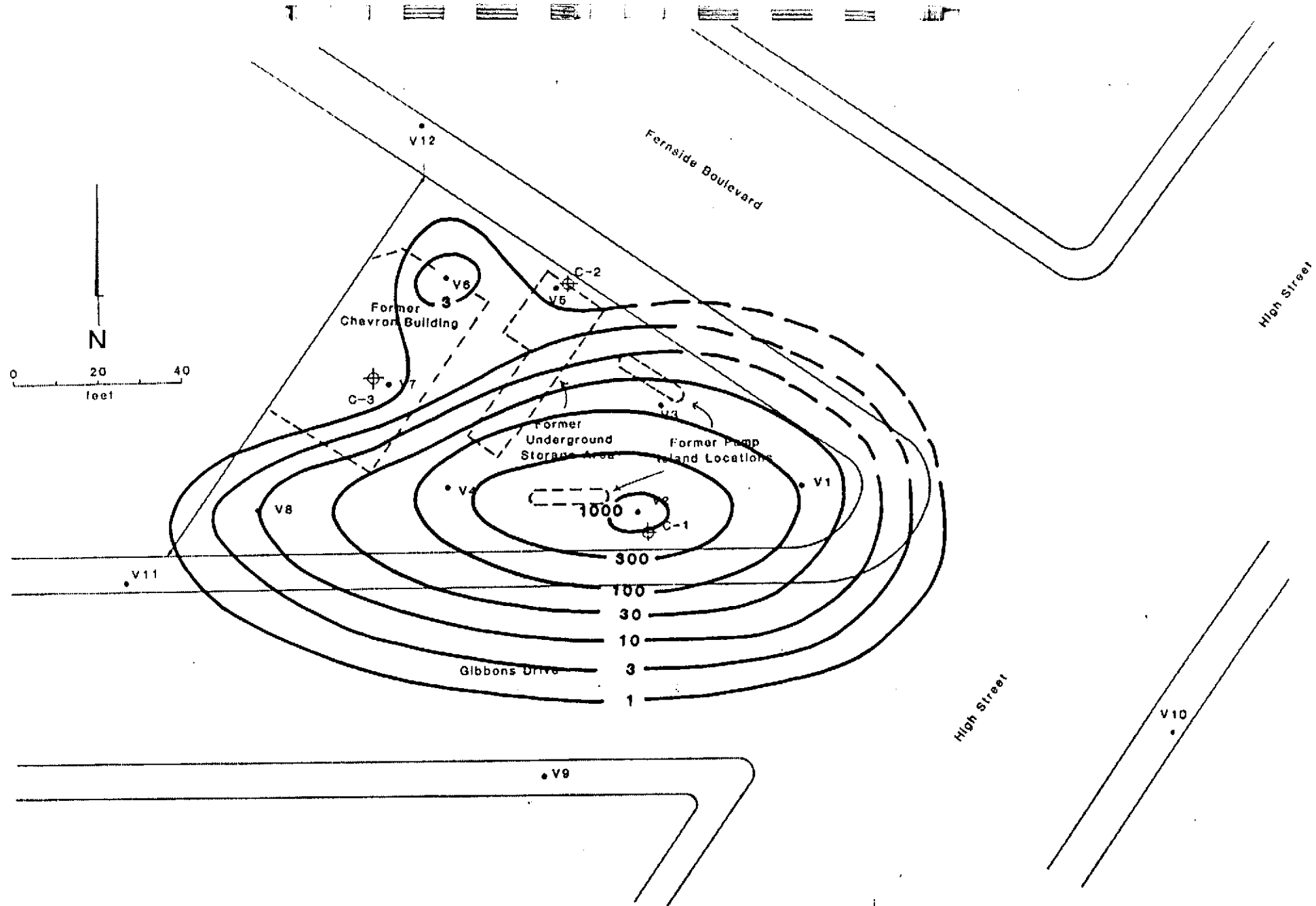
Figure 9. Isoconcentrations (VS, log-scaled) of compounds eluting after benzene (except toluene), in the vicinity of Chevron SS 9-1153, Alameda, CA.

pump island. This suggests that the present soil contamination
may have come from a leak in a delivery line near the east end of
that island. Soil samples recovered during the boring of the
nearby boring C7 were reported to have a strong gasoline odor at
depths of 1.5 and 4-6 feet; faint odor was reported at 9-10 feet,
and none at greater depths (EMCON 1986). Strong gasoline odor
was also reported from boring C2 at depths of 4-6 feet; this was
probably due to a leak or overflow at the filling hole of the
northernmost storage tank. Table 1 shows that the maximum total
petroleum hydrocarbon concentration in ground water occurs in C1
(15 mg/L) and the minimum in C3 (0.05 mg/L; this is in agreement
with the other data.

Comparison of a hydrocarbon compound's concentration in soil
vapor in the vadose zone with that in water in the saturated zone
is useful in estimating the transport direction of the compound
between the two media (Hinchee and Reisinger 1987). The Henry's
Law constant, described in Section 1.2, is the basis for this
comparison. Considering data for V2 and C1:

	Benzene	Toluene
V2 vapor concentration (ppm)	1,900	500
(atmospheres)	1.9×10^{-3}	5×10^{-4}
C1 ground water (mg/L)	0.76	0.82
Ratio (atm·L/mole)	195	56
Henry's Law constant (atm.L/mole)	4.5	5.2

The direction of benzene and toluene transport appears to be from
the vapor phase into solution in ground water. This indicates
that the primary means of transport at this site is in the vapor
phase, and not in the ground water.

The lower flammable limit (LFL) of gasoline vapor in air is about
1.4 percent by volume or about 6 percent (60,000 ppm) by weight.
The constituent weight concentrations at V2 sum to approximately

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3. RISK ASSESSMENT

The risk assessment process, as applied to fuel-contaminated sites, is described in detail by Hinchee et al. (1986). It is a step-wise progression in which the level of effort and approach to both site characterization and remediation are developed to ensure that the level of risk posed by the site is acceptable, realizing that we do not live in a risk-free world. A risk assessment need not be excessively lengthy, since fuel-contaminated sites have much in common and a standardized approach can be used. The following steps are typically applied:

- <u>Site Characterization</u> - This is the process of identifying the source and extent of contamination at the site in three dimensions, along with the physical features that may influence contaminant fate. This step has been carried out in Chapter 2.

- <u>Hazard Identification</u> - In this step, the substances found on the site through the characterization are examined, and a determination is made of the level of hazard they pose to human health and the environment. At the Alameda site, as with any gasoline-contaminated site, benzene is the substance of greatest concern.

- <u>Transport and Fate Analysis</u> - Following the identification of compounds of potential concern at a site, the pathways through which contaminants may migrate, and their ultimate fates, are identified and migration rates are estimated. This analysis includes determination of the physical properties of the compounds of interest, determination of the relevant site physical characteristics, and determination of the ways the compounds and the site interact. Interactions frequently examined include solubilization, volatilization, adsorption/desorption, photo-oxidation,

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and biodegradation. For this site, the fate analysis will focus on threat or lack of threat to ground water and on vapor phase transport.

. Exposure Assessment - Receptors, human or environmental, are identified that may be affected by exposure to contaminants identified in the hazard identification by the pathways identified in the fate analysis. In this step, the receptor's potential exposure to these compounds is quantified. For the Alameda site, the exposure assessment consists of comparing projected ground-water concentrations to established standards.

This risk assessment process has been be conducted in a manner compatible with California state guidance as outlined in the California Department of Health Services Site Mitigation Decision Tree (DHS 1985, 1986).

3.1 TRANSPORT AND FATE ANALYSIS

At the Alameda site the ultimate fate of most of the contaminant will most probably be volatilization to the atmosphere. This is true of most subsurface gasoline spills (Baehr 1984). Due to the low levels of soil vapor contamination seen at this site, mass discharge via this mechanism is extremely slow. The other potentially important migratory pathway is migration to the ground water.

As noted in Chapter 2, there is no evidence that free product is or has been in direct contact with ground water; BTX in water may reach concentrations in excess of 28 mg/L, but the greatest observed BTX concentration at the site was only 3 mg/L, in MW C1. Contaminant migration to ground water would be expected to occur through aqueous solution in the vadose zone. This is confirmed by the nature of the gasoline components observed in solution in ground water at the site. Once it is dissolved, the ultimate

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fate of most of the contamination will be volatilization, not migration to ground water, because infiltration in this area is typically extremely limited, generally less than one inch per year (EPA 1983). At this particular site, infiltration can be expected to be even slower, because pavement covers the area.

In Section 1.2 it was stated that ground water flow is likely to be easterly, towards the Tidal Canal, 400 feet to the east. Only one well (monitoring well 1701-2) is located in that direction and within one-half mile of the site. However, it lies on the opposite side of the Tidal Canal, which should intercept any contaminated ground water originating at the site. On this basis, it appears that no well is threatened by contamination originating at the subject site.

The rate of movement (v) of contaminated ground water toward the Tidal Canal may be calculated as

$$v = Ki/n.$$

For the silty-clayey sand aquifer at shallow depths (4-10 feet), K (hydraulic conductivity) probably does not exceed 10^{-5} m/sec, n (porosity of the soil) is about 0.3, and i, the gradient, has been estimated as 0.002 (Section 2.2). The value for v is calculated to be 7×10^{-8} m/sec, about 1.2 feet per year.

Thus, it may take about 330 years for the contaminated water to travel the 400 feet to the canal. In such a long time, it is expected that any fuel contaminants in the ground water will be completely degraded by oxidation, volatilization, and biodegradation. The mechanism of biodegradation is discussed below. It is expected that no significant contamination could ever reach the canal.

The highest reported concentration of benzene in ground water beneath the site is 0.76 mg/L. The Department of Health Services

action level for benzene in surface waters is 0.7 mg/L. There is no doubt that the concentration of benzene in contaminated ground water originating at the site and entering the canal will be far under 0.7 mg/L after 300 years. Dilution in waters of the canal would reduce even a benzene concentration of 0.76 mg/L to insignificant levels, far below 0.7 mg/L. In ground water, a number of mechanisms, including biodegradation, volatilization, and sorption, will serve to attenuate the dissolved hydrocarbons (API 1985).

Fuel hydrocarbons (represented here by benzene) are readily biodegraded under aerobic conditions (Raymond et al. 1976). Stoichiometrically, this degradation occurs according to the following reaction:

$$C_6H_6 + 7\text{-}1/2\ O_2 \longrightarrow 6CO_2 + 3H_2O$$
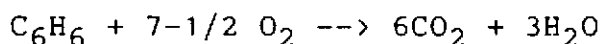
Complete oxidation requires an oxygen/hydrocarbon ratio (by weight) of approximately 3/1 (oxygen to hydrocarbon). Typically, following a subsurface spill, the first hydrocarbons to contact ground water rapidly deplete the available oxygen, resulting in anaerobic conditions. Assuming an initial oxygen content of 8 mg/L, approximately 2.6 mg/L of hydrocarbons may be degraded in this fashion.

Anaerobic biodegradation of fuel hydrocarbons does occur and has recently been documented both in field and laboratory research, (Batterman and Werner 1987; Schink 1985; Choteau et al. 1982; Kahn and Zeyer 1986; Vogel and Grbic-Galic 1986; Wilson et al. 1986), although generally at rates lower and somewhat less predictable than those characterizing aerobic biodegradation (Healy and Daughton 1986).

Laboratory and field evidence suggests that microbial populations can utilize minute amounts of oxygen to initiate hydrocarbon oxidation, and that subsequent oxidation is sustained by alterna-

tive electron acceptors, such as nitrate or sulfate. Swain et al. (1971) reported that Pseudomonas aeruginosa degrades octane both aerobically and by denitrification if trace amounts of oxygen (<0.05 mg/L) are present. When oxygen was entirely excluded, however, degradation did not proceed. Kuznetsova and Gorlenko (1965) reported that aerobic pseudomonas initiate attack on hydrocarbons at the upper edges or rims of oil fields, and that the partially oxidized products of this process are further oxidized by sulfate reducers with concomitant formation of H_2S.

In nature, electron acceptors are used preferentially in the order:

Aerobic   Anaerobic

$$O_2 > NO_3^- > SO_4^{-2} > CO_2$$
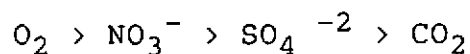
Thus, oxygen is preferred over nitrate, nitrate over sulfate and sulfate over carbon dioxide (methane fermentation). The reduced products of these electron acceptors are water, nitrogen gas, hydrogen sulfide, and methane, respectively.

Following depletion in ground water, any nitrate present may be used as an electron acceptor, resulting in denitrification according to the following reaction (Mitchell 1974):

$$_-C_6H_6 + 5NO_3 \longrightarrow 6CO_2 + 2\text{-}1/2N_2 + 3H_2O$$
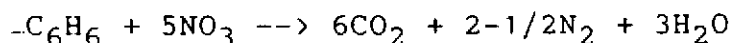
By weight, approximately one part of hydrocarbon is degraded for every 4.8 parts of nitrate (the ratio would be about 1/1 for nitrate reported as nitrogen). This biodegradation mechanism is the basis of a remedial technology demonstrated in Germany (Battermann and Werner 1984) and in Canada (Berry-Spark et al. 1986). In both cases nitrates were added to ground water, resulting in significantly accelerated degradation of fuel hydro-carbons. This process has not, apparently, been used in the United States, probably because of restrictions on injection of

nitrate (a Primary Drinking Water Standard compound) to ground
water.

3.2 EXPOSURE ASSESSMENT

As described in Chapter 2, most of the hydrocarbon contaminants
originating on the subject site are confined to soil above the
water table. Contaminant transport in ground water in this area
is very slow, and the ultimate fate of the small amount of
hydrocarbon contaminants remaining after biodegradation and
volatilization is to be mixed with tidal waters flowing in the
Tidal Canal. After mixing has occurred, benzene and toluene are
expected to have concentrations far below 700 and 5,000 ppb,
which are the Department of Health Services action levels for
benzene and toluene in surface waters.

**The fate of most of the mass of fuel contaminants would be
eventual transport in the vapor phase from soil into the
atmosphere,** if no action is taken. There is a minor risk that
fuel odors could develop in a building sited over the most-
contaminated soils.

4. CONCLUSIONS AND RECOMMENDATIONS

On the basis of this investigation, the following conclusions are drawn:

1. Moderate levels of hydrocarbons are present in soil vapor and ground water beneath the site and adjacent streets.

2. Due to hydrogeological conditions, no threat to human health or the environment is posed by this contamination.

3. Although hydrocarbon levels in soil vapor are well below the lower flammable limit, potential for an odor nuisance exists.

The following possible courses of action are recommended:

1. Monitor existing wells annually for three years to confirm the natural degradation of contaminants in ground water.

2. If construction over the more contaminated site locations is considered, the potential for nuisance odors may be eliminated by one of the following alternatives:

   a. installation of a synthetic membrane vapor barrier (20-mil PVC should be adequate) beneath buildings

   b. installation of ventilation pipes in any gravel sub-base so that if vapors accumulate a blower could be used to vent the sub-base

c.   installation of shallow (2-3 feet deep) horizontal vents in the area of greatest contamination using a low-flow/high-vacuum blower at a rate of 20-50 cfm.

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EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

SVCA DATA SHEET

Project Number: CHV72C

Project Manager: _____

Site Location: Alameda - Fernside + Gibbons

Date: 21 July 1987

Analysts: CAP/RMG

Pump Number: 55 9-1153

Grid Location	Time	Depth (ft)	OVA (ppm)	Purge Time	Vacuum Reading	Soil Type	Comments
V1		3		10	0		surface sand
V2		3		10	0		`` ``
V3		3		20	0		`` ``
V4		3		10	0		`` ``
V5		3		10	0		very easy driving — probably in tank field back fill
V6		3		10	0		surface sand
V7		3		10	0		``
V8		3		10	0		`` ``
V9		3		10	0		in planter lawn
V10		3		10	0		in planter
V11		3		10	0		`` ``
V12		3		10	0		`` ``

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

Photovac 10S70 Chromatogram report sheet

Project Number: **CHV72C**

Date: **21 July 1987**

Sample: **STANDARD**

Analysts: **CAP**

Vol. Inj: **100 µl**

Std. Vol. Inj: **100 µl**

Comments: _____

_____

_____

Sample: **BLANK**

Vol. Inj: **100 µl**

Comments: _____

_____

_____

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

Photovac 10S70 Chromatogram report sheet

Project Number: __CHV72C__   Date: __21 July 1987__

Sample: __V1__   Analysts: __CAP__

Vol. Inj: __1 ml of 1:40 dilution__   Std. Vol. Inj: __100 µl__

Comments: __1.4 dilution__
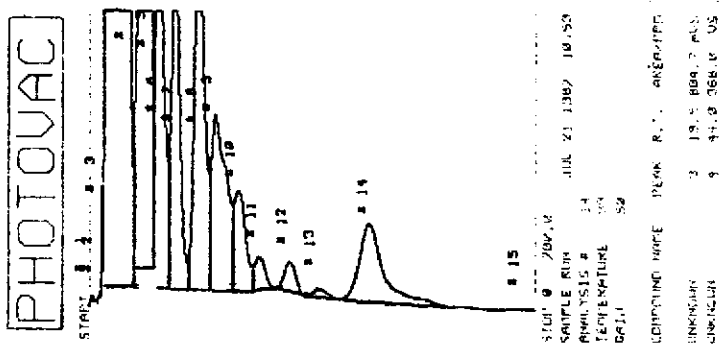
Sample: __V2__   Vol. Inj: __100 µl of 1:40 dilution__

Comments: __1.40 dilution__
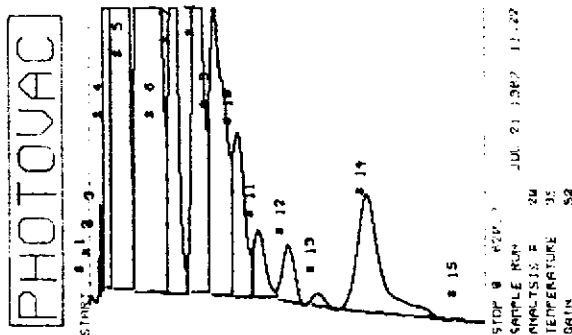
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

Photovac 10S70 Chromatogram report sheet

Project Number: _CHV72C_
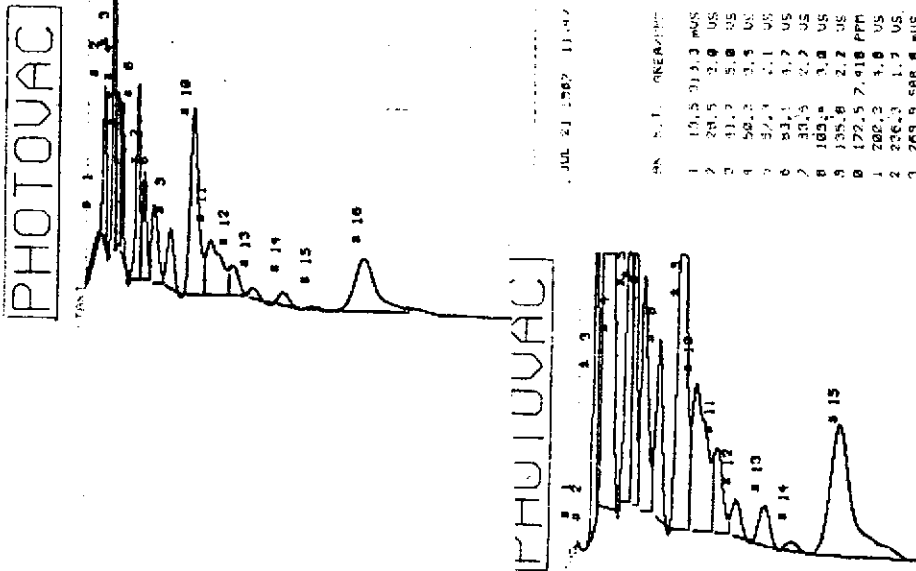
Date: _21 July 1987_

Sample: _V3_

Analysts: _CPP_

Vol. Inj: 1) _500 µl of 1:40 dilution_

Std. Vol. Inj: _100 µl_

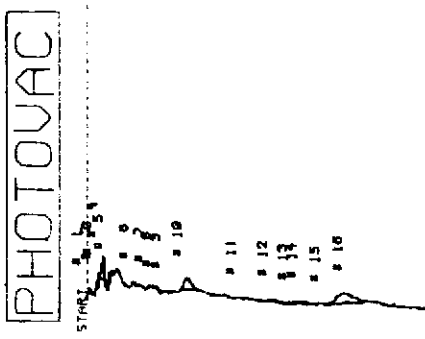Comments: _x8 dilution 2) 1ml of 1:40 dilution = x4 dilution_

Sample: _BLANK_

Vol. Inj: _100 µl_

Comments: _____

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

Photovac 10S70 Chromatogram report sheet

Project Number: _CHV72C_

Sample: _V4_

Vol. Inj: _1ml of 1:40 dilution_

Comments: _1.4 dilution_

Date: _21 July 1987_

Analysts: _CHP_

Std. Vol. Inj: _100 µl_

Sample: _V5_

Comments:

Vol. Inj: _100 µl_

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

Photovac 10S70 Chromatogram report sheet

Project Number: _CHV72C_

Sample: _V6_

Vol. Inj: _100 μl_

Comments: _____

Date: _21 July 1987_

Analysts: _CAP_

Std. Vol. Inj: _100 μl_

PHOTOVAC

STOP # 564.2
SAMPLE RUN
ANALYSIS # 30
TEMPERATURE 35
GAIN 50

JUL 21 1987 13:32

COMPOUND NAME	PEAK	R.T.	AREA/PPM	
UNKNOWN	3	70.3	52.8	mVS
UNKNOWN	4	90.9	1.9	US
UNKNOWN	5	98.9	1.1	US
UNKNOWN	6	55.7	281.3	mVS
UNKNOWN	7	90.3	4.1	US
UNKNOWN	8	98.3	2.8	US
UNKNOWN	9	105.5	3.5	US
UNKNOWN	10	123.5	2.7	US
BENZENE	11	162.4	11.01	PPM
UNKNOWN	12	187.3	8.1	US
UNKNOWN	13	220.3	2.4	US
UNKNOWN	14	251.3	1.3	US
UNKNOWN	15	295.0	1.5	US
UNKNOWN	16	337.3	431.5	mVS
TOLLENE	17	411.7	14.82	PPM

Sample: _V7_

Vol. Inj: _100 μl_

Comments: _____

PHOTOVAC
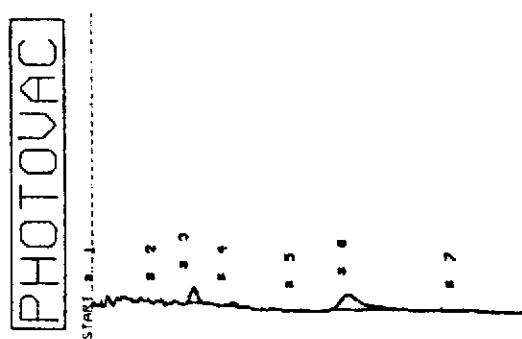
STOP # 700.0
SAMPLE RUN
ANALYSIS # 31
TEMPERATURE 35
GAIN 50

JUL 21 1987 13:46

COMPOUND NAME	PEAK	R.T.	AREA/PPM	
BENZENE	3	185.3	0.500	PPM
UNKNOWN	4	220.3	122.4	mVS
TOLUENE	6	412.1	1.730	PPM

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Photovac 10S70 Chromatogram report sheet

Project Number: **CHV72C**

Sample: **V8**

Vol. Inj: **100 µl**

Comments: _____

Date: **21 July 1987**

Analysts: **CAP**

Std. Vol. Inj: **100 µl**

PHOTOVAC

STOP @ 700.0
SAMPLE RUN   JUL 21 1987 13:55
ANALYSIS #   32
TEMPERATURE   34
GAIN   50

COMPOUND NAME	PEAK	R.T.	AREA/PPM	
UNKNOWN	2	15.3	527.2	mVS
UNKNOWN	3	18.0	233.8	mVS
UNKNOWN	4	26.2	91.4	mVS
UNKNOWN	5	41.2	937.0	mVS
UNKNOWN	8	63.5	613.3	mVS
UNKNOWN	9	80.9	1.0	US
UNKNOWN	10	91.9	335.9	mVS
UNKNOWN	11	120.8	196.1	mVS
UNKNOWN	12	135.5	2.3	US
BENZENE	13	167.3	4.040	PPM
UNKNOWN	14	192.3	1.5	US
UNKNOWN	15	230.3	3.4	US
UNKNOWN	16	257.3	197.1	mVS
UNKNOWN	17	304.8	305.6	mVS
UNKNOWN	18	348.5	2.6	US
TOLUENE	19	420.7	7.799	PPM
UNKNOWN	20	559.8	336.0	mVS

Sample: **V9**

Vol. Inj: **100 µl**

Comments: _____

PHOTOVAC

STOP @ 525.3
SAMPLE RUN   JUL 21 1987 14:12
ANALYSIS #   33
TEMPERATURE   34
GAIN   50

COMPOUND NAME	PEAK	R.T.	AREA/PPM	
UNKNOWN	2	160.1	117.4	mVS
UNKNOWN	4	433.6	649.2	mVS

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Photovac 10S70 Chromatogram report sheet

Project Number: __CHV72C__   Date: __21 July 1987__

Sample: __V10__   Analysts: __CAP__

Vol. Inj: __100 μl__   Std. Vol. Inj: __100 μl__

Comments: _____

_____

_____

_____


```
STOP @   688.0        JUL 21 1987  19:25
SAMPLE RUN          34
ANALYSIS #          32
TEMPERATURE         50
GAIN

COMPOUND NAME    PEAK  R.T.   AREA/PPM

UNKNOWN            1  173.3  78.3 AVS
UNKNOWN            9  158.6  759.2 AVS
```
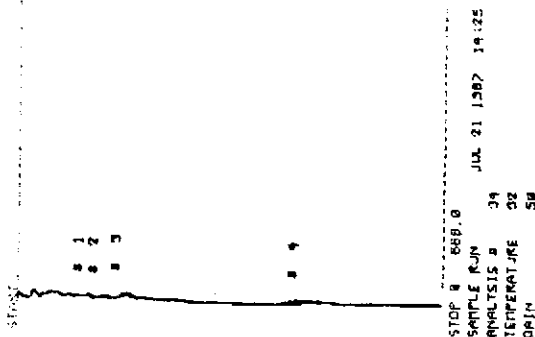
Sample: __V11__   Vol. Inj: __100 μl__

Comments: _____

_____

_____


```
STOP @   608.0        JUL 21 1987  19:36
SAMPLE RUN          35
ANALYSIS #          33
TEMPERATURE         50
GAIN

COMPOUND NAME    PEAK  R.T.   AREA/PPM

UNKNOWN            4  158.6  299.6 AVS
```
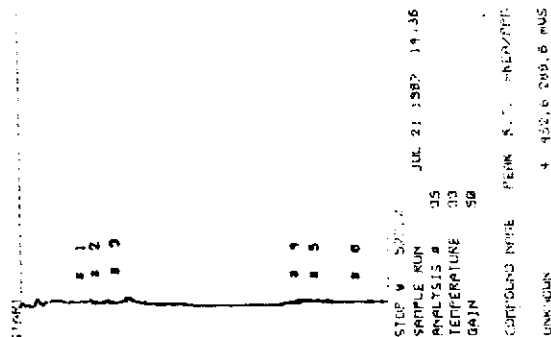
EA **EA ENGINEERING,**
SCIENCE, AND
TECHNOLOGY, INC.

Western Regional Operations
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(415) 283-7077

21 September 1987

Robert S. Stolz
Engineer, West Central Division
Chevron U.S.A. Inc.
2 Annabel Lane, Suite 200
San Ramon, California 94583

RE: EA Report (August 1987) for SS 9-1153
      Alameda, California

Dear Bob:

This letter is to correct an error in the above-referenced
report, concerning the flammability of the soil vapor.

On page 11, in the last paragraph, we referred to "...weight
concentrations at V2...", although this should have read "volume
concentrations at V2". The following statement, "This is well
below the LFL..." is incorrect, and should read, "This is at the
LFL...".

On page 18, conclusion number 3 states that hydrocarbon levels in
soil vapor are well below the LFL. This is incorrect, at least
for vapor point V2. At distances more than 40 feet from V2,
total hydrocarbon levels would be less than 0.3 percent (volume),
or about one-fifth the LFL, which is certainly safe.

We regret any inconvenience this error may have caused Chevron
U.S.A.

                         Sincerely,

                         Roger W. Greensfelder, Ph.D., P.G.

RWG:ds