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Tier II Human Health Risk Appraisal

Oakland Vehicle Maintenance Facility
Oakland, California
10/11/99

This report has been prepared for:

United States Postal Service
1675 7th Street, Room 328W, Oakland, California 94615-9988

October 11, 1999

Project No. 864-40B

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Mr. Sean McFadden
UNITED STATES POSTAL SERVICE
1675 7th Street, Room 328W
Oakland, California 94615-9988

RE: TIER II HUMAN HEALTH RISK APPRAISAL
OAKLAND VEHICLE MAINTENANCE FACILITY
OAKLAND, CALIFORNIA

Dear Mr. McFadden:

As requested, we have performed a Tier II human health risk assessment for the Oakland Vehicle Maintenance facility, located in Oakland, California. This report was prepared in accordance with our agreement dated December 25, 1999.

We refer you to the text of the report for details regarding this study. Thank you for choosing us to assist you. If you have any questions, please call and we will be glad to discuss them with you.

Very truly yours,

LOWNEY ASSOCIATES

Ron L. Helm, R.G., R.E.A.
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RLH:DWM:tjc

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TIER II HUMAN HEALTH RISK ASSESSMENT
OAKLAND VEHICLE MAINTENANCE FACILITY
OAKLAND, CALIFORNIA

1.0 EXECUTIVE SUMMARY

This report presents a Tier II human health risk appraisal (HRA) of the USPS Oakland Vehicle Maintenance Facility, located at 1675 7th Street in Oakland, California. The objective of this appraisal was to evaluate the human health risks posed by the petroleum hydrocarbon compounds detected in soil and ground water beneath the site. The chemicals evaluated in this assessment included gasoline- and diesel-range petroleum hydrocarbons and benzene, toluene, ethyl benzene, and total xylenes (BTEX).

The HRA contains estimates of carcinogenic risks from the chemicals of concern. Cancer risk findings are compared to a range of acceptable risk levels, $1x10^{-7}$ to $1x10^{-4}$, cited in the EPA National Contingency Plan (NCP) in order to place the risk estimates in perspective. A $1x10^{-6}$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 70-year lifetime as a result of the exposure conditions evaluated.

The principal findings of the HRA follow.

1.1 Potential Health Risks Under the Commercial Use Scenario

For the proposed commercial use scenario, the estimated excess cancer risks were estimated to in the range of $1.8x10^{-8}$ (construction worker) to $2.1x10^{-6}$ (indoor worker), which is well within the US EPA's acceptable risk range cited in the NCP.

1.1.1 Uncertainties Associated With Health Risk Estimates

Because risk characterization serves as a bridge between risk assessment and risk management, major assumptions, scientific judgments, and estimates of uncertainties must be described in the assessment. Risk assessment methods are designed to be highly conservative to address the uncertainties associated with each step in the risk assessment process. Thus, "true" site risks are very unlikely to be greater than, and may be significantly less than, risks estimated using standard risk assessment methods. In this assessment, the key factors that contribute to the overestimation of risks include the following.

- Use of conservative estimates of exposure point concentrations for all exposure pathways and use of conservative intake assumptions to estimate reasonable maximum exposures,

- Use of toxicity values that incorporate uncertainty factors or other techniques devised to be health protective, and
- Use of conservative assumptions relative to the constant exposure point concentrations for the 25-year exposure period evaluated in this assessment.

2.0 INTRODUCTION

The purpose of this Tier II human health risk appraisal (HRA) is to evaluate the potential health risks posed by TPHg chemical constituents found on-site including BTEX. The HRA relies on soil and ground water quality data contained in the June 1997 *Request for Site Closure*, prepared by Harding Lawson Associates (HLA). Within this HRA report, chemicals of potential concern are identified for relevant receptors, exposure to potential chemicals of concern are assessed, and the risks associated with potential exposures to these chemicals are quantified. The remaining sections of the HRA are organized according to steps common to most risk assessments, including identification of chemicals of potential concern, exposure assessment, and risk characterization.

3.0 METHODS USED

This section describes the calculation of chemical-specific human health risks for chemicals in site soil and ground water. Calculation of the health risks incorporates exposure assumptions, exposure point estimation, and toxicity values for each chemical of interest, for all pathways of concern. The primary guidance used in the development of this HRA was taken from Risk Assessment Guidance (RAGS) (U.S. EPA 1989a), Department of Toxic Substances Control (DTSC) supplemental guidance (CALEPA 1992), and Risk-Based Corrective Action (RBCA) applied at petroleum release sites (ASTM).

The chemicals of concern, exposure scenarios, exposure assumptions, methods of calculation, and parameter values used are described below.

3.1 Chemicals of Concern

Chemicals in on-site soil and ground water have been identified by previous investigations. The investigations show that site soil and ground water display a range of chemicals and concentrations. The chemicals include petroleum hydrocarbons (gasoline, diesel) and BTEX.

The following chemicals were selected as chemicals of concern (COCs).

- TPHd
- TPHg
- benzene
- toluene
- ethyl benzene
- xylenes

3.2 Exposure Assessment

3.2.1 Exposure Setting Overview

Located at 1675 7th Street in Oakland, California, the site overlays soil and ground water that has been determined to be impacted by a release of petroleum hydrocarbon compounds, which may have leaked from a previous underground gasoline storage tank (UST) and/or fuel dispensers. The property is located in a predominantly commercial and industrial area and is currently occupied by the USPS Oakland Vehicle Maintenance Facility, which includes one building. Site use is not anticipated to change, and residential development is unlikely.

Residential
is not
excluded

According to HLA, two 10,000-gallon diesel fuel USTs, one 5,000-gallon gasoline UST, one 750-gallon waste oil UST, and associated product piping were removed from the site in November 1991. Ten soil samples collected from the tank excavations showed elevated levels of TPHd, TPHg, and BTEX. In the summer of 1992, impacted soil in the vicinity of the two former diesel USTs were removed from the site.

In June 1992, an additional 10,000-gallon diesel UST was removed from the site. Soil and ground water samples collected from this excavation indicated the presence of elevated petroleum hydrocarbon compounds in the ground water. Apparently, sidewall soil samples were non-detect for target compounds.

During September 1993, a subsurface investigation was performed on-site that included advancement of nine soil borings (five of which were converted to monitoring wells) and the collection and analysis of soil and ground water samples. From the 9 completed borings, 25 soil samples were collected at various depths ranging from 3 to 13½ feet below ground surface (bgs).

Table 1 summarizes the analytical information from the September 1993 soil investigation.

Table 1. Soil Analytical Data

Chemical	Frequency of Detection	Range (mg/kg)	Location of the Max.	Average (mg/kg)	UCL* (mg/kg)
TPHd	2/25	<5 -2400	MW4	104	264
TPHg	2/25	<0.5 - 180	B8	9.8	22.2
benzene	2/25	<0.003 - 0.15	B8	0.012	0.023
toluene	1/25	<0.003 - 0.35	B8	0.018	0.042
ethyl benzene	1/25	<0.003 - 2.1	B8	0.088	0.23
xylenes	3/25	<0.003 - 13	B8	0.53	1.4

* UCLs (95% upper bound estimate of the mean) calculated with censored data (non - detects) assumes the chemical is present at ½ the detection limit.

With respect to ground water quality, according to HLA, quarterly monitoring was initiated on-site in January 1994. In January 1995, with the approval of Alameda County Department of Environmental Health (ACDEH), up-gradient monitoring well MW-5 was abandoned. In March 1996, ACDEH approved the discontinuation of the analysis of TPHg and BTEX in wells MW-1 through MW-3, and ACDEH also approved a reduced sampling frequency to biannual monitoring. Table 2 summarizes analytical data from MW-1 to MW-5.

Table 2. Site-Wide Ground Water Analytical Data

Chemical	Frequency of Detection	Range (ug/l)	Location of the Max.
TPHd	34/53	<50 - 23,000	MW-4
TPHg	11/47	<50 - 24,000	MW-4
benzene	11/47	<0.5 - 0.8	MW-3
toluene	0/47	NA	NA
ethyl benzene	5/47	<0.5 - 1.0	MW-4
xylenes	1/47	<.5 - 0.8	MW-4

3.2.2 Exposure Scenarios and Hypothetical Receptors

EXPOSURE SCENARIOS QUANTIFIED

An exposure pathway is the course a chemical takes from a source to an exposed organism. Exposure pathways include the following four elements: (1) a source; (2) a mechanism for release, retention, or transport of a chemical in a given medium (e.g., air, water, soil); (3) a point of contact with the affected medium; and (4) an exposure route at the point of contact (e.g., ingestion, inhalation). If any of these elements is missing, the pathway is considered "incomplete" (i.e., it does not present a means of exposure).

Since dissolved phase volatile organic hydrocarbon compounds (VOCs) will partition into a vapor phase above the water table, migration into a building is more likely when a source of contamination is close to the foundation (EPA 1992). Soil-bound VOCs also will partition to a vapor phase within the pore spaces of the soil media, providing a mechanism of release and chemical transport.

This report addresses the potential risks associated with contaminant volatilization from impacted ground water and soil and the migration of those contaminants into occupied spaces within the above building. In addition, this assessment also evaluates the potential risks associated with a construction worker's exposure to shallow soil beneath the site. Complete exposure pathways for each type of receptor are presented below.

For selected chemicals, this assessment will address the following:

- On-site commercial workers occupying an office building that overlies contaminated soil and ground water. In this exposure scenario, inhalation of volatile chemicals migrating through the vadose zone and into occupied office space is addressed.

- On-site construction workers contacting impacted soil through construction-related activities. In this exposure scenario, ingestion and dermal contact with contaminated soil and ambient inhalation of chemicals volatilizing from site soil is addressed.

EXPOSURE SCENARIOS CONSIDERED BUT NOT QUANTIFIED

Contaminant volatilization from ground water and migration into an occupied space is a far more significant exposure pathway than volatilization from ground water with migration into ambient air. If indoor exposure estimates are low, then ambient exposure estimates will be much lower (see Appendix A).

3.2.3 Exposure Assumptions

Exposure estimates (intakes or administered doses) of site-related chemicals are defined as the mass of a substance taken into the body, per unit of body weight, per unit of time. Methods used to calculate chemical intakes for chronic exposure, or chronic daily intakes (CDIs), are described in RAGS (U.S. EPA 1989a) and DTSC supplemental guidance (CALEPA 1992). Estimates of chemical intake are based on exposure concentrations at the exposure point (exposure point concentrations) and on the estimated magnitude of exposure to affected media.

For this assessment, DTSC (1992) and U.S. EPA (1989a; 1991a) guidance were the primary sources used for exposure quantification. Exposure factors (body weights, breathing rates, etc.) used in the exposure algorithms were also taken from DTSC (1992) and U.S. EPA (1994). For all exposure scenarios, the default body weight of 70 kg is used. In addition an exposure duration of 25 years is assumed for indoor workers for the commercial exposure scenario.

The averaging time used to determine the CDI of a chemical is dependent on the type of toxic effect being assessed. For assessing carcinogenic effects, CDIs are calculated by prorating the exposure period cumulative dose over a lifetime; the average lifespan is assumed to be 70 years (U.S. EPA 1991a). For assessing non-cancer effects, CDIs are calculated by averaging intakes only over the period of exposure.

The following subsections describe exposure parameters and assumptions used to calculate CDIs for each exposure pathway. The exposure algorithms used in this assessment are presented in Appendix A.

INHALATION PATHWAY ASSUMPTIONS

On-site indoor workers are assumed to be exposed to volatile chemicals volatilizing from soil and ground water. Table A1 (Appendix A) shows the exposure algorithm for potential exposures to chemicals in ambient and indoor air. An inhalation rate of 8m³/day indoors (for an eight-hour work day) is assumed for the indoor worker exposure scenario. The exposure frequency for indoor workers is 250 days per ✓ year and an exposure duration of 25 years ✓ is assumed. 30yr for Carcinogen

Conservative assumptions for on-site construction worker inhalation exposure during construction activities include exposure for eight hours per day for 188 "dry days" per year using a default inhalation rate of 20m³/day.✓ It is also assumed that a construction worker has a four-year on-site exposure duration.

DERMAL CONTACT WITH SOIL PATHWAY ASSUMPTIONS

Table A2 (Appendix A) show the algorithms for calculating the absorbed dose from dermal contact with soil. On-site construction workers are assumed to have 5,000 cm² of skin exposed to on-site soil. For this exposure scenario, a soil-to-skin adherence factor of 0.2 mg per cm² of exposed skin and a soil-bound chemical absorption factor of 0.1 are used. ✓ (.5 for volatiles) 0.5 ASTM value

not default #s

INGESTION OF SOIL PATHWAY ASSUMPTIONS

Table A3 (Appendix A) shows the algorithm for calculating the absorbed dose from incidental ingestion of contaminated soil. An on-site construction worker is assumed to ingest 480 mg of soil per day for the 188-day exposure period per year for a four-year duration. In addition, it was assumed that 100 percent of the soil-bound chemical is absorbed via ingestion.

SUMMARY OF EXPOSURE VARIABLES

Table 3 summarizes key exposure variables for on-site receptors.

Table 3. Exposure Variables ✓ high

	Breathing Rate (m³/d) indoor/ambient		Surface Area skin (cm²) soil	Soil Ingestion (mg/d)	Exposure Duration (yrs)	Pathways
On-site: indoor[a]	8	1	-	-	25	soil/ground water volatilization
construction[b]	-	20 ✓	5,000 ✓	480	4	soil volatilization, soil contact

"-" indicates not applicable. Units: (m³/d)=cubic meters per day, cm² =square centimeters, mg/d = milligrams per day, yrs = years, gw = ground water

a. Indoor worker is assumed to breathe 1 m³/hr (U.S. EPA 1997). An eight-hour exposure period is assumed: eight hours inside.

b. Construction worker's skin surface area for soil contact is taken from U.S. EPA 1996 PRGs. Soil ingestion rate is from U.S. EPA 1997.

3.2.4 Exposure Point Estimation

To estimate the human health risks for the chemicals of concern, the site is divided into two units:

- Impacted soil, and
- Impacted ground water

Each unit is treated separately to calculate exposure points, chronic daily intake, and each unit's contribution to risks. Risks are then summed (Section 4) to provide total site risks for each receptor.

VOLATILIZATION FACTORS

Volatilization factors (VF) are used to address soil to air and ground water to air pathways for volatile chemicals. These factors relate soil and ground water chemical concentrations to air chemical concentrations that may be inhaled on-site and off-site. The mathematical expressions for each VF used in this assessment are presented in Appendix A. This section describes the volatilization factors and underlying assumptions in their use.

Volatilization from Subsurface Soil to Indoor Air To estimate chemical volatilization from subsurface soil and migration into indoor air spaces using site-specific soil parameters, the subsurface soil volatilization model from ASTM is used. The calculations incorporate site-specific source parameters, diffusion paths, and building parameters. Within this VF expression, there is a partitioning model which, based on a chemical's soil concentration (sorbed phase), predicts the vapor phase concentration within the soil pore space.

Volatilization from Ground Water to Indoor Air ASTM also has a VF for the ground water to indoor air exposure pathway that estimates vapor flux by incorporating the capillary fringe, the vadose zone, and the building foundation pad to the diffusion path of the chemical. This model assumes a thin capillary fringe (5 cm) with default moisture and density parameters. The capillary fringe is known to retard vapor mass transport (EPA 1992, McCarthy), and the ASTM VF predicts an exponential decay of vapor concentration above the fringe with increasing fringe thickness. Site-specifically, the fringe thickness is unknown; however, it can be assumed that it is much thicker than 5 cm because of the clayey soil encountered. This assessment assumes a capillary fringe thickness of 30.5 cm (1 foot).

VF Assumptions The volatilization factor calculations assume (1) chemical concentrations in soil and ground water over time remain constant, (2) isotropic soil, and (3) linear equilibrium partitioning within the soil matrix between sorbed, dissolved, and vapor phases. In addition, for enclosed space vapors, it is assumed that convective transport into the building through foundation cracks or openings is negligible in comparison with diffusive transport. With respect to chemical migration indoors, the intrusion of vapor into the building is assumed to be governed by the relative rates of diffusion through the soil and foundation.

Volatilization from Subsurface Soil to Ambient Air To address the soil to ambient air pathway for volatile chemicals, the VF_s from U.S. EPA 1996 PRGs is used to risks. The VF_s equation is broken into two separate models: an emission model to estimate emissions of the chemical from the soil, and a dispersion model to simulate the dispersion of the chemical in the atmosphere.

The emission term used in the VF_s is based on Jury 1984 and describes the vapor phase diffusion of the chemicals to the soil surface to replace that lost by volatilization to the atmosphere. The major assumptions of this model include:
(1) chemicals are uniformly incorporated in the soil to an infinite depth;
(2) isotropic soil; (3) no water flux through the soil; (4) bare, uncovered soil; and
(5) linear equilibrium partitioning within the soil matrix between sorbed, dissolved and vapor phases. The basic principle of the VF_s model is applicable only if the soil chemical concentration is at or below soil saturation.

The dispersion term within the VF is derived from a modeling exercise by the U.S. EPA using meteorological data from 29 locations across the United States. The dispersion model used by the U.S. EPA is the AREA-ST, an updated version of the Office of Air Quality Planning and Standards, Industrial Source Complex Model, ISC2. The U.S. EPA has selected Los Angeles as the 90th percentile data set for volatiles and a default source size of 0.5 acre was chosen for the PRG calculations. According to the U.S. EPA Region 9, this is consistent with the default exposure area over which Region 9 typically averages chemical concentrations in soil (U.S. EPA 1996 PRGs).

3.2.5 Site Specific Data and Chemical Parameters

Site-specific soil and chemical data were used for exposure and risk calculations. This section describes key data used for the calculation process, and identifies physico-chemical parameters and toxicity constants used.

PHYSICAL PARAMETERS FOR SOIL

According to HLA, the site is underlain by medium dense to dense silty sand, clayey sand, and sand to 21 feet below ground surface. Ground water monitoring indicates that depth to ground water at the site is between 9½ and 11 feet bgs.

Since site-specific parameters were not available, and ASTM parameters are not generally reflective of Bay Area soil, this assessment incorporates parameters conservatively derived from Bay Area soil measurements. The parameters used are identified in Table 5.

Table 5. Soil Parameters

Location	Total Porosity	Moisture Content (cm^3/cm^3)	Air filled Porosity (cm^3/cm^3)	Organic Carbon (g/g)
ASTM Default[1]	.38	.12	.26	.01
Industrial Road, San Carlos[2]	.373	.353	.02	.04 (.023)[a]
Lewis Road, San Jose[3]	.391	.322	.069	.05 (.029)[a]
3810 Broadway, Oakland[4]	.354	.307	.047	.035 (.02)[a]
Junction Ave, San Jose[5]	.391	.322	.069	.05 (.029)[a]
Assumed Site Parameters	.38	.28	.1	.01

1. ASTM Default Parameters
2. Average of four samples collected between 3 to 6½ feet bgs.
3. Average of three samples collected between 5 to 10 feet bgs.
4. Average of three samples collected at 5 feet bgs.
5. Average of 15 vadose zone samples.

a. Value in parenthesis is measured total organic mater (om), organic carbon (foc) converted from om based on Dragun 1988.

PHYSICO-CHEMICAL PARAMETERS

The physico-chemical parameters used in this assessment and the sources of the information are summarized in the Table 6.

Table 6. Physico-Chemical Parameters
Non-Halogenated VOCs

	Henry's Constant Dimensionless	Carbon-Water Sorption Koc (cm^3/g)	Permeability Constant (cm/hr)	Diffusivity Air (cm^2/s)	Diffusivity Water (cm^2/s)
Benzene	.22	38	.021	.087	9.8E-06
Toluene	.27	260	.045	7.8E-02	8.6E-06
Ethyl Benzene	.32	220	.074	7.5E-02	7.8E-06
Xylenes	.29	240	.08	7E-02	8.4E-06

Henry's Constant, Koc, and diffusivities are from U.S. EPA 1996 PRGs. Permeability constants are from Cal EPA PEA Guidance 1993. Diffusivities for benzene are from U.S. EPA 1996b.

TOXICITY PARAMETERS

EPA-derived toxicity values used in risk assessments are termed slope factors and reference doses (RfDs). Slope factors are used to estimate the incremental lifetime risk of developing cancer corresponding to CDIs calculated in the exposure assessment. The potential for non-cancer health effects is evaluated by comparing estimated daily intakes with reference doses (RfDs) or reference concentrations (RfCs), which represent daily intakes at which no adverse effects are expected to occur over a lifetime of exposure. Both slope factors and RfDs are specific to the route of exposure (e.g., inhalation, or ingestion [oral] exposure). For assessing non-carcinogenic effects associated with inhalation exposures, EPA has begun issuing reference concentrations (RfCs) that represent exposure concentrations at which no adverse effects are expected to occur. Where the California cancer potency factors are more stringent than those derived by EPA, the California values are used in the HRA to estimate potential cancer risks from exposure to chemicals at the site.

The toxicity parameters (slope factors and reference doses) used in the risk calculations are summarized in Table 7.

Table 7. Toxicity Parameters for Non-Halogenated VOCs

	Sfo per mg/kg-day	Sfi per mg/kg-day	RfDi mg/kg-day	RfDo mg/kg-day
Benzene	.11c	.11c	.0017 r	.0017 n
Toluene	NA	NA	.11	.2
Ethyl Benzene	NA	NA	.29	.1
Xylenes	NA	NA	.2	2

c = California Value, all other values from U.S. EPA 1996 PRGs.
NA =not applicable

4.0 RESULTS

Cancer risks for a single carcinogen are calculated by multiplying the carcinogenic CDI of the chemical by its slope factor. A $1x10^{-6}$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 70-year lifetime as a result of the exposure conditions evaluated. Because cancer risks are assumed to be additive, risks associated with simultaneous exposure to more than one carcinogen in a given medium are aggregated to determine a total pathway cancer risk. For the commercial exposure scenario total cancer risks are summed to determine the total cancer risk for the population of concern.

Unlike carcinogenic effects, non-cancer effects are not expressed as a probability. Instead, these effects are expressed as the ratio (HI) of the estimated exposure over a specified time period to the RfD derived for a similar exposure period (e.g., CDI:chronic RfD). This ratio is termed a hazard quotient. If the CDI exceeds the RfD (i.e., hazard quotient >1), there may be concern for non-cancer adverse health effects. Exposures resulting in a hazard quotient ≤1 are very unlikely to result in non-cancer adverse health effects. Hazard quotients for individual chemicals are conservatively summed for each exposure pathway to determine a hazard index. Calculation results and risk presentation (Table 12) are provided at the end of this section.

4.1 Source Terms

The calculation and/or identification of the "source term" is the starting point of the exposure estimation process. The source terms (based on upper bound estimates of the chemical concentrations in site media) as described in Section 3.1 of this document are presented in Table 8.

Table 8. Source Terms

Source	Benzene	Toluene	Ethyl Benzene	Xylenes
Soil	0.023 mg/kg	0.042 mg/kg	0.229 mg/kg	1.4 mg/kg
Ground Water	.80 ug/l	NA	1.0 ug/l	0.8 ug/l

4.2.2 Air Exposure Point Concentration Estimates

The calculated exposure point concentration estimates derived from source terms and VFs are provided in Table 9.

Table 9. Exposure Point Concentration Estimates

Source	Benzene	Toluene	Ethyl Benzene	Xylenes
Indoor Worker				
Soil	2.9E-04 mg/m3	1.2E-04 mg/m3	8.8E-04 mg/m3	4.3E-03 mg/m3
Ground Water	9.4E-07	NA	1.3E-06	1.9E-07
Construction Worker				
Ambient Air (Soil)	1.3E-05	1.1E-05	6.9E-05	3.8E-04

4.3 Calculated Risks

Exposure point concentrations and/or source terms were used to calculate the chronic daily intake (dose). The resultant dose, for the exposure conditions examined were then multiplied by a carcinogenic potency factor or compared to a reference dose for non-carcinogenic risks. Tables 10 and 11 summarize the estimated risk posed by the site.

Table 10. Risk Summary
Commercial Worker Exposure Scenario

Source	Benzene Carcinogenic	Toluene HI	Ethyl Benzene HI	Xylenes HI
Soil	2.1E-06	3.2E-04	8.6E-04	6.2E-03
Ground Water	6.6E-09	NA	1.3E-06	2.7E-07
Total	2.1E-06	<<1	<<1	<<1

Table 11. Risk Summary
Construction Worker Exposure Scenario

Source	Benzene Carcinogenic	Toluene HI	Ethyl Benzene HI	Xylenes HI
Soil				
Skin	9.7E-11	3.7E-07	3.3E-06	1.1E-06
Ingestion	4.6E-10	1.4E-06	1.6E-05	4.8E-06
Inhalation	1.1E-8	2.9E-05	6.8E-05	5.4E-04
Total	1.1E-08	<<<1	<<<1	<<<1

4.3.1 Conclusions

The estimated maximum carcinogenic risks due to the inhalation of volatile contaminants, primarily from benzene volatilizing from shallow ground water and soil and intruding into occupied spaces, is approximately at 2.1E-06. Non-carcinogenic risks, expressed as a hazard quotient, are less than unity. For the commercial worker exposure scenario, the estimated risks are considered lower than the acceptable target risk of 1E-05 as set by various regulatory agencies.

For a hypothetical construction worker, the estimated maximum carcinogenic risks due to the inhalation of volatile contaminants, skin contact with contaminated soil and ground water, and incidental ingestion of contaminated soil during construction-related activities are estimated at 1.1E-08. Non- carcinogenic risks, expressed as a hazard quotient, are less than unity. The estimated risks are considered lower than the acceptable range for the chemicals of concern.

UNCERTAINTY

This assessment has evaluated the maximum exposure case. The conservative assumptions and parameters used likely to contribute risk over-estimation. The most sensitive parameters for the exposure point estimates include soil moisture content (air filled porosity), areal extent of the contamination, and assumptions relative to an infinite source of contamination.

Soil moisture and porosity parameters used in this assessment are more conservative than measured values for typical Bay Area soil. In addition, this assessment conservatively assumed that site wide average soil concentrations of chemicals were represented by the 95 percent upper bound estimate of the mean (UCL), and assumed that ground water concentrations are represented by the maximum detected concentration from any on-site well. In addition, it was assumed that 100 percent of a commercial building's footprint overlays impacted soil and ground water. The primary chemical of concern, benzene, was detected in site soil in only 2 of 25 samples. In addition, the model used assumes that an infinite source exists below the site, and that there is no mass loss due to volatilization and/or biodegradation of the petroleum hydrocarbons over a 25-year exposure period.

Factors which could cause risk underestimation include the intentional or unintentional elimination of chemicals of concern. This assessment evaluates the volatile fraction of the petroleum hydrocarbons as BTEX compounds. Gasoline and diesel are composed of hundreds of different hydrocarbon compounds. In addition, polycyclic aromatics (PAHs) were not evaluated due to the lack of analytical information. With respect to other hydrocarbon compounds, they are generally not expected to be a concern since they are generally considered to have a lower potency than BTEX compounds. With respect to PAHs, they are not expected to be of concern due to their relatively low concentrations in diesel fuel.

5.0 LIMITATIONS

This report was prepared with generally accepted standards of environmental practice in California at the time of its preparation. Evaluation of the chemical conditions of the site media for purposes of this assessment is made from a limited number of observations. There are no representations, warranties, or guarantees that the chemical information relied upon in the preparation of this report, are a complete and accurate representation of the site conditions.

6.0 REFERENCES

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APPENDIX A

Exposure Algorithms, Volatilization Models, And Input Parameters

TABLE A1. INHALATION EXPOSURE ALGORITHM

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times EF \times ED}{BW \times AT}$$

where:

CA = chemical concentration in air (mg/m^3)
IR = inhalation rate (m^3/day)
EF = exposure frequency (days/years)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time(days)
- carcinogenic effects:70-year lifetime × 365 days/year
- noncarcinogenic effects: ED × 365 days/year

Exposure Assumptions[a]

Parameter	Indoor Worker Commercial Scenario	Construction Worker
CA	Chemical Specific	Chemical Specific
IR	(8)	20
EF	250	188
ED	25	4
BW	70	70

[a] See text Section

TABLE A2. SOIL DERMAL EXPOSURE ALGORITHM

$$\text{Absorbed dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS = chemical concentration in soil (mg/kg)
CF = conversion factor (10^{-6} kg/mg)
SA = skin surface area available for contact (cm^2/event)
AF = soil-to-skin adherence factor (mg/cm^2)
ABS = absorption factor (unitless)
EF = exposure frequency (events/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)
- carcinogenic effects: 70-year lifetime × 365 days/year
- noncarcinogenic effects: ED × 365 days/year

Typical Exposure Assumptions[a]

Parameter	Commercial Scenario Onsite Construction Worker
CS	Chemical Specific
SA	5000
AF	.2
ABS [b]	.1
EF	188
ED[c]	4
BW	70

[a] All exposure assumptions from U.S. EPA 1996 PRGs unless otherwise noted.

[b] Cal EPA PEA Guidance, .1 for volatile organic compounds (see text).

[c] Exposure scenario assumption, see text.

Table A3. SOIL INGESTION EXPOSURE ALGORITHM

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times EF \times ED \times CF}{BW \times AT}$$

where:

CS = chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg/day)
EF = exposure frequency (days/years)
ED = exposure duration (years)
CF = conversion factor (10^{-6}kg/mg)
BW = body weight (kg)
AT = averaging time (dyas)
- carcinogenic effects: 70-year lifetime × 365 days/year
- noncarcinogenic effects: ED× 365 days/year

Exposure Assumptions[a]

Parameter	Commercial Scenario Onsite Construction Worker
CW	Chemical Specific
IR	480
EF	188
ED	4
BW	70

[a] See text.

GROUNDWATER VOLATILIZATION

For indoor air exposure estimates, volatile groundwater contaminant flux is estimated by the following volatization factor (based on ASTM 1994) :

Migration to enclosed spaces:

$$VF_{WESP}\frac{(mg/m3)}{(mg/l)}=\frac{H((D_{effws}/L_{GW})/(ERxL_B))}{1+((D_{effws}/L_{GW})/(ERxL_B))+((D_{effws}/L_{GW})/(D_{effcrk}/L_{crk})n))}x10^3L/m3$$

Where:

$$D_{effws}(cm2/s)=\frac{(h_c+h_v)}{(h_c/D_{effcap})+(h_v/D_{effs})}$$

$$D_{effs}(cm2/s)=D_a(\theta_{as}^{3.33}/\theta_t^2)+D_w(\theta_{ws}^{3.33})/(H\theta_t^2)$$

$$D_{effcrk}(cm2/s)=D_a(\theta_{acrk}^{3.33})/(\theta_t^2)+D_w(\theta_{wcrk}^{3.33})/(H\theta_t^2)$$

$$D_{effcap}(cm2/s)=D_a(\theta_{acap}^{3.33})/(\theta_t^2)+D_w(\theta_{wcap}^{3.33})/(H\theta_t^2)$$

SOIL VOLATILIZATION

For indoor air exposure estimates, volatile soil contaminant flux is estimated by the following volatization factor (based on ASTM 1994) :

Migration to enclosed spaces:

$$VF\,\frac{(mg/m3)}{(mg/kg)} = \frac{((H\rho_s)/(\theta_{ws}+k_s\rho_s+H\theta_{as}))((D^{effsoil}/L_s)/ERL_B))}{1+((D^{effsoil}/L_s)/(ERL_B))+((D^{effsoil}/L_s)/(D^{effcrack}/L_{crack})\eta)}\,x(10^3 cm3-kg/m3-g)$$

where:

$$D^{effcrack}(cm2/s)=D^{air}\frac{\theta crack^{3.33}}{\theta T^2}+D^{wat}(1/H)\frac{\theta wcrack^{3.33}}{\theta T^2}$$

$$D^{effsoil}(cm2/s)=D^{air}\frac{\theta s^{3.33}}{\theta T^2}+D^{wat}(1/H)\frac{\theta ws^{3.33}}{\theta T^2}$$

Migration into Ambient Air:

$$VF_s(m^3/kg) = (Q/C)\ x\ \frac{(3.14\ x\ D_A\ x\ T)^{1/2}}{(2\ x\ \rho_b\ x\ D_A)}\ x\ 10^{-4}(m^2/cm^2)$$

$$D_A = \frac{[(\Theta_a^{10/3}D^{air}H + \Theta_w^{10/3}D_w)/n^2]}{\rho_B K_d + \Theta_w + \Theta_a H}$$

Parameter	Definition (units)	Value
VF	Volatilization factor (mg/m^3 /mg/kg, mg/m^3/mg/l)	Calculation
Q/C	Dispersion Parameter (g/m2-s per kg/m3)	69.55(Bay Area)
T	Exposure Interval (seconds)	9.5E+ 08
ρ_b	Dry soil bulk density (g/cm^3)	1.65 ASTM
Θ_{as}	Air filled soil porosity (L_{air}/L_{soil})	0.1
Θ_t	Total soil porosity (L_{pore}/L_{soil})	0.38
Θ_{ws}	Water-filled soil porosity (L_{water}/L_{soil})	0.28
ρ_s	Soil particle density (g/cm^3)	2.65 ASTM
D^{air}	Diffusivity in air (cm^2 /s)	Chemical-specific
D_A	Apparent Diffusivity(cm^2/s)	Calculation
H	Dimensionless Henry's Law constant	Chemical -specific
D_w	Diffusivity in water (cm^2/s)	Chemical-specific
K_d	Soil-water partition coefficient (cm^3/g) = K_{oc} f_{oc}	Chemical-specific
K_{oc}	Soil organic carbon-water partition coefficient (cm^3/g)	Chemical-specific
f_{oc}	Fraction organic carbon in soil (g/g)	.01(ASTM)
n	Aerial fraction of cracks in foundation wall (cm^2-cracks/cm^2-total area)	.01(ASTM-default)
Ls	depth to subsurface sources, cm	91.44 (3 ft)
D_{effs}	effective diffusion coefficient in soil (cm^2/sec)	calculated
D_{effws}	effective diffusion coefficient between groundwater and soil surface (cm^2/sec)	calculated
D_{effcap}	effective diffusion coefficient through capillary fringe	calculated
ER	enclosed space air exchange rate (s^{-1})	.00023(ASTM-default)
LB	enclosed space volume /infiltration ratio (cm)	300(ASTM-default)
D_{effcrk}	effective diffusion coefficient through foundation cracks (cm^2/s)	Calculated
Θ_{acrk}	volumetric air content in foundation /wall cracks (cm^{3}air/cm^3 total volume)	.26 (ASTM - default)
Θ_{wcrk}	volumetric water content in foundation /wall cracks (cm^3 air/ cm^3 soil)	.12 (ASTM - default)
Θ_{tcrk}	total soil porosity in foundation cracks (cm^3/cm^3-soil)	.38 (ASTM - default)
L_{crck}	enclosed-space foundation or wall thickness (cm)	15 (ASTM - default)
Θ_{acap}	volumetric air content in capillary fringe (cm^{3}air/cm^3 total volume)	.038 (ASTM - default)
Θ_{wcap}	volumetric water content in capillary fringe (cm^3 air/ cm^3 soil)	.342 (ASTM - default)
hv	thickness of the vadose zone	274 (9 ft)
hc	thickness of the capillary fringe	30.5 (1 ft)

```
Soil Vol/IndoorVF/Equilibrium Soil- Vapor Conc
Post Office
                                             Default                     ethyl
                                             Param.            Benz     toluene  benzene  xylene
Henry's
Henry's Dimensionless               H                              0.22     0.27     0.32     0.29
Diff Air cm2/s                      di cm2/s                      0.087    0.078    0.075    0.072
Dif Watercm2/s                      dw cm2/s                   0.000009 0.000008 0.000007 0.000008
Koc cm3/g                           Koc                              38      260      220      240
                                    S mg/l   EPA      ASTM         1780
foc                                 Foc        0.006     0.01     0.01     0.01     0.01     0.01
Kd soil water partition coeffcm3/g  Kd                             0.38      2.6      2.2      2.4
Total Porosity                      Tp          0.43     0.38     0.38     0.38     0.38     0.38
Moisture Content cm3 h2o/cm3-soil   Tm          0.15     0.12     0.28     0.28     0.28     0.28

Air filled porosity cm3air/cm3 soil Ta          0.28     0.26      0.1      0.1      0.1      0.1
Dry Bulk Density g/cm3              Bd           1.5      1.7     1.65     1.65     1.65     1.65
Particalbulk density g/cm3          Pd          2.65     2.65     2.65     2.65     2.65     2.65
Q/C (replaces box)                             68.81              69.55    69.55    69.55    69.55
T exposure interval (sec)                    9.5E+08           15600000 15600000 15600000 15600000
                                    sat mg/kg                  1002.193        0        0        0
Apparent Diffusivity Da             Da                         6.73E-05 1.49E-05 1.98E-05 1.59E-05
Vf(mg3/kg)=(Q/C)*(3.14*Da*T)^1/2)/(2*Pb*Da)* 10E-04(m2/cm2)
                           Ambient  Vf(m3/kg)                  1.80E+03 3.82E+03 3.32E+03 3.70E+03
---------------------------
Effective Diffusivity Soil (cm2/s)           Deffs cm2/s       0.000284 0.000253 0.000243 0.000234
Effective Diffusivity (found. cracks) cm2/s  Deffcrkcm2/s      0.006759 0.006060 0.005827 0.005594
Foundation & Crack soils:
air poros.cm3/cm3     0.26 fnd L(cm)      15
moisture cm3/cm3      0.12 N            0.01
total porosity        0.38
---------------
Source Characteristics                                                           ethyl
         Dflt     Site                                         Benz     toluene  benzene  xylene
         ----     -----
Total
Dpth Ls c     100       61 Cs       Soil conc (mg/kg)             0.023   0.0421    0.229      1.4
ERS 1/s   0.00023  0.00023 (givn Cs)Equil vapor conc (mg/m3)   8.987082 4.079954 30.67275 156.9219
200.6617 mg/m3
Lbvol/in      300      300          soil gas measmnt (mg/m3)
                           Cs calc  equil soil conc(mg/m3)            0        0        0        0
                                             ASTM:             390.7427 96.91102 133.9421 112.0871
                  Soil                       VF(mg/m3)/(mg/kg) 0.012968 0.002879 0.003821 0.003073
                           Indoor Air Conc   Ac(mg/m3)         2.98E-04 1.21E-04 8.75E-04 4.30E-03
                                             ug/m3             0.298275 0.121214 0.875127 4.303101
                  Soil Gas                   VF(mg/m3)/(mg/m3) 3.32E-05 2.97E-05 2.85E-05 2.74E-05
                           Indoor Air Conc   Ac(mg/m3)         0.00E+00 0.00E+00 0.00E+00 0.00E+00
                                                               B
                  Risk Based Soil   (indoor) Acc Soil mg/kg:   1.10E-02    133.7    265.6    227.7
                                    outdoor                    0.257313
```

```
                                    construction              2.032574
                                             acc sg mg/m3      43.11015 12958.71 35575.21 25527.02
                                                                                               Car      Ncar
                                                                         Car      ncar     Conv      ExpFact Exp Fact
Onsite
soil        IR       SA       AF       ABS      EF       ED    BWT^-1     AT^-1  AT^-1    10-6Kg/mg
inh(ind_       20        1        1        1      250       25 0.014285 0.000039  0.00016        1 6.99E-02 0.285714
indoor
   amb          1        1        1        1      250       25 0.014285 0.000039  0.00016        1 3.49E-03 0.014285
ambient
ing-cons      480        1        1        1      188        4 0.014285 0.000039 0.001329 0.000001 2.02E-07 0.000006
ingest-const-
derm-cons       1     5000      0.2      0.1      188        4 0.014285 0.000039 0.001329 0.000001 4.20E-08 0.000001
dermal-const
const amb      20        1        1        1      188        4 0.014285 0.000039 0.001329        1 8.41E-03 0.285714
ambient-const
out-amb        20        1        1        1      250       25 0.014285 0.000039  0.00016        1 6.99E-02 0.285714
outdoor
                  (tol)    ethyl
         Benz     toluene  benzene  xylene   nonane
SFo           0.1
SFi           0.1
RFDi     *            0.11     0.29      0.2      0.6
RFDo     *             0.2      0.1        2      0.6
                                             Risk Characterization
                                                                                 ethyl
                                                               Benz     toluene  benzene  xylene
                                    Soil
                                    Indoor Worker (CAR)        2.08E-06
                                             NCAR                       3.15E-04 8.62E-04 6.15E-03
                                             Total    CAR:     2.08E-06 NCAR:    0.007324
                                    Construction (CAR)         CAR      NCAR                       Total NCAR
                                             AC (mg/m3)        1.28E-05 1.10E-05 6.90E-05 3.79E-04
                                                      Inha     1.08E-08 2.86E-05 6.80E-05 5.41E-04
                                                      Derm      9.7E-11  3.0E-07  3.3E-06  1.0E-06
                                                      Ingest   4.64E-10 1.44E-06 1.57E-05 4.80E-06
                                                      Total    1.13E-08 3.04E-05 8.70E-05 5.47E-04 6.64E-04
                                                                                 ethyl
                                    GroundWater                Benz     toluene  benzene  xylene
                                    Indoor   VF                1.18E-03 1.23E-03 1.33E-03 2.32E-04
                                             GW con mg/l)        0.0008             0.001   0.0008
                                             AC mg/m3          9.44E-07          1.33E-06 1.86E-07

                                             Risk (CAR)        6.60E-09          1.31E-06 2.65E-07
```