100 Pine Street, 10th Floor
San Francisco, CA 94111
(415) 434-9400 • FAX (415) 434-1365

GEOMATRIX

ENVIRONMENTAL
PROTECTION

97 JUL 28 PM 3:58

28 July 1997
Project 3182.01

STID 1184

Ms. Susan Hugo
Alameda County Health Department
Department of Environmental Health
Hazardous Materials Division
1131 Harbor Bay Parkway
Alameda, California 94502

Dr. Ravi Arulanantham
California Regional Water Quality Control Board,
San Francisco Bay Region
2101 Webster Street, Suite 500
Oakland, California 94612

Subject: Revised Risk Assessment and Long-Term Site Management Program for Petroleum Product and a Response to Aetna's Concerns Regarding the Proposed Long-Term Management Strategy
Powell Street Plaza and Shellmound III, Emeryville, California

Dear Ms. Hugo and Dr. Arulanantham:

Geomatrix Consultants, Inc. (Geomatrix) is pleased to submit on behalf of the Former Eastshore Partners, the above-referenced documents for Powell Street Plaza and Shellmound III (the sites) located in Emeryville, California. The Risk Assessment and Long-Term Management Strategy was revised from the draft submitted on 25 April 1997 to incorporate comments submitted by Dames & Moore on behalf of Allegis Realty Investors, LLC (Allegis). The letter, dated 28 July 1997, was written in response to concerns submitted by Morrison & Foerster on behalf of Aetna Real Estate Associates, LLP (Aetna). Relevant considerations from the comments on behalf of Aetna were also incorporated into the Risk Assessment and Long-Term Management Strategy.

The conclusions of the screening assessment of potential human health and ecological risks remained the same after the comments were incorporated. Potential adverse human health effects are not associated with activities by current and future occupants of the sites, specifically future construction workers, current and future maintenance workers, current and future commercial building occupants, and current and future off-site receptors. The assessment of potential migration of dissolved-phase petroleum hydrocarbons to Temescal Creek indicated that human recreational users and ecological receptors are not likely to be adversely affected by migration of the chemicals of interest from the sites. Assuming noninvasive activities, potential adverse health effects were not associated with residual petroleum product at the sites because only a small amount of residual petroleum product remains at the site following product removal activities. Additionally, the residual petroleum product remaining is essentially immobile.? A long-term site management strategy was developed to address the potential effects of residual petroleum product during invasive activities.

The response to comments on behalf of Aetna primarily addresses two concerns: the need for removal of residual petroleum product from the site and the effects of residual petroleum product on the eventual redevelopment of the property. With regard to the first concern, ~~removal of residual petroleum product from the site is not required based on the discretion given local agencies to require cleanup only "to the extent practicable"~~. Other possible remedial alternatives are evaluated in the response letter, but they are less practicable than the ongoing passive bioremediation and do not improve protection of human health, safety, or the environment compared with passive bioremediation. With regard to the second concern, ~~passive bioremediation will impact future development less than active remediation because~~ remediation activities will not be interfering with other uses of the sites. Passive and active bioremediation will both require many years to remove the residual petroleum product and, therefore, both will also require implementation of a long-term site management plan.

Based on the information presented, the sites should be considered low risk groundwater cases under the California Regional Water Quality Control Board, San Francisco Bay Region (RWQCB), Guidance on Low Risk Fuel Sites. As outlined in the response letter to Aetna, the following criteria have been met:

- The leak has been stopped and ongoing sources have been removed or remediated.
- The site has been adequately characterized.
- The dissolved hydrocarbon plume is not migrating.
- No water wells, deeper drinking water aquifers, surface water, or other sensitive receptors are likely to be impacted.
- The site presents no significant risk to human health
- The site presents no significant risk to the environment.

Based on our evaluation of site parameters, continuation of the on-going passive bioremediation is recommended as the appropriate remedial strategy for residual petroleum at the subject sites.

If you have any questions, please contact either of the undersigned.

Sincerely,

GEOMATRIX CONSULTANTS, INC.

Ann Holbrow

Ann Holbrow
Senior Scientist

Tom Graf, P.E.
Vice President

AH/TG:ldu
I:\RISK\POWELL\CVLTR723.DOC

cc:
Kevin Graves, RWQCB
Tom Gram, The Martin Group
Richard Hutton, PES Environmental, Inc.
Randy Brandt, Dames & Moore
Ron Gerber, Emeryville Redevelopment Agency

2069

GEOMATRIX

RISK ASSESSMENT AND LONG-TERM MANAGEMENT STRATEGY FOR PETROLEUM PRODUCT

Powell Street Plaza and Shellmound III
Emeryville, California

ENVIRONMENTAL
PROTECTION
97 JUL 28 PM 3:58

Prepared by:

Geomatrix Consultants, Inc.
San Francisco, California

Prepared for:

Eastshore Partners
Emeryville, California

July 1997
Project No. 3182.01 E

GEOMATRIX

RISK ASSESSMENT AND LONG-TERM MANAGEMENT STRATEGY FOR PETROLEUM PRODUCT

Powell Street Plaza and Shellmound III
Emeryville, California

Prepared by:

Geomatrix Consultants, Inc.
San Francisco, California

Prepared for:

Eastshore Partners
Emeryville, California

July 1997
Project No. 3182.01 E

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (cont'd)

LIST OF APPENDICES

RISK ASSESSMENT AND LONG-TERM MANAGEMENT STRATEGY FOR PETROLEUM PRODUCT

Powell Street Plaza and Shellmound III
Emeryville, California

1.0 INTRODUCTION

This report has been prepared by Geomatrix Consultants, Inc. (Geomatrix) on behalf of the former Eastshore Partners to evaluate potential health and environmental effects associated with petroleum hydrocarbons detected in soil and groundwater at the Powell Street Plaza (PSP) site and Shellmound III site located in Emeryville, California (sites). The purpose of the report is to provide a basis for developing a long-term site management plan for petroleum hydrocarbon impacted soil and groundwater. The report was prepared in accordance with Geomatrix's "Proposed Work Plan to Develop a Long-Term Site Management Program" dated 11 August 1995 (Proposed Work Plan) and the revisions to the work plan dated 28 October 1996.

The specific issues of concern at the site related to petroleum hydrocarbons identified by the Alameda County Health Care Services Agency (ACHCSA) and the San Francisco Bay Regional Water Quality Control Board (RWQCB) are:

- Human health risks for current and future commercial building occupants, construction workers and recreational users of Temescal Creek;
- Potential risks to aquatic organisms associated with migration of dissolved petroleum hydrocarbon constituents to Temescal Creek; and
- Migration potential for free product (i.e., separate-phase material that is potentially mobile) present on the shallow groundwater

A site conceptual model was developed to identify the main tasks to be performed as part of this scope of work Following a discussion of the site's background, this report summarizes the site conceptual model, the results of additional sampling activities, an assessment of environmental fate and transport, and a screening assessment of potential health and/or environmental effects to:

- Construction and maintenance workers from exposure to chemicals vaporized from the subsurface and direct contact with groundwater;
- Current building occupants from exposure to chemicals vaporized from the subsurface;
- Off-site building occupants from exposure to chemical vaporized from the subsurface; and
- Recreational users and aquatic organisms in Temescal Creek from migration of dissolved-phase material to Temescal Creek.

Based on the results of the human health and ecological risk assessment and to address other environmentally-related concerns, a long-term management plan for the site was developed to:

- Present guidelines for appropriate health and safety measures for future site activities;
- Present guidelines for short-term and long-term management of residual petroleum hydrocarbons present at the sites; and
- Present considerations associated with the potential for methane generation at the sites.

2.0 BACKGROUND

This section presents a description of the site setting and current use, historical site uses, and previous environmental investigations conducted at the sites.

2.1 SITE SETTING AND CURRENT USE

The two sites are located along the eastern margin of San Francisco Bay in Emeryville, California (Figure 1). The two sites consist of approximately 17 acres and are bounded by Temescal Creek to the south, Highway 80 to the west, Shellmound Street to the east, and Powell Street to the north (Figure 2). San Francisco Bay is located approximately 0.1 mile west of the two sites. The PSP site consists of an approximate 13-acre parcel in the northern portion that is currently developed as a commercial retail center; the Shellmound III site consists of a 4-acre parcel south of the PSP site that is currently undeveloped. The PSP site is covered by asphalt pavement or buildings; the Shellmound III site is unpaved and contains mounds of ungraded fill on the eastern part of the property.

2.2 HISTORICAL SITE USAGE

According to PES Environmental, Inc. (PES; 9 January 1995), the two sites were formerly a tideland and marsh area of the San Francisco Bay. The 1856 shoreline of the bay was located east of the sites, generally along the current Shellmound Street. The sites were gradually filled by 1969. Pacific Intermountain Express (P.I.E.) operated a truck maintenance and fueling facility on the PSP site from 1944 to 1986. P.I.E. installed and operated eight underground fuel storage tanks (USTs) at the site; the USTs were reportedly removed by Blymyer and Sons Engineers, Inc. (Blymyer) in July 1986. The PSP site was purchased by Eastshore Partners in 1986 and the Powell Street Plaza was constructed in 1987 Eastshore Partners reportedly conveyed this property to Aetna in February 1990 and Aetna is the current owner.

The Shellmound III site is currently owned by the City of Emeryville Redevelopment Agency. According to Applied Geotechnology Inc. (18 May 1994), the Shellmound III site has been used for tractor trailer storage and disposal or storage of debris and slag from the Judson Steel site, located approximately 0.1 mile southeast of the site, since 1930. PES reported that metal slag has been observed in the fill at the Shellmound III site (PES, 9 January 1995). It should be noted that, with exception of petroleum hydrocarbons in the subsurface that have migrated from the PSP site, the City of Emeryville Redevelopment Agency is responsible for environmental conditions at the Shellmound III site.

2.3 PREVIOUS SITE INVESTIGATIONS

Numerous investigations have been conducted at the sites since the USTs were removed in 1986. These investigations have included:

- Geotechnical Investigation by Geomatrix in April and October 1986;
- Soil and Groundwater Investigation by Groundwater Technology, Inc. in August 1986;
- Soil and Groundwater Investigation by Peter Kaldveer and Associates, Inc. in August 1986;
- Soil Investigation by Geomatrix in September and December, 1987;
- Environmental Assessment of the Shellmound III site by Earth Metrics in August 1987;
- Soil Investigation by Alton Geosciences in October 1987;
- Soil and Groundwater Investigation by Alton Geosciences in March 1988;
- Soil and Groundwater Investigation by Tenera Environmental Services in July 1987.
- Soil and Groundwater Investigation of the Shellmound III property by Earth Metrics in April 1990;
- Hydrogeologic Investigation by PES in May 1990;
- Soil and Groundwater Investigation by PES in July 1990;

- Soil and Groundwater Investigation by PES in March 1991;
- Groundwater Assessment by PES in May 1992;
- Soil and Groundwater Investigation of the Shellmound III property by Wahler Associates in May 1992;
- Quarterly groundwater monitoring conducted by PES since 1992;
- Soil and groundwater remedial investigation of the Shellmound I, II and III properties by Klienfelder and Associates in 1995; and
- Human health risk assessment for soil and groundwater at the Shellmound I, II and III properties by Soma Environmental Engineering in 1996.

Currently, there are 17 shallow (completed at or above 20 feet below grade) groundwater monitoring wells at the sites and one shallow groundwater monitoring well located west of the sites (Figure 2). Previously, 22 monitoring wells existed on the sites and two wells were located off-site. Monitoring wells MW-5, MW-15, MW-7, MW-4 and MW-18 are believed to have been destroyed during the installation of the East Bay Municipal Utility District's sewer collection line in 1995.

According to PES (9 January 1995), separate-phase petroleum product, which appears to be primarily diesel, has been detected in wells in the southern portion of the PSP site and the northern portion of the Shellmound III site. Subsurface soil on both sites reportedly contain total petroleum hydrocarbons characterized as diesel (TPHd) primarily at the groundwater table; surface soil at the sites does not appear to have been affected by the former presence of the USTs.

Two groundwater/product extraction trenches were reportedly installed in the southwestern corner of the PSP site in late 1988 (PES, 9 January 1995). The extraction system was operated for 15 months, during which time approximately 1.3 million gallons of groundwater and 800 gallons of separate-phase petroleum product were extracted. Operation of the extraction system ceased in June 1990. Based on our review of available data, it appears that most of the extractable separate-phase material was removed. The most recent data collected by PES (PES, August 1996) indicates that separate-phase material measured in the monitoring wells at the sites has continued to decrease over the last few years.

Groundwater at the sites is currently monitored quarterly for the presence of total petroleum hydrocarbons characterized as gasoline (TPHg), TPHd, total petroleum hydrocarbons characterized as motor oil (THPmo); and benzene, toluene, ethylbenzene, and xylenes (collectively referred to as BTEX). The chemical analysis results for groundwater at the sites are difficult to interpret and may not be representative of actual dissolved petroleum hydrocarbon concentrations. The sites are located in a former marsh setting and site sediments in the shallow water bearing zone reportedly consist of fill and bay mud clay. Both of these soil types could contain a significant amount of naturally occurring organic compounds that can interfere with the chemical analyses for petroleum hydrocarbons. Sample preparation consisting of sediment removal and silica gel cleanup to remove naturally occurring organics prior to sample analysis is important for groundwater samples collected at sites with settings similar to the subject sites. Sediment removal and silica gel cleanup does not appear to have been conducted on samples collected at the sites. The approximate extent of dissolved TPHg, TPHd, and BTEX appears to have been adequately defined to the east and to the north; however, the southern and western extent of dissolved petroleum hydrocarbons in groundwater is not clear.

In the most recent study of the Shellmound III site, SOMA (1996) conducted screening-level evaluations for human health and ecological risk associated with chemicals of concern in soil and groundwater. One of the assessment points evaluated is directly related to a point of interest in this assessment SOMA evaluated the potential migration of chemicals in groundwater, including BTEX, to Temescal Creek This conservative assessment indicated that BTEX compounds in the shallow groundwater are unlikely to reach concentrations in Temescal Creek that pose a risk to aquatic organisms

3.0 SITE CONCEPTUAL MODEL

As described in the U.S. EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (1988a), the purpose of a site conceptual model is to describe what is currently known about chemical sources, likely migration pathways, exposure routes, and possible exposure scenarios at the time of study design. The potential scenarios for exposure to petroleum hydrocarbon related chemical constituents identified in the site conceptual model were presented in Geomatrix's Proposed Work Plan as follows:

- Current building occupants who could be exposed to chemicals volatilized to air from the subsurface, but would not be exposed to subsurface conditions based on the current and proposed future (i.e., hotel) site uses;
- Construction/maintenance workers who could be exposed to subsurface soils, chemicals volatilized to air from the subsurface, and direct contact with shallow groundwater;
- Off-site receptors who could be exposed to chemicals volatilized to air from the subsurface and particulates in ambient air associated with construction activities; and
- Recreational users and non-human receptors who could be exposed to chemicals migrating to Temescal Creek or the San Francisco Bay.

As proposed in the work plan, groundwater was not assumed to be a potential source of drinking water. Shallow groundwater at the site is not a current source of drinking water. Based on conversation with Dr. Ravi Arulanantham at the RWQCB (July 1997), shallow groundwater at the sites would not be considered a future potential source of drinking water because:

- Shallow groundwater is contact with utilities (i.e., sewers) that present a potential for contamination.
- The sites are in a highly industrial area with known impacts to shallow groundwater.

- The sites are near a major freeway with potential for run-off to impact shallow groundwater.
- The site is within 1000 feet of the Bay with potential for salt water intrusion.

Since the original site conceptual model was developed, the approach for addressing exposure has been further clarified following a more detailed evaluation of the site data. As discussed in our amendments to the Proposed Work Plan, Geomatrix proposed to address potential exposures to construction/maintenance workers in the long-term management plan for the sites rather than in the screening human health risk assessment. This recommendation was based on our review of the information available at that time and several conversations with RWQCB staff on this and other projects. However, Geomatrix has since concluded that potential exposures to construction/maintenance workers are best addressed as part of the risk assessment to provide a general foundation for the long-term management plan. Therefore, the potential receptors and general exposure pathways remain the same with the following clarifications:

- Dermal exposure to groundwater and separate-phase material have been separated to reflect the differing risk assessment techniques used to evaluate each pathway.
- Construction and maintenance workers operate outside of buildings, and thus, are not exposed to indoor air.
- The USTs formerly located at PSP were in contact with the shallow groundwater, and thus, leaked directly to groundwater bypassing impact to subsurface soil in the vadose zone. Subsurface soil impacted by petroleum hydrocarbons is limited to soil near or below the groundwater table and as such has characteristics associated with saturated soils. For this reason, resuspension of particulates in ambient air and inhalation of dust are not considered viable exposure pathways.

The revised site conceptual model is presented in Figure 3.

4.0 FIELD INVESTIGATION

This section describes the field sampling activities and the results of the chemical analyses conducted as described in the Proposed Work Plan (Geomatrix, 1995) and amendments discussed in the letter to Alameda County and the RWQCB dated 28 October 1996. These activities included the sampling and analysis of separate-phase material and groundwater to assess the potential for volatile and water-soluble petroleum hydrocarbon constituents to migrate to points of potential exposure for human or ecological receptors.

4.1 SEPARATE-PHASE RESIDUAL PRODUCT SAMPLING AND ANALYSIS

The purpose of the separate-phase material sampling and analysis was to gather information that could be used to evaluate the potential for: (1) volatile constituents to vaporize to ambient air or the indoor air of current or future buildings on the sites; (2) residual petroleum product to migrate to Temescal Creek; and (3) biodegradation.

Geomatrix collected a separate-phase material sample from monitoring well MG-1 (Figure 2) on 21 November 1996. Approximately 0.04 to 0.06 feet (0.5 to 0.7 inches) of separate-phase material was present in MG-1. Three 40-milliliter (ml) VOAs were filled with a mixture of separate-phase material and water from a disposable bailer. The material appeared very viscous and the limited amount available in well MG-1 made it difficult to pour into sample containers. Monitoring wells MW-13 and MW-3 were also inspected to determine if a greater quantity of separate-phase material could be collected. The field crew was unable to access well MW-13; no separate-phase material was found in well MW-3. An attempt was also made to sample separate-phase material from an irrigation valve box located near well MW-13. The box contained a sheen of oil, but it was not sufficient to collect a sample

Although a sample was not collected from the PSP property, the residual product beneath both properties is believed to originate from the same source, USTs on the PSP property (PES, 1995). Product migration from the source on the PSP property to the Shellmound III property is consistent with the groundwater flow direction (Figure 2). Thus, the residual separate-phase product sample. Collected from MG-1 is believed to be representative of material beneath both properties.

The samples from MG-1 were packaged on ice and shipped to Friedman and Bruya , Inc., in Seattle, Washington for analysis. The separate-phase material analyses request included:

- Polynuclear aromatic hydrocarbons (PAHs) by EPA method 8270;
- BTEX by aliphatic/aromatic fractionation;
- Viscosity by ASTM Method D445; and
- Density by ASTM Method D1217.

Friedman and Bruya was able to collect only enough sample from the three VOAs to conduct the PAH and BTEX analyses. Each VOA was reported to contain no more than 1 ml of separate-phase material on top of the water. An additional sample of approximately 10 ml, consisting of mostly separate-phase material with some water, was collected from monitoring well MG-1 on 3 December 1996. This sample was combined with the material remaining from the original samples collected on 21 November 1996 to get sufficient separate-phase material for the viscosity and density measurements. The results of the these analyses and supporting field documentation are presented in Appendix A.

The separate-phase material analytical results are summarized in Table 1. The aliphatic/aromatic fractionation analysis results indicate that the separate-phase material is dominated by $>C_{10}$ to C_{21} (compounds with more than 10 and less than or equal to 21 carbon atoms) aliphatic compounds (71% by weight) and $>C_{10}$ to C_{16} aromatic compounds (27% by weight) These percentages were normalized to 100% by the laboratory to eliminate the influence of the water that was entrained in the sample. Aromatic compounds in the $>C_{16}$ to C_{35} range were not detected ($<0.42\%$ by weight).

Chemical-specific analyses for BTEX compounds indicate that benzene, toluene, ethylbenzene and total xylenes were present in the separate-phase material at concentrations of 41 mg/kg, 10 mg/kg, 12 mg/kg, and <8 mg/kg, respectively. Twelve PAHs were detected in the MG-1 sample. The reported concentrations were greatest for four lightweight PAHs: acenaphthene at 220 mg/kg, fluorene at 610 mg/kg, anthracene at 990 mg/kg, and pyrene at 90 mg/kg. The remaining compounds that were detected were reported at concentrations ranging from 20 to 30 mg/kg.

The viscosity measurement reported a kinematic viscosity of 0.12 centimeters/second (cm/sec) for the MG-1 separate-phase material sample. The measured density was 0.945 grams/ milliliter (g/ml) at 20°F.

The quality assurance/quality control analytical results, presented in Appendix A, indicate that all analyses were performed within acceptable limits. It should be noted that compounds were present in the separate-phase material sample that interfered with the quantitation of three PAH compounds (2-methylnaphthalene, acenaphthene, and fluorene). As mentioned above the separate-phase material sample collected from monitoring well MG-1 was very small in quantity and contained a significant amount of water that was entrained in the sample because the layer in the well was very thin (less than 1 inch). As a result, the analytical results for the aliphatic/aromatic fractionation, and the density and viscosity measurements are considered to be good estimates, but may not accurately depict the true values for these parameters in the residual petroleum product at the sites.

4.2 OXIDATION/REDUCTION POTENTIAL MEASUREMENTS

Oxidation/reduction potential (ORP) measurements were made at four of the monitoring wells after they were purged (MW-6, located upgradient of the separate-phase material, MG-2, where dissolved-phase analyses were conducted; MG-1, where separate-phase analyses were conducted; and MW-7, located downgradient of the separate-phase material). Following purging, ORP measurements were -103 millivolts (mV) at MW-6, -150 mV at

MG-2, -118 mV at MG-1, and -100 mV at MW-7. These negative values indicate that anaerobic conditions exist at the sites primarily resulting from its close proximity to San Francisco Bay.

Assuming a southerly gradient, upgradient well MW-6 exhibited a low ORP, characteristic of groundwater outside of a hydrocarbon plume. Monitoring wells MG-1 and MG-2, located within the separate-phase material plume, had higher ORP. Downgradient well MG-7 exhibited a lower ORP similar to upgradient conditions. The fluctuation in ORP across the site, increasing through the area impacted with petroleum hydrocarbons and decreasing outside this area, indicates that natural degradation of the petroleum hydrocarbons is occurring at the site.

4.3 GROUNDWATER SAMPLING AND ANALYSIS

The objectives of the groundwater sampling from monitoring wells MG-2 and MG-7 were to evaluate:

- Whether or not the TPHd sample results previously reported were representative of dissolved petroleum hydrocarbons; and
- Whether or not dissolved PAHs were present in the groundwater at concentrations that may pose a risk to receptors in Temescal Creek.

To evaluate these conditions, samples were collected from monitoring wells MG-2 and MG-7 on 17 November 1996. Well MG-7 was sampled to determine if PAHs or dissolved phase TPHd are present in groundwater at this downgradient well that is located immediately upgradient of Temescal Creek. Well MG-2 was sampled to determine if PAHs or dissolved phase TPHd is present in the groundwater in the immediate vicinity of the residual petroleum product plume. Groundwater samples were collected for analysis of TPHd with and without filtration and silica gel cleanup by Method 8015 modified, and for PAHs with and without filtration by EPA method 8310. The samples were sent to AEN Laboratory via courier under chain-of-custody procedures.

The analytical results for groundwater are provided in Table 2. The groundwater samples from wells MG-2 and MG-7 analyzed for TPHd by Method 8015 modified without filtration or silica gel cleanup were reported to contain 1.5 mg/l and 0.74 mg/l TPHd, respectively. Conversely, the groundwater samples that were subject to filtration and silica gel cleanup contained no detectable TPHd at a reporting limit of 0.05 mg/l. These results indicate that no detectable dissolved-phase TPHd is present in either of these wells; one (MG-2) that previously contained measurable separate-phase material and is in the immediate vicinity of residual petroleum product (detected in MW-3 and MG-1); and one (MG-7) that is 200 feet downgradient of monitoring well MG-1. The material detected as TPHd in the samples that were not filtered or subject to silica gel cleanup could be biogenic material resulting from the degradation of the residual petroleum hydrocarbons or naturally occurring materials associated with the former wetlands at the sites. These results indicate that recent data for the sites reported as TPHd inaccurately depict the shallow groundwater as being affected by dissolved-phase TPHd.

The analytical results for PAHs in groundwater indicate that very low part per billion (ppb) level concentrations of light molecular weight PAHs are present in the groundwater in the vicinity of monitoring well MG-2. Essentially, the same results were reported for the filtered groundwater sample from monitoring well MG-2, which contained four PAHs ranging in concentration from 0.2 to 3.2 µg/l (Table 2). The unfiltered groundwater sample from monitoring well MG-2 contained four PAHs ranging in concentration from 0.2 to 2.3 µg/l. Three compounds were detected in both samples: fluorene, phenanthrene, and fluoranthene. Pyrene was detected in the unfiltered sample and acenaphthylene was detected in the filtered sample. These results indicate that PAHs associated with the separate-phase material are not present at significant concentrations in groundwater in the immediate vicinity of the residual petroleum product. The groundwater samples from monitoring well MG-7 contained a detectable concentration of a single light-weight PAH compound (pyrene) at a concentration of 0.3 µg/l in the unfiltered sample. The filtered sample contained no detectable PAH compounds. These results indicate that dissolved phase PAHs have not migrated significantly downgradient of the residual petroleum product plume areas.

The quality assurance/quality control analytical results indicate that no significant interferences were encountered in the chemical analysis of the groundwater samples. The QA/QC results for the groundwater samples analyzed by AEN are presented in Appendix A.

5.0 RESIDUAL PETROLEUM PRODUCT MIGRATION EVALUATION

This section describes the distribution and physical properties of residual petroleum product at the sites and evaluates the potential for the residual product to migrate and enter Temescal Creek. As Temescal Creek serves as the only possible significant conduit between the sites and San Francisco Bay, the results of this assessment will also indicate whether migration of residual product to the Bay is possible. The East Bay Municipal Utility District interceptor line that was installed in 1995 is not expected to serve as a preferential conduit for transport residual petroleum product from the PSP property. According to Mr. Rob Crops of PES the backfill installed along the EBMUD interceptor line was designed to have the same permeability as the fill material on the PSP and Shellmound III sites (personal communication). Modeling conducted by PES demonstrated that this backfill approach minimized the potential for the interceptor line to function as a conduit for residual petroleum hydrocarbon at the site. As a result this migration pathway is not specifically addressed in this evaluation.

There are several factors that will influence the potential for the residual petroleum hydrocarbon product to act as free product and migrate to, and enter, Temescal Creek including:

- distribution and physical properties of the residual petroleum material;
- thickness of the residual petroleum;
- migration potential of the residual petroleum; and
- presence of physical barriers to migration (i.e., the concrete lining on the northern side of the creek).

Each of these factors is addressed in the following sections

5.1 DISTRIBUTION AND PHYSICAL PROPERTIES OF RESIDUAL PETROLEUM PRODUCT

Product removal efforts conducted at the PSP site between 1988 and 1990 removed more than 800 gallons of free product and product thickness observed in wells since that time has been generally less than about 0.01 feet in most of the wells at the site. The distribution of residual petroleum material at the sites is limited to an approximate area encompassing wells MW-7, MW-14, and MW-13 on the PSP site and a limited area near wells MG-3 and MG-1 on the Shellmound III site (Figure 4). Approximately 0.06 feet of product was observed in well MG-1 in November 1996. Well MG-3 has reportedly been inaccessible since 1995; however, between 1990 and 1995, the median product thickness in this well has been approximately 0.09 feet. Product thickness has ranged from a trace amount to 0.18 feet in well MW-14 and between approximately 0.02 and 0.61 feet in well MW-13 in the past year. Well MW-7 was abandoned in 1995; only trace amounts (less than 0.01 feet) of product were measured in this well in the year prior to abandonment. With the exception of trace amounts reported in wells MW-8 and MW-9 for June 1996 by PES, product has not been observed in other wells at the sites for the past year or more.

The product observed in well MG-1 in November 1996 was very viscous and did not flow readily. It was almost black in color, opaque and appeared heavily degraded. Physical analysis of the product by Friedman & Bruya indicated an approximate density of 0.945 grams per liter (g/l) and a kinematic viscosity of 0.12 centimeters per second (cm/s).

5.2 EVALUATION OF THE MIGRATION POTENTIAL OF THE RESIDUAL PRODUCT

The thickness of product observed in a well exaggerates the actual thickness of free (mobile) product in the formation. To evaluate the migration potential of the product, Geomatrix reviewed available literature to better understand the true residual product thickness, estimated the potential migration rate of the residual product, and evaluated the biodegradation potential for the product at the site setting. The true product thickness is necessary to estimate the volume of residual product in site sediment and to better understand the migration potential. The migration rate and biodegradation potential were then evaluated to assess the potential for residual product to act as free phase product and to migrate to and enter Temescal Creek.

5.2.1 Assessment of True Thickness

Our review of literature describing the occurrence and movement of free phase petroleum product suggests that the product observed in wells at the site after product removal is not mobile. Many studies have shown that the actual or "true" free phase product thickness in the formation will be significantly less than the thickness measured in an adjacent monitoring well screened across the water table and product layer (van Dam, 1967). De Pastrovich et al. (1979) suggested that the true thickness of product is approximately one quarter of that observed in monitoring wells. This estimate proved to be too simplistic to explain the difference between true product and well product thicknesses observed in subsequent laboratory experiments and many different methods have since been proposed to estimate the true product thickness (Hall et al., 1984; Abdul, et al., 1989, Lenhard and Parker, 1990; Farr et al., 1990; Kemblowski and Chiang, 1990).

In addition, according to Hughes et al (1988) observed product thicknesses of several inches may indicate there is no free or mobile product in the formation. The observed product in the well results from the difference in the permeability of the filter pack and the surrounding formation, which allows migration of otherwise non-mobile residual product into the well. Experimental results reported by Hughes et al. (1988) suggest that several inches to a foot of product can accumulate in a monitoring well in this manner. Because the layer of residual product at the site is very thin, the amount of product would not create sufficient head in the product to move on its own and should therefore only be influenced by the gradient of the water table at the site This condition suggests that the residual product at the sites is unlikely to be mobile.

5.2.2 Assessment of Migration Potential

Although the above literature review suggests that the residual product remaining at the sites after free product removal was completed in 1990 is not mobile, Geomatrix conducted a conservative assessment of the potential rate of migration of residual product at the sites, if it were in fact mobile. Once the potential rate of migration was estimated, an estimate of the possible thickness of product at the creek was calculated and biodegradation was considered in the over all assessment of the plausibility of residual product reaching Temescal Creek in the future. The following describes the results of this assessment.

To assess the potential migration rate, Geomatrix estimated the conductivity of the product assuming the hydraulic conductivity and porosity parameters presented in Freeze & Cherry (1979) the density and kinematic viscosity of the product reported by Friedman & Bruya. A velocity of product was then estimated assuming that the product would flow at the gradient of the water table. It should be noted that this assumption does not account for the capillary forces within the formation and the influence of the free product thickness on the rate of flow; thus, it provides a very conservative estimate of the potential product migration rate. In addition, the density and viscosity measurements reported by Friedman & Bruya were influenced by water entrained in the samples, which indicates that these measurements may be more representative of a mix of water and product, not solely the product. This also leads to a more conservative estimate of the potential product migration rate.

The results of this evaluation indicate a product velocity of approximately 2 feet per year. Calculations and parameter values used to obtain this rate are presented in Appendix B. As noted above, this is a conservative estimate that may significantly overestimate the actual migration rate and potential for residual petroleum product at the sites.

To estimate the thickness of product that could reach the concrete wall on the north side of the creek, it was assumed that the volume of product currently presented in a limited area near well MG-1 at the Shellmound III site (Figure 4), would spread evenly across the area between well MG-1 and the creek, and the true product thickness is one-quarter of that currently observed in the monitoring wells. Results of these calculations indicate a product thickness less than 0.01 feet at the creek; this calculation is presented in Appendix B. It should be noted that again this is a conservative estimate because it assumes that all of the product will spread towards the creek and not in other directions.

5.2.3 Physical Barriers RPDA)

The migration pathway between MG-1 and Temescal Creek passes through unconsolidated fill material that abuts a concrete lining for Temescal Creek. SOMA (1996) reported that Temescal Creek is a U shaped channel that is 30 feet wide with vertical wells. Observations by Geomatrix indicate the wells are approximately 14 feet deep. The channel is constructed of steel reinforced 1-foot thick concrete with 6-inch diameter subsurface drains. These subsurface drains are perpendicular to the well, are spaced 80 feet apart, and are set at a depth of 12 feet below the ground surface. Groundwater at the site has historically occurred at a depth of 6 to 8 feet bgs, and was most recently reported at monitoring well MG-7 at 9 feet bgs. Under these conditions it is evident that should the residual product migrate to the wall it could not enter Temescal Creek, because the drains exist approximately 3 feet below the water table surface (Figure 5). In addition, field observations indicate that the drain holes are below the sediment surface in the channel, further inhibiting the potential for residual petroleum to reach a point of exposure in Temescal Creek.

Based on our conservative estimate of the potential migration rate of the residual product, it would take at least 100 years for the product to reach the creek (i.e., the distance between well MG-1 and the creek is over 200 feet and the potential migration rate is estimated to be 2 feet per year). ORP measurements (Section 4.0) recently collected at the sites indicate that the sites have a high potential biodegradation rate, suggesting that residual product at the sites will be readily biodegraded. Given a high rate of biodegradation, the limited amount of residual product, and the lengthy time of travel to the creek (100 years or more), it does not appear plausible that the residual product will reach the creek. In addition, should the product migrate to the concrete barrier on the northern side of Temescal Creek the groundwater surface is well above the wall drains preventing the product from entering the creek. Because Temescal Creek is the only significant conduit from the sites to the San Francisco Bay, under the above conditions the Bay is extremely unlikely to be affected by residual product migration.

6.0 SCREENING-LEVEL RISK ASSESSMENT

The potential for human and non-human health effects resulting from exposure to chemicals at the sites are evaluated in this section. Based on the site conceptual model, three basic exposure pathways/scenarios are evaluated for the site: (1) migration of dissolved-phase material to Temescal Creek potentially resulting in exposure of recreational users and aquatic organisms in the Creek or in San Francisco Bay; (2) potential risks for exposure to current or future building occupants on the sites associated with vaporized components of dissolved- and residual product from groundwater; and 3) potential risks for exposure of construction and maintenance workers associated with inhalation of vapors, and dermal contact and incidental ingestion of COPCs in the shallow groundwater and residual product. This section identifies chemicals of potential concern (COPCs), evaluates environmental fate and transport, provides a screening assessment of potential human health effects, and evaluates the potential for ecological effects.

6.1 CHEMICALS OF POTENTIAL CONCERN

For the purposes of this assessment, COPCs associated with the sites are volatile and semi-volatile hydrocarbon constituents of gasoline (measured as TPHg) and diesel (measured as TPHd). Gasoline and diesel represent variable mixtures of chemicals that do not have descriptive health criteria; therefore, they are not considered directly in this evaluation process. Potential health risks associated with these materials are generally evaluated by considering the aggregate toxicity of key individual chemicals within the mixture. Concentrations of several components of petroleum products exceeded their respective detection limits in one or more groundwater samples collected at the site since May 1995. Benzene, toluene, ethylbenzene, and xylenes (BTEX) and four polynuclear aromatic compounds (PAHs) (acenaphthylene, fluorene, fluoranthene and phenanthrene) are considered COPCs in the dissolved-phase portions of this assessment. Samples collected from the residual petroleum product contained BTEX and twelve PAHs above their respective detection limits. Thus, BTEX, acenaphthylene, anthracene, fluorene, fluoranthene, phenanthrene, pyrene, 2-methylnaphthalene, acenaphthene, benzo(a)anthracene, chrysene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k) fluoronthene, indeno (1,2,3-cd) pyrene, and benzo(g,h,i) perylene were identified as COPCs for this assessment.

6.2 ENVIRONMENTAL FATE AND TRANSPORT

The environmental fate and transport processes that could result in chemical migration to Temescal Creek and/or vaporization to the surface (into indoor air or ambient air) are evaluated in this section. Specifically addressed are migration of dissolved COPCs in shallow groundwater and volatilization of COPCs from groundwater and residual product.

Potential migration of dissolved chemicals in groundwater to Temescal Creek (the Creek) was evaluated using a simple model presented by SOMA in their previous assessment of BTEX migration (1996). The model accounts for migration of chemicals in groundwater to the creek and chemical mixing once groundwater reaches the creek. As Temescal Creek is the only significant conduit for groundwater migration from the sites to San Francisco Bay, the results of this analysis will also indicate whether the Bay may be impacted by migration of dissolved chemicals.

Estimation of chemical concentrations in indoor air is a two-part process: (1) estimating chemical flux rate from groundwater or residual product; and (2) estimating chemical concentrations in air within the building. Estimation of chemical concentrations in ambient air is also a similar two-part process: (1) estimating chemical flux from groundwater or residual product; and (2) estimating chemical concentrations in ambient air. Indoor and ambient air concentrations were estimated separately for volatile compounds in groundwater and (separate-phase) residual product because the presence of residual product on the groundwater surface will preclude the volatilization of dissolved volatile constituents in the underlying groundwater.

6.2.1 Dissolved Phase Migration to Temescal Creek

Concentrations of PAHs in the Creek resulting from groundwater migration were estimated using a model presented by SOMA in their previous assessment of BTEX migration (1996). The COPCs evaluated for potential migration to the creek included only PAHs dissolved in groundwater (acenaphthylene, fluorene, phenanthrene, and fluoranthene) because BTEX had been previously evaluated. The SOMA model uses a two-step process. In the first step, the volume of discharged groundwater into the Creek is calculated using Darcy's law, and is based on the assumption that the flux of groundwater into the creek will be highest during low tide periods. The second step estimates the maximum concentration of chemical in the Creek during the low tide based on the maximum detected groundwater concentration. Geomatrix has used the SOMA model in this assessment because it provides a conservative estimate of the chemical concentration that would be found in the Creek, and allows for consistent interpretation of the BTEX and PAH assessments for aquatic receptors and human recreators. Equations and input parameters used in the SOMA model are presented in Appendix C.

Conservative, site-specific assumptions were made to estimate the volume of discharged groundwater and determine the maximum concentration of COPCs in the groundwater. Data for PAH compounds detected in the groundwater are limited to results from two groundwater monitoring wells (MG-2 and MG-7) for a single sampling event (November 1996), presented in Section 4.2. The sum of the maximum detected concentrations of dissolved PAHs (5.5 μg/l) was used as the maximum concentration of total dissolved PAHs in the groundwater beneath the sites. Using the SOMA model, an estimated concentration of 0.0002 μg/l for total dissolved PAHs was predicted for Temescal Creek. (Concentrations of total dissolved PAHs were estimated because water quality criteria were not available for comparison to the individual PAHs)

orig.
→ 0.0094 ug/l

6.2.2 Volatilization of Chemicals Dissolved in Groundwater

The Farmer model was used to estimate emissions of dissolved chemicals in groundwater (EPA, 1992). The Farmer model is based on Fick's Law of Diffusion. This screening model assumes that all phases of the chemical are in equilibrium (vapor, liquid, and solid) and that the source remains constant over time (i.e., does not account for source depletion). The vapor phase concentration above the saturated zone can be estimated using a chemical-specific Henry's Law Constant, which describes a chemical's tendency to volatilize out of solution. Once in the vapor phase, a chemical can diffuse upward through the soil column, the rate of which is dependent on characteristics of the soil (e.g., soil porosity, air-filled pore space), the path length for diffusion (i.e., the distance from the source to the surface), and chemical-specific properties (e.g., air diffusion coefficient). The equations and input parameters used to estimate emissions from groundwater are presented in Appendix D.

Conservative, site-specific assumptions were made in estimating vaporization of dissolved chemicals. BTEX, acenaphthylene, fluorene, and phenanthrene were identified and evaluated as volatile compounds because their molecular weights are less than 200 g/mole and Henry's Law constants are greater than 1.0×10^{-5} (U.S. EPA, 1996). Fluoranthene did not meet this criteria and was not considered volatile. The maximum concentration of each volatile COPC detected in samples since May 1995, regardless of well location, was used as the input concentration for the model (Table 3). BTEX compounds were monitored quantitatively from a suite of wells on the sites between May 1985 and the present, but because concentrations have decreased over time the more recent data provide a more accurate estimate for current and future exposure. Data for PAH compounds are limited to results from two groundwater monitoring wells (MG-2 and MG-7) for a single sampling event (November 1996). Although depth to groundwater at the Site varies by over 2 feet, groundwater was assumed to be at the shallowest depth (6 feet bgs).

6.2.3 Volatilization of Chemicals from Residual Petroleum Product

EPA methods (1992) for estimating soil vapor concentrations of chemicals from soil or groundwater measurements are based on the critical assumption that the soil or groundwater is not saturated with those chemicals. These methods are not applicable to a limited area of this site where residual petroleum hydrocarbons are present on the shallow groundwater. In this case, soil vapor concentrations were estimated based on an application of Dalton's law, which states that the partial pressure of one component in a mixture of gases is related to its fraction in the mixture. The soil vapor concentration of that component can then be calculated from the estimated partial pressure.

A fingerprint analysis of a residual petroleum product sample was used to characterize the components of the mixture by estimating the concentrations of groups of hydrocarbons (aliphatic and aromatic) for several ranges of carbon chain lengths (e.g., C_5-C_6 aliphatic hydrocarbons)(Section 4.1). Additional analyses were conducted to identify concentrations of individual COPCs (identified in Section 6.1) in the same sample. The volatile COPCs identified in the residual product included benzene, ethylbenzene, toluene, anthracene, and pyrene. As discussed further in Appendix D, the results of these analyses were then used to estimate soil vapor phase concentrations of those COPCs considered volatile based on their molecular weight and Henry's Law constant. Once soil vapor concentrations were estimated, the vapor flux rate and indoor air concentration were estimated using the Farmer Model outlined in the previous section.

6.2.4 Indoor Air Concentrations

Indoor air concentrations were estimated using the vapor flux rate (either dissolved- or residual product results) and a box model (Cal-EPA, 1994a) to account for dilution in indoor air. The box model is a mass balance equation that is based on the concept of a theoretically enclosed space, or box, over the area of interest. The model assumes that vapors emanating from the subsurface enter the box and are diluted by the movement of ambient air through the box as a result of ventilation. The equation and input parameters used to calculate concentrations of chemicals in indoor air also are presented in Appendix D.

6.2.5 Ambient Air Concentrations

Ambient air concentrations were also estimated using the box model (Cal-EPA, 1994), but accounted for dilution outdoors resulting from air movement (wind) across the area of interest. The equation and input parameters used to calculate concentrations of chemicals in ambient air are presented in Appendix D.

6.3 SCREENING HUMAN HEALTH RISK ASSESSMENT

A screening human health risk assessment was conducted to evaluate potential human health effects associated with chemicals in groundwater and residual product beneath the sites. The risk assessment has three components: exposure assessment, toxicity assessment, and risk characterization. The exposure assessment identifies exposure scenarios and pathways to be evaluated for the sites (per the site conceptual model) and develops estimates of exposure. The toxicity assessment presents quantitative criteria for assessing the potential adverse health effects (both carcinogenic and non-carcinogenic) associated with the estimated levels of exposure to the COPCs. The risk characterization uses the exposure estimates and toxicity criteria to evaluate the potential for adverse health effects associated with conditions at the site.

6.3.1 Exposure Assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of exposure. The principal elements of exposure assessment consist of:

- Evaluation of the influence of fate and transport processes for the COPCs,
- Identification of potential exposure scenarios and pathways,
- Calculation of representative chemical concentrations, and
- Estimation of potential chemical uptake.

Exposure assessment is conducted within the framework of a site conceptual model. As described in Section 3.0, a site conceptual model was developed for the PSP and Shellmound III sites based on the soil and groundwater conditions, future land use, and physical and chemical characteristics of the COPCs (see Figure 3). The fate and transport of the COPCs was described in detail in Section 6.2. Each of the remaining components of the exposure assessment is discussed below.

6.3.1.1 Identification of Potential Exposure Scenarios and Pathways

Potential human receptors at the PSP and Shellmound III sites include construction or maintenance workers, building occupants, off-site receptors during construction, and recreational users of Temescal Creek or the San Francisco Bay. The pathways through which these receptors may be exposed to chemicals at the sites are described below.

Construction/Maintenance Workers

During construction of new buildings or utilities (Shellmound III site) or maintenance of existing or future buildings or utilities (both sites), workers may come into contact with COPCs present in residual product (on the shallow groundwater or entrained in subsurface soil in the saturated zone or capillary fringe) or dissolved in groundwater. This contact may occur via dermal contact and incidental ingestion. It should be noted, however, that the potential for exposure to residual product or groundwater via the ingestion pathway is considered limited and inconsequential relative to other pathways; therefore, this pathway is not considered further in this screening assessment. Construction and maintenance workers also may be exposed to chemicals present in ambient air as vapors (i.e., from volatilization of chemicals in separate-phase material or groundwater). Separate evaluations are conducted for the construction and maintenance workers because the level and duration of exposure is expected to be different between these two worker populations (e.g., construction workers would be expected to be exposed for a shorter period of time than long-term maintenance workers).

Potential exposures via dermal contact with groundwater and inhalation of vapors by construction and maintenance workers are evaluated quantitatively in this screening assessment. Potential exposures to residual product via dermal contact cannot be evaluated quantitatively using standard risk assessment techniques because the assumptions for evaluating these exposures were developed based on exposure to chemicals present in a soil or water matrix. These assumptions would not be appropriate for evaluating exposure to chemicals present in a matrix such as oil (e.g., dermal absorption of chemicals in soil or water is expected to be very different from dermal absorption of chemicals in oil). Therefore, the potential health risks associated with exposure to the residual product is evaluated qualitatively in the risk characterization.

Building Occupants

The PSP site is completely covered by commercial buildings, parking lots, and landscaping; therefore, with the possible exception of the maintenance workers described above, building occupants would not be exposed to residual product or groundwater. Current building occupants (i.e., workers or shoppers) may be exposed to chemicals present in indoor air as vapors. Future use of the Shellmound III site is expected to be similar to the PSP site (i.e., commercial use, including the possibility of a hotel). Therefore, potential exposure to future building occupants is also assumed to be limited to inhalation of indoor air. It should be noted that the potential exposure pathways for future building occupants would be similar even if either site was developed for high density residential use because the entire site would be covered by buildings, parking lots, and landscaping. Potential exposures via inhalation of vapors by current or future building occupants are evaluated quantitatively in this screening assessment.

Off-Site Receptors

Off-site receptors, primarily workers or shoppers as there are no residents within 0.25 miles of the sites, may be exposed to chemicals present in ambient air as vapors during construction. Off-site receptors are not expected to be exposed to chemicals in indoor air; by definition, this receptor population exists outside the site boundaries. Access to the Shellmound III site would be restricted during construction, and off-site receptors are not expected to come into contact with chemicals in residual product or groundwater in the construction zone. Potential exposures via inhalation of vapors by off-site receptors are less than those experienced by construction workers located on site; therefore, the potential health risks to this receptor population are evaluated qualitatively in the risk characterization based on the results of the construction and maintenance worker scenario.

Recreational Users

Recreational users of Temescal Creek or the San Francisco Bay may be exposed to chemicals in surface water via incidental ingestion and dermal contact. Recreational users are not expected to be exposed to chemicals via consumption of fish and shellfish because the COPCs do not bioaccumulate. Potential exposures to recreational users are not evaluated quantitatively in this screening assessment. Instead, estimated concentrations of COPCs in Temescal Creek are compared with water quality criteria set by the RWQCB for marine environments in the risk characterization. This comparison is considered conservative because the criteria consider exposure via fish and shellfish consumption.

6.3.1.2 Calculation of Representative Chemical Concentrations

Representative chemical concentrations were estimated for each exposure medium identified in the site conceptual model based on fate and transport modeling of the detected maximum COPC concentration as outlined in Section 6.2, where applicable:

- Groundwater concentrations are based on the maximum detected dissolved COPC concentrations in groundwater beneath the sites.

- Indoor and ambient air concentrations are based on the maximum detected concentrations of dissolved volatile COPCs in groundwater or concentrations of volatile COPCs present in residual product beneath the sites.

- Surface water concentrations in Temescal Creek are based on the maximum detected dissolved concentrations of COPCs in groundwater beneath the sites.

These representative concentrations are presented in Table 3.

6.3.1.3 Estimation of Potential Chemical Uptake

Potential chemical uptake (or dose) was estimated for the following exposure pathways based on an average daily dose (ADD) and lifetime average daily dose (LADD):

- Dermal contact with COPCs dissolved in groundwater and inhalation of volatile COPCs in ambient air by construction workers,

- Dermal contact with COPCs dissolved in groundwater and inhalation of volatile COPCs in ambient air by maintenance workers, and

- Inhalation of volatile COPCs in indoor air by building occupants.

The ADD and LADD both provide quantitative estimates of an individual's daily exposure to a chemical. The difference between the two estimates is the time over which the exposure is averaged. Noncarcinogenic health effects are assumed to occur only after a threshold dose is reached; therefore, the ADD represents the average daily dose for the period of exposure (i.e., if an individual is exposed for six years, the dose is averaged over six years). Conversely, carcinogenic health risk is not considered to be threshold phenomena (i.e., there is zero risk only at zero dose); rather, exposure to carcinogens is considered to have a cumulative effect over a lifetime. Therefore, the LADD represents the average daily dose over a lifetime (i.e., the daily dose averaged over 70 years) The components of each exposure equation are presented in Appendix E; values that were used for each input parameter, including source and rationale, are summarized in Tables 4 through 6 for the construction worker, maintenance worker, and building occupant, respectively

6.3.2 Toxicity Assessment

Health risks for exposure to carcinogens are defined in terms of probabilities that quantify the likelihood of a carcinogenic response in an individual receiving a given dose of a particular compound. The carcinogenic potency slope factor (SF), which is expressed in units of $(mg/kg\text{-}day)^{-1}$, is defined as the 95 percent upper confidence limit (95% UCL) of the probability of a carcinogenic response per unit daily intake of a chemical over a lifetime (assumed to be 70 years). By using the 95% UCL, the estimate of carcinogenic response will be conservative and will purposefully over-estimate the actual risk posed by the chemical.

Health risks for exposure to noncarcinogens are defined in terms of an acceptable dose at or below which no adverse health effects are expected to occur, the Reference Dose (RfDs). Results from animal studies, which identify the most sensitive health effect for the most sensitive species are typically used as the basis for determining the RfD. Uncertainty factors and modifying factors are used to extrapolate from animals to humans, account for the existence of sensitive populations, and account for the quality and quantity of supporting data.

Toxicity assessments have been completed by the Cal-EPA and/or U.S. EPA for all COPCs considered in this assessment. Tables 7 and 8 summarize the toxicity criteria applied in this assessment for carcinogenic and non-carcinogenic effects, respectively.

6.3.3 Risk Characterization

As described previously, both quantitative and qualitative assessments of health effects were conducted as part of this risk characterization. For the quantitative evaluation, this section describes how the assessment of exposure (Section 6.3.1) and the toxicity criteria (Section 6.3.2) were combined to estimate carcinogenic risk and the hazard index for noncarcinogenic health risk. The remainder of this section outlines the quantitative approaches for assessing potential carcinogenic and noncarcinogenic health effects. Following this discussion, potential health effects are presented separately for each exposure scenario and presented in Tables 9 and 10 for carcinogenic and noncarcinogenic health effects, respectively.

Quantitative Assessment of Potential Carcinogenic Health Risks

Carcinogenic health risks are defined in terms of the probability of an individual developing cancer as the result of exposure to a given chemical at a given concentration. Lifetime excess cancer risks were estimated as follows:

$$\text{Risk} = \text{LADD} * \text{SF}$$

Where:

LADD = Lifetime average daily does (mg/kg-day)
SF = Slope Factor

To evaluate cumulative carcinogenic risk, the individual risks associated with a particular chemical can be summed to provide an estimate of total risk. The levels are then compared with the range of risks generally considered acceptable by U.S. EPA (1×10^{-6} to 1×10^{-4}) (U.S. EPA, 1990a and 1990b). In addition, these levels are well below the no significant risk level of 1×10^{-5} set by the State of California in the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65).

Quantitative Assessment of Potential Non-Carcinogenic Health Risks

For noncarcinogenic effects, potential adverse health effects are evaluated by comparing the ADD to the appropriate RfD for each chemical. This comparison is expressed in terms of a hazard quotient, and is calculated as follows:

$$\text{Hazard Quotient} = \text{ADD}/\text{RfD}$$

Where:

ADD = Average Daily Dose (mg/kg-day)
RfD = Reference Dose (mg/kg-day)

A hazard quotient less than or equal to one indicates that the predicted exposure should not pose a significant noncarcinogenic health risk (EPA, 1989). In cases where individual chemicals potentially act on the same organs or result in the same health endpoint (e.g., respiratory irritants), additive effects can be addressed by summing the hazard quotients for these individual chemicals, the result of which is the hazard index. A hazard index less than or equal to one is also indicative of acceptable levels of exposure for chemicals having an additive effect. A screening approach for assessing noncarcinogenic health risk, is to estimate a hazard index based on the sum of the hazard quotients for all chemicals, regardless of endpoint. This approach will overestimate the potential for noncarcinogenic health effects due to simultaneous exposure to multiple chemicals if those chemicals have different toxicological endpoints.

6.3.3.1 Construction Worker

The potential carcinogenic risk for construction workers exposed to benzene dissolved in groundwater (dermal contact and inhalation) was estimated to be 3×10^{-7}. The potential carcinogenic risk for construction workers exposed to benzene in residual product (inhalation only) was estimated to be 6×10^{-10}. Thus, the concentrations of carcinogenic COPCs present at the site should not result in excess carcinogenic risk to construction workers beyond levels generally considered acceptable by regulatory agencies.

The potential noncarcinogenic risk for construction workers exposed to chemicals dissolved in groundwater (dermal contact and inhalation) was 0.06. The potential noncarcinogenic risk for construction workers exposed to chemicals present in residual product (inhalation only) was estimated to be 0.0001. Thus, concentrations of COPCs present at the site should not result in noncarcinogenic risks to construction workers beyond levels generally considered acceptable by regulatory agencies.

As discussed in Section 6.3.1.1, the potential health effects associated with short-term exposure to the separate-phase material by construction and maintenance workers cannot be evaluated using standard risk assessment techniques However, a qualitative evaluation of potential health effects can be conducted based on information published in the scientific literature. The residual product at the sites contains primarily $>C_{10}$ to C_{21} aliphatic and aromatic hydrocarbons (see Section 4.1 and Appendix A). This composition is characteristic of a middle distillate petroleum mixture such as diesel fuel. The primary health effect associated with short-term dermal contact with middle distillate petroleum mixtures is skin irritation; longer term exposures can lead to chronic dermatitis due to defatting of the skin. More severe effects, such as alterations in kidney function, have only been observed following massive and/or prolonged skin contact (e.g., use of pure diesel fuel as a shampoo or to clean hands and arms over several weeks) (Gosselin et al., 1984). Given the limited extent of residual product at the sites and the relatively short period of time that construction or maintenance activities would require intrusion down to the shallow groundwater table, it is expected that skin irritation would be the most severe adverse health effect, if any, experienced by construction and maintenance workers. Appropriate hazard communication information can be provided to minimize this potential hazard (see Section 7.2).

6.3.3.2 Maintenance Worker

The potential carcinogenic risk for maintenance workers exposed to benzene dissolved in groundwater (dermal contact and inhalation) was estimated to be 1×10^{-6}. The potential carcinogenic risk for maintenance workers exposure to benzene in residual product (inhalation only) was estimated to be 5×10^{-9}. Thus, the concentrations of carcinogenic COPCs present at the site should not result in excess carcinogenic risk to maintenance workers beyond levels generally considered acceptable by regulatory agencies.

The potential noncarcinogenic risk for maintenance workers exposed to chemicals dissolved in groundwater (dermal contact and inhalation) was 0.02. The potential noncarcinogenic risk for maintenance workers exposed to chemicals present in residual product (inhalation only) was estimated to be 0.00008. Thus, concentrations of COPCs present at the site should not result in noncarcinogenic risks to maintenance workers beyond levels generally considered acceptable by regulatory agencies.

The discussion of direct contact with residual product in the previous section is also applicable to maintenance workers.

6.3.3.3 On-Site Building Occupant

The potential carcinogenic risk for building occupants exposed to benzene dissolved in groundwater (via inhalation) was estimated to be 5×10^{-7}. The potential carcinogenic risk for building occupants exposed to benzene in residual product (via inhalation) was estimated to be 2×10^{-9}. Both of these risks are well below the acceptable risk level of 1×10^{-5}. Thus, the concentrations of carcinogenic COPCs present at the sites should not result in excess carcinogenic risk to current or future building occupants beyond levels considered generally acceptable by regulatory agencies.

The potential noncarcinogenic risk for building occupants exposed to chemicals dissolved in groundwater (dermal contact and inhalation) was 0.008. The potential noncarcinogenic risk for building occupants exposed to chemicals present in residual product (inhalation only) was estimated to be 0.0003. Thus, concentrations of noncarcinogenic COPCs present at the site should not result in noncarcinogenic risks to building occupants beyond levels generally considered acceptable by regulatory agencies.

6.3.3.4 Off-Site Receptors

Off-site commercial/industrial exposures to site COPCs during construction activities are expected to be less than those for the on-site construction worker due to the distance from the source and the absence of direct-contact exposure. Potential health effects for off-site receptors are not considered significant because the estimate of potential risks to the on-site construction worker were less than risks considered acceptable by regulatory agencies.

6.3.3.5 Recreational Exposures

Recreational users were evaluated for exposure to dissolved PAHs in the shallow groundwater potentially migrating to Temescal Creek and San Francisco Bay from the sites.

Exposure pathways considered for recreational use of the Creek include direct contact with water and ingestion of fish caught in the Creek. However, the latter exposure pathway is not expected to be complete because the COPCs are unlikely to bioaccumulate. The 1995 San Francisco Bay Regional Water Quality Control Board Water Quality Objective for PAHs assuming 24-hour average exposure (15.0 µg/l) was used for comparison to concentrations at the Site. Water quality criteria were not available for comparison to the individual PAHs identified in groundwater samples from the sites. The U.S. EPA National Ambient Water Quality (1986) criterion for total PAHs was not used in this assessment because assumptions used to develop the criterion are not consistent with site conditions (e.g., a freshwater environment).

Potential PAH concentrations in the Creek were estimated using the maximum concentration of total PAHs in the groundwater beneath the Site, i.e., 5.5 µg/l. Using the SOMA model presented in Section 6.2.1, the total PAH concentration predicted for the Creek was 0.0094 µg/l. The maximum concentrations of total PAHs detected in groundwater beneath the sites and the total PAH concentration in the Creek estimated using the SOMA model were well below the total PAH water quality criterion of 15.0 µg/l. Thus, it is highly unlikely that the PAH concentrations pose a health risk to the recreational users of Temescal Creek. As concentrations in San Francisco Bay could not exceed those in Temescal Creek, and likely would be much lower, it is also highly unlikely that the PAH concentrations pose a health risk to the recreational users of San Francisco Bay.

6.3.6 Uncertainty Assessment

Uncertainty is inherent in many aspects of the risk assessment process, and generally arises from a lack of knowledge of: (1) site conditions; (2) toxicity and dose-response of the COPCs, and (3) the extent to which an individual will be exposed to those chemicals. This lack of knowledge means that assumptions must be made based on information presented in the scientific literature or professional judgment. While some assumptions have significant scientific basis, others have much less. The assumptions that introduce the greatest amount of uncertainty and their effect on the carcinogenic and noncarcinogenic risk estimates are discussed below. This discussion is qualitative in nature, reflecting the difficulty in quantifying the uncertainty in specific assumptions. In general assumptions were selected in a manner that purposefully biases the process toward health conservatism.

Environmental Fate and Transport of Residual Petroleum Hydrocarbon Product

As discussed in Section 5.0, the measurable separate-phase material in the monitoring wells on site is not representative of the true thickness of the product in the surrounding formation, which is likely to be negligible. Thus, the assessment of potential migration is based on an overestimate of the volume of product in the formation. In addition, the presence of water in the samples analyzed for viscosity and density produced results representative of a material more mobile than the separate-phase material at the site.

Environmental Fate and Transport of Dissolved-Phase Hydrocarbons

The assessment of migration of dissolved-phase material was based on simplistic assumptions about the migration of groundwater in the subsurface that overestimated the potential for the dissolved material to reach Temescal Creek.

Exposure Point Concentrations

Maximum concentrations detected in environmental media were used as the basis for estimating exposure point concentrations. The use of maximum concentrations were selected to provide the most conservative estimates of exposure point concentrations. In the case of separate-phase material at the sites, the limited number of samples and the presence of water in the samples dictated the use of maximum concentrations.

Exposure Assumptions and Parameters

This screening assessment evaluated a reasonable maximum exposed individual (RME) for all scenarios quantitatively evaluated. The RME scenario is defined by the U S EPA as the highest exposure that could reasonably be expected to occur for a given exposure pathway at a site (EPA, 1989). In order to achieve this goal, the RME scenario uses highly conservative exposure assumptions that likely overestimate potential exposure to most individuals.

Toxicity Criteria

The largest source of uncertainty in any risk assessment is associated with the scientific community's limited understanding of the toxicity of most chemicals in humans following exposure to the low concentrations generally encountered in the environment. The majority of available toxicity data are from animal studies, which are then extrapolated using mathematical models or multiple uncertainty factors to generate toxicity criteria used to predict what might occur in humans. Sources of conservatism in the toxicity criteria used in this screening assessment include:

- The use of conservative methods and assumptions to extrapolate from high dose animal studies to predict the possible response in humans at exposure levels far below those administered to animals;
- The assumption that chemicals considered to be carcinogens do not have thresholds (i.e., for all doses greater than zero, some risk is assumed to be present); and
- The fact that epidemiological studies (i.e., human exposure studies) are limited and are not generally considered in a quantitative manner in deriving toxicity values.

6.4 SCREENING ECOLOGICAL RISK ASSESSMENT

The purpose of the screening ecological risk assessment is to evaluate the potential risk to aquatic organisms associated with migration of dissolved petroleum hydrocarbon constituents in groundwater to Temescal Creek through a simple criteria comparison approach. As discussed in Section 6.1, the COPCs associated with dissolved phase groundwater migration in this analysis are BTEX and PAHs. Based on SOMA's conservative evaluation of the migration of BTEX (1996), which predicted that these constituents do not pose a risk to aquatic organisms in the creek, BTEX are not addressed further in this screening assessment.

6.4.1 Exposure Assessment

Groundwater sampling results indicate that dissolved PAHs were detected at very low concentrations in groundwater in monitoring well MG-2, which is located immediately adjacent to the plume where separate-phase material was previously detected (Table 1). In calculating the estimated PAH concentration in Temescal Creek, the maximum concentration of total dissolved PAHs in the groundwater beneath the Site of 5.5 µg/l was used. Using the SOMA model presented in Section 6.2.1, an estimated concentration of 0.0002 µg/l for total dissolved PAHs was predicted for Temescal Creek.

6.4.2 Toxicity Assessment

Chemical-specific toxicity criteria for PAHs in marine waters are not available. For the purposes of this screening-level ecological risk assessment two water criteria are used to represent the potential toxicity of PAHs to aquatic organisms: 1) the U.S. EPA National Ambient Water Quality Criterion (AWQC) for total PAHs for the protection of marine aquatic life (assumed to include benthic and water column species) of 300 µg/l total PAHs; and 2) the RWQCB Basin Plan, Water Quality Objective (WQO) for total PAHs (15.0 µg/l) in waters with salinity greater that 5 parts per thousand (Table III-3)(RWQCB, 1995). The RWQCB WQO does not appear to be based on an ecological risk endpoint, but has been conservatively adopted for protection of marine organisms in the RWQCB Basin Plan, and therefore, will be used for comparison purposes in this assessment.

6.4.3 Risk Characterization

This section presents the comparison between the representative COPC concentrations and selected toxicity criteria to evaluate potential risks to aquatic organisms in Temescal Creek. The maximum total dissolved PAH concentration conservatively estimated for Temescal Creek (0.0002 µg/l) using the SOMA model (1996) is more three orders of magnitude less than the RWQCB WQO of 15.0 µg/l for total PAHs and four orders of magnitude less than the EPA AWQC of 300 µg/l. This result and the results predicted by SOMA (1996) for

BTEX compounds indicate that it is highly unlikely that dissolved COPC concentrations detected in groundwater at the sites pose a risk to aquatic organisms in Temescal Creek.

This evaluation is considered to provide a conservative estimate of potential risk with a substantial margin of safety. This margin of safety is primarily based on two factors:

- The maximum dissolved concentration of total PAHs (5.5 µg/l) detected at monitoring well MG-2, which at one time contained measurable separate-phase material, is well below the water quality criteria; and
- Dissolved PAHs were not detected in monitoring well MG-7, which is located between the separate-phase material detected in monitoring well MG-1 and Temescal Creek.

It should be noted that this analysis is based on the results of a single groundwater sampling round for which all field and laboratory QA/QC results are in good order.

6.5 CONCLUSION

A quantitative and qualitative assessment of potential adverse ecological and human health effects associated with dissolved- and separate-phase material present beneath the sites was conducted. A quantitative assessment of potential human health effects indicated that adverse effects are not associated with activities at the sites by:

- Future construction workers at the Shellmound III site;
- Current and future maintenance workers;
- Current and future building occupants; and
- Current or future off-site receptors.

A quantitative assessment of potential migration of separate- and dissolved-phase materials from the sites to Temescal Creek or the San Francisco Bay indicated that recreational users and ecological receptors are not likely to be adversely impacted by migration of the chemicals from the sites.

Potential health effects associated with dermal contact with separate-phase material by construction or maintenance workers was not evaluated quantitatively in the screening human health risk assessment; however, the results of the qualitative evaluation indicate that short-term contact with this material may cause skin irritation, which is addressed in the long-term management plan for the sites.

7.0 RECOMMENDATIONS FOR LONG-TERM SITE MANAGEMENT

This section describes recommendations for long-term management of the potential issues related to residual petroleum hydrocarbons at the sites. Other COPCs potentially present at the sites are beyond the scope of this management plan.

7.1 OBJECTIVES

Residual petroleum hydrocarbons are present at the sites as separate-phase material (on the shallow groundwater or entrained in subsurface soil in the saturated zone or capillary fringe) or dissolved in groundwater. The current distribution of the residual petroleum appears to be limited to the south-central and southwestern areas of the PSP site, and the northwestern and central areas of the Shellmound III site (Figure 4). Detectable concentrations of dissolved hydrocarbons in groundwater are more widely distributed in the southern portion of the PSP site and northern and central portions of the Shellmound III site.

As described in Section 6.4, the results of the screening ecological risk assessment indicate that residual petroleum hydrocarbons do not present an unacceptable risk to aquatic organisms in Temescal Creek or the San Francisco Bay. With regard to potential human health risks, residual petroleum hydrocarbons do not present an unacceptable risk to: (1) current or future building occupants or off-site receptors during construction that could be exposed to chemicals in indoor or ambient air (as a result of vaporization from groundwater or separate-phase material); (2) recreational users of Temescal Creek or the San Francisco Bay that could be exposed to chemicals dissolved in surface water; and (3) construction and maintenance workers that could be exposed to chemicals in ambient air or dissolved in groundwater (see Section 6.3). Potential health effects associated with dermal contact with residual petroleum by construction or maintenance workers were not evaluated quantitatively in the screening human health risk assessment; however, the results of the qualitative evaluation indicate that short-term contact with this material may cause skin irritation. Therefore, the objectives of the long-term site management plan are

- To present guidelines for appropriate health and safety precautions for future on-site construction or maintenance workers that may access subsurface soil to a depth that would encounter the residual petroleum (i.e., excavation to a depth of about 6 feet below grade); and

- To present recommendations for short-term (i.e., during initial construction activities) and long-term management of the residual petroleum hydrocarbons present at the sites.

- To present procedures to manage potential nuisance or explosion hazard issues associated with residual petroleum hydrocarbons entering existing or future subsurface utility vaults.

- To address concerns raised by interested parties regarding the potential for methane production associated with residual petroleum at the site.

Each of these objectives is addressed in the following sections.

7.2 GUIDELINES FOR CONSTRUCTION WORKER HEALTH AND SAFETY

The Shellmound III site is expected to be for future commercial use, which may include construction of a hotel. During development, construction workers may need to excavate or access soils below a depth of 6 feet in areas where residual petroleum may be present. In addition, although less likely, future on-site maintenance workers may need to access the subsurface soil below a depth 6 feet in these areas (e.g., to access utilities). As stated previously, short-term dermal contact with the residual petroleum may cause skin irritation. Therefore, future on-site construction or maintenance workers accessing soil below a depth of 6 feet in areas where residual petroleum may be present should be made aware of the potential for skin irritation and should wear personal protective equipment (e.g., Tyvek coveralls, nitrile or similar gloves) to reduce the potential for direct contact with this material. In addition, it may be prudent to monitor organic vapors in the event that the residual petroleum is encountered in a relatively confined space (e.g., a narrow utility trench).

7.3 SOIL MANAGEMENT PROCEDURES

The following two sections provide recommendations for soil management procedures that may be appropriate during and following proposed site development.

7.3.1 Soil Management Guidelines for Site Construction

Soil management activities during site construction should include the following:

Soil Handling

Figure 4 illustrates the estimated extent of residual petroleum (referred to herein as the "potential residual petroleum area"). The residual petroleum historically has been observed at or below a depth of 6 feet. Therefore, soil excavated at or below 6 feet in this area should be segregated from other excavated soil.

Soil Stockpiling

Temporary stockpiling of excavated soil may be needed during site construction. Soil excavated at or below 6 feet in the potential residual petroleum area and segregated from other excavated soil should be placed on and covered by plastic sheeting until removed from the site.

Soil Disposal

If soil excavated and segregated as above is to be disposed of offsite, the soil should be profiled and the appropriate landfill facility (e.g., Class I, Class II, Class III, or recycling) should be selected for disposal based on the soil profiling results. Chemical analysis results for hydrocarbons in soil samples collected during previous investigations indicate that the soil may likely require disposal to a Class II facility; it may also be suitable for recycling. Soil containing petroleum hydrocarbons may also be returned to the excavation, if contained at least one foot above the water table and two feet below grade.

Excavation Dewatering

Preparations should be made to remove, store, characterize, and dispose of standing water from excavations during construction and maintenance trenching activities. Appropriate precautions may include having a temporary storage tank (e.g., Baker tank) on site and prearranged disposal arrangements (e.g., disposal to sanitary sewer).

Site Access

Site access should be limited via a fence surrounding the site during construction activities or a fence surrounding construction and associated soil stockpile areas during maintenance work.

7.3.2 Long-Term Soil Management

Long-term soil management includes guidelines for handling, stockpiling, and disposing of soil from the potential residual petroleum area during future site maintenance activities, and maintaining a cover over the site. The residual petroleum addressed in this report is at or below a depth of approximately 6 feet. Based on the soil management guidelines for site construction presented in Section 7.3.1, soil containing petroleum hydrocarbons that is excavated during construction and returned to the site, must be contained at least two feet below grade. This creates a minimum of 2 feet of soil cover over the residual petroleum. The site development plans include construction of a commercial building or buildings, possibly a hotel, and paved parking areas, which will provide a further cover to minimize access to petroleum hydrocarbon containing soil. It is not plausible that the 2-foot soil cover and the pavement/building foundation cover will be breached to allow access to the residual petroleum unless it is for planned site construction or maintenance work. Therefore, a program for inspecting and maintaining an additional cover over this 2-foot soil cover is not needed. Guidelines and recommendations presented in Sections 7.1 and 7.2 of this report should be followed for future site maintenance work requiring soil excavation below 6 feet. If the proposed and current uses for the sites change, further evaluation of potential risk to exposure to chemicals in the separate-phase material or dissolved in groundwater may be warranted.

7.4 MANAGEMENT OF POTENTIAL NUISANCE OR EXPLOSION HAZARDS ASSOCIATED WITH SUBSURFACE VAULTS

Subsurface utility vaults located in the potential residual petroleum area should be inspected semi-annually for the presence of petroleum hydrocarbons. Although vapors associated with residual petroleum at the site are unlikely, an explosion meter should be used at the time of inspection to evaluate the potential for an explosion in the vault due to the presence of residual petroleum hydrocarbons in soil near the vault. If petroleum hydrocarbons are observed in a vault, the petroleum should be removed and the seams of the vault sealed to prevent future entry of petroleum hydrocarbons. Petroleum hydrocarbons removed from a vault should be disposed of or recycled in accordance with local and state laws. New subsurface vaults installed at the site should be sealed in a manner that prevents the entry of petroleum hydrocarbons from adjacent soil into the vaults.

7.5 POTENTIAL FOR METHANE PRODUCTION

A final issue raised by interested parties at the sites is the potential for methane production from the residual petroleum and subsequent accumulation in buildings on site. Methane is one of many bi-products associated with biodegradation of petroleum products and other organic matter. Methane production results from anaerobic degradation processes, which occur once the reservoir of oxygen in the subsurface is depleted. Methane concentrations in soil gas have been shown to correlate with the subsurface location of separate-phase hydrocarbon plumes, reflecting on-going anaerobic degradation processes (Marrin, 1987). However, a quantitative relationship between methane production and the volume of separate-phase material has not been developed based on a review of the literature

The negative ORP potential measurements at the sites indicate that anaerobic processes dominate the degradation of the residual petroleum at the sites. Thus, some methane is likely being produced. If a site-specific measure of methane production is determined to be necessary, then direct-soil gas measurements should be conducted. However, based on the lack of problems associated with methane production at the PSP site and the limited and attenuating presence of residual petroleum in the subsurface, the likelihood is low that sufficient quantities of methane are being generated to adversely affect buildings constructed at either site.

8.0 REFERENCES

Abdul, A.S., S.F. Kia, and T.L. Gibson, 1989, Limitations of monitoring wells for the detection and quantification of petroleum products in soils and aquifer: Groundwater Monitoring Report, v. 9, p. 90-99.

American Conference of Government Industrial Hygienists, Inc. (ACGIH), 1991, Documentation of the Threshold Limit values and Biological Exposure Indices, Sixth Edition.

Applied Geotechnology, Inc., 1994, Work Plan - Environmental Site Characterization, Shellmound Parcels I, II, and III, Emeryville, California.

California - Regional Water Quality Control Board, San Francisco Bay Region, 1995, Water Quality Control Plan, Oakland, California.

Cal-EPA, 1992, Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities, Office of Scientific Advisory, Department of Toxic Substances Control, Sacramento, California.

Cal-EPA, 1994a, Preliminary Endangerment Assessment Guidance Manual: Department of Toxic Substances Control, Sacramento, California.

Cal-EPA, 1994b, California Cancer Potency Factors: Update, Office of Environment Health Hazard Assessment, Sacramento, California.

De Pastrovich, T.L., Y. Baradat, R. Barthel, A. Chiarelli and D.R. Fussell, 1979, Protection of groundwater from oil pollution. CONCAWE, report 3/79, Den Haag. Netherland, p. 61.

Farr, A.M., R.J. Houghtalen and D.B. McWorter, 1990, Volume estimation of light nonaqueous phase liquids in porous media: Groundwater, v. 28, p. 48-56.

Freeze, R.A. and J.A. Cherry, 1979, Groundwater, New Jersey: Prentice-Hall, Inc.

Geomatrix, 1995, Proposed Work Plan to Develop Long-Term Site Management Program, Powell Street Plaza, Emeryville, California.

Gosselin, R.E., R.P. Smith, and H.C. Hodge, 1984, Clinical Toxicology of Commercial Products, Williams & Wilkins, Baltimore, Maryland.

Hall, R.A., S.B. Blake and S.C. Champlin, Jr., 1984, Determination of Hydrocarbon Thicknesses in Sediments Using Borehole Data. Proceedings of the Fourth National Symposium on Aquifer Restoration and Ground Water Monitoring. National Water Well Association, Worthington, Ohio, p. 300-304.

Hughes, J.P., Sullivan, C.R., and Zinner, R.E., 1988, Two techniques for determining hydrocarbon thickness in an unconfined sandy aquifer: Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, American Petroleum Institute, Nov. 9-11.

Integrated Risk Information Systems (IRIS), 1996, on-line database.

Kemblowski, M.W. and Chiang, C.Y., 1990, Hydrocarbon thickness fluctuation in monitoring wells: Ground Water, v. 28, no. 2, p. 244-252.

Lenhard, R.J. and J.C. Parker, 1990, Measurement and prediction of saturation-pressure relationships in three-phase porous media systems. J. Contaminant Hydro. 1:407-424.

Lide, D.R. (ed.), 1996, Handbook of Chemistry and Physics, 76th Edition," New York, CRC Press.

Marrin, Donn L., 1987, Soil Gas Analysis of Methane and Carbon Dioxide: Delineating and Monitoring Petroleum Hydrocarbons, Proceedings of the NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water -- Prevention, Detection and Restoration, Houston, Texas, Nov. 17-19.

Montgomery, J.H. and L.M. Welkom, 1989, Groundwater Chemical Desk Reference, Lewis Publishers, Chelsea, Michigan.

PES Environmental, Inc. (PES), 1994, Characterization of Petroleum Hydrocarbons in Soil and Groundwater at Powell Street Plaza and Shellmound III Properties, Emeryville, California.

PES Environmental, Inc. (PES), 1995, Characterization of Petroleum Hydrocarbons in Soil and Groundwater at Powell Street Plaza and Shellmound III Properties, Emeryville, California, January 1995.

PES Environmental, Inc (PES), 1996a, Quarterly Groundwater Monitoring Report August

PES Environmental, Inc. (PES), 1996b, Quarterly Monitoring Report, Fourth Quarter 1996, Powell Street Plaza and Shellmound III Site, Emeryville, California, January 31, 1996.

SOMA, 1996, Human Health Risk Assessment, Shellmound Parcels I, II, and III, Emeryville, California, September 1996.

U.S. EPA, 1986, Quality Criteria for Water, Office of Water Regulations and Standards, Washington, D.C.

U.S. EPA, 1988, Guidance for Remedial Investigations and Feasibility Studies under CERCLA: Office of Emergency and Remedial Response, Washington, D.C.

U.S. EPA, 1989b, Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A, Interim Final, Office of Emergency and Remedial Response, Washington, D.C.

U.S. EPA 1990a, Health Effects Assessment Summary Tables, FY-1990 Annual, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA, 1990b, Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities, Proposed Rule, 55 FR 3078, January.

U.S. EPA, 1990c, National Oil and Hazardous Substances Pollution Contingency Plan, 55 FR 8666, 8 March.

U.S. EPA 1991, Human Health Evaluation Manual, Supplemental Guidance: “Standard Default Exposure Factors”, Office of Emergency and Remedial Response, Washington, DC.

U.S. EPA, 1992, Assessing Potential Air Impacts for Superfund Sites, EPA-451/R-92-002, Air/Superfund National Technical Guidance Series, U.S. Environmental Protection Agency, Office of Air Quality, Research Triangle Park, NC.

U.S. EPA 1995, Health Effects Assessment Summary Tables, FY-1995 Annual, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA, 1996a, Region IX Preliminary Remediation Goals (PRGs), Washington, DC.

U.S. EPA, 1996b, Soil Screening Guidance: technical Background Document and User’s Guide, Office of Solid Waste and Emergency Response, Washington DC, EPA/540/R-95/128.

Van Dam, J., 1967, The migration of hydrocarbons in a water-bearing stratum. In: The Joint Problems of the Oil and Water Industries. P. Hepple, ed Inst. Petrol., London, p. 55-96.

TABLES

TABLE 1

ANALYTICAL RESULTS FOR SEPARATE-PHASE PRODUCT SAMPLE

Powell Street Plaza and Shellmound III
Emeryville, California

Aliphatic/Aromatic Fractionation[1]			PAHs by EPA Method 8270	
Fraction	**Percent[2]**	**Concentration (mg/kg)[3]**	**Chemical**	**Concentration (mg/kg)**
C_5-C_6 Aliphatics	0.10	550	Naphthalene	<10
>C_6-C_8 Aliphatics	0.53	2800	2-Methylnaphthalene	20[4]
C_9 Aliphatics	0.25	1300	Acenaphthylene	<10
C_{10} Aliphatics	0.23	1200	Acenaphthene	220[4]
>C_{10}-C_{12} Aliphatics	8.3	44,000	Dibenzofuran	<10
>C_{12}-C_{16} Aliphatics	38	200,000	Fluorene	610[4]
>C_{16}-C_{21} Aliphatics	25	130,000	Phenanthrene	<10
>C_{21}-C_{35} Aliphatics	1.4	7500	Anthracene	990
Benzene	0.0077	41	Carbazole	<10
Toluene	0.0018	10	Fluoranthene	<10
Ethylbenzene	0.0023	12	Pyrene	90
Total xylenes	0.0000	<8	Benzo(a)anthracene	20
C_9 Aromatics	0.083	440	Chrysene	30
C_{10} Aromatics	0.11	560	Benzo(a)pyrene	30
>C_{10}-C_{12} Aromatics	9.2	49,000	Benzo(b)fluoranthene	20
>C_{12}-C_{16} Aromatics	18	93,000	Benzo(k)fluoranthene	20
>C_{16}-C_{21} Aromatics	BDL[5]	<2500	Indeno(1,2,3-cd)pyrene	20
>C_{21}-C_{35} Aromatics	BDL[5]	<2500	Dibenz(a,h)anthracene	<10
--	--	--	Benzo(g,h,i)perylene	20

Notes:

[1] Aliphatic and aromatic chemical groups analyzed by gas chromatography with flame ionization detection (FID).

[2] Percent mass added up to only 53% because of water entrained in sample. Percentages were normalized to 100%.

[3] Milligrams per kilogram of residual petroleum product

[4] Compounds were present that interfered with quantitation of the analyte

[5] BDL = Below the Detection Limit

TABLE 2

ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES

Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	MG-2 (filtered)[2] (µg/l)	MG-2 (unfiltered) (µg/l)	MG-7 (filtered)[2] (µg/l)	MG-7 (unfiltered) (µg/l)
PAHs[1]				
Naphthalene	< 0.5	<0.5	<0.5	<0.5
Acenaphthylene	3.2	<1.0	<1.0	<1.0
Acenaphthene	<1.0	<1.0	<1.0	<1.0
Fluorene	1.8	2.3	<0.1	<0.1
Phenanthrene	0.27	0.32	<0.05	<0.05
Anthracene	<0.05	<0.05	<0.05	<0.05
Fluoranthene	0.2	0.2	<0.1	<0.1
Pyrene	<0.1	0.2	<0.1	0.3
Benzo(a)anthracene	<0.1	<0.1	<0.1	<0.1
Chrysene	<0.1	<0.1	<0.1	<0.1
Benzo(b)fluoranthene	<0.1	<0.1	<0.1	<0.1
Benzo(k)fluoranthene	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene	<0.1	<0.1	<0.1	<0.1
Dibenzo(a,h)anthracene	<0.1	<0.1	<0.1	<0.1
Benzo(g,h,i)perylene	<0.1	<0.1	<0.1	<0.1
Indeno(1,2,3-cd)pyrene	<0.1	<0.1	<0.1	<0.1
	MG-2 (filtered with silica gel cleanup) (mg/l)	**MG-2 (unfiltered) (mg/l)**	**MG-7 (filtered with silica gel cleanup) (mg/l)**	**MG-7 (unfiltered) (mg/l)**
TPHd[3]	<0.05	1.5	<0.05	0.74

Notes:

[1] Polynuclear aromatic hyrodcarbons (PAHs) were analyzed by EPA Method 8310

[2] Samples were filtered to remove suspended sediment using a TCLP glass-fiber filter

[3] Total petroleum hydrocarbons as diesel analyzed by Method 8015 modified (unfiltered) and following filteration using a TCLP glass-fiber filter and silca gel cleanup

TABLE 3

REPRESENTATIVE CONCENTRATIONS
Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	Surface Water[1] (ug/l)	Groundwater[2] (mg/l)	Indoor Air		Outdoor Air (Construction Worker)		Outdoor Air (Maintenance Worker)	
			Dissolved-phase (mg/m^3)	Residual Petroleum (mg/m^3)	Dissolved-phase (mg/m^3)	Residual Petroleum (mg/m^3)	Dissolved-phase (mg/m^3)	Residual Petroleum (mg/m^3)
Acenaphthylene	NA	0.0032	3.1E-10	NA	1.2E-09	NA	8.0E-10	NA
Anthracene	NA	NA	NA	2.4E-12	NA	9.6E-12	NA	6.4E-12
Benzene	NA	0.098	7.0E-05	2.5E-07	2.8E-04	9.9E-07	1.8E-04	6.6E-07
Ethylbenzene	NA	0.001	8.6E-07	1.5E-08	3.4E-06	5.9E-08	2.3E-06	3.9E-08
Fluorene	NA	0.0018	6.1E-09	NA	2.4E-08	NA	1.6E-08	NA
Phenanthrene	NA	0.00027	5.9E-10	NA	2.3E-09	NA	1.5E-09	NA
Pyrene	NA	NA	NA	6.5E-16	NA	2.6E-15	NA	1.7E-15
Toluene	NA	0.003	2.5E-06	7.4E-09	1.0E-05	2.9E-08	6.6E-06	2.0E-08
Xylene (total)	NA	0.003	2.3E-06	NA	9.1E-06	NA	6.0E-06	NA
Total PAHs	0.0002	NA	NA	NA	NA	NA	NA	NA

Notes

[1] Modeled value based on maximum detected dissolved (filtered) concentrations in groundwater.

[2] Groundwater concentration based on maximum detected values. Samples were filtered prior to PAH analysis.

TABLE 4

EXPOSURE PARAMETERS FOR FUTURE CONSTRUCTION WORKER SCENARIO

Powell Street Plaza and Shellmound III
Emeryville, California

Exposure Parameter	Units	Reasonable Maximum Exposed Individual (RME)	
GENERAL EXPOSURE PARAMETERS			
Exposure Frequency (EF)	days/year	Value:	250 (inhalation) 150 (dermal)
		Reference:	Cal-EPA, 1992; U.S. EPA, 1991; Site-specific - The hypothetical construction scenario is expected to occur over 250 days/year. Subterranean activities are assumed to last for 60 percent of the time.
Exposure Duration (ED)	years	Value:	2 (inhalation) 1 (dermal)
		Reference:	Site-specific - The hypothetical construction scenario is estimated to last for 2 years, reflected in inhalation exposure. The subterranean activities are assumed to last for 1 year.
Body Weight (BW)	kg	Value:	70
		Reference:	Cal-EPA, 1992; U.S. EPA, 1991
Averaging Time (AT)	days	Value:	25,550 (carcinogens) 730 (noncarcinogens - inhalation) 365 (noncarcinogens - dermal contact)
		Reference:	Cal-EPA, 1992; U.S. EPA, 1991; Site-specific based on exposure assumption.
INHALATION OF VAPORS			
Inhalation Rate (IR_A)	m^3/work day	Value:	20
		Reference:	Cal-EPA, 1992; U.S. EPA, 1991
DERMAL CONTACT WITH GROUNDWATER			
Exposed Skin Surface Area (SA)	cm^2	Value:	2000
		Reference:	U.S. EPA, 1992 (mean value for hands and forearms for a male adult)
Exposure Time (ET)	hours/day	Value:	2
		Reference:	Site-specific based on estimate of potential daily contact with groundwater during construction activities

TABLE 5

EXPOSURE PARAMETERS FOR FUTURE MAINTENANCE WORKER SCENARIO

Powell Street Plaza and Shellmound III
Emeryville, California

Exposure Parameter	Units	Reasonable Maximum Exposed Individual (RME)
GENERAL EXPOSURE PARAMETERS		
Exposure Frequency (EF)	days/year	Value: 250 (inhalation) 5 (dermal) Reference: Cal-EPA, 1992; U.S. EPA, 1991; Site-specific - The hypothetical maintenance worker scenario is expected to occur over 250 days/year as reflected in inhalation exposure. Subterranean activities to the depth of groundwater are assumed to occur infrequently, i.e., five days/year.
Exposure Duration (ED)	years	Value: 25 Reference: Cal-EPA, 1992; U.S. EPA, 1991
Body Weight (BW)	kg	Value: 70 Reference: Cal-EPA, 1992; U.S. EPA, 1991
Averaging Time (AT)	days	Value: 25,550 (carcinogens) 9125 (noncarcinogens) Reference: Cal-EPA, 1992; U.S. EPA, 1991
INHALATION OF VAPORS		
Inhalation Rate (IR_A)	m^3/work day	Value: 20 Reference: Cal-EPA, 1992; U.S. EPA, 1991
DERMAL CONTACT WITH GROUNDWATER		
Exposed Skin Surface Area (SA)	cm^2	Value: 2000 Reference: U.S. EPA, 1992 (mean value for hands and forearmns for a male adult)
Exposure Time (ET)	hours/day	Value: 2 Reference: Site-specific based on estimate of potential daily contact with groundwater during construction activities

TABLE 6

EXPOSURE PARAMETERS FOR FUTURE ON-SITE BUILDING OCCUPANT SCENARIO

Powell Street Plaza and Shellmound III
Emeryville, California

Exposure Parameter	Units	Reasonable Maximum Exposed Individual (RME)
GENERAL EXPOSURE PARAMETERS		
Exposure Frequency (EF)	days/year	Value: 250 Referencee: Cal-EPA, 1992; U.S. EPA, 1991
Exposure Duration (ED)	years	Value: 25 Referencee: Cal-EPA, 1992; U.S. EPA, 1991
Body Weight (BW)	kg	Value: 70 Referencee: Cal-EPA, 1992; U.S. EPA, 1991
Averaging Time (AT)	days	Value: 25,550 (carcinogens) 9125 (noncarcinogens) Referencee: Cal-EPA, 1992; U.S. EPA, 1991
INHALATION OF VAPORS		
Inhalation Rate (IR_A)	m^3/work day	Value: 20 Referencee: Cal-EPA, 1992; U.S. EPA, 1991

TABLE 7

CARCINOGENIC TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN

Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	**SF_{oral}**[1] (mg/kg-day)$^{-1}$	**SF_{inhal}**[2] (mg/kg-day)$^{-1}$	**EPA Group**	**Reference**	**Target Organ**	**Critical Effect**	**Reference**
Benzene	1.0E-01	1.0E-01	A	IRIS, 1996	Blood	Leukemia	Cal-EPA, 1994b
Ethylbenzene	NA	NA	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA
Xylenes	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	NA	NA	NA	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	NA	NA	NA

Notes
NA not applicable

1 Oral cancer slope factor (Cal-EPA, 1994b)
2 Inhalation cancer slope factor (Cal-EPA, 1994b).

TABLE 8

NONCARCINOGENIC TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN

Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	RFD_{oral}[1] (mg/kg-day)	RFD_{inhal}[2] (mg/kg-day)	Target Organ	Critical effect	Reference
Benzene	1.7E-03	1.7E-03	Blood	Dysrasia	ACGIH, 1991
Ethylbenzene	1.0E-01	2.9E-01	Liver, Kidney	Hepatoxicity, Nephrotoxicity	EPA, 1990
Toluene	2.0E-01	1.1E-01	Liver, Kidney	Altered Weight	EPA, 1995
Xylenes	2.0E+00	2.0E-01	Central Nervous System	Hyperactivity, nose and throat irritation	EPA, 1990
Acenaphthylene[3]	6.0E-02	6.0E-02	NA	NA	NA
Anthracene	3.0E-01	3.0E-01	None observed	NA	EPA, 1995
Fluorene	4.0E-02	4.0E-02	Erythrocytes	Decreased Count	EPA, 1995
Fluoranthene	4.0E-02	4.0E-02	Kidney, Liver, Blood	Nephropathy, Weight Changes, Hematological Changes	EPA, 1995
Phenanthrene[4]	3.0E-01	3.0E-01	NA	NA	NA
Pyrene	3.0E-02	3.0E-02	Kidney	Effects	EPA, 1995

Notes
NA - not available

1. Oral reference dose (U.S. EPA, 1996a).
2. Inhalation reference dose (U.S. EPA, 1996a).
3. Toxicity criteria were not available for acenaphthylene; the toxicity criteria for acenaphthene was used as a surrogate based on similarity in chemical structure and physical properties.
4. Toxicity criteria were not available for phenanthrene; the toxicity criteria for anthracene was used as a surrogate based on similarity in chemical structure and physical properties.

TABLE 9

RESULTS OF SCREENING HEALTH RISK ASSESSMENT CARCINOGENIC CHEMICALS

Powell Street Plaza and Shellmound III
Emeryville, California

Scenario	**Pathway**		
	Inhalation-Residual Petroleum	**Inhalation-Dissolved Phase**	**Dermal Contact**
Construction Worker	6×10^{-10}	2×10^{-7}	7×10^{-8}
Maintenance Worker	5×10^{-9}	1×10^{-6}	6×10^{-8}
Building Occupant	2×10^{-9}	5×10^{-7}	NA

TABLE 10

RESULTS OF SCREENING HEALTH RISK ASSESSMENT NONCARCINOGENIC CHEMICALS

Powell Street Plaza and Shellmound III
Emeryville, California

Scenario	Pathway		
	Inhalation-Residual Petroleum	**Inhalation-Dissolved Phase**	**Dermal Contact**
Construction Worker	0.0001	0.03	0.03
Maintenance Worker	0.00008	0.02	0.001
Building Occupant	0.00003	0.008	NA

FIGURES

Map Source: U.S.G.S. Oakland West Quadrangle - California
7.5 Minute Series (Topographic)

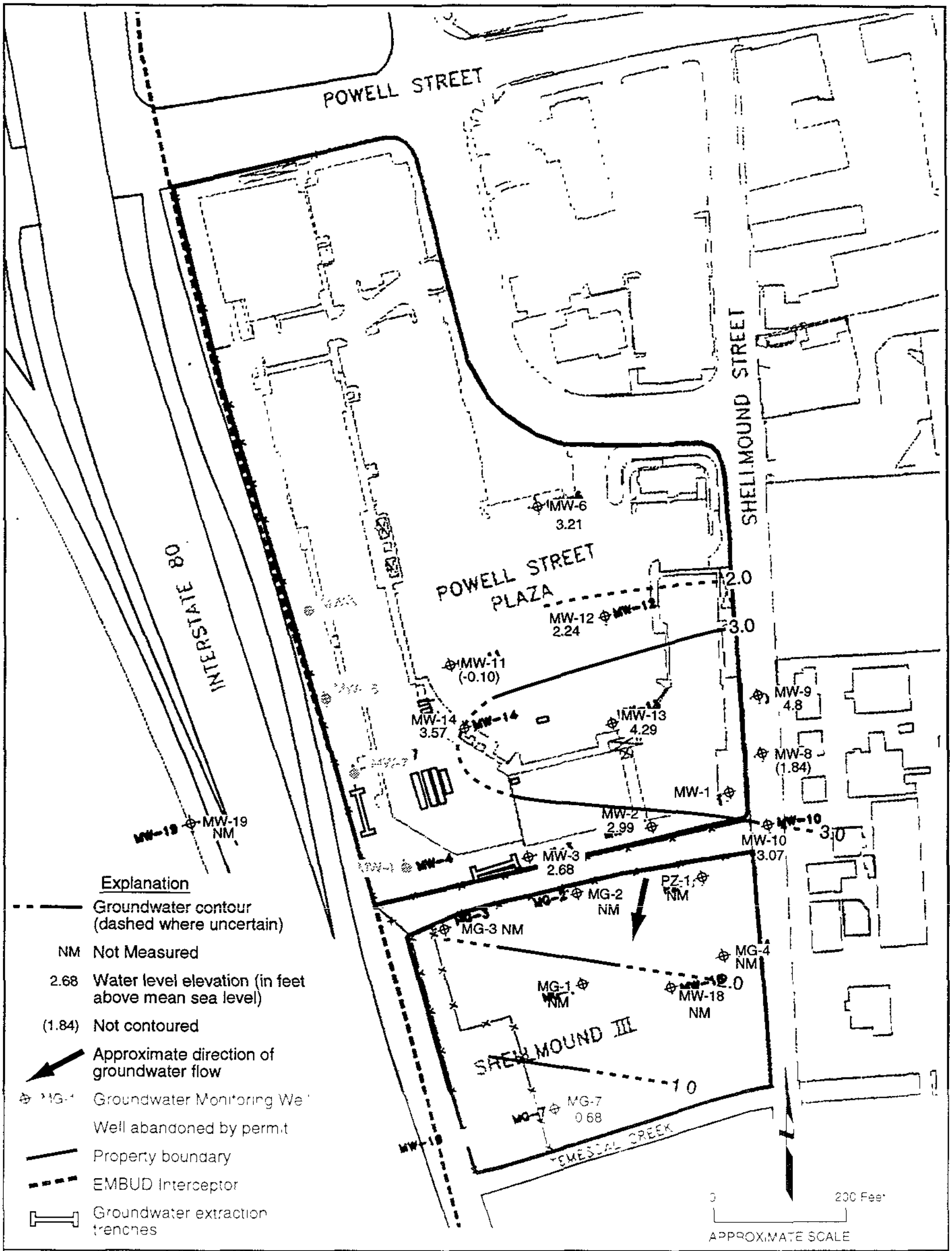
0 2000 Feet

GEOMATRIX

VICINITY MAP
Powell Street Plaza and Shellmound III Properties
Emeryville, California

Figure	1
Project No	3182

3182 003



GEOMATRIX

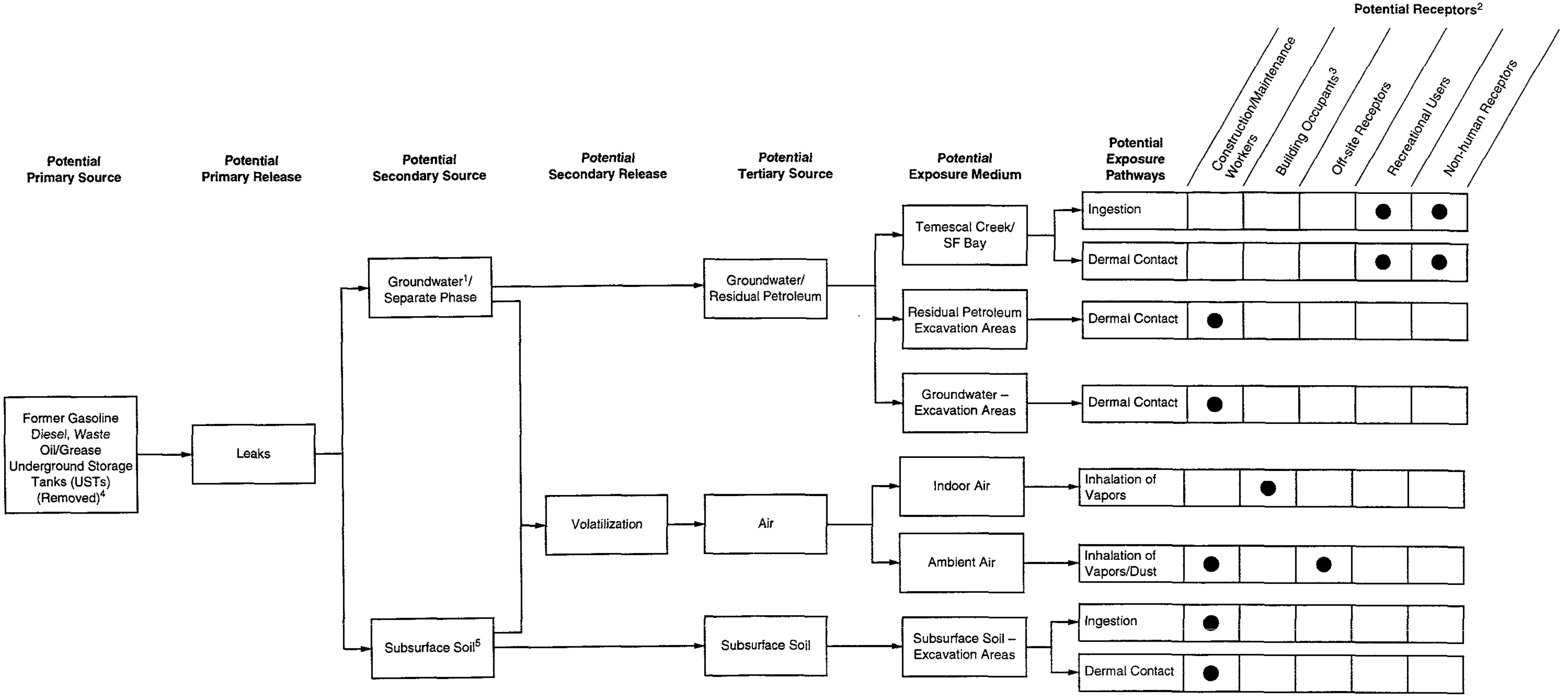
SITE PLAN, LOCATION OF MONITORING WELLS, AND GROUNDWATER CONTOURS*
Powell Street Plaza and Shellmound III Properties
Emeryville, California

*PES 1996

Figure
2

Project No
3182

3182.004



Potential Exposure Medium	Potential Exposure Pathways	Construction/Maintenance Workers	Building Occupants[3]	Off-site Receptors	Recreational Users	Non-human Receptors
Temescal Creek/ SF Bay	Ingestion				●	●
	Dermal Contact				●	●
Residual Petroleum Excavation Areas	Dermal Contact	●				
Groundwater – Excavation Areas	Dermal Contact	●				
Indoor Air	Inhalation of Vapors		●			
Ambient Air	Inhalation of Vapors/Dust	●		●		
Subsurface Soil – Excavation Areas	Ingestion	●				
	Dermal Contact	●				

Notes

1. It has been assumed that shallow groundwater is not currently used and is not likely to be used as a drinking water source.
2. Other "receptors" include water quality and adjacent properties potentially affected by off-site migration. These receptors will be evaluated throughout the assessment process
3. Current building occupants include workers and shoppers; future occupants will likely be the same, but could include residents if the site is developed for high density residential use
4. USTs formerly located at Powell Street Plaza property.
5. Petroleum impacted soil is limited to soil near or below the groundwater table and as such has characteristics associated with saturated soils.

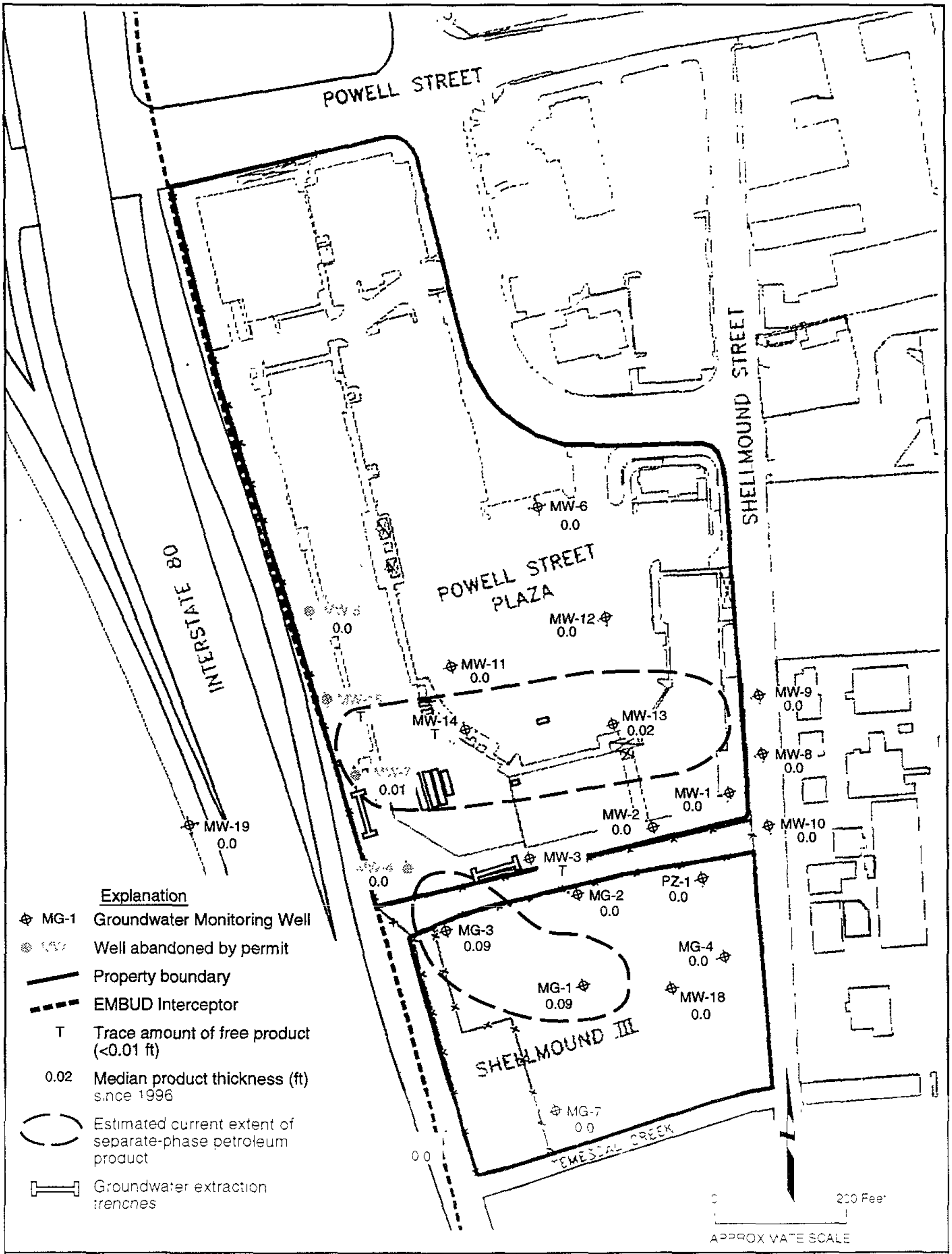
EXPLANATION

● Receptor/pathway evaluated in this risk assessment

SITE CONCEPTUAL MODEL
Powell Street Plaza and Shellmound III
Emeryville, California

GEOMATRIX	Project No	Figure
	3182	3

3182.01E.001

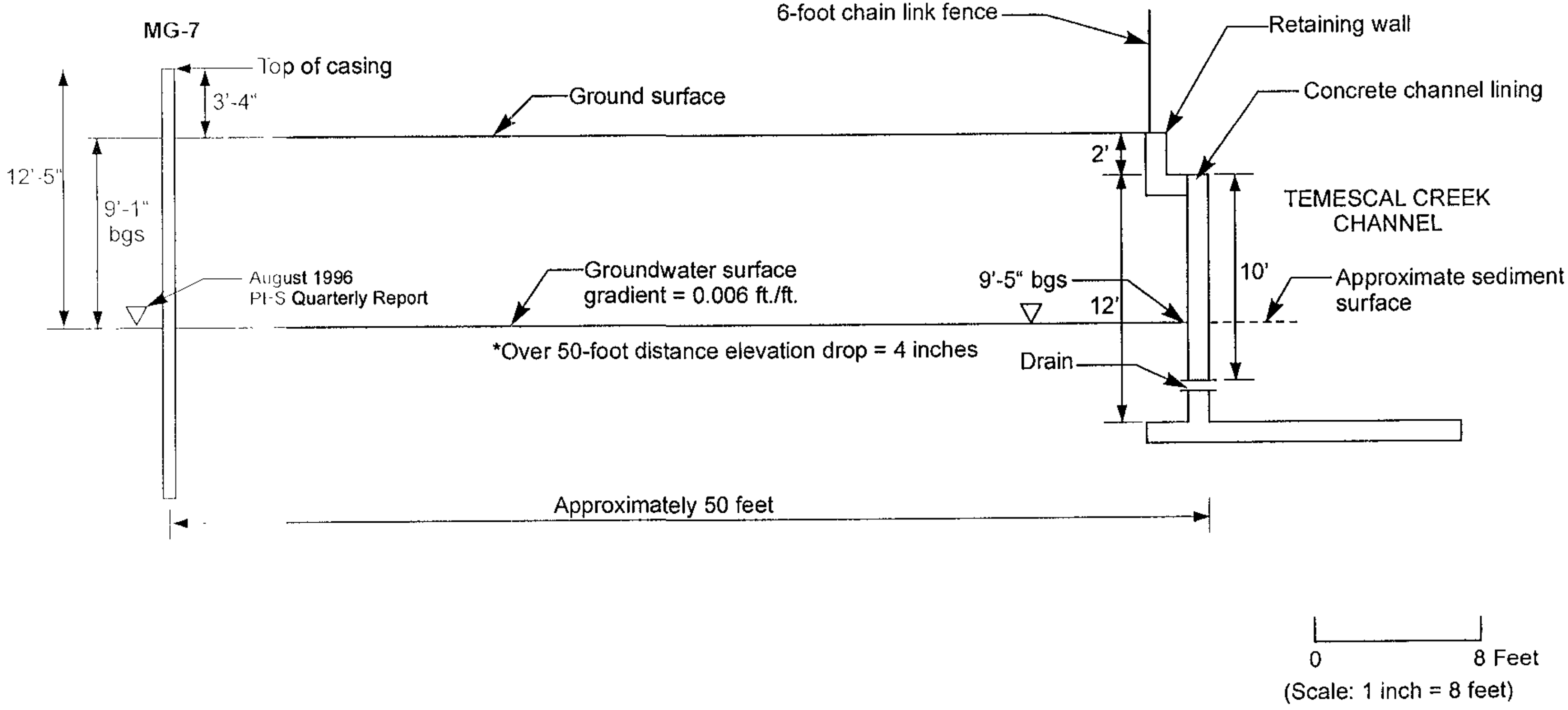


GEOMATRIX

MEDIAN PRODUCT THICKNESS IN WELLS SINCE 1990
Powell Street Plaza and Shellmound III Properties
Emeryville California

Figure
4

Project No
3182.01E



GEOMATRIX

SHELLMOUND III SITE
POTENTIAL ORIENTATION OF MONITORING WELL MG-7 TO THE CONCRETE CHANNEL LINING TEMESCAL CREEK
Powell Street Plaza and Shellmound II Properties
Emeryville, California

Figure
5

Project No.
3182.01E

3182 01E 001 cdr

APPENDICES

APPENDIX A

ANALYTICAL RESULTS

American Environmental Network

Certificate of Analysis

GEOMATRIX CONSULTANTS
100 PINE ST., SUITE 1000
SAN FRANCISCO, CA 94111

ATTN: TOM GAVIGAN
CLIENT PROJ. ID: 3182.01

C.O.C. NUMBER: 8656

REPORT DATE: 12/03/96

DATE(S) SAMPLED: 11/17/96

DATE RECEIVED: 11/18/96

AEN WORK ORDER: 9611253

PROJECT SUMMARY:

On November 18, 1996, this laboratory received 2 water sample(s).

Client requested sample(s) be analyzed for chemical parameters. Portions for EPA 8310 were subcontracted to a DOHS certified laboratory; subcontract report will follow at a later date. Results of analysis are summarized on the following page(s). Please see quality control report for a summary of QC data pertaining to this project.

Samples will be stored for 30 days after completion of analysis, then disposed of in accordance with State and Federal regulations. Samples may be archived by prior arrangement.

If you have any questions, please contact Client Services at (510) 930-9090.

Larry Klein
Laboratory Director

GEOMATRIX CONSULTANTS

SAMPLE ID: MG-2
AEN LAB NO: 9611253-01A
AEN WORK ORDER: 9611253
CLIENT PROJ. ID: 3182.01

DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/18/96
REPORT DATE: 12/03/96

ANALYTE	METHOD/ CAS#	RESULT	REPORTING LIMIT	UNITS	DATE ANALYZED
#Sample Filtration	GFF 0.7 um	-		Filtr Date	11/19/96
#Silica gel Cleanup	EPA 3630M	-		Cleanup	11/22/96
#Extraction for TPH	EPA 3510	-		Extrn Date	11/21/96
TPH as Diesel	GC-FID	ND	0.05	mg/L	11/22/96

ND = Not detected at or above the reporting limit
* = Value at or above reporting limit

GEOMATRIX CONSULTANTS

SAMPLE ID: MG-2
AEN LAB NO: 9611253-01B
AEN WORK ORDER: 9611253
CLIENT PROJ. ID: 3182.01

DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/18/96
REPORT DATE: 12/03/96

ANALYTE	METHOD/ CAS#	RESULT	REPORTING LIMIT	UNITS	DATE ANALYZED
#Extraction for TPH	EPA 3510	-		Extrn Date	11/21/96
TPH as Diesel	GC-FID	1.5 *	0.05	mg/L	11/22/96

ND = Not detected at or above the reporting limit
* = Value at or above reporting limit

GEOMATRIX CONSULTANTS

SAMPLE ID: MG-7
AEN LAB NO: 9611253-02A
AEN WORK ORDER: 9611253
CLIENT PROJ. ID: 3182.01

DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/18/96
REPORT DATE: 12/03/96

ANALYTE	METHOD/ CAS#	RESULT	REPORTING LIMIT	UNITS	DATE ANALYZED
#Sample Filtration	GFF 0.7 um	-		Filtr Date	11/19/96
#Silica gel Cleanup	EPA 3630M	-		Cleanup	11/22/96
#Extraction for TPH	EPA 3510	-		Extrn Date	11/21/96
TPH as Diesel	GC-FID	ND	0.05	mg/L	11/22/96

ND = Not detected at or above the reporting limit
* = Value at or above reporting limit

GEOMATRIX CONSULTANTS

SAMPLE ID: MG-7
AEN LAB NO: 9611253-02B
AEN WORK ORDER: 9611253
CLIENT PROJ. ID: 3182.01

DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/18/96
REPORT DATE: 12/03/96

ANALYTE	METHOD/ CAS#	RESULT	REPORTING LIMIT	UNITS	DATE ANALYZED
#Extraction for TPH	EPA 3510	-		Extrn Date	11/21/96
TPH as Diesel	GC-FID	0.74 *	0.05	mg/L	11/22/96

ND = Not detected at or above the reporting limit
* = Value at or above reporting limit

AEN (CALIFORNIA)
QUALITY CONTROL REPORT

AEN JOB NUMBER: 9611253

CLIENT PROJECT ID: 3182.01

Quality Control and Project Summary

All laboratory quality control parameters were found to be within established limits.

Definitions

Laboratory Control Sample (LCS)/Method Spike(s): Control samples of known composition. LCS and Method Spike data are used to validate batch analytical results.

Matrix Spike(s): Aliquot of a sample (aqueous or solid) with added quantities of specific compounds and subjected to the entire analytical procedure. Matrix spike and matrix spike duplicate QC data are advisory.

Method Blank: An analytical control consisting of all reagents, internal standards, and surrogate standards carried through the entire analytical process. Used to monitor laboratory background and reagent contamination.

Not Detected (ND): Not detected at or above the reporting limit.

Relative Percent Difference (RPD): An indication of method precision based on duplicate analysis.

Reporting Limit (RL): The lowest concentration routinely determined during laboratory operations. The RL is generally 1 to 10 times the Method Detection Limit (MDL). Reporting limits are matrix, method, and analyte dependent and take into account any dilutions performed as part of the analysis.

Surrogates: Organic compounds which are similar to analytes of interest in chemical behavior, but are not found in environmental samples. Surrogates are added to all blanks, calibration and check standards, samples, and spiked samples. Surrogate recovery is monitored as an indication of acceptable sample preparation and instrumental performance.

D: Surrogates diluted out.

#: Indicates result outside of established laboratory QC limits.

QUALITY CONTROL DATA

AEN JOB NO: 9611253
AEN LAB NO. 1121-BLANK
DATE EXTRACTED: 11/21/96
DATE ANALYZED: 11/22/96
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID
Method Blank

	Result (mg/L)	Reporting Limit (mg/L)
Diesel	ND	0.05

AEN LAB NO: 1121-BLANK
DATE EXTRACTED: 11/21/96
DATE ANALYZED: 11/22/96
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID, 3630M
Method Blank

	Result (mg/L)	Reporting Limit (mg/L)
Diesel	ND	0.05

QUALITY CONTROL DATA

AEN JOB NO: 9611253
DATE EXTRACTED: 11/21/96
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID
Surrogate Standard Recovery Summary

Date Analyzed	Client Id.	Lab Id.	Percent Recovery n-Pentacosane
11/22/96	MG-2	01	109
11/22/96	MG-7	02	93
QC Limits:			65-125

DATE EXTRACTED: 11/21/96
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID, 3630M
Surrogate Standard Recovery Summary

Date Analyzed	Client Id.	Lab Id.	Percent Recovery n-Pentacosane
11/22/96	MG-2	01	91
11/22/96	MG-7	02	93
QC Limits			56-122

QUALITY CONTROL DATA

AEN JOB NO: 9611253
DATE EXTRACTED: 11/21/96
DATE ANALYZED: 11/22/96
SAMPLE SPIKED: LCS
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID
Laboratory Control Sample

Analyte	Spike Added (mg/L)	LCS Result (mg/L)	Percent Recovery	QC Limits Percent Recovery
Diesel	4.00	3.46	86	60-110

DATE EXTRACTED: 11/21/96
DATE ANALYZED: 11/22/96
SAMPLE SPIKED: LCS
INSTRUMENT: C
MATRIX: WATER

METHOD: EPA 3510 GCFID, 3630M
Laboratory Control Sample

Analyte	Spike Added (mg/L)	LCS Result (mg/L)	Percent Recovery	QC Limits Percent Recovery
Diesel	4.00	3.22	81	60-110

*** END OF REPORT ***

R-3, 5-D

9611233

CHAIN-OF-CUSTODY RECORD

Nº 8656

Date: 11/17/96

Page 1 of 1

Project No. 318201

Samplers (Signatures)

ANALYSES

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8020 (BTEX only)	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	EPA METHOD 8310	Cooled	Soil (S), Water (W), or Vapor (V)	Acidified	Number of containers
A-T	11/17/96	1500	MG-2							X	X	X	W		6
A-T	↓	1630	MG-7							X	X	X	W		6

REMARKS

Additional Comments

PLEASE PROVIDE RESULTS FOR TPHd:
(a) SUBSEQUENT TO FILTRATION w/ 1.0 µ GLASS-FIBER FILTER, AND SILICA GEL CLEANUP, and,
(b) WITHOUT FILTRATION OR SILICA GEL CLEANUP

PLEASE PROVIDE RESULTS FOR 8310
(a) SUBSEQUENT TO FILTRATION w/ 1.0 µ GLASS FIBER FILTER, and,
(b) WITHOUT FILTRATION

Turnaround time: STANDARD 7-DAY

Results to: JAMIE TULL

Total No. of containers: 12

Relinquished by (signature)	Date:	Relinquished by (signature)	Date:	Relinquished by (signature)	Date
	11/18/96				
Printed Name: TOM GAVIGAN	Time: 1135	Printed Name:	Time	Printed Name	Time:
Company: GEOMATRIX		Company:		Company:	
Received by (signature)	**Date:** 11/18/96	**Received by (signature)**	**Date**	**Received by (signature)**	**Date**
Printed Name: Lucian Podkanorski	Time: 1815	Printed Name:	Time	Printed Name	Time:
Company: A.E.N		Company:		Company:	

Method of Shipment: AEN COURIER (PICKUP AT WAREHOUSE)

Laboratory Comments and Log No.

Geomatrix Consultants
100 Pine Street, 10th Floor
San Francisco, California 94111
415 434 9400

GEOMATRIX

Form [illegible] (Revised 12/95)

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James E. Bruya, Ph.D.
Beth M. Albertson, M.S.
Bradley T. Benson
Kelley D. Wilt

3012 16th Avenue West
Seattle, WA 98119-2029
TEL: (206) 285-8282
FAX: (206) 283-5044

December 5, 1996

Jamie Tull, Project Manager
Geomatrix Consultants, Inc.
100 Pine Street, Suite 1000
San Francisco, CA 94111-5112

Dear Mr. Tull:

Included are the results from the testing of material submitted on November 22, 1996 from your 3182.01B project.

The sum of the aliphatic and aromatic fractions of sample MG-1 added to 53%. We believe the low recovery is due to our inability to separate the water and product phases of the sample. The three VOA's containing MG-1 held mostly water, with small amounts (<1 ml) of floating product on top. We needed approximately 1/2 of a milliliter to do the semivolatile work. When trying to remove this aliquot, we believe that we obtained some water with the product.

The actual percent material in each fraction is best calculated by normalizing the fractionation results to 100%. Using this technique, the following numbers are obtained.

Fraction	Percent
C_5-C_6 Aliphatics	0.10
>C_6-C_8 Aliphatics	0.53
C_9 Aliphatics	0.25
C_{10} Aliphatics	0.23
>C_{10}-C_{12} Aliphatics	8.3
>C_{12}-C_{16} Aliphatics	38
>C_{16}-C_{21} Aliphatics	25
>C_{21}-C_{35} Aliphatics	1.4
Benzene	0.0077
Toluene	0.0018
Ethylbenzene	0.0023
Total Xylenes	0.0000
C_9 Aromatics	0.083
C_{10} Aromatics	0.11
>C_{10}-C_{12} Aromatics	9.2
>C_{12}-C_{16} Aromatics	18
>C_{16}-C_{21} Aromatics	BDL
>C_{21}-C_{35} Aromatics	BDL

BDL - Analyte was not seen above the detection limit of 0.5%

We were unable to perform the viscosity or density analysis due to the limited sample size. We hope this does not caus you a major problem.

We appreciate this opportunity to be of service to you and hope you will call if you should have any questions.

Sincerely,

FRIEDMAN & BRUYA, INC.

Bradley T Benson
for Beth Albertson
Chemist

keh
Enclosures
GMC1205R.DOC

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B
Date Samples Extracted: November 26, 1996
Date Extracts Analyzed: November 27, 1996

RESULTS FROM THE ANALYSIS OF THE PRODUCT SAMPLE FOR VOLATILE ALIPHATICS BY GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION (FID)

Samples Processed Using Method 5030

Results Reported as µg/g (ppm)

Sample ID	C_5-C_6 Aliphatics	>C_6-C_8 Aliphatics	C_9 Aliphatics	C_{10} Aliphatics	Surrogate (% Recovery)
MG-1	550	2,800	1,300	1,200	93
Method Blank	<8	<8	<8	<8	108

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B
Date Samples Extracted: November 26, 1996
Date Extracts Analyzed: November 28, 1996

RESULTS FROM THE ANALYSIS OF THE PRODUCT SAMPLE FOR SEMIVOLATILE AROMATICS BY GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION (FID)

Results Reported as µg/g (ppm)

Sample ID	$>C_{10}-C_{12}$ Aromatics	$>C_{12}-C_{16}$ Aromatics	$>C_{16}-C_{21}$ Aromatics	$>C_{21}-C_{35}$ Aromatics	Surrogate (% Recovery)
MG-1	49,000	93,000	<2,500	<2,500	125
Method Blank	<2,500	<2,500	<2,500	<2,500	112

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B
Date Samples Extracted: November 26, 1996
Date Extracts Analyzed: November 28, 1996

RESULTS FROM THE ANALYSIS OF THE PRODUCT SAMPLE FOR SEMIVOLATILE ALIPHATICS BY GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION (FID)

Results Reported as µg/g (ppm)

Sample ID	$>C_{10}$-C_{12} Aliphatics	$>C_{12}$-C_{16} Aliphatics	$>C_{16}$-C_{21} Aliphatics	$>C_{21}$-C_{35} Aliphatics	Surrogate (% Recovery)
MG-1	44,000	200,000	130,000	7,500	116
Method Blank	<2,500	<2,500	<2,500	<2,500	114

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Analysis For Polynuclear Aromatic Compounds By EPA Method 8270

Client Sample ID:	MG-1	Client:	Geomatrix Consultants, Inc.
Date Received:	11/22/96	Project:	3182.01B
Date Extracted:	11/22/96	Lab ID:	74141
Date Analyzed:	11/23/96	Data File:	112222.D
Matrix:	Product	Instrument:	GCMS#2
Units:	ug/g (ppm)	Operator:	kwilt

Surrogates:	% Recovery	Lower Limit	Upper Limit
Nitrobenzene-d5	155 ip	25	121
2-Fluorobiphenyl	124 ip	24	113
Terphenyl-d14	99	23	120

Compounds:	Concentration ug/g (ppm)
Naphthalene	<10
2-Methylnaphthalene	20 ip
Acenaphthylene	<10
Acenaphthene	220 ip
Dibenzofuran	<10
Fluorene	610 ip
Phenanthrene	<10
Anthracene	990
Carbazole	<10
Fluoranthene	<10
Pyrene	90
Benzo[a]anthracene	20
Chrysene	30
Benzo(a)pyrene	30
Benzo(b)flouranthene	20
Benzo(k)flouranthene	20
Indeno(1,2,3-cd)pyrene	20
Dibenz(a,h)anthracene	<10
Benzo(g,h,i)perylene	20

ip - Compounds were present that interfered with the quantitation of the analyte.

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B
Date Samples Extracted: November 26, 1996
Date Extracts Analyzed: November 27, 1996

RESULTS FROM THE ANALYSIS OF THE PRODUCT SAMPLE FOR VOLATILE AROMATICS BY GAS CHROMATOGRAPHY WITH PHOTOIONIZATION DETECTION (PID)

Samples Processed Using Method 5030

Results Reported as µg/g (ppm)

Sample ID	Benzene	Toluene	Ethyl-benzene	Total Xylenes	C_9 Aromatics	C_{10} Aromatics	Surrogate (% Recovery)
MG-1	41	10	12	<8	440	560	93
Method Blank	<8	<8	<8	<8	<8	<8	108

Analysis For Polynuclear Aromatic Compounds By EPA Method 8270

Client Sample ID:	Method Blank	Client:	Geomatrix Consultants, Inc.
Date Received:	11/22/96	Project:	3182.01B
Date Extracted:	11/22/96	Lab ID:	Method Blank 06-728
Date Analyzed:	11/23/96	Data File:	112215.D
Matrix:	Product	Instrument:	GCMS#2
Units:	ug/g (ppm)	Operator:	kwilt

Surrogates:	% Recovery	Lower Limit	Upper Limit
Nitrobenzene-d5	104	25	121
2-Fluorobiphenyl	102	24	113
Terphenyl-d14	97	23	120

Compounds:	Concentration ug/g (ppm)
Naphthalene	<10
2-Methylnaphthalene	<10
Acenaphthylene	<10
Acenaphthene	<10
Dibenzofuran	<10
Fluorene	<10
Phenanthrene	<10
Anthracene	<10
Carbazole	<10
Fluoranthene	<10
Pyrene	<10
Benzo[a]anthracene	<10
Chrysene	<10
Benzo(a)pyrene	<10
Benzo(b)flouranthene	<10
Benzo(k)flouranthene	<10
Indeno(1,2,3-cd)pyrene	<10
Dibenz(a,h)anthracene	<10
Benzo(g,h,i)perylene	<10

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF PRODUCT SAMPLES FOR SEMIVOLATILE AROMATICS BY GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION

Laboratory Code: 74141 (Duplicate)

Analyte	Reporting Units	Sample Result	Duplicate Result	Relative Percent Difference	Acceptance Criteria
$>C_{10}-C_{12}$	ug/g (ppm)	49,000	52,000	6	0-30
$>C_{12}-C_{16}$	ug/g (ppm)	93,000	95,000	2	0-30
$>C_{16}-C_{21}$	ug/g (ppm)	<2,500	<2,500	nm	0-30
$>C_{21}-C_{35}$	ug/g (ppm)	<2,500	<2,500	nm	0-30

Laboratory Code: 74141 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
$>C_{10}-C_{12}$	ug/g (ppm)	50,000	49,000	53 b	65 b	50-150	20 b
$>C_{12}-C_{16}$	ug/g (ppm)	100,000	93,000	57 b	79 b	50-150	32 b
$>C_{16}-C_{21}$	ug/g (ppm)	100,000	<2,500	97	115	50-150	17
$>C_{21}-C_{35}$	ug/g (ppm)	50,000	<2,500	75	94	50-150	22

Laboratory Code: Spike Blank

Analyte	Reporting Units	Spike Level	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
$>C_{10}-C_{12}$	ug/g (ppm)	50,000	79	83	50-150	5
$>C_{12}-C_{16}$	ug/g (ppm)	100,000	76	79	50-150	4
$>C_{16}-C_{21}$	ug/g (ppm)	100,000	86	90	50-150	5
$>C_{21}-C_{35}$	ug/g (ppm)	50,000	73	76	50-150	4

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable.

b - The analyte was spiked at a level that was less than five times that present in the sample. Matrix spike recoveries and RPD's may not be meaningful.

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF PRODUCT SAMPLES FOR SEMIVOLATILE ALIPHATICS BY GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION

Laboratory Code: 74141 (Duplicate)

Analyte	Reporting Units	Sample Result	Duplicate Result	Relative Percent Difference	Acceptance Criteria
$>C_{10}-C_{12}$	ug/g (ppm)	44,000	47,000	7	0-30
$>C_{12}-C_{16}$	ug/g (ppm)	200,000	210,000	5	0-30
$>C_{16}-C_{21}$	ug/g (ppm)	130,000	140,000	7	0-30
$>C_{21}-C_{35}$	ug/g (ppm)	7,500	10,000	29	0-30

Laboratory Code: 74141 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
$>C_{10}-C_{12}$	ug/g (ppm)	50,000	44,000	111 b	137 b	50-150	21
$>C_{12}-C_{16}$	ug/g (ppm)	50,000	200,000	ai	ai	50-150	ai
$>C_{16}-C_{21}$	ug/g (ppm)	50,000	130,000	ai	ai	50-150	ai
$>C_{21}-C_{35}$	ug/g (ppm)	100,000	7,500	68	80	50-150	16

Laboratory Code: Spike Blank

Analyte	Reporting Units	Spike Level	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
$>C_{10}-C_{12}$	ug/g (ppm)	50,000	125	126	50-150	1
$>C_{12}-C_{16}$	ug/g (ppm)	50,000	85	82	50-150	4
$>C_{16}-C_{21}$	ug/g (ppm)	50,000	60	75	50-150	22
$>C_{21}-C_{35}$	ug/g (ppm)	100,000	55	62	50-150	12

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable.

b - The analyte was spiked at a level that was less than five times that present in the sample. Matrix spike recoveries may not be meaningful

ai - The amount spiked was insufficient to give meaningful recovery data

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF PRODUCT SAMPLES FOR VOLATILE AROMATICS AND ALIPHATICS BY GAS CHROMATOGRAPHY

Laboratory Code: 74141 (Duplicate)

Analyte	Reporting Units	Sample Result	Duplicate Result	Relative Percent Difference	Acceptance Criteria
Benzene	ug/g (ppm)	41	35	16	0-20
Toluene	ug/g (ppm)	10	9	11	0-20
Ethylbenzene	ug/g (ppm)	12	12	0	0-20
Xylenes	ug/g (ppm)	<8	<8	nm	0-20
C_9 Aromatics	ug/g (ppm)	440	440	0	0-20
C_{10} Aromatics	ug/g (ppm)	560	560	0	0-20
C_5-C_6 Aliphatics	ug/g (ppm)	550	480	14	0-20
>C_6-C_8 Aliphatics	ug/g (ppm)	2800	2600	7	0-20
C_9 Aliphatics	ug/g (ppm)	1300	1200	8	0-20
C_{10} Aliphatics	ug/g (ppm)	1200	1300	8	0-20

Laboratory Code: 74141 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
Benzene	ug/g (ppm)	800	41	82	84	65-135	2
Toluene	ug/g (ppm)	800	10	85	87	65-135	2
Ethylbenzene	ug/g (ppm)	800	12	83	85	65-135	2
Xylenes	ug/g (ppm)	1600	<8	90	92	65-135	2
C_9 Aromatics	ug/g (ppm)	800	440	ai	ai	65-135	ai
C_{10} Aromatics	ug/g (ppm)	800	560	ai	ai	65-135	ai
C_5-C_6 Aliphatics	ug/g (ppm)	800	550	ai	ai	65-135	ai
>C_6-C_8 Aliphatics	ug/g (ppm)	800	2800	ai	ai	65-135	ai
C_9 Aliphatics	ug/g (ppm)	800	1300	ai	ai	65-135	ai
C_{10} Aliphatics	ug/g (ppm)	800	1200	ai	ai	65-135	ai

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable

ai- The amount spiked was insufficient to give meaningful recovery data .

Date of Report: December 5, 1996
Date Received: November 22, 1996
Project: 3182.01B

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF PRODUCT SAMPLES FOR VOLATILE AROMATICS AND ALIPHATICS BY GAS CHROMATOGRAPHY

Laboratory Code: Spike Blank

Analyte	Reporting Units	Spike Level	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
Benzene	ug/g (ppm)	800	96	93	65-135	3
Toluene	ug/g (ppm)	800	99	97	65-135	2
Ethylbenzene	ug/g (ppm)	800	99	98	65-135	1
Xylenes	ug/g (ppm)	1600	99	99	65-135	0
C_9 Aromatics	ug/g (ppm)	800	99	100	65-135	1
C_{10} Aromatics	ug/g (ppm)	800	96	97	65-135	1
C_5-C_6 Aliphatics	ug/g (ppm)	800	111	116	65-135	4
>C_6-C_8 Aliphatics	ug/g (ppm)	800	112	121	65-135	8
C_9 Aliphatics	ug/g (ppm)	800	106	118	65-135	11
C_{10} Aliphatics	ug/g (ppm)	800	98	110	65-135	12

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 5, 1996
Date Received: 11/22/96
Project: 3182.01B

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF PRODUCT SAMPLES FOR POLYNUCLEAR AROMATICS BY EPA METHOD 8270

Laboratory Code: 74141 (Duplicate)

Analyte	Reporting Units	Sample Result	Duplicate Result	Relative Percent Difference	Acceptance Criteria
Acenaphthene	µg/g (ppm)	220	220	0	0-20
Pyrene	µg/g (ppm)	90	80	12	0-20

Laboratory Code: 74141 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
Acenaphthene	µg/g (ppm)	500	220	94	92	46-118	2
Pyrene	µg/g (ppm)	500	90	88	85	23-127	3

Laboratory Code: Spike Blank

Analyte	Reporting Units	Spike Level	% Recovery MS	% Recovery MSD	Acceptance Criteria	Relative Percent Difference
Acenaphthene	µg/g (ppm)	500	93	99	46-118	6
Pyrene	µg/g (ppm)	500	94	97	23-127	3

CHAIN-OF-CUSTODY RECORD

N° 8664

Date 11/21/96

Page 1 of

Project No. 3182 01 B

Samplers (Signature) Tom Gavigan

Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8020 (BTEX only)	EPA Method 8240	EPA Method 8270 ①	TPH as gasoline	TPH as diesel	② ALIPHATIC/AROMATIC FRACTIONATION	② VISCOSITY	② DENSITY	LAB ID #	Cooled	Soil (S), Water (W), or Vapor (V)	Acidified	Number of containers
11/21/96	0955	MG-1					X			X	X	X	74180-42	X	*	No	3

REMARKS

Additional Comments

① PNA LIST ONLY. PLEASE PERFORM THIS ANALYSIS ON THE Product.

② PLEASE PERFORM THESE ANALYSES ON THE PRODUCT

* WATER + PRODUCT

Turnaround time: STANDARD

Results to: JAMIE TULL

Total No. of containers: 3

Relinquished by (signature): Tom Gavigan

Date: 11/21/96

Printed Name: Tom Gavigan

Time: 1115

Company: GEOMATRIX

Received by (signature): Scott O. [illegible]

Date: 11/22/96

Printed Name: S. Olson

Time: 07:30

Company: [illegible]

Relinquished by (signature)

Date

Printed Name

Time

Company

Received by (signature)

Date

Printed Name

Time

Company

Relinquished by (signature)

Date

Printed Name

Time

Company

Received by (signature)

Date

Printed Name

Time

Company

Method of Shipment: UPS

Laboratory Comments and Log No.

Geomatrix Consultants
100 Pine Street, 10th Floor
San Francisco, California 94111
415 434 9400

American Environmental Network, Inc.
17400 SW Upper Boones Ferry Road • Suite 270 • Portland, OR 97224 • (503) 684-0447

AEN I.D. 611617

December 10, 1996

Bill Svoboda
AEN - California
3440 Vincent Rd.
Pleasant Hill, CA 94523

Project Name/Number: 9611253 / 3182.01

Attention: Bill Svoboda

On November 20, 1996, American Environmental Network (OR), Inc. received four water samples for analysis for the above listed project. The samples were analyzed with EPA methodology or equivalent methods. The results of these analyses and the quality control data, which follow each set of analyses, are enclosed. The results from these samples relate only to the items tested. This report shall not be reproduced, except in full, without the written approval of the laboratory.

If you have any questions or comments, please do not hesitate to contact us at (503)684-0447.

Andi Hoevet
Project Manager

Steven E. Stanley
Laboratory Manager

AH SES:alm
Enclosure

SAMPLE CROSS REFERENCE SHEET

CLIENT: AEN-CA
PROJECT #: 3182.01
PROJECT NAME:
AEN I.D.: 611617

AEN #	CLIENT DESCRIPTION	DATE SAMPLED	MATRIX
611617-1	MG-2 (filtered)	11/17/96	WATER
611617-2	MG-2 (unfiltered)	11/17/96	WATER
611617-3	MG-7 (filtered)	11/17/96	WATER
611617-4	MG-7 (unfiltered)	11/17/96	WATER

AEN STANDARD DISPOSAL PRACTICE

The samples from this project will be disposed of in thirty (30) days from the date of the report. If an extended storage period is required, please contact our sample control department before the scheduled disposal date.

[illegible]

ANALYTICAL SCHEDULE

CLIENT: AEN-CA **AEN I.D.:** 611617
PROJECT #: 3182.01
PROJECT NAME:

ANALYSIS	TECHNIQUE	REFERENCE	LAB
PAHs	HPLC/UV/FLUOR	EPA 8310	PLD

PLD = AEN - Portland
PHX = AEN - Phoenix
PNR = AEN - Pensacola
CA = AEN - Pleasant Hill
MD = AEN - Columbia
SUB = Subcontract

[illegible]

LIQUID CHROMATOGRAPHY RESULTS

METHOD: 8310
CLIENT I.D.: MG-2 (filtered)
CLIENT: AEN-CA
PROJECT #: 3182
PROJECT NAME:
SAMPLE MATRIX: WATER

AEN I.D.: 611617-1
DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/20/96
DATE EXTRACTED: 11/22/96
DATE ANALYZED: 11/22/96
DILUTION FACTOR: 1
UNITS: ug/L

PARAMETER	RESULTS
NAPHTHALENE	< 0.5
ACENAPHTHYLENE	3.2
ACENAPHTHENE	< 1.0
FLUORENE	1.8
PHENANTHRENE	0.27
ANTHRACENE	< 0.05
FLUORANTHENE	0.2
PYRENE	< 0.1
BENZO(a)ANTHRACENE	< 0.1
CHRYSENE	< 0.1
BENZO(b)FLUORANTHENE	< 0.1
BENZO(k)FLUORANTHENE	< 0.1
BENZO(a)PYRENE	< 0.1
DIBENZO(a,h)ANTHRACENE	< 0.1
BENZO(g,h,i)PERYLENE	< 0.1
INDENO(1,2,3-cd)PYRENE	< 0.1
SURROGATE:	
BIPHENYL (28%-125%)	82%

Analyst. ________

Reviewer: ________

LIQUID CHROMATOGRAPHY RESULTS

METHOD: 8310
CLIENT I.D.: MG-2 (unfiltered)
CLIENT: AEN-CA
PROJECT #: 3182
PROJECT NAME:
SAMPLE MATRIX: WATER

AEN I.D.: 611617-2
DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/20/96
DATE EXTRACTED: 11/22/96
DATE ANALYZED: 11/22/96
DILUTION FACTOR: 1
UNITS: ug/L

PARAMETER	RESULTS	
NAPHTHALENE	<	0.5
ACENAPHTHYLENE	<	1.0
ACENAPHTHENE	<	1.0
FLUORENE		2.3
PHENANTHRENE		0.32
ANTHRACENE	<	0.05
FLUORANTHENE		0.2
PYRENE		0.2
BENZO(a)ANTHRACENE	<	0.1
CHRYSENE	<	0.1
BENZO(b)FLUORANTHENE	<	0.1
BENZO(k)FLUORANTHENE	<	0.1
BENZO(a)PYRENE	<	0.1
DIBENZO(a,h)ANTHRACENE	<	0.1
BENZO(g,h,i)PERYLENE	<	0.1
INDENO(1,2,3-cd)PYRENE	<	0.1

SURROGATE:
BIPHENYL (28%-125%) 92%

Analyst ________

Reviewer: ________

LIQUID CHROMATOGRAPHY RESULTS

METHOD: 8310
CLIENT I.D.: MG-7 (filtered)
CLIENT: AEN-CA
PROJECT #: 3182
PROJECT NAME:
SAMPLE MATRIX: WATER

AEN I.D.: 611617-3
DATE SAMPLED: 11/17/96
DATE RECEIVED: 11/20/96
DATE EXTRACTED: 11/22/96
DATE ANALYZED: 11/22/96
DILUTION FACTOR: 1
UNITS: ug/L

PARAMETER	RESULTS
NAPHTHALENE	< 0.5
ACENAPHTHYLENE	< 1.0
ACENAPHTHENE	< 1.0
FLUORENE	< 0.1
PHENANTHRENE	< 0.05
ANTHRACENE	< 0.05
FLUORANTHENE	< 0.1
PYRENE	< 0.1
BENZO(a)ANTHRACENE	< 0.1
CHRYSENE	< 0.1
BENZO(b)FLUORANTHENE	< 0.1
BENZO(k)FLUORANTHENE	< 0.1
BENZO(a)PYRENE	< 0.1
DIBENZO(a,h)ANTHRACENE	< 0.1
BENZO(g,h,i)PERYLENE	< 0.1
INDENO(1,2,3-cd)PYRENE	< 0.1

SURROGATE:	
BIPHENYL (28%-125%)	70%

Analyst: 12/13/96

Reviewer: [illegible]

LIQUID CHROMATOGRAPHY RESULTS

METHOD:	8310	**AEN I.D.:**	611617-4
CLIENT I.D.:	MG-7 (unfiltered)	**DATE SAMPLED:**	11/17/96
CLIENT:	AEN-CA	**DATE RECEIVED:**	11/20/96
PROJECT #:	3182	**DATE EXTRACTED:**	11/22/96
PROJECT NAME:		**DATE ANALYZED:**	11/22/96
SAMPLE MATRIX:	WATER	**DILUTION FACTOR:**	1
		UNITS:	ug/L

PARAMETER	RESULTS
NAPHTHALENE	< 0.5
ACENAPHTHYLENE	< 1.0
ACENAPHTHENE	< 1.0
FLUORENE	< 0.1
PHENANTHRENE	< 0.05
ANTHRACENE	< 0.05
FLUORANTHENE	< 0.1
PYRENE	0.3
BENZO(a)ANTHRACENE	< 0.1
CHRYSENE	< 0.1
BENZO(b)FLUORANTHENE	< 0.1
BENZO(k)FLUORANTHENE	< 0.1
BENZO(a)PYRENE	< 0.1
DIBENZO(a,h)ANTHRACENE	< 0.1
BENZO(g,h,i)PERYLENE	< 0.1
INDENO(1,2,3-cd)PYRENE	< 0.1

SURROGATE:	
BIPHENYL (28%-125%)	80%

Analyst:

Reviewer:

LIQUID CHROMATOGRAPHY BLANK SPIKE RESULTS

METHOD:	8310	**AEN I.D.:**	611617
CLIENT:	AEN-CA	**QC SAMPLE:**	Method Blank
PROJECT #:	3182	**DATE EXTRACTED:**	11/22/96
PROJECT NAME:		**DATE ANALYZED:**	11/22/96
SAMPLE MATRIX:	WATER	**DILUTION FACTOR:**	1
		UNITS:	ug/L

PARAMETER		SAMPLE RESULT	SPIKE CONC.	SPIKED RESULT	% REC.	DUP. SPIKED RESULT	DUP. % REC.	RPD
ACENAPHTHYLENE	<	1.0	10.0	7.2	72	7.7	77	7
PHENANTHRENE	<	0.05	1.0	0.70	70	0.75	75	7
PYRENE	<	0.1	1.0	1.0	100	1.0	100	0
BENZO(k)FLUORANTHENE	<	0.1	1.0	0.9	90	0.8	80	12
DIBENZO(a,h)ANTHRACENE	<	0.1	1.0	0.6	60	0.7	70	15
SURROGATE:								
BIPHENYL (28% - 125%)				79%		79%		

CONTROL LIMITS

	% REC	RPD
ACENAPHTHYLENE	40 - 155	37
PHENANTHRENE	59 - 128	38
PYRENE	60 - 140	36
BENZO(k)FLUORANTHENE	50 - 100	32
DIBENZO(a,h)ANTHRACENE	50 - 140	30

Analyst ______

Reviewer ______

[redacted]

3440 Vincent Road, Pleasant Hill, CA 94523
Phone (510) 930-9090
FAX (510) 930-0256

REQUEST FOR ANALYSIS / CHAIN OF CUSTODY

1. Client AEN
Address
Contact Bill [illegible]
Alt. Contact [illegible]

Address Report To
2. #1

Send Invoice To:
3. #1

Lab Job Number: 611617
Lab Destination: AENOP
Date Samples Shipped: 11-19-96
Lab Contact:
Date Results Required: 11-27-96
Date Report Required: ASAP
Client Phone No.:
Client FAX No.:

Send Report To (1 or 2) (Circle one)
Client P.O. No. [illegible]
Client Project I.D. No. 3182.01
Sample Team Member(s)

Lab Number	Client Sample Identification	Air Volume	Date/ Time Collected	Sample Type*	Pres.	No. of Cont	Type of Cont	E310 (1)	E310 (2)	Comments / Hazards
1	HC-[illegible] Filtered		11-17-96	7	COLD	1	AMB	X		Include P.O. # and project ID on report and invoices.
2	\ N/F		↓	↓	↓	↓	↓		X	Please provide results for E310:
3	HC-[illegible] Filtered							X		(1) Subsequent to filtration w/ 1.0µ glass fiber filter
4	↓ N/F								X	(2) Without filtration

RUSH

	DATE	TIME		DATE	TIME
Relinquished by (Signature) [illegible]	11-19-96	1500	Received by: (Signature)	11/20/96	10:20
Relinquished by (Signature)			Received by: (Signature)		
Relinquished by (Signature)			Received by: (Signature)		

Method of Shipment

Lab Comments

*Sample type (Specify) 1) 37mm 0.8 µm MCEF 2) 25mm 0.8 µm MCEF 3) 25mm 0.4 µm polycarb. filter
4) PVC filter, diam. pore size 5) Charcoal tube 6) Silica gel tube 7) Water 8) Soil 9) Bulk Sample
10) Other 11) Other

COPIES: WHITE-LAB FILE YELLOW-PROJECT FILE PINK-CLIENT

CHAIN-OF-CUSTODY RECORD

№ 8656

Date: 11/17/96

Page 1 of 1

Project No 3182.01

Samplers (Signatures) Tom

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8020 (BTEX only)	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	EPA Method 8310	Cooled	Soil (S) Water (W) or Vapor (V)	Acidified	Number of containers
1A-F	11/17/96	1500	MG-2							X	X	X	W		6
1A-F	↓	1630	MG-7							X	X	X	W		6

REMARKS

Additional Comments

PLEASE PROVIDE RESULTS FOR TPH_D:

(a) SUBSEQUENT TO FILTRATION w/ TCLP GLASS-FIBER FILTER, AND SILICA GEL CLEANUP, and,

(b) WITHOUT FILTRATION OR SILICA GEL CLEANUP

PLEASE PROVIDE RESULTS FOR 8310:

(a) SUBSEQUENT TO FILTRATION w/ TCLP GLASS-FIBER FILTER, and,

(b) WITHOUT FILTRATION

Turnaround time: STANDARD 7-day

Results to: JAMIE TULL

Total No. of containers: 12

Relinquished by (signature): Tom	Date: 11/18/96	Relinquished by (signature):	Date:	Relinquished by (signature):	Date:
Printed Name: TOM GAVIGAN	Time: 1135	Printed Name:	Time:	Printed Name:	Time:
Company: GEOMATRIX		Company:		Company:	
Received by (signature): Lurena Podkomorski	Date: 11/18/96	Received by (signature):	Date:	Received by (signature):	Date:
Printed Name: Lurena Podkomorsk.	Time: 18:15	Printed Name:	Time:	Printed Name:	Time:
Company: AEN		Company:		Company:	

Method of Shipment: AEN COURIER (PICKUP AT WAREHOUSE)

Laboratory Comments and Log No.:

Geomatrix Consultants
100 Pine Street, 10th Floor
San Francisco, California 94111
415 434 9400

GEOMATRIX

Forms(PT) 012 (Revised 12/95)

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James E. Bruya, Ph.D.
Beth M. Albertson, M.S.
Bradley T. Benson
Kelley D. Wilt

3012 16th Avenue West
Seattle, WA 98119-2029
TEL: (206) 285-8282
FAX: (206) 283-5044

December 11, 1996

Jamie Tull, Project Manager
Geomatrix Consultants, Inc.
100 Pine Street, Suite 1000
San Francisco, CA 94111-5112

Dear Mr. Tull:

Included are the results from the testing of material submitted on December 4, 1996 from your 3182.01 B project. The product sample was an emulsion. The density and viscosity results may not represent the true density and viscosity of the product, but should act as a good estimate.

We appreciate this opportunity to be of service to you and hope you will call if you should have any questions.

Sincerely,

FRIEDMAN & BRUYA, INC.

Bradley T Benson

Bradley T. Benson
Chemist

keh
Enclosures
GMC1211R.DOC

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 11, 1996
Date Received: December 4, 1996
Project: 3182.01 B
Date Samples Extracted: December 5, 1996
Date Extracts Analyzed: December 5, 1996

RESULTS FROM THE ANALYSIS OF WATER/PRODUCT SAMPLES FOR DENSITY

Results Reported 20°F

Sample ID	Density
FP-1	0.945 g/ml

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 11, 1996
Date Received: December 4, 1996
Project: 3182.01 B

QUALITY ASSURANCE RESULTS FOR DENSITY

Laboratory Code: 74376 (Duplicate)

Analyte:	Reporting Units	Sample Result	Duplicate Result	Relative Percent Difference
Density	@ 20.0°C	0.945	0.945	0

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Date of Report: December 11, 1996
Date Received: December 4, 1996
Project: 3182.01 B
Date Samples Extracted: December 9, 1996
Date Extracts Analyzed: December 9, 1996

RESULTS FROM THE ANALYSIS OF THE WATER/PRODUCT SAMPLE FOR KINEMATIC VISCOSITY

Sample ID	Kinematic Viscosity
FP-1	12

APPENDIX B

RESIDUAL PETROLEUM HYDROCARBON PRODUCT MIGRATION RATE ESTIMATION

APPENDIX B

RESIDUAL PETROLEUM HYDROCARBON PRODUCT MIGRATION RATE ESTIMATION

B-1 Product Migration Rate

The potential velocity of residual product at the sites was estimated assuming that the product would move at the gradient of the water table and, therefore, the velocity could be estimated by:

$$v = K_p * i / n$$

where:

v = velocity of product (ft/day)
K_p = product conductivity (ft/day)
I = groundwater gradient (ft/ft)
n = porosity (percent)

The groundwater gradient at the site is approximately 0.006 (ft/ft) between the residual product area and the creek, based on data contained in the March and June 1995 reports prepared by PES. The sediment in the upper 12 feet at the site are reportedly primarily clays, sandy clay and sand; bay mud clay is encountered below a depth of about 12 feet. Therefore, a porosity of 35 percent was assumed (Freeze & Cherry, 1979; page 37).

Conductivity can be calculated by the following equation (Freeze & Cherry, 1979; page 30):

$$K_f = (k * \rho * g) / \mu$$

where:

K_f = conductivity of the fluid (ft/sec)
k = permeability (cm^2)
ρ = density of the fluid (grams per cubic centimeter; g/cm^3)
g = gravitational acceleration (ft/sec^2)
μ = dynamic viscosity of the fluid (poise)

The permeability is a property of the sediment and does not change based on the type of fluid moving through the sediment. Therefore,

$$k = \mu_p * K_p * \rho_p * g = \mu_w * K_w \ \rho_w * g$$

and so,

$$K_p = (\mu_w * \rho_p * K_w)/(\mu_p * \rho_w)$$

The dynamic viscosity of water at 20 degrees centigrade (μ_w) is equal to 0.01 poise and the density (ρ_w) is equal to 1 g/cm^3 (Lide, 1996). Measurements performed by Friedman & Bruya, Inc. of Seattle, Washington indicated a density of 0.945 g/cm^3 and a kinematic viscosity of 0.12 centimeters squared per second. The dynamic viscosity can be calculated by multiplying the kinematic viscosity by the density. Therefore, the dynamic viscosity of the product is 0.113 grams per second per centimeter (poise).

Using the hydraulic conductivity (K_w) for the sites assumed by SOMA (1996) of 40 feet per day indicates a product velocity of approximately 20 feet per year. This hydraulic conductivity appears to overestimate the permeability of the sediments at the site because, if accurate, product should have reached well MG-7. Based on our understanding of the site, the wells are screened primarily across bay mud clay; when the water table is high, the groundwater may flow through fill material consisting of clay, sandy clay, and fine-grained sand intermixed with construction debris. To provide a conservative evaluation of the product migration rate, the product velocity was estimated assuming flow through the fill material. According to Freeze & Cherry (1979), a conservative estimate of the hydraulic conductivity for the fill material would be approximately 4 feet per day. Therefore, the product velocity was reevaluated assuming a hydraulic conductivity of 4 feet per day, indicating a product velocity of approximately 2 feet per year.

B-2 Product Thickness at Temescal Creek

The volume of free product can be estimated by:

$$V_p = t * A * n$$

where;

V_p = volume of the free product (ft^3)
t = true thickness of the free product (ft)
A = areal extent of the product (ft^2)
n = porosity (percent)

The mean product thickness observed in well MW-3 between 1990 and 1994 is 0.05 feet Recent product thickness measured in well MG-1 was 0.06 feet. The area between MW-3 and MG-1 that may contain free product is illustrated on Figure 4 and can be estimated by a rectangle with dimensions of 350 feet by 150 feet. As described in Section B-1, a porosity of 0.35 can be assumed for the sediments at the sites. Assuming a true product thickness of one-quarter of the observed product thickness and assuming the product extends between wells MW-3 and MG-1 as shown on Figure 4 at an average

DRAFT

APPENDIX C

CALCULATIONS OF THE MAXIMUM CONCENTRATIONS OF COPCs IN TEMESCAL CREEK

Maximum concentrations of the PAHs detected in groundwater were used as the groundwater concentrations (C_{ag}) for the purpose of conservatively estimating potential impact to the Creek. In determining default values for the equations, SOMA (1996) reported that Temescal Creek is a U shaped channel that is 30 feet wide with vertical walls 12 feet deep. The channel is constructed of steel reinforced 1-foot thick concrete with 6-inch diameter subsurface drains installed perpendicular to each wall and spaced 80 feet apart. Based on the results of tidal elevation measurements, SOMA (1996) determined that the groundwater on the Shellmound III site discharges into the Creek during the low tide periods when the level of the creek is lower than that of the water in the adjacent monitoring wells. During high tide periods, the level of water in the Creek is higher than that in the monitoring wells and groundwater discharge is unlikely to occur. Therefore, the volume of groundwater discharged to the Creek during the low tide periods was calculated using Darcy's law as:

$$Q_d = K * \left(\frac{h_{well} - h_{creek}}{l} \right) * A * n_{drain} * t$$

Where:

Q_d = Volume of the groundwater discharged into the Creek during time period t (feet^3)

K = Hydraulic conductivity of the slag/fill material (assumed to be 40 feet/day)

h_{well}[1] = Groundwater level elevation during the low tide adjacent to the creek (0.14 feet)

h_{creek}[1] = Water level elevation in the creek during low tide (-3.51 feet)

A = Area of cross-section of the drain holes (0.2 feet^2)

n_{drain} = Number of drain holes (7)

t = Average duration of low tide during 1 24-hour day (525 minutes or 0.365 days)

---

[1] The water level measurements were made in December 1994 (PES, 1995)

~~1~~ = Unit length (feet)

l = Distance (50ft)

Based on this equation, SOMA estimated the volume of groundwater flowing into the Temescal Creek as approximately 75 feet^3 per day. The conservative average flow rate of the Creek was assumed to be 0.5 cubic feet per second (43,200 cubic feet per day). The concentration of chemical in the creek (C_{ci}) after mixing with groundwater was estimated as follows:

$$C_{ci} = \frac{Q_d {}^* C_{ag} + Q_s {}^* C_c}{Q_d + Q_s}$$

Where:

C_{ci} = Concentration of chemical in the Creek (µg/l)

Q_d = Volume of groundwater discharged to the Creek during time period t (feet^3)

Q_s = Flow volume upstream of discharge (43,200 cubic feet per day)

C_{ag} = Concentration of chemical in groundwater (µg/l)

C_c = Concentration of the chemical in the upstream water in the Creek (assumed to be 0 µg/l)

The resulting calculated equations for the total dissolved PAH concentrations were:

$$Q_d = 40\text{ft}/\text{d} * \left(\frac{0.14\text{ft} - (-3.51\text{ft})}{1\text{ft}}\right) * 0.2\text{ft}^2 * 7 * 0.365\text{d}$$

$$Q_d = 75 \text{ ft}^3 \text{ per day}$$

Given that C_{ag} = 5.5 µg/l;

$$C_{ci} = \frac{75\text{ft}^3/\text{d} * 5.5\ \mu\text{g}/\text{l} + 43200\text{ft}^3/\text{d} * 0\ \mu\text{g}/\text{l}}{75\text{ft}^3/\text{d} + 43200\text{ft}^3/\text{d}}$$

$$C_{ci} = 0.0094\ \mu\text{g}/\text{l}$$

Based on this calculation, an estimated total dissolved PAH concentration of 0.0094 μg/l was predicted for Temescal Creek.

100 Pine Street, 10th Floor
San Francisco CA 94111
(415) 434-9400 • FAX (415) 434-1365

GEOMATRIX

ENVIRONMENTAL
PROTECTION

97 JAN 21 AM 8:47

STID 1184

20 January 1997
Project 3182.01

Ms. Susan Hugo
Alameda County Health Care Services Agency
Department of Environmental Health
Hazardous Materials Division
1131 Harbor Bay Parkway
Alameda, CA 94502

Mr. Sum Arigala
California Regional Water
Quality Control Board
San Francisco Bay Region
2101 Webster Street, Suite 500
Oakland, CA 94612

Subject: Draft Risk Assessment and Long-Term Site Management Program for Petroleum Hydrocarbons at Powell Street Plaza and Shellmound III, Emeryville, California

Dear Ms. Hugo and Mr. Arigala:

Geomatrix Consultants, Inc. (Geomatrix) is pleased to submit on behalf of the Former Eastshore Partners, a Draft of the above referenced document for your review and comment. This report has been prepared in accordance with the requirements of the approved work plan[1] and amendments[2]. The purpose of this report is to provide a human health and ecological risk basis for developing a long-term site management plan for petroleum hydrocarbon-impacted soil and groundwater at the Powell Street Plaza (PSP) and the Shellmound III (sites) located in Emeryville, California. The petroleum hydrocarbons characterized as gasoline and diesel fuels are believe to have been released directly to the shallow groundwater from underground storage tanks located on the PSP site when it was operated as a Pacific Intermountain Express (PIE) trucking facility. Following a summary of data gathered to fill information gaps, this report addresses potential human health risks to current and future commercial building occupants, maintenance workers, and construction workers; potential risks to aquatic organisms and human recreational users of Temescal Creek; and migration potential of petroleum product that is present on the shallow groundwater. Based on the results of the human health and ecological risk assessment and to address other environmentally-related concerns, recommendations for a long-term management plan for the site were developed

---

[1] Geomatrix 1995 Proposed Work Plan to Develop a Long-Term site Management Program *Prepared for the Former Eastshore Partners, Emeryville, California*

[2] Geomatrix 28 October, 1996 Letter to Alameda County Department of Environmental Health and the Regional Water Quality Control Board

Geomatrix Consultants, Inc.
Engineers, Geologists, and Environmental Scientists

Chemical analysis of two groundwater samples for PAHs indicated that dissolved PAHs are not present at significant concentrations in the shallow groundwater. Sampling and analysis at monitoring wells associated with separate-phase product demonstrated that: 1) separate-phase product was present in very small quantities in the wells (<0.06 ft depth of product at MG-1 and only trace amounts in MW-3 and the irrigation junction box near MW-13); and 2) the product has the characteristics of weathered diesel fuel that is dominated by middle boiling range aliphatic and aromatic compounds. Measurements of oxidation-reduction potential at four wells along the groundwater gradient at the site were all negative, indicating that subsurface conditions are favorable for anaerobic degradation of petroleum throughout the sites.

An evaluation of the physical characteristics and migration potential of the free product indicated that: 1) consistent decreases in the depth of free product in site monitoring wells supports a conclusion that a very small amount of product is present at the site following product removal activities between 1990 and 1992; 2) the residual free product is essentially immobile because there is not sufficient product to generate the head necessary for significant product migration to occur; and 3) the density and viscosity of the product are such that product migration is unlikely to occur.

A quantitative assessment of potential human health effects indicated that adverse effects are not associated with activities at the sites by:

- Future construction workers at the Shellmound III site (dermal contact with groundwater, and inhalation of vapors from groundwater and separate-phase product);
- Current and future maintenance workers (dermal contact with groundwater, and inhalation of vapors from groundwater and separate-phase product);
- Current and future commercial building occupants (inhalation of vapors from groundwater and separate-phase product) , and
- Current and future off-site receptors (inhalation of vapors from groundwater and separate-phase product).

A quantitative assessment of potential migration of dissolved-phase petroleum hydrocarbons from the sites to Temescal Creek indicated that human recreational users and ecological receptors (e.g., benthic invertebrates, water column organisms) are not likely to be adversely impacted by migration of the chemicals of interest from the sites. The results of the screening human health and ecological risk assessments indicate that no unacceptable risks exist under the conditions evaluated. As a result Geomatrix recommends that the site be closed without further remediation or monitoring of the petroleum hydrocarbon conditions associated with the releases from the former PIE USTs.

Based on the results of the risk assessment, recommendations for a long-term soil and groundwater management plan were developed to address other environmental issues associated with excavation of soil in areas where residual separate-phase product may be present. These recommendations address such issues as: 1) personal protective equipment to minimize direct dermal contact with separate-phase product; 2) air monitoring while working in restricted air spaces (e.g., narrow utility trenches); and 3) soil stockpiling and runoff control measures.

If you have any questions, please contact either of the undersigned.

Sincerely,

GEOMATRIX CONSULTANTS, INC.

James D. Tull
Senior Scientist

Tom Graf, P.E.
Principal Engineer

JDT/TG:ldu
I:\RISK\POWELL\3182_I.DOC

cc: Ravi Arulanantham, Ph D., RWQCB
Amanda Spencer, Geomatrix
Greg Brorby, Geomatrix

DRAFT

APPENDIX B

FREE PRODUCT MIGRATION RATE ESTIMATION

B-1 Product Migration Rate

The potential velocity of free phase product at the sites was estimated assuming that the product would move at the gradient of the water table and, therefore, the velocity could be estimated by:

$$v = K_p * i / n$$

where:

v = velocity of product (ft/day)
K_p = product conductivity (ft/day)
I = groundwater gradient (ft/ft)
n = porosity (percent)

The groundwater gradient at the site is approximately 0.006 (ft/ft) between the product area and the creek, based on data contained in the March and June 1995 reports prepared by PES. The sediments in the upper 12 feet at the site are reportedly primarily clays, sandy clay and sand; bay mud clay is encountered below a depth of about 12 feet. Therefore, a porosity of 35 percent was assumed (Freeze & Cherry, 1979; page 37).

Conductivity can be calculated by the following equation (Freeze & Cherry, 1979; page 30):

$$K_f = (k * \rho * g) / \mu$$

where:

K_f = conductivity of the fluid (ft/sec)
k = permeability (cm^2)
Ψ = density of the fluid (grams per cubic centimeter; g/cm^3)
g = gravitational acceleration (ft/sec^2)
T = dynamic viscosity of the fluid (poise)

The permeability is a property of the sediments and does not change based on the type of fluid moving through the sediments. Therefore,

$$k = \mu_p * K_p * / \rho_p * g = \mu_w * K_w / \rho_w * g$$

and so,

$$K_p = (\mu_w * \rho_p * K_w) / (\mu_p * \rho_w)$$

The dynamic viscosity of water at 20 degrees centigrade (μ_w) is equal to 0.01 poise and the density (ρ_w) is equal to 1 g/cm^3 (Lide, 1996). Measurements performed by Friedman & Bruya, Inc. of Seattle, Washington indicated a density of 0.945 g/cm^3 and a kinematic viscosity of 0.12 centimeters squared per second. The dynamic viscosity can be calculated by multiplying the kinematic viscosity by the density. Therefore, the dynamic viscosity of the product is 0.113 grams per second per centimeter (poise).

Using the hydraulic conductivity (K_w) for the sites assumed by SOMA (1996) of 40 feet per day indicates a product velocity of approximately 20 feet per year. This hydraulic conductivity appears to overestimate the permeability of the sediments at the site because, if accurate, product should have reached well MG-7. Based on our understanding of the site, the wells are screened primarily across bay mud clay; when the water table is high, the groundwater may flow through fill material consisting of clay, sandy clay, and fine-grained sand intermixed with construction debris. To provide a conservative evaluation of the product migration rate, the product velocity was estimated assuming flow through the fill material. According to Freeze & Cherry (1979), a conservative estimate of the hydraulic conductivity for the fill material would be approximately 4 feet per day. Therefore, the product velocity was reevaluated assuming a hydraulic conductivity of 4 feet per day, indicating a product velocity of approximately 2 feet per year.

B-2 Product Thickness at Temescal Creek

The volume of free product can be estimated by:

$$V_p = t * A * n$$

where:

V_p = volume of the free product (ft^3)
t = true thickness of the free product (ft)
A = areal extent of the product (ft^2)
n = porosity (percent)

The mean product thickness observed in well MW-3 between 1990 and 1994 is 0.05 feet. Recent product thickness measured in well MG-1 was 0.06 feet. The area between MW-3 and MG-1 that may contain free product is illustrated on Figure 4 and can be estimated by a rectangle with dimensions of 350 feet by 150 feet. As described in Section B-1, a porosity of 0.35 can be assumed for the sediments at the sites. Assuming a true product thickness of one-quarter of the observed product thickness and assuming the product extends between wells MW-3 and MG-1 as shown on Figure 4 at an average observed thickness of 0.055 feet, the volume of free phase product is estimated to be approximately 250 cubic feet.

The thickness at the creek can be estimated by:

$$tc = V_p / (Ac * n)$$

where:

tc = true thickness at the creek (ft)
Ac = area between MW-3, MG-1 and the creek (ft^2)

The area between MW-3, MG-1 and the creek is approximately 360 feet by 300 feet (Figure 4). This leads to an estimated thickness of free product at the creek of approximately 0.007 feet.

and so,

$$K_p = (\mu_w * \rho_p * K_w) / (\mu_p * \rho_w)$$

The dynamic viscosity of water at 20 degrees centigrade (μ_w) is equal to 0.01 poise and the density (ρ_w) is equal to 1 g/cm^3 (Lide, 1996). Measurements performed by Friedman & Bruya, Inc. of Seattle, Washington indicated a density of 0.945 g/cm^3 and a kinematic viscosity of 0.12 centimeters squared per second. The dynamic viscosity (T) can be calculated by multiplying the kinematic viscosity by the density. Therefore, the dynamic viscosity of the residual product is 0.113 grams per second per centimeter (poise).

Using the hydraulic conductivity (K_w) for the sites assumed by SOMA (1996) of 40 feet per day indicates a product velocity of approximately 20 feet per year. This hydraulic conductivity is considered to be extremely conservative and appears to overestimate the permeability of the sediment at the site because, if accurate, product should have reached well MG-7 already. This conservative modeling approach was appropriate for the screening-level evaluation for dissolved phase constituents. No further refinements in the model parameters were required because all potential human health and ecological risks were within acceptable limits (Section 6.5 this report; and SOMA 1996). However, the initial results of the residual product migration model indicate that the K_w value of the 40 feet per day does not accurately represent conditions at the site. Therefore, the model was refined based on a more realistic estimate of K_w.

Based on our understanding of the site, the wells are screened primarily across bay mud clay; when the water table is high, the groundwater may flow through fill material consisting of clay, sandy clay, and fine-grained sand intermixed with construction debris. To provide a conservative evaluation of the product migration rate, the product velocity was estimated assuming flow through the fill material. According to Freeze & Cherry (1979), a conservative estimate of the hydraulic conductivity for the fill material would be approximately 4 feet per day. Therefore, the product velocity was reevaluated assuming a hydraulic conductivity of 4 feet per day, indicating a product velocity of approximately 2 feet per year.

B-2 Product Thickness at Temescal Creek

The volume of residual product can be estimated by:

$$V_p = t * A * n$$

where:

V_p = volume of the residual product (ft^3)
t = true thickness of the residual product (ft)

A = areal extent of the residual product (ft^2)
n = porosity (percent)

The mean product thickness observed in well MG-3 between 1990 and 1994 is 0.05 feet. Recent product thickness measured in well MG-1 was 0.06 feet. The area between MG-3 and MG-1 that may contain residual product is illustrated on Figure 4 and can be estimated by a rectangle with dimensions of 350 feet by 150 feet. As described in Section B-1, a porosity of 0.35 can be assumed for the sediment at the sites. Assuming a true product thickness of one-quarter of the observed product thickness and assuming the product extends between wells MG-3 and MG-1 as shown on Figure 4 at an average observed thickness of 0.055 feet, the volume of residual product is estimated to be approximately 250 cubic feet.

The potential thickness that could occur on the upgradient side of north channel wall of the creek can be estimated by:

$$tc = V_p / (Ac * n)$$

where:

tc = true thickness at the wall (ft)
Ac = area between MW-3, MG-1 and the creek (ft^2)

The area between MW-3, MG-1 and the creek is approximately 360 feet by 300 feet (Figure 4). This leads to an estimated potential thickness of residual product at the wall of approximately 0.007 feet.

APPENDIX C

CALCULATIONS OF THE MAXIMUM CONCENTRATIONS OF COPCS IN TEMESCAL CREEK

APPENDIX C

CALCULATIONS OF THE MAXIMUM CONCENTRATIONS OF COPCs IN TEMESCAL CREEK

Maximum concentrations of the PAHs detected in groundwater were used as the groundwater concentrations (C_{ag}) for the purpose of conservatively estimating potential impact to the Creek. In determining default values for the equations, SOMA (1996) reported that Temescal Creek is a U shaped channel that is 30 feet wide with vertical walls 12 feet deep and an additional 2-foot high retaining wall (based on Geomatrix site observations). The channel is constructed of steel reinforced 1-foot thick concrete with 6-inch diameter subsurface drains installed perpendicular to each wall and spaced 80 feet apart. Based on the results of tidal elevation measurements, SOMA (1996) determined that the groundwater on the Shellmound III site discharges into the Creek during the low tide periods when the level of the creek is lower than that of the water in the adjacent monitoring wells. During high tide periods, the level of water in the Creek is higher than that in the monitoring wells and groundwater discharge is unlikely to occur. Therefore, the volume of groundwater discharged to the Creek during the low tide periods was calculated using Darcy's law as:

$$Q_d = K * \left(\frac{h_{well} - h_{creek}}{\ell} \right) * A * n_{drain} * t$$

Where:

Q_d = Volume of the groundwater discharged into the Creek during time period t (feet^3)

K = Hydraulic conductivity of the slag/fill material (assumed to be 40 feet/day)

h_{well}[1] = Groundwater level elevation during the low tide adjacent to the creek (0.14 feet)

h_{creek}[1] = Water level elevation in the creek during low tide (-3.51 feet)

A = Area of cross-section of the drain holes (0.2 feet^2)

n_{drain} = Number of drain holes (7)

---

[1] The water level measurements were made in December 1993 (PES, 1995)

t = Average duration of low tide during 1 24-hour day (525 minutes or 0.365 days)

ℓ = Distance between monitoring point (MG-7) and the wall of Temescal Creek (50 feet)

Based on this equation, SOMA estimated the volume of groundwater flowing into the Temescal Creek as approximately 1.5 feet^3 per day. The conservative average flow rate of the Creek was assumed to be 0.5 cubic feet per second (43,200 cubic feet per day). The concentration of chemical in the creek (C_{ci}) after mixing with groundwater was estimated as follows:

$$C_{ci} = \frac{Q_d {}^{*} C_{ag} + Q_s {}^{*} C_c}{Q_d + Q_s}$$

Where:

C_{ci} = Concentration of chemical in the Creek (µg/l)

Q_d = Volume of groundwater discharged to the Creek during time period t (feet^3)

Q_s = Flow volume upstream of discharge (43,200 cubic feet per day)

C_{ag} = Concentration of chemical in groundwater (µg/l)

C_c = Concentration of the chemical in the upstream water in the Creek (assumed to be 0 µg/l)

The resulting calculated equations for the total dissolved PAH concentrations were:

$$Q_d = 40\text{ft}/\text{d} * \left(\frac{0.14\text{ft} - (-3.51\text{ft})}{50\text{ ft}}\right) * 0.2\text{ft}^2 * 7 * 0.365\text{d}$$

$$Q_d = 1.5\text{ ft}^3\text{ per day}$$

Given that C_{ag} = 5.5 µg/l.

$$C_{ci} = \frac{1.5\text{ft}^3/\text{d} * 5.5\ \mu\text{g}/\text{l} + 43200\text{ft}^3/\text{d} * 0\ \mu\text{g}/\text{l}}{1.5\text{ft}^3/\text{d} + 43200\text{ft}^3/\text{d}}$$

$$C_{ci} = 0.00019\ \mu g/l$$

Based on this calculation, an estimated total dissolved PAH concentration of 0.0002 µg/l was predicted for Temescal Creek.

APPENDIX D

ESTIMATION OF CHEMICAL VOLATILIZATION FROM GROUNDWATER AND SEPARATE-PHASE MATERIAL

APPENDIX D

ESTIMATION OF CHEMICAL VOLATILIZATION FROM GROUNDWATER AND SEPARATE-PHASE MATERIAL

This section presents the methodology for estimating ambient and indoor air concentrations of volatile chemicals resulting from dissolved and residual petroleum hydrocarbons at the PSP and Shellmond III sites. Because the dissolved and residual petroleum do not have the same distribution at the site, potential ambient and indoor air concentrations were estimated separately. Spreadsheets summarizing the calculation results are presented at the end of this section. Table D-1 presents physical constants for the COPCs evaluated herein.

Estimation of Flux from Dissolved-Phase Petroleum Hydrocarbons

The Farmer model was used to estimate emissions from groundwater (U.S. EPA, 1992). The Farmer model is based on Fick's Law of Diffusion, and is a simple screening model that assumes that all phases are in equilibrium (vapor, liquid, and solid) and that the source remains constant over time. For chemicals in shallow groundwater, the vapor phase concentration above the saturated zone can be estimated using chemical-specific Henry's Law Constants, which describe a chemical's tendency to volatilize out of solution. Once in the vapor phase, a chemical can diffuse upward through the soil column, the rate of which is dependent on the characteristics of the soil (e.g., soil porosity, volumetric air content), the path length for diffusion, and chemical-specific properties. The equation used to estimate emissions from groundwater is provided below:

$$E_i = [C_{sg} * D_i * P_a^{3.333} F] / (L * P_t^2)$$

Where:

E = Vaporization rate through the soil surface (mg/cm^2-sec)

C_{sg} = Soil-gas concentration (mg/cm^3)
where $C_{sg} = C_w * 0.001 * H/(R*T)$

C_w = Concentration in groundwater (mg/l)

H = Chemical-specific Henry's Law constant (atm-m^3/mole)

R = Universal Gas Constant (8.2×10^{-5} atm-m^3/mole-°K)
T = Absolute temperature (298 °K)
D_i = Chemical-specific diffusivity in air (cm^2/sec)
P_a = Volumetric air content
L = Depth to groundwater (cm)
P_t = Total soil porosity

The concentration in groundwater used in this evaluation was the maximum concentration detected for each chemical, regardless of well location. Chemical-specific values were used for the Henry's Law Constant and the diffusivity in air (DTSC, 1994), and conservative default values were used for volumetric air content and total soil porosity (DTSC, 1994). The depth to shallow groundwater was estimated to be 6 feet bgs based on a conservative interpretation of site-specific conditions. The results of this analysis are shown in Table D-2.

Estimation of Vapor Flux from Residual Petroleum Hydrocarbons

Chemical vapor flux from residual petroleum hydrocarbons was estimated based on an application of Dalton's law, which states that the partial pressure of one component in a mixture of gases is related to its fraction in the mixture and the total vapor pressure of the mixture. Once the soil gas concentration of COPCs was estimated based on their partial pressures, the Farmer Model was used to estimate vapor flux at the surface.

A fingerprint analysis was conducted to provide information on the overall characteristics of the residual petroleum (Section 4.1). The analysis results provided concentrations for groups of aliphatic and aromatic hydrocarbons based on carbon chain length (e.g., aliphatic hydrocarbons with five to six carbon atoms). Secondary analyses were conducted to provide information on concentrations of potential COPCs (i.e.. BTEX and PAHs). The volatile COPCs identified in the secondary analyses were benzene, toluene, ethylbenzene, anthracene and pyrene

To estimate mole fractions of each COPC as required for Darcy's Law, an average molecular weight (MW) for the mixture was developed, based on the total moles of all carbon groups and their respective MWs. A representative hydrocarbon compound was identified for each group of carbon chain lengths (carbon group), typically a compound that fell in the middle of the overall range. The selection of the representative compound does not reflect the presence or absence of that particular compound, but is used only to represent the contribution of the carbon group to the estimate of MW for the mixture. The fraction of the MW contributed by each carbon group to the overall mixture (moles of carbon group per grams of mixture) was calculated as:

$$M_{cg} = \%CG / MW_{cg}$$

Where:

M_{cg} = Moles of carbon group contributing to mixture (moles of carbon group per grams of mixture (moles/g of mix))

%CG = Fraction of carbon group in mixture (g of carbon group/g of mix)

MW_{cg} = Molecular weight for carbon group (g of carbon group/moles of carbon group; based on representative compound)

For example, to estimate the contribution of aliphatic hydrocarbons with nine carbon atoms (C9), nonane was selected as the representative compound. To estimate the moles of C9 in a gram of the mixture, the following equation was used:

$$\underset{\text{(moles of nonane/g of mix)}}{\text{Moles of nonane (represent C-9)}} \quad \frac{0.0025 \text{ g of nonane/1 g of mix}}{114.23 \text{ g of nonane/moles of nonane}}$$

To develop a molecular weight for the mixture of chemicals, the moles of each carbon group per gram of mixture (Mcg) was summed for all carbon groups, as follows:

$$\underset{\text{(moles of mix/g of mix)}}{\text{1/MW of mix}} = \frac{\text{Moles } CG_1}{\text{g of mix}} + \frac{\text{Moles } CG_2}{\text{g of mix}} + \frac{\text{Moles } CG_3}{\text{g of mix}} + \ldots + \frac{\text{Moles } CG_n}{\text{g of mix}}$$

The reciprocal of this value is the estimated molecular weight of the mixture (MWmix; g of mix/mole of mix). The estimation of molecular weight for the mixture is shown in Table D-3.

The mole fraction of each COPC was estimated based on the concentration of the COPC in the mixture:

$$X_1 = (W_1 / MW_1) / (W_{mix} / MW_{mix})$$

Where:

X_1 = Mole fraction of component 1
W_1 = Weight of component 1 in 1 kg of mix (g of component 1)
MW_1 = MW of component 1 (g of component 1 / mol of component 1)
W_{mix} = 1 kg of mix
MW_{mix} = MW of mix (g of mix / mol of mix)

The mole fraction was then used to estimate the partial pressure of the COPCs:

$$P_1 = P^o{}_1 * X_1$$

Where:

P_1 = Partial pressure of component 1 (atm)
$P^o{}_1$ = Pure phase vapor pressure of component 1 at 25°C (atm)
X_1 = Mole fraction of component 1 in the mix

The soil gas concentration was then estimated based on the partial pressure of the gas:

$$C_{sg1} = (P_1 * MW_1) / (R*T*CF)$$

Where:

C_{sg} = Soil gas concentration of component 1 (g cm^3)
P = Partial pressure of component 1 (atm)
MW_1 = Molecular weight of component 1 (g mol)
R = Universal gas constant (atm-m^3 mol-°K)
T = Temperature (°K)

CF = Conversion Factor (cm^3/m^3)

The resulting soil gas concentration was input into the Farmer Model discussed in the previous section to estimate chemical volatilization to air. The estimation of soil gas concentrations is shown in Table D-4.

Estimation of Indoor Air Concentrations

The methodology for estimating ambient air concentrations was similar for the two areas of the site. The vapor flux rates were used in a box model to estimate ambient air concentrations (U.S. EPA, 1991, DTSC, 1994). The box model places a hypothetical box over the site and estimates the rate of flux into the box, accounting for chemical dilution from air mixing within the box. The formula is as follows:

$$Conc_{air} = (E_i * A * F) / ((ACH / CF) * V)$$

Where:

$Conc_{air}$ = Indoor air concentration ($\mu g/m^3$)
E_i = Vaporization rate through the soil surface (mg/m^2-sec)
A = Emitting area (m^2)
F = Fraction of floor that is cracked (unitless)
ACH = Air exchange rate (/hr)
CF = Conversion Factor (sec/hr)
V = Volume of Air in Building (m^3)

For this screening evaluation, the emitting area was estimated to be the area of a small subunit on the Powell Street Plaza property, approximately 2,200 m^2. The mixing height is assumed to be the ceiling height of a typical commercial building, approximately 3 meters. The air exchange rate for a typical commercial building is estimated as 1 5 per hour. A factor representing the limitation of chemical movement through cracks in a cement slab floor ("crack factor") was estimated to be 1 percent

The estimates of air concentrations indoors are shown in Table D-5 for separate-phase material and in Table D-2 for dissolved phase material.

Estimation of Outdoor Air Concentrations

The methodology for estimating ambient air concentrations was similar for the two areas of the site. The vapor flux rates were used in a box model to estimate ambient air concentrations (U.S. EPA, 1991, DTSC, 1994). The box model places a hypothetical box over the site and estimates the rate of flux into the box, accounting for chemical dilution from air mixing within the box. The formula is as follows:

$$Conc_{air} = (E_i * A) / (LS * WS * MH)$$

Where:

$Conc_{air}$ = Ambient air concentration ($\mu g/m^3$)
Ei = Vaporization rate through the soil surface (mg/cm^2-sec)
A = Emitting area (cm^2)
LS = Length of side of box (m)
WS = Wind speed (m/sec)
MH = Mixing height (m)

For this screening evaluation, the emitting area for a maintenance worker on the Powell Street property was estimated to be the main area of the parking lot, approximately 90,000 ft^2 ($8.5*10^7$ cm^2). The emitting area for a construction worker on the Shellmound III property was estimated to be the entire site, approximately 200,000 ft^2 ($1.85*10^8$ cm^2). The length of the side of a box was estimated to be the average of the two sides of the property (130 m). Windspeed was assumed to be minimal to represent a minimal amount of dispersion (2.25 m/sec). The mixing height is assumed to be approximately 2 meters (6.5 ft.)

The estimates of ambient air concentrations for the construction and maintenance worker scenarios are shown in Tables D-6 and D-7 for residual petroleum and dissolved-phase material, respectively.

TABLE D-1

PHYSICAL CONSTANTS FOR CHEMICALS OF POTENTIAL CONCERN[1]

Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	**Molecular Weight**[2] (g/mole)	**Vapor Pressure**[3] (atm.)	**Organic Carbon Partition Coefficient (Koc)** (l/kg)	**Henry's Law Constant (H)** (atm-m^3/mole)	**Solubility (S)** (mg/l)	**Diffusivity in Air (Di)** (cm^2/sec)
Benzene	78.1	0.125	5.89E+01	5.6E-03	1.75E+03	0.088
Ethylbenzene	106.17	0.0126	3.63E+02	7.9E-03	1.69E+02	0.075
Toluene	92.14	0.0374	1.82E+02	6.6E-03	5.26E+02	0.087
Xylenes[4]	106.2	NA	3.86E+02	6.7E-03	1.74E+02	0.078
Acenaphthylene[5]	152.2	NA	7.08E-03	1.6E-04	4.42E+00	0.0421
Anthracene	178	2.57×10^{-7}	2.95E-04	6.5E-05	4.34E-02	0.0324
Fluorene	166.2	NA	1.38E+04	6.4E-05	1.98E+00	0.0363
Fluoranthene[6]	202.26	NA	NA	1.6E-05	NA	NA
Phenanthrene	178.24	NA	1.67E+04 [2]	2.6E-05 [2]	0.93 [2]	0.058
Pyrene	202.26	9.01×10^{-10}	1.05E+05	1.1E-05	1.4E-01	0.0272

Notes

NA not applicable

1 Referenced from EPA, 1996b unless otherwise noted.
2 Montgomery & Welkom, 1989, average of all provided values when applicable.
3 CRC, 1996, vapor pressure at 25°C.
4 Average of the values for the three forms of xylene present.
5 Physical constants were not available for this chemical Acenaphthene was used as a surrogate based on the similarity between chemical structures.
6 Not considered volatile

Table D-2
Estimation of Vaporization of Dissolved-phase Material to Indoor Air

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Step 1 Estimate Flux from Groundwater

Emission Rate = $(Di*C_i*Pa^{3.33})/(L*Pt^2)$

Where $C_i = 1E\text{-}03*Cw*(H/R*T)$

Chemical	Groundwater Conc. (Cw) (mg/l)	Diffusivity in Air (Di) (cm²/sec)	Soil Vapor Conc. (C_i) (mg/cm³)	Henry's Law Constant (H) (atm-m³/mole)	Air-filled Soil Porosity (Pa)	Universal Gas Constant (R) (atm-m³/mole-K)	Absolute Temp. (T) (K)	Total Porosity (Pt)	Depth (L) (cm)	RME Emission Rate (E_i) (mg/sec-cm²)	RME Emission Rate (E_i) (mg/sec-m²)
Benzene	0 098	0 088	2 23E-05	5 56E-03	0 284	8.20E-05	298	0 434	180	8 75E-10	8 8E-06
Ethylbenzene	0 001	0 075	3 22E-07	7.87E-03	0.284	8 20E-05	298	0 434	180	1.08E-11	1 1E-07
Toluene	0 003	0.087	8 14E-07	6 63E-03	0 284	8 20E-05	298	0.434	180	3 16E-11	3.2E-07
Xylene (total)	0 003	0.078	8 26E-07	6.73E-03	0 284	8.20E-05	298	0 434	180	2 87E-11	2 9E-07
Acenaphthylene	0 0032	0 042	2.03E-08	1 55E-04	0.284	8 20E-05	298	0.434	180	3 81E-13	3.8E-09
Fleurene	0 0018	0 0363	4.69E-09	6.37E-05	0.284	8 20E-05	298	0.434	180	7.59E-14	7 6E-10
Phenanthrene	0 00027	0.058	2 83E-10	2 56E-05	0 284	8 20E-05	298	0 434	180	7.32E-15	7 3E-11

Step 2 Calculate Indoor Air Concentration

$C_{in} = (E_i*A*F)/((ACH/CF)*V)$

Chemical	Emission Rate (E_i) (mg/sec-m²)	Emission Area (A) (m²)	Frctn of Flr that is Crkd (F)	Air Exchange Rate (ACH) (hr)⁻¹	Volume of Air in Bldg. (V) (m³)	Conversion Factor (sec/hr)	RME Indoor Air Conc. (C_{in}) (mg/m³)
Benzene	8 75E-06	2200	0 01	1 5	6600	3600	7 00E-05
Ethylbenzene	1 08E-07	2200	0.01	1.5	6600	3600	8.62E-07
Toluene	3 16E-07	2200	0.01	1.5	6600	3600	2.53E-06
Xylene (total)	2 87E-07	2200	0 01	1.5	6600	3600	2.30E-06
Acenaphthylene	3 81E-09	2200	0 01	1 5	6600	3600	3 05E-08
Fleurene	7 59E-10	2200	0 01	1 5	6600	3600	6.07E-09
Phenanthrene	7 32E-11	2200	0 01	1 5	6600	3600	5.85E-10

Table D-3
Estimation of Molecular Weight for the Residual Petroleum Hydrocarbon Mixture

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Hydrocarbon Type	Carbon Group (CG)[1]	%CG (g of CG/g of mix)	MW$_{CG}$ (g/mol)	M$_{CG}$ (mol of CG/g of mix)	Representative Compound
Aliphatic	C5-C6	0.001	86.12	1.16E-05	Hexane
Aliphatic	>C6-C8	0.0053	114.23	4.64E-05	Octane
Aliphatic	C9	0.0025	128.26	1.95E-05	Nonane
Aliphatic	C10	0.0023	142.29	1.62E-05	Decane
Aliphatic	>C10-C12	0.083	170.34	4.87E-04	Dodecane
Aliphatic	>C12-C16	0.38	212.42	1.79E-03	Pentadecane
Aliphatic	>C16-C21	0.25	268.53	9.31E-04	Nonadecane
Aliphatic	>C21-C35	0.014	394.78	3.55E-05	Octadecane
Aromatic	Benzene	0.000077	78.12	9.86E-07	Not applicable
Aromatic	Toluene	0.000018	92.15	1.95E-07	Not applicable
Aromatic	Ethylbenzene	0.000023	106.17	2.17E-07	Not applicable
Aromatic	C9	0.00083	116.16	7.15E-06	Indene
Aromatic	C10	0.0011	128.19	8.58E-06	Azulene
Aromatic	>C10-C12	0.092	154.21	5.97E-04	Acenaphthene
Aromatic	>C12-C16	0.18	178.24	1.01E-03	Anthracene
Aromatic	>C16-C21	BDL			Not applicable
Aromatic	>C21-C35	BDL			Not applicable
Aromatic	C17-C22[2]	0.0005	252.32	1.98E-06	Benzo(a)pyrene
TOTAL		**101%**		**4.96E-03**	
			Mol. Wt.	**201.54**	

Representative compounds were selected based on an average carbon chain length for the group.

M$_{CG}$	Moles of carbon group contributing to mixture
%CG	Fraction of carbon group in mixture
MW$_{CG}$	Molecular weight of carbon group

[1] Notation for carbon groups represents the number of carbon atoms in compounds in the range. For example, ">C10-C21" represents compounds with more than 10 and less than or equal to 21 carbon atoms.

[2] This carbon group represents compounds detected in the PAH analysis, but at levels below the detection limit for the fingerprint analysis.

Table D-4
Estimation of Soil Gas Concentration from Residual Petroleum

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Mole Fraction of VOCi

$X_i = (C_i/MW_i)/(C_{mix}/MW_{mix})$

Chemical	Ci (g/kg)	MWi (g/mol)	Cmix (g/kg)	MWmix (g/mol)	Xi
Benzene	0.077	78.12	1000	201.54	1.99E-04
Toluene	0.018	92.15	1000	201.54	3.94E-05
Ethylbenzene	0.023	106.17	1000	201.54	4.37E-05
Anthracene	0.99	178.24	1000	201.54	1.12E-03
Pyrene	0.09	202.26	1000	201.54	8.97E-05

Ci - Concentration of VOCi in soil
MWi - Molecular weight of VOCi
Cmix - Concentration of total mixture in soil
MWmix - Estimated molecular weight of total mixture

Partial Pressure of VOCi

$P_i = Po_i * X_i$

Chemical	Poi (atm)	Xi	Pi (atm)
Benzene	1.25E-01	1.99E-04	2.49E-05
Toluene	3.74E-02	3.94E-05	1.47E-06
Ethylbenzene	1.26E-02	4.37E-05	5.52E-07
Anthracene	2.57E-07	1.12E-03	2.87E-10
Pyrene	9.01E-10	8.97E-05	8.08E-14

Poi - pure-phase vapor pressure of VOCi at 25°C (CRC, 1996)
Xi - Mole fraction of VOCi in mixture
Pi - Partial pressure of VOCi

Soil Gas Concentration of VOCi

$Csg\text{-}i=(Pi*MWi)/(R*T*CF)$

Chemical	Pi (atm)	MWi (g/mol)	R (atm-m3/mol-°K)	T (°K)	CF (cm3/m3)	Csg-i (g/cm3)
Benzene	2.49E-05	78.12	8.20E-05	298	1.00E+06	7.96E-08
Toluene	1.47E-06	92.15	8.20E-05	298	1.00E+06	5.55E-09
Ethylbenzene	5.52E-07	106.17	8.20E-05	298	1.00E+06	2.40E-09
Anthracene	2.87E-10	178.24	8.20E-05	298	1.00E+06	2.10E-12
Pyrene	8.08E-14	202.26	8.20E-05	298	1.00E+06	6.69E-16

Csg-i - Soil gas concentration of VOCi
Pi - Partial pressure of VOCi
R - Universal gas constant
T - Temperature of soil
CF - Conversion Factor

Table D-5
Estimation of Vaporization of Residual Petroleum to Indoor Air

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Step 1 Estimate Flux from Residual Petroleum

Emission Rate = $(Di*C_{sg}*Pa^{3.33})/(L*Pt^2)$

Where C_{sg} is based on partial pressure of component in mixture.

Chemical	Diffusivity in Air (Di) (cm^2/sec)	Soil Vapor Conc. (C_{sg}) (mg/cm^3)	Henry's Law Constant (H) ($atm\text{-}m^3/mole$)	Air-filled Soil Porosity (Pa)	Universal Gas Constant (R) ($atm\text{-}m^3/mole\text{-}K$)	Absolute Temp. (T) (K)	Total Porosity (Pt)	Depth (L) (cm)	RME Emission Rate (E_i) ($mg/sec\text{-}cm^2$)	RME Emission Rate (E_i) ($mg/sec\text{-}m^2$)
Benzene	0.088	7.96E-08	5.56E-03	0.284	8.20E-05	298	0.434	180	3.12E-12	3.12E-08
Ethylbenzene	0.075	5.55E-09	7.87E-03	0.284	8.20E-05	298	0.434	180	1.86E-13	1.86E-09
Toluene	0.087	2.40E-09	6.63E-03	0.284	8.20E-05	298	0.434	180	9.30E-14	9.30E-10
Anthracene	0.0324	2.10E-12	6.50E-05	0.284	8.20E-05	298	0.434	180	3.03E-17	3.03E-13
Pyrene	0.0272	6.69E-16	1.10E-05	0.284	8.20E-05	298	0.434	180	8.12E-21	8.12E-17

Step 2 Calculate Indoor Air Concentration

$C_{in} = (E_i*A*F)/((ACH/CF)*V)$

Chemical	Emission Rate (E_i) ($mg/sec\text{-}m^2$)	Emission Area (A) (m^2)	Frctn of Flr that is Crkd (F)	Air Exchange Rate (ACH) ($hr)^{-1}$	Volume of Air in Bldg (V) (m^3)	Conversion Factor (sec/hr)	RME Indoor Air Conc. (C_{in}) (mg/m^3)
Benzene	3.12E-08	2200	0.01	1.5	6600	3600	2.50E-07
Ethylbenzene	1.86E-09	2200	0.01	1.5	6600	3600	1.49E-08
Toluene	9.30E-10	2200	0.01	1.5	6600	3600	7.44E-09
Anthracene	3.03E-13	2200	0.01	1.5	6600	3600	2.42E-12
Pyrene	8.12E-17	2200	0.01	1.5	6600	3600	6.49E-16

Table D-6
Estimation of Vaporization of Dissolved-phase Material to Outdoor Air

Human Health Risk Assessment
Powell Street Plaza and Shellmound III
Emeryville, California

Step 1 Estimate Flux from Groundwater

Emission Rate = $(Di*C_{sg}*Pa^{3.33})/(L*Pt^2)$ Where C_{sg} = 1E-03*Cw*(H/R*T)

Chemical	Groundwater Conc. (Cw) (mg/l)	Diffusivity in Air (Di) (cm^2/sec)	Soil Vapor Conc. (C_{sg}) (mg/cm^3)	Henry's Law Constant (H) ($atm\text{-}m^3$/mole)	Air-filled Soil Porosity (Pa)	Universal Gas Constant (R) ($atm\text{-}m^3$/mole-K)	Absolute Temp (T) (K)	Total Porosity (Pt)	Depth (L) (cm)	RME Emission Rate (E_i) (mg/sec-cm^2)
Benzene	0.098	0.088	2.23E-05	5.56E-03	0.284	8.20E-05	298	0.434	180	8.75E-10
Ethylbenzene	0.001	0.075	3.22E-07	7.87E-03	0.284	8.20E-05	298	0.434	180	1.08E-11
Toluene	0.003	0.087	8.14E-07	6.63E-03	0.284	8.20E-05	298	0.434	180	3.16E-11
Xylene (total)	0.003	0.078	8.26E-07	6.73E-03	0.284	8.20E-05	298	0.434	180	2.87E-11
Acenaphthylene	0.0032	0.0042	2.03E-08	1.55E-04	0.284	8.20E-05	298	0.434	180	3.81E-14
Fluorene	0.0018	0.036	4.69E-09	6.37E-05	0.284	8.20E-05	298	0.434	180	7.59E-14
Phenanthrene	0.00027	0.058	2.83E-10	2.56E-05	0.284	8.20E-05	298	0.434	180	7.33E-15

Step 2a Calculate Ambient Air Concentration for Construction Worker

Ca = Ei * A / (LS*WS*MH)

Chemical	Emission Rate (Ei) (mg/sec-cm²)	Construction Area (A) (cm^2)	Length of Side (LS) (m)	Wind Speed (WS) (m/sec)	Mixing Height (MH) (m)	Ambient Air Conc. (Ca) (mg/m^3)
Benzene	8.75E-10	1.85E+08	130	2.25	2	2.77E-04
Ethylbenzene	1.08E-11	1.85E+08	130	2.25	2	3.41E-06
Toluene	3.16E-11	1.85E+08	130	2.25	2	9.99E-06
Xylene (total)	2.87E-11	1.85E+08	130	2.25	2	9.09E-06
Acenaphthylene	3.81E-14	1.85E+08	130	2.25	2	1.21E-08
Fluorene	7.59E-14	1.85E+08	130	2.25	2	2.40E-08
Phenanthrene	7.33E-15	1.85E+08	130	2.25	2	2.32E-09

Step 2b Calculate Ambient Air Concentration for Maintenance Worker

Ca = Ei * A / (LS*WS*MH)

Chemical	Emission Rate (Ei) (mg/sec-cm²)	Construction Area (A) (cm^2)	Length of Side (LS) (m)	Wind Speed (WS) (m/sec)	Mixing Height (MH) (m)	Ambient Air Conc. (Ca) (mg/m^3)
Benzene	8.75E-10	8.50E+07	90	2.25	2	1.84E-04
Ethylbenzene	1.08E-11	8.50E+07	90	2.25	2	2.26E-06
Toluene	3.16E-11	8.50E+07	90	2.25	2	6.63E-06
Xylene (total)	2.87E-11	8.50E+07	90	2.25	2	6.03E-06
Acenaphthylene	3.81E-14	8.50E+07	90	2.25	2	8.00E-09
Fluorene	7.59E-14	8.50E+07	90	2.25	2	1.59E-08
Phenanthrene	7.33E-15	8.50E+07	90	2.25	2	1.54E-09

Table D-7
Estimation of Vaporization of Separate-phase Material to Outdoor Air

Human Health Risk Assessment
Powell Street Plaza and Shellmound III
Emeryville, California

Step 1 Estimate Flux from Groundwater

Emission Rate = (Di*C_{sg}*$Pa^{3.33}$)/(L*Pt^2)

Where C_{sg} is based on partial pressure of component in mixture

Chemical	Diffusivity in Air (Di) (cm^2/sec)	Soil Vapor Conc. (C_{sg}) (mg/cm^3)	Henry's Law Constant (H) (atm-m^3/mole)	Air-filled Soil Porosity (Pa)	Universal Gas Constant (R) (atm-m^3/mole-K	Absolute Temp. (T) (K)	Total orosity (Pt	Depth (L) (cm)	RME Emission Rate (E_i) (mg/sec-cm^2)
Benzene	0.088	7.96E-08	5.56E-03	0.284	8.20E-05	298	0.434	180	3.12E-12
Ethylbenzene	0.075	5.55E-09	7.87E-03	0.284	8.20E-05	298	0.434	180	1.86E-13
Toluene	0.087	2.40E-09	6.63E-03	0.284	8.20E-05	298	0.434	180	9.31E-14
Anthracene	0.0324	2.10E-12	6.50E-05	0.284	8.20E-05	298	0.434	180	3.03E-17
Pyrene	0.0272	6.69E-16	1.10E-05	0.284	8.20E-05	298	0.434	180	8.12E-21

Step 2a Calculate Ambient Air Concentration for Construction Worker

Ca = Ei * A (LS*WS*MH)

Chemical	Emission Rate (Ei) (mg/sec-cm^2)	Construction Area (A) (cm^2)	Length of Side (LS) (m)	Wind Speed (WS) (m/sec)	Mixing Height (MH) (m)	Ambient Air Conc. (Ca) (mg/m^3)
Benzene	3.12E-12	1.85E+08	130	2.25	2	9.88E-07
Ethylbenzene	1.86E-13	1.85E+08	130	2.25	2	5.87E-08
Toluene	9.31E-14	1.85E+08	130	2.25	2	2.94E-08
Anthracene	3.03E-17	1.85E+08	130	2.25	2	9.60E-12
Pyrene	8.12E-21	1.85E+08	130	2.25	2	2.57E-15

Step 2b Calculate Ambient Air Concentration for Maintenance Worker

Ca = Ei * A (LS*WS*MH)

Chemical	Emission Rate (Ei) (mg/sec-cm^2)	Construction Area (A) (cm^2)	Length of Side (LS) (m)	Wind Speed (WS) (m/sec)	Mixing Height (MH) (m)	Ambient Air Conc. (Ca) (mg/m^3)
Benzene	3.12E-12	8.50E+07	90	2.25	2	6.56E-07
Ethylbenzene	1.86E-13	8.50E+07	90	2.25	2	3.90E-08
Toluene	9.31E-14	8.50E+07	90	2.25	2	1.95E-08
Anthracene	3.03E-17	8.50E+07	90	2.25	2	6.37E-12
Pyrene	8.12E-21	8.50E+07	90	2.25	2	1.70E-15

APPENDIX E

ESTIMATION OF EXPOSURE

APPENDIX E

ESTIMATION OF EXPOSURE

Potential exposure to COPCs was quantitatively assessed for the following exposure pathways:

- Inhalation of volatile COPCs (both indoor and ambient air)
- Dermal contact with COPCs dissolved in groundwater

The equations used to quantitatively estimate exposure are presented in this section. The parameters relevant to each exposure scenario are presented in Tables 4 through 6 of the main text for construction workers, maintenance workers, and building occupants, respectively. Table E-1 presents the chemical-specific dermal permeability coefficients used to assess dermal contact with groundwater (DTSC, 1994). The results of the exposure assessment are included in Tables E-2 through E-9.

Inhalation of Volatile COPCs

Exposure to the concentrations of chemicals in indoor or ambient air was estimated using the following exposure equations:

$$\mathrm{Dose}_{IV} = (\mathrm{Conc}_{air} * IR * EF * ED)/(AT * BW)$$

Where:

Dose_{IV} = Dose received through inhalation of vapors from groundwater or residual petroleum hydrocarbon product (mg/kg-day)

Conc_{air} = Concentration in air (mg/m^3)

IR = Inhalation rate (m^3/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

AT = Averaging time (days)

BW = Body weight (kg)

Dermal Contact with COPCs Dissolved in Groundwater

Dermal exposure to chemicals in groundwater was estimated using the following exposure equations:

$$\text{Dose}_{\text{wtr}} = (\text{Conc}_{\text{wtr}} * \text{SA} * \text{Kp} * \text{CF} * \text{ET} * \text{EF} * \text{ED})/(\text{BW} * \text{AT})$$

Where:

Dose_{wtr} = Dose received through dermal contact with groundwater (mg/kg-day)
Conc_{wtr} = Concentration in water (mg/l)
SA = Exposed skin surface area (cm^2)
Kp = Dermal permeability coefficient (cm/hour)
CF = Conversion factor (l/cm^3)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
AT = Averaging time (days)
BW = Body weight (kg)

TABLE E-1
DERMAL PERMEABILITY FOR CHEMICALS OF POTENTIAL CONCERN
Powell Street Plaza and Shellmound III
Emeryville, California

Chemical	Dermal Permeability Coefficient (Kp) [1] (cm/hour)
Benzene	0.021
Ethylbenzene	0.074
Toluene	0.045
Xylenes 3	0.08
Acenaphthylene4	0.36 [2]
Anthracene	NA
Fluorene	0.36 [2]
Fluoranthene	0.36
Phenanthrene	0.27
Pyrene	NA

Notes:

NA = not applicable.

1. Referenced from Cal-EPA, 1994a.
2. Physical constants were not available for this chemical. Fluoranthene was used as a surrogate based on the similarity between chemical structures.

Table E-2
Estimation of Carcinogenic Risk
Construction Worker

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
San Francisco, California

Inhalation of Groundwater Vapors (Residual **Petroleum**)

LADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Excess Cancer Risk = LADD*SFi

Chemical	Ambient Air Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)$^{-1}$	Excess Cancer Risk
Benzene	9.88E-07	20	250	2	70	25550	5.52E-09	1.0E-01	6E-10
Ethylbenzene	5.87E-08	20	250	2	70	25550	NA	NA	NA
Toluene	2.94E-08	20	250	2	70	25550	NA	NA	NA
Anthracene	9.60E-12	20	250	2	70	25550	NA	NA	NA
Pyrene	2.57E-15	20	250	2	70	25550	NA	NA	NA

Inhalation of Groundwater Vapors - Dissolved-**phase**

LADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Excess Cancer Risk = LADD*SFi

Chemical	Ambient Air Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)$^{-1}$	Excess Cancer Risk
Benzene	2.77E-04	20	250	2	70	25550	1.55E-06	1.0E-01	2E-07
Ethylbenzene	3.41E-06	20	250	2	70	25550	1.90E-08	NA	NA
Toluene	9.99E-06	20	250	2	70	25550	5.59E-08	NA	NA
Xylene (total)	9.09E-06	20	250	2	70	25550	5.08E-08	NA	NA
Acenaphthylene	1.21E-08	20	250	2	70	25550	6.74E-11	NA	NA
Fluorene	2.40E-08	20	250	2	70	25550	1.34E-10	NA	NA
Phenanthrene	2.32E-09	20	250	2	70	25550	1.30E-11	NA	NA

Dermal Contact with Exposed Groundwater

LADD = (Cw*SA*Kp*CF*ET*EF*ED)/(BW*AT)

Excess Cancer Risk = LADD*SFo

Chemical	Maximum Detected Groundwater Conc. (Cw) (mg/l)	Exposed Skin Surface Area (SA) (cm^2)	Dermal Permeability Coefficient (Kp) (cm/hour)	Conversion Factor (CF) (l/cm^3)	Exposure Time (ET) (hours/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Oral Cancer Slope Factor (SFo) (mg/kg-day)$^{-1}$	Excess Cancer Risk
Benzene	0.098	2000	0.021	1.00E-03	2	150	1	70	25550	6.90E-07	1.0E-01	7E-08
Ethylbenzene	0.001	2000	0.074	1.00E-03	2	150	1	70	25550	2.48E-08	NA	NA
Toluene	0.003	2000	0.045	1.00E-03	2	150	1	70	25550	4.53E-08	NA	NA
Xylene (total)	0.003	2000	0.08	1.00E-03	2	150	1	70	25550	8.05E-08	NA	NA
Acenaphthylene	0.0032	2000	0.36	1.00E-03	2	150	1	70	25550	3.86E-07	NA	NA
Fluorene	0.0018	2000	0.36	1.00E-03	2	150	1	70	25550	2.17E-07	NA	NA
Phenanthrene	0.00027	2000	0.27	1.00E-03	2	150	1	70	25550	2.45E-08	NA	NA
Fluoranthene	0.0002	2000	0.36	1.00E-03	2	150	1	70	25550	2.42E-08	NA	NA

Table E-3
Estimation of Noncarcinogenic Risk
Construction Worker

Human Health Risk Assessment
Powell Street Plaza and Shellmound III
Emeryville, California

Inhalation of Groundwater Vapors (Residual **Petroleum**)

ADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDi

Chemical	Ambient Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	9.88E-07	20	250	2	70	730	1.93E-07	1.7E-03	1E-04
Ethylbenzene	5.87E-08	20	250	2	70	730	1.15E-08	2.9E-01	4E-08
Toluene	2.94E-08	20	250	2	70	730	5.76E-09	1.1E-01	5E-08
Anthracene	9.60E-12	20	250	2	70	730	1.88E-12	3.0E-01	6E-12
Pyrene	2.57E-15	20	250	2	70	730	5.02E-16	3.0E-02	2E-14
								Hazard Index	**1E-04**

Inhalation of Groundwater Vapors (Dissolved-**phase**)

ADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDi

Chemical	Ambient Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	2.77E-04	20	250	2	70	730	5.42E-05	1.7E-03	3E-02
Ethylbenzene	3.41E-06	20	250	2	70	730	6.67E-07	2.90E-01	2E-06
Toluene	9.99E-06	20	250	2	70	730	1.96E-06	1.10E-01	2E-05
Xylene (total)	9.09E-06	20	250	2	70	730	1.78E-06	2.00E-01	9E-06
Acenaphthylene	1.21E-08	20	250	2	70	730	2.36E-09	6.00E-02	4E-08
Fluorene	2.40E-08	20	250	2	70	730	4.70E-09	4.00E-02	1E-07
Phenanthrene	2.32E-09	20	250	2	70	730	4.54E-10	3.00E-01	2E-09
								Hazard Index	**3E-02**

Dermal Contact with Groundwater

ADD = (Cw*SA*Kp*CF*ET*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDo

Chemical	Maximum Detected Groundwater Conc. Cw (mg/l)	Exposed Skin Surface Area (SA) (cm^2)	Dermal Permeability Coefficient (Kp) (cm/hour)	Conversion Factor (CF) (l/cm^3)	Exposure Time (ET) (hours/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Oral Reference Dose (RfDo) (mg/kg-day)	Hazard Quotient
Benzene	0.098	2000	0.021	1.00E-03	2	150	1	70	365	4.83E-05	1.7E-03	3E-02
Ethylbenzene	0.001	2000	0.074	1.00E-03	2	150	1	70	365	1.74E-06	1.0E-01	2E-05
Toluene	0.003	2000	0.045	1.00E-03	2	150	1	70	365	3.17E-06	2.0E-01	2E-05
Xylene (total)	0.003	2000	0.08	1.00E-03	2	150	1	70	365	5.64E-06	2.0E+00	3E-06
Acenaphthylene	0.0032	2000	0.36	1.00E-03	2	150	1	70	365	2.71E-05	6.0E-02	5E-04
Fluorene	0.0018	2000	0.36	1.00E-03	2	150	1	70	365	1.52E-05	4.0E-02	4E-04
Phenanthrene	0.00027	2000	0.27	1.00E-03	2	150	1	70	365	1.71E-06	3.0E-01	6E-06
Fluoranthene	0.0002	2000	0.36	1.00E-03	2	150	1	70	365	1.69E-06	4.0E-02	4E-05
											Hazard Index	**3E-02**

Kp for fluorene based on fluoranthene
Kp for acenaphthylene based on fluoranthene

Table E-4
Estimation of Carcinogenic Risk
Maintenance Worker

Human Health Risk Assessment
Powell Street Plaza and Shellmound III
Emeryville, California

Inhalation of Groundwater Vapors (Separate **phase**)

LADD = $(Ca*IR_a*EF*ED)/(BW*AT)$

Excess Cancer Risk = LADD*SFi

Chemical	Ambient Air (GW) Concentration (Ca) (mg/m³)	Inhalation Rate (IR_a) (m³/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)⁻¹	Excess Cancer Risk
Benzene	6.55E-07	20	250	25	70	25550	4.58E-08	1.0E-01	5E-09
Ethylbenzene	3.96E-08	20	250	25	70	25550	NA	NA	NA
Toluene	1.9[illegible]E-08	20	250	25	70	25550	NA	NA	NA
Anthracene	6.3[illegible]E-12	20	250	25	70	25550	NA	NA	NA
Pyrene	1.7[illegible]E-15	20	250	25	70	25550	NA	NA	NA

Inhalation of Groundwater Vapors (Dissolved **phase**)

Chemical	Ambient Air (GW) Concentration (Ca) (mg/m³)	Inhalation Rate (IR_a) (m³/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)⁻¹	Excess Cancer Risk
Benzene	1.8[illegible]E-04	20	250	25	70	25550	1.28E-05	1.0E-01	1E-06
Ethylbenzene	2.25E-06	20	250	25	70	25550	NA	NA	NA
Toluene	6.63E-06	20	250	25	70	25550	NA	NA	NA
Xylene (total)	6.0[illegible]E-06	20	250	25	70	25550	NA	NA	NA
Acenaphthylene	8.00E-09	20	250	25	70	25550	NA	NA	NA
Fluorene	1.59E-08	20	250	25	70	25550	NA	NA	NA
Phenanthrene	1.5[illegible]E-09	20	250	25	70	25550	NA	NA	NA

Dermal Contact with Exposed Groundwater

LADD = (Cw*SA*Kp*CF*ET*EF*ED)/(BW*AT)

Excess Cancer Risk = LADD*SFo

Chemical	Maximum Detected Groundwater Conc (Cw) (mg/L)	Exposed Skin Surface Area (SA) (cm²)	Dermal Permeability Coefficient (Kp) (cm/hour)	Conversion Factor (CF) (l/cm³)	Exposure Time (ET) (hours/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Oral Cancer Slope Factor (SFo) (mg/kg-day)⁻¹	Excess Cancer Risk
Benzene	0.[illegible]	2000	0.021	1.00E-03	2	5	25	70	25550	5.75E-07	1.0E-01	6E-08
Ethylbenzene	0.[illegible]	2000	0.074	1.00E-03	2	5	25	70	25550	NA	NA	NA
Toluene	0.[illegible]	2000	0.045	1.00E-03	2	5	25	70	25550	NA	NA	NA
Xylene (total)	0.0[illegible]	2000	0.08	1.00E-03	2	5	25	70	25550	NA	NA	NA
Acenaphthylene	0.0[illegible]	2000	0.36	1.00E-03	2	5	25	70	25550	NA	NA	NA
Fluorene	0.[illegible]	2000	0.36	1.00E-03	2	5	25	70	25550	NA	NA	NA
Phenanthrene	0.0[illegible]	2000	0.27	1.00E-03	2	5	25	70	25550	NA	NA	NA
Fluoranthene	0.0[illegible]	2000	0.36	1.00E-03	2	5	25	70	25550	NA	NA	NA

Table E-5
Estimation of Noncarcinogenic Risk
Maintenance Worker

Human Health Risk Assessment
Powell Street Plaza and Shellmound III
Emeryville, California

Maintenance Worker: Reasonable Maximum Exposure (RME) Scenario
Noncarcinogenic Health Risks

Inhalation of Groundwater Vapors (Separate phase)

ADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDi

Chemical	Ambient A[illegible] Soil) Concentratio[illegible] (Ca) (mg/[illegible]	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	6 5[illegible]E[illegible]	20	250	25	70	9125	1 28E-07	1 7E-03	8E-05
Ethylbenzene	3 90E[illegible]	20	250	25	70	9125	7 62E-09	2 9E-01	3E-08
Toluene	1 95E[illegible]	20	250	25	70	9125	3 82E-09	1 1E-01	3E-08
Anthracene	6 37E[illegible]	20	250	25	70	9125	1 25E-12	3 0E-01	4E-12
Pyrene	1 70E[illegible]	20	250	25	70	9125	3 33E-16	3 0E-02	1E-14
								Hazard Index	**8E-05**

Inhalation of Groundwater Vapors (Dissolved phase)

ADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDi

Chemical	Ambient A[illegible] W) Concentratio[illegible] (Ca) (mg/[illegible]	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	1 8[illegible]	20	250	25	70	9125	3 59E-05	1 7E-03	2E-02
Ethylbenzene	2 26E[illegible]	20	250	25	70	9125	4 42E-07	2 9E-01	2E-06
Toluene	6 63E[illegible]	20	250	25	70	9125	1 30E-06	1 1E-01	1E-05
Xylene (total)	6 03E[illegible]	20	250	25	70	9125	1 18E-06	2 0E-01	6E-06
Acenaphthylene	8 00E[illegible]	20	250	25	70	9125	1 57E-09	6 0E-02	3E-08
Fluorene	1 59E[illegible]	20	250	25	70	9125	3 12E-09	4 0E-02	8E-08
Phenanthrene	1 54E[illegible]	20	250	25	70	9125	3 01E-10	3 0E-01	1E-09
								Hazard Index	**2E-02**

Dermal Contact with Groundwater

ADD = (Cw*SA*Kp*CF*ET*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDo

Chemical	Maximum D[illegible]ted Groundwater [illegible]onc Cw (mg/l)	Exposed Skin Surface Area (SA) (cm^2)	Dermal Permeability Coefficient (Kp) (cm/hour)	Conversion Factor (CF) (l/cm^3)	Exposure Time (ET) (hours/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Oral Reference Dose (RfDo) (mg/kg-day)	Hazard Quotient
Benzene	0 [illegible]98	2000	0 021	1 00E-03	2	5	25	70	9125	1 61E-06	1 7E-03	9E-04
Ethylbenzene	0 001	2000	0 074	1 00E-03	2	5	25	70	9125	5 79E-08	1 0E-01	6E-07
Toluene	0 00[illegible]	2000	0 045	1 00E-03	2	5	25	70	9125	1 06E-07	2 0E-01	5E-07
Xylene (total)	0 003	2000	0 08	1 00E-03	2	5	25	70	9125	1 88E-07	2 0E+00	9E-08
Acenaphthylene	0 003	2000	0 36	1 00E-03	2	5	25	70	9125	9 02E-07	6 0E-02	2E-05
Fluorene	0 0018	2000	0 36	1 00E-03	2	5	25	70	9125	5 07E-07	4 0E-02	1E-05
Phenanthrene	0 000[illegible]	2000	0 27	1 00E-03	2	5	25	70	9125	5 71E-08	3 0E 01	2E-07
Fluoranthene	0 000[illegible]	2000	0 36	1 00E-03	2	5	25	70	9125	5 64E-08	4 0E-02	1E-06
											Hazard Index	**1E-03**

Table E-6
Estimation of Carcinogenic Risk
Building Occupant

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Inhalation of Vapors from Groundwater - **Dissolved Phase**

LADD = $(Ca*IR_a*ET*EF*ED)/(BW*AT)$

Excess Cancer Risk = LADD*SFi

Chemical	Indoor Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR_a) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)$^{-1}$	Excess Cancer Risk
Benzene	7.0E-05	20	250	25	70	25550	4.89E-06	1.0E-01	4.9E-07
Ethylbenzene	8.6E-07	20	250	25	70	25550	6.02E-08	NA	NA
Toluene	2.5E-06	20	250	25	70	25550	1.77E-07	NA	NA
Xylene (total)	2.3E-06	20	250	25	70	25550	1.61E-07	NA	NA
Acenaphthylene	3.1E-08	20	250	25	70	25550	2.13E-09	NA	NA
Flourene	6.1E-09	20	250	25	70	25550	4.24E-10	NA	NA
Phenanthrene	5.9E-10	20	250	25	70	25550	4.09E-11	NA	NA

Table E-7
Estimation of Noncarcinogenic Risk
Building Occupant

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Inhalation of Vapors from Groundwater - **Dissolved Phase**

ADD = (Ca*IR$_a$*EF*ED)/(BW*AT)

Hazard Quotient = ADD/RfDi

Chemical	Indoor Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	7.00E-05	20	250	25	70	9125	1.37E-05	1.7E-03	8E-03
Ethylbenzene	8.62E-07	20	250	25	70	9125	1.69E-07	2.9E-01	6E-07
Toluene	2.53E-06	20	250	25	70	9125	4.95E-07	1.1E-01	4E-06
Xylene (total)	2.30E-06	20	250	25	70	9125	4.50E-07	2.0E-01	2E-06
Acenaphthylene	3.05E-08	20	250	25	70	9125	5.97E-09	6.0E-02	1E-07
Flourene	6.07E-09	20	250	25	70	9125	1.19E-09	4.0E-02	3E-08
Phenanthrene	5.85E-10	20	250	25	70	9125	1.15E-10	3.0E-01	4E-10
								Hazard Index	**8E-03**

Table E-8
Estimation of Carcinogenic Risk
Building Occupant

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Inhalation of Vapors from Groundwater - Residual Petroleum LADD = (Ca*IR$_a$*ET*EF*ED)/(BW*AT) Excess Cancer Risk = LADD*SFi

Chemical	Indoor Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR$_a$) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Lifetime Average Daily Dose (LADD) (mg/kg-day)	Inhalation Cancer Slope Factor (SFi) (mg/kg-day)$^{-1}$	Excess Cancer Risk
Benzene	2.50E-07	20	250	25	70	25550	1.75E-08	1.0E-01	1.7E-09
Ethylbenzene	1.49E-08	20	250	25	70	25550	1.04E-09	NA	NA
Toluene	7.44E-09	20	250	25	70	25550	5.20E-10	NA	NA
Anthracene	2.42E-12	20	250	25	70	25550	1.69E-13	NA	NA
Pyrene	6.49E-16	20	250	25	70	25550	4.54E-17	NA	NA

Table E-9
Estimation onf Noncarcinogenic Risk
Building Occupant

Human Health Risk Evaluation
Powell Street Plaza and Shellmound III
Emeryville, CA

Inhalation of Vapors from Groundwater - Residual Petroleum

ADD = $(Ca*IR_a*EF*ED)/(BW*AT)$

Hazard Quotient = ADD/RfDi

Chemical	Indoor Air (GW) Concentration (Ca) (mg/m^3)	Inhalation Rate (IR_a) (m^3/day)	Exposure Frequency (EF) (days/year)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	Average Daily Dose (ADD) (mg/kg-day)	Inhalation Reference Dose (RfDi) (mg/kg-day)	Hazard Quotient
Benzene	2.50E-07	20	250	25	70	9125	4.89E-08	1.7E-03	3E-05
Ethylbenzene	1.49E-08	20	250	25	70	9125	2.91E-09	2.9E-01	1E-08
Toluene	7.44E-09	20	250	25	70	9125	1.46E-09	1.1E-01	1E-08
Anthracene	2.42E-12	20	250	25	70	9125	4.74E-13	3.0E-01	2E-12
Pyrene	6.49E-16	20	250	25	70	9125	1.27E-16	3.0E-02	4E-15
								Hazard Index	**3E-05**