

**RISK ASSESSMENT REPORT
FOR
THE GRAND STREET AND
FORTMANN WAY PROPERTY
ALAMEDA, CALIFORNIA**

SECOR Job No. 50182-001-01

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October 28, 1997

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LIST OF ACRONYMS

ACHCS	Alameda County Health Care Services Agency
AGT	Above ground tank
ASTM	American Society for Testing and Materials
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylenes
COPC	Chemical of potential concern
CSF	Cancer slope factor
CSM	Conceptual site model
EPC	Exposure point concentration
HTB	Harbor Tug and Barge
PAH	Polycyclic aromatic hydrocarbon
RBSL	Risk-based screening level
RfD	Reference dose
RME	Reasonable maximum exposure
RWQCB	Regional Water Quality Control Board
SF	Slope factor
TPHd	Total petroleum hydrocarbons as diesel
TPHg	Total petroleum hydrocarbons as gasoline
TPHo	Total petroleum hydrocarbons as oil
UCL	Upper confidence limit
USEPA	United States Environmental Protection Agency
UST	Underground storage tank
VOC	Volatile organic compound

1.0 INTRODUCTION

SECOR International Incorporated (SECOR) has prepared this report to document the rationale for requesting closure of the Grand Street and Fortmann Way Property (the "Site") located north of the intersection of Grand Street and Fortmann Way in Alameda, California. Standard risk assessment techniques presented in the American Society for Testing and Materials (ASTM) *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (ASTM, 1995) and U.S. Environmental Protection Agency's (USEPA) *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual* (USEPA, 1989a) were used to estimate potential health risks to both current and future on-site receptors under a reasonable maximum exposure (RME) scenario.

The use of ASTM is in accordance with the January 5, 1996, Memorandum from the California Regional Water Quality Control Board (RWQCB), San Francisco Bay Region, regarding Regional Board Supplemental Instructions to the State Water Board on December 8, 1995, *Interim Guidance on Required Cleanup at Low-Risk Fuel Sites*.

1.1 Background

The Grand Marina Facility includes an office located at 2099 Grand Street, as well as a marina with docking and repair facilities. A Site location map is provided in Figure 1-1. Above ground tanks (AGTs) were formerly located in the central portion of the Site. These AGTs were used to store gasoline, diesel fuel, lube oil, aviation fuel, and slop oil/bilge water. An underground storage tank (UST) formerly located in the southern portion of the Site was used to store gasoline. The tanks have since been demolished, although the concrete-floored and bermed containment structure for the AGT farm remains, along with various underground conveyance pipelines. There are currently USTs located beneath the parking area, north of the former AGT farm. These USTs were installed in 1990 and supply fuel to the marina dock.

The Site investigatory and remedial activities are under the regulatory jurisdiction of the Alameda County Health Care Services Agency (ACHCS) (the lead agency) and the RWQCB, San Francisco Bay Region. Site assessment and remedial activities have been conducted since 1987.

1.2 Purpose

The purposes of this risk assessment were to:

- Analyze potential human health risks to both current and future potential receptors under a range of land use scenarios to help identify the need, if any, for action at the Site
- Provide a basis for estimating levels of chemicals that can remain on-site and still be adequately protective of human health.

- Provide a basis for determining which chemicals are driving the human health risk under various sets of exposure assumptions to help guide risk management decisions.
- Provide the required documentation for Site regulatory closure intended to satisfy the requirements of the ACHCS and the RWQCB.

1.3 Scope

This risk assessment provides an evaluation of the potential human health risks associated with exposure to residual petroleum compounds detected in subsurface soils and groundwater at the Site. The scope is limited to an assessment of complete exposure pathways using simple analytical models provided in ASTM (1995) and risk assessment techniques outlined by USEPA (1989a). As a general rule, this risk assessment was based on use of ASTM (1995) and USEPA (1989a) reasonable maximum exposed (RME) default assumptions. Any deviations from this rule are noted in this report where applicable.

On January 19, 1996, SECOR and ACHCS discussed a preliminary conceptual site model (CSM) (presented in Section 4.2) which tentatively identified potentially complete and significant pathways at the Site. The preliminary CSM was used to guide the scope of this risk assessment.

1.4 Organization of the Report

The report is organized as follows:

- Section 2.0 Site Description and History, which presents a description of the Site and identifies past investigators.
- Section 3.0 Summary of Past Site Investigations, which summarizes the results of past soil and groundwater sampling activities conducted at the Site. It also identifies the specific data set that was used to conduct the risk assessment.
- Section 4.0 Selection of Chemicals of Potential Concern (COPCs), which identifies the chemicals that were quantitatively evaluated in the risk assessment.
- Section 5.0 Exposure Assessment, which includes a detailed analysis of potential exposure pathways and presents estimates of chemical intakes from exposure to Site chemicals.
- Section 6.0 Toxicity Assessment, presents toxicity values for each of the chemicals quantitatively evaluated
- Section 7.0 Risk Characterization, which provides a characterization of the potential cancer risks and noncancer effects associated with estimated exposure the COPCs.

Section 8.0 Uncertainty Analysis, which identifies the major uncertainties associated with each component of the risk assessment.

Section 9.0 Summary and Conclusions, which briefly summarizes the risk assessment and provides general conclusions.

Section 10.0 References, which provides citations of the information sources used in the report.

2.0 SITE DESCRIPTION AND HISTORY

2.1 Site Description and Background

The Site is located within an irregularly-shaped parcel along the southern edge of Alameda Harbor in Alameda, California (Figure 2-1). The parcel is approximately 1,300 feet from east to west and approximately 1,225 feet from north to south. The northern and eastern portions of the parcel includes harbor facilities located within the San Francisco Bay. The land portion was created with fill placed in the late nineteenth and early twentieth centuries. The Site is bounded to the south by Grand Street, to the west by Fortmann Way, to the north by the Marin Barge and Tug facility, and to the east by Fortmann Basin. This Site is currently used as a harbor for launching and berthing boats (SECOR, 1995).

An Environmental Assessment performed by Harding Lawson Associates (HLA, 1987) for Encinal Marina and a site history compiled by Bloomfield (1987) provided site history information, which is summarized herein. An AGT farm was previously operated on-site and was used until 1989. According to the documentation provided by Unocal (1994), gasoline, diesel fuel, fuel oils, kerosene, lube oil, aviation fuel, stove oil, and slop oil/bilge water were previously stored by Unocal within the AGTs. The materials stored in the AGTs were conveyed to or from the AGT farm and the pier via underground pipelines. A 1,000-gallon UST, located approximately 300 feet south of the AGT farm, was used to store gasoline (SECOR, 1995). The UST was removed in May 1988.

A history of likely Site uses is as follows:

1839 to 1940s	Alaska Packer Association operated a fleet of fishing vessels.
1906 to 1917	Taylor and Company operated a lumber yard.
1917 to 1983	The City of Alameda Corporation Yard used the facility for a variety of activities including auto repair, carpentry, blacksmith, and an animal shelter.
1930 to 1952	Union Oil Company (Union) leased a portion of the Site from Harbor Tug and Barge (HTB) and used the Site for fuel storage as early as 1930. Union was responsible for constructing the AGT farm and stored gasoline, diesel fuel, fuel oil, kerosene, aviation fuel, and other petroleum compounds in the AGTs.
1953 to 1959	W.D. McElwain, d.b.a. Bay City Fuel Oil Company, assumed the lease with the City of Alameda and operated the AGT farm as a bunker fuel depot.
1926 to 1989	Portions of the Site were reportedly leased by HTB.
1959 to 1979	HTB purchased, maintained, and operated the AGT farm.

1980 to 1986	Healy-Tibbets Construction Company used a portion of the Site for storage of marine construction equipment.
1986 to present	Grand Marina purchased the Site and currently operates a marina.

2.2 Site Investigation History

Previous Site investigations and activities were initiated by HLA during April 1987, which included installing six groundwater monitoring wells (W-1 through W-5 and B-7) and advancing six soil borings in the vicinity of the AGT farm (see Figure 2-1). HLA also dug six test trenches at various on-site locations during this investigation. In November 1987, approximately 285 tons of petroleum hydrocarbon-impacted soil were excavated to a maximum depth of 5 feet below ground surface (bgs) from the vicinity of the AGT farm. The soils were subsequently disposed of off-site. Free-phase petroleum hydrocarbons were observed within the limits of the excavation (SECOR, 1995). In May 1988, Uriah, Inc., removed a 1,000-gallon capacity gasoline UST and found soil adjacent to the UST to be impacted with petroleum hydrocarbons. More recent and complete data are currently available, and the majority of impacted soil found by HLA has been removed from the Site. As a result, data obtained from HLA's investigation were not used in this assessment.

In June 1990, Versar, Inc., (Versar) performed an environmental risk assessment at the Site. Versar collected water samples from the estuary, four groundwater monitoring wells, and the sump within the AGT farm area. Versar also collected soil samples from two areas of discolored soil and removed nine additional cubic yards of soil from the vicinity of the AGT farm (SECOR, 1995).

In January 1992, Zaccor Corporation (Zaccor) conducted a Limited Environmental Site Assessment. This assessment included removing the AGTs with the exception of the concrete foundation and the product lines. Zaccor advanced soil borings and collected soil samples from the vicinity of the AGT farm, the former 1,000-gallon UST, and the product lines. Zaccor also installed four additional groundwater monitoring wells (MW-1 through MW-4) and detected elevated concentrations of petroleum hydrocarbons (primarily diesel) and oil and grease in both soil and groundwater beneath the Site during this phase of the investigation. Detailed information is presented in SECOR's May 12, 1995 Additional Subsurface Investigation report for the Grand Marina Facility and in Zaccor (1992).

In general, the Site investigations revealed the greatest hydrocarbon concentrations in soils at depths to 2 feet bgs beneath the AGT farm floor and beneath the former pump house. Samples collected from depths of 3 to 7 feet bgs beneath the AGT farm, the pump house adjacent to the northern edge of the AGT farm, and in the vicinity of the former UST indicated elevated, but lower hydrocarbon concentrations. Groundwater samples collected from on-site monitoring wells in June 1992 revealed elevated gasoline, diesel, and benzene concentrations in monitoring well MW-2 near the former UST (Figure 2-1). Groundwater samples collected from monitoring wells W-1, W-2, W-3, and MW-4 indicated substantially lower concentrations of total petroleum hydrocarbons as gasoline (TPHg), as diesel (TPHd), and/or benzene (SECOR, 1995).

In October 1993, SECOR conducted a Site investigation composed of an historic records review, a pipeline integrity test, and a subsurface investigation. The results of this investigation are detailed in SECOR (1995). Appendix Tables A-1 (soil) and A-2 (groundwater) summarize the data considered relevant and used in this risk assessment from these historical investigations, as further discussed in Section 3.1. Zaccor demolished the AGTs in 1992.

Nearby leaking UST cases listed by the RWQCB included Encinal Marina (the Site), Alameda Fire Station (1705 Grand Street), Pennzoil (2015 Grand Street), and Weyerhauser (1801 Hibbard Street) (SECOR, 1995). Historic site use appears to represent the most significant potential source of hydrocarbons identified in on-site soil and groundwater.

3.0 SUMMARY OF PAST SITE INVESTIGATIONS

This section summarizes the results of past soil and groundwater sampling activities conducted at the Site relevant for use in the risk assessment. As described in Section 2.2, Site subsurface soil and groundwater have been sampled from April 1987 to March 1996 during several Site investigation activities. Because organic compounds degrade over time (i.e., volatilize or breakdown), the most recent Site investigation data provides the most accurate representation of current conditions at the Site. However, as an added measure of conservatism, this risk assessment incorporates soil and groundwater data collected over the last five years. Specifically, data collected from April and May 1992 and October 1994 investigations were used to evaluate potential exposures to soil (see Table A-1 of Appendix A for complete data summary). Potential exposures to groundwater were based on data collected at monitoring wells MW-1 through MW-8 on May 12, 1992, and the quarterly sampling rounds conducted on these wells between November 1, 1994 and June 24, 1996 (see Table A-2 of Appendix A for the complete summary).

ASTM acknowledges the impracticality of evaluating health risks associated with every compound present in a petroleum product. ASTM recommends that TPH measurements should not be used for "individual chemical" type risk assessments because they provide insufficient information about the amounts of individual compounds present. ASTM therefore recommends selecting benzene, toluene, ethylbenzene, and xylenes (BTEX) and polycyclic aromatic hydrocarbons (PAHs) as indicator compounds for gasoline and diesel, respectively (ASTM, 1995).

3.1 Soil Investigation Results

Results of the Site subsurface soil analyses for BTEX are presented in Table A-1 of Appendix A and summarized in Table 3-1. Seventy-one soil samples were collected between April 30, 1992 and October 26 and 27, 1994. Sixty-five samples were analyzed for BTEX, TPHg, and total petroleum hydrocarbons as oil and grease (TPHo) and sixty two samples were analyzed for TPHd.

ASTM (1995) recommends using PAHs as potential indicator compounds when diesel is detected at a site. PAHs were not analyzed in any soil samples. Therefore, concentrations for the carcinogenic PAH with the highest USEPA toxicity value, benzo(a)pyrene (B(a)P), were conservatively estimated from actual detected TPHd concentrations. The ACHCS (State of California, 1989), recommends that the concentration of B(a)P assumed to be present in diesel fuel #2 is 0.07 micrograms per gram ($\mu\text{g}/\text{gm}$) or 7×10^{-8} mg of B(a)P per 1 kilogram of TPHd. B(a)P concentrations in soil were estimated by multiplying the detected concentrations of TPHd by 7×10^{-8} . TPHd was detected in 54 samples, at concentrations ranging from 13 mg/kg to 21,000 mg/kg. The maximum detection of TPHd of 21,000 mg/kg occurred at sample boring number 3 on April 30, 1992 at 0 - 0.5 ft bgs. Using the methodology discussed above, this leads to a maximum estimated B(a)P concentration of 1.47×10^{-5} mg/kg (Table A-1 of Appendix A).

3.2 Groundwater Investigation Results

Results of the groundwater analyses for BTEX are presented in Table A-2 of Appendix A and summarized in Table 3-1. Four monitoring wells (MW-1, MW-2, MW-3, and MW-4) were sampled in May 1992 and nine wells (MW-1 through MW-4, MW-5, MW-6, MW-6a, MW-7, and MW-8) were sampled on a quarterly basis between November 1, 1994 and June 24, 1996. During this time, no BTEX constituents were detected in samples collected from monitoring wells MW-4, MW-5, MW-6, MW-6A, MW-7, or MW-8.

During the January 19, 1996, discussion of the preliminary CSM, the ACHCS requested an analysis of PAHs in groundwater. A total of seven groundwater samples were subsequently collected and analyzed for PAHs and the analytical results are presented on Table 3-2. Seven monitoring wells were sampled in March 1996 for the following 16 PAHs: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, B(a)P, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3)pyrene, naphthalene, phenanthrene, and pyrene.

Fluorene and naphthalene were the sole PAH constituents detected at respective concentrations of 0.9 and 9.3 $\mu\text{g/L}$ in the sample collected from monitoring well MW-2. No other PAH compounds were detected in the sample from monitoring well MW-2. No PAHs or other semi-volatile organic compounds (SVOCs) were detected in samples collected from monitoring wells MW-1, MW-4, MW-5, MW-6, MW-7, or MW-8 using USEPA Method 8270.

4.0 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

Chemicals of Potential Concern (COPCs) were selected to focus the risk assessment on the most persistent and potentially harmful chemicals at the Site. The COPC selection process may involve any number of acceptable criteria such as evaluating the frequency of detection. However, for the purposes of this risk assessment, chemicals were selected as COPCs if their maximum detected concentrations anywhere on-site exceeded Tier 1 risk-based screening levels (RBSLs). In all cases but one, Tier 1 RBSLs were obtained from ASTM (1995). In the absence of an ASTM developed value for fluorene, the Preliminary Remediation Goal (PRG) developed for fluorene by USEPA Region IX (1996b) was used as the Tier 1 RBSL. Unlike the industrial worker-based ASTM (1995) RBSL, the USEPA (1996b) fluorene PRG is conservatively based on a residential use direct contact scenario.

4.1 Subsurface Soil Chemicals of Potential Concern

Tier 1 soil RBSLs were estimated by ASTM (1995) for the following potential routes of exposure to chemicals in soil:

- Indoor inhalation of vapor originating from soil beneath a building;
- Outdoor inhalation of vapor originating from soil; and,
- Ingestion of soil (which also considers dermal contact with soil and inhalation of airborne particulates).

Table 4-1 compares the maximum detected concentrations of BTEX anywhere on the Site in vadose zone subsurface soil with Tier 1 soil RBSLs for each identified exposure pathway. None of the concentrations of BTEX exceed the Tier 1 RBSL. Furthermore, the estimated maximum concentration of B(a)P in soil was more than three orders of magnitude below the RBSL (0.0015 mg/kg versus 3.04 mg/kg). However, as an added measure of conservatism, and in consideration of the uncertainty associated in estimating the concentrations, B(a)P was selected as the COPC for soil.

4.2 Groundwater Chemicals of Potential Concern

Tier 1 groundwater RBSLs were estimated by ASTM for the following potential routes of exposure to chemicals in groundwater:

- Indoor inhalation of vapor originating from groundwater;
- Outdoor inhalation of vapor originating from groundwater; and,
- Ingestion of groundwater.

Table 4-1 also compares the maximum detected concentrations of BTEX, naphthalene, fluorene, and B(a)P in groundwater anywhere on the Site with Tier 1 groundwater RBSLs for these three exposure pathways. As shown on Table 4-1, the maximum detected groundwater concentration of benzene exceeds the groundwater RBSL for the exposure route involving indoor inhalation of vapor originating from groundwater. Maximum detected concentrations of toluene, ethylbenzene, fluorene, naphthalene, and total xylenes did not exceed the Tier 1 groundwater RBSLs. Only benzene exceeded the Tier 1 RBSL and was therefore the chemical selected as a COPC for groundwater.

5.0 EXPOSURE ASSESSMENT

The objective of the exposure assessment was to estimate the type and magnitude of potential exposure to current and future potential receptors from the COPCs identified at the Site. This section outlines the methodologies and assumptions that were used to calculate the potential daily exposure to each Site COPC. These methodologies and assumptions are discussed by USEPA (1989a; 1989b; 1991b; 1992a; and 1996b). The results of the exposure assessment are combined with chemical-specific toxicity information (Section 6.0) to estimate potential cancer risks and noncancer adverse health effects (Section 7.0).

The exposure assessment consists of the following three components:

- Characterize potentially exposed human populations (i.e., receptors) under expected land use conditions.
- Identify actual or potential exposure pathways.
- Quantitatively estimate the degree of exposure.

These three components are described below.

5.1 Characterization of Potentially Exposed Human Receptors

Potentially exposed human receptors were selected for evaluation under current and hypothetical future land use conditions. Land use at and surrounding the Site is currently industrial and commercial. Development plans for the Site include the construction of two, 2-story office/commercial buildings, in addition to a 2-story restaurant/commercial building. Therefore, commercial/industrial land use was evaluated and considered representative of future as well as current conditions.

Under these land use conditions, on-site exposures are expected to be limited to potential occupational exposures. Three types of occupational receptors were selected for evaluation:

- An on-site outdoor construction worker.
- An on-site outdoor landscape worker.
- An on-site indoor commercial worker.

The on-site worker scenarios are based on different assumptions to provide three distinctly different scenarios and risk estimates. The construction worker is assumed to be exposed only during the construction period, which involves direct contact with COPC-impacted soil and groundwater. The on-site worker is assumed to work indoors at the same on-site location for their entire career. After the construction period, it is assumed that the Site will be landscaped and/or paved and that the on-site commercial worker will not have direct contact with petroleum impacted soil. To account for possible outdoor exposure following further redevelopment of the Site, the outdoor landscape worker was also evaluated in this assessment. For the purposes of this assessment, it was assumed that the landscape receptor would contact COPC-impacted

surficial soil during initial soil preparation and planting of vegetation. Grounds keeping activities after planting, however, (e.g., watering, pruning, mowing) are not expected to involve direct contact with COPC-impacted soil.

Potential risks were conservatively estimated for these three hypothetical worker receptors assuming the presence of COPCs at levels detected during the past five years do not decrease (i.e., degrade) over time. It is assumed that these potential occupational receptors will have free access to the entire Site and could potentially contact COPCs at any location. Therefore, site-wide exposures were estimated using data collected from across the entire Site.

As noted, two office/commercial buildings are proposed for construction on the southeast portion of the Site, with one building planned for development on the corner of Grand Street and Fortmann Way. The restaurant/commercial building is planned for construction north of the office buildings, on the waterfront of the marina/harbor.

The proposed Grand Street office building will be adjacent to monitoring well MW-2, the location where BTEX compounds were detected in groundwater. To evaluate potential exposure to COPCs in this area, a localized risk analysis was conducted. In this scenario, it was assumed that the on-site construction and indoor commercial workers are exposed to COPC concentrations representative of the Grand Street office building area. This proposed future building was selected because it represents potential exposure closest to the detected COPCs groundwater. Since this scenario does not involve site-wide exposure, separate summary statistics were calculated using only data from sampling locations near the proposed Grand Street office building (monitoring wells MW-2 and MW-4). These groundwater summary statistics are presented in Table 5-1. Due to the small number of subsurface soil samples from the proposed Grand Street building area, and because earth-moving activities associated with building construction and Site preparation may not be limited to the area of the foundation, analysis of risk from exposure to subsurface soil will use the same data set relevant for site-wide exposures (Table 3-1).

5.2 Identification of Exposure Pathways

An exposure pathway describes how a receptor may be exposed to COPCs present at the Site. Four elements comprise an exposure pathway. These elements, shown below, are used to identify potential exposure pathways at the Site.

- A chemical source and a mechanism of chemical release to the environment.
- An environmental transport medium (e.g., air, groundwater) for the released chemical.
- A point of contact between the contaminated medium and the receptor (i.e., the exposure point).
- An exposure route (e.g., ingestion of contaminated soil) at the exposure point.

All four of these elements must be present for an exposure pathway to be potentially complete

Information concerning chemical waste sources, chemical release and transport mechanisms, locations of potentially exposed receptors, and potential exposure routes is used to develop a conceptual understanding of the Site. This information is typically outlined schematically in a conceptual site model (CSM) figure. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in exposures to aid in identifying data gaps, and to aid in identifying effective cleanup measures that target any and all significant contaminant sources and exposure pathways.

On January 19, 1996, SECOR and ACHCS discussed a preliminary CSM which tentatively identified potentially complete and significant pathways at the Site. The preliminary CSM was used to guide the scope of this exposure assessment.

5.2.1 Potentially Complete and Significant Exposure Pathways

The CSM as discussed in January 1996 indicates that the exposure pathways discussed below are potentially complete and significant for the on-site indoor commercial, outdoor construction worker, and landscape worker receptors selected for evaluation. These pathways were quantitatively evaluated in the risk assessment.

5.2.1.1 Identified Exposure Pathways for the On-site Construction Worker

The on-site construction worker may be exposed to COPCs via the following potentially complete exposure pathways:

Incidental ingestion of soil. Incidental ingestion of soil containing COPCs may occur during construction activities involving soil excavation. Therefore, exposure via this pathway was quantitatively evaluated.

Dermal contact with soil. Dermal contact with soil containing COPCs may occur during construction activities involving soil excavation. Therefore, exposure via this pathway was quantitatively evaluated.

Inhalation of airborne soil particulates. Airborne soil particulates may be emitted during on-site construction and excavation activities and result in inhalation of COPCs. Therefore, exposure via this pathway was quantitatively evaluated.

Dermal contact with groundwater. Dermal contact with groundwater may occur during excavation in areas of shallow depth to groundwater. Therefore, exposure via this pathway was quantitatively evaluated.

Inhalation of VOCs that emanate from Site subsurface soil to ambient air Although this pathway was identified in the preliminary CSM as a potentially complete and significant pathway, no volatile COPCs were identified in subsurface soil. B(a)P was evaluated as a subsurface soil COPC, but according to ASTM (1995), the solubility, Henry's constant, and log K_{oc} for B(a)P all indicate that it sorbs strongly to soils and is not subject to appreciable volatilization. Therefore, volatilization of B(a)P from Site subsurface soil to ambient air is not expected and this pathway was not quantitatively evaluated.

Inhalation of VOCs that emanate from Site groundwater to ambient air. A volatile COPC (benzene) is present in groundwater. This compound may volatilize and the vapor may migrate upward through the soil/air interface to ambient air. Because construction workers might be working in trenches and semi-enclosed spaces, chemicals may accumulate in these areas. For this reason, this exposure pathway was quantitatively evaluated in the risk assessment.

5.2.1.2 Identified Exposure Pathways for the On-site Landscape Worker

The on-site landscape worker may be exposed to COPCs via the following potentially complete exposure pathways:

Incidental ingestion of soil. Incidental ingestion of soil containing COPCs may occur during landscaping. Therefore, exposure via this pathway was quantitatively evaluated.

Dermal contact with soil. Dermal contact with soil containing COPCs may occur during landscaping involving soil excavation. Therefore, exposure via this pathway was quantitatively evaluated.

Inhalation of airborne soil particulates. Airborne soil particulates may be emitted during on-site landscaping activities and result in inhalation of COPCs. Therefore, exposure via this pathway was quantitatively evaluated.

Inhalation of chemical vapors emanating from groundwater. Although this meets all the requirements for a complete exposure pathway, exposure is expected to be minimal. Chemicals that migrate into outdoor air will disperse into the prevailing wind. This pathway is expected to lead to higher exposures for the on-site construction worker receptor, and is quantified for that receptor. For these reasons, this pathway was not quantitatively evaluated for the on-site landscape worker in the risk assessment.

5.2.1.3 Identified Exposure Pathways for the On-site Indoor Commercial Worker

The on-site indoor commercial worker may be exposed to COPCs via the following potentially complete exposure pathways:

Inhalation of volatile organic compounds (VOCs) that emanate from Site subsurface soil to indoor air. Although this pathway was identified in the preliminary CSM as a potentially complete and significant pathway, no volatile COPCs were identified in subsurface soil. B(a)P was evaluated as a subsurface soil COPC, but according to ASTM (1995), the solubility, Henry's constant, and $\log K_{ow}$ for B(a)P all indicate that it sorbs strongly to soils and will not appreciably volatilize. Therefore, volatilization of B(a)P from Site subsurface soil to indoor air was not quantitatively evaluated.

Inhalation of VOCs that emanate from Site groundwater to indoor air. A volatile COPC (benzene) is present in groundwater. This may volatilize and the vapor may migrate upward through the foundation of an on-site building to enclosed-space air. Therefore, exposure via this pathway was quantitatively evaluated in the risk assessment.

5.2.2 Incomplete Exposure Pathways

The following exposure pathways are considered to be incomplete. These incomplete exposure pathways are not further addressed in the risk assessment. In the following descriptions, the term "occupational" includes both the on-site indoor commercial worker and the on-site construction worker.

Ingestion and dermal contact with Site soil for the on-site commercial worker. It is assumed that the on-site commercial worker is engaged in indoor activities. Therefore, exposure via these pathways is not expected.

Inhalation of VOCs that emanate from Site subsurface soil to outdoor air for the on-site commercial worker. It is assumed that the on-site commercial worker is engaged in indoor activities. Therefore, exposure via this pathway is incomplete.

Inhalation of VOCs that emanate from Site groundwater to outdoor air for the on-site commercial worker. It is assumed that the on-site commercial worker is engaged in indoor activities. Therefore, exposure via this pathway is incomplete.

Inhalation of VOCs emanating from Site subsurface soil to indoor air for the on-site construction worker. It is assumed that all construction activities occur outdoors. Therefore, exposure via this pathway is incomplete.

Inhalation of VOCs emanating from Site groundwater to indoor air for the on-site construction worker. It is assumed that all construction activities occur outdoors. Therefore, exposure via this pathway is incomplete.

Ingestion and dermal contact with Site groundwater for the on-site commercial worker. Areas on-site are currently using a public water supply. Therefore, contact with groundwater is not expected.

Ingestion of Site groundwater for the on-site construction for the landscape worker. Although the on-site construction worker may come in direct use of groundwater during excavation activities, the volume of ingested groundwater is expected to be negligible.

Inhalation of VOCs volatilized from indoor Site groundwater use by the on-site construction or landscape worker. Areas on-site are currently not using a public water supply. Therefore, inhalation of VOCs volatilized from indoor groundwater use is not expected.

✓ **Inhalation of VOC vapors in outdoor ambient air by the on-site landscape worker.** This pathway meets all four criteria of a complete exposure pathway. However, due to the low VOC concentrations in the groundwater and the dilution that will occur in ambient air once vapors reach the surface soil, exposure to the on-site the landscape worker via this route is expected to be negligible.

Table 5-2 summarizes the receptor-specific pathways that were quantitatively evaluated in this assessment.

The exposure pathway analysis also indicated that no impacts to aquatic receptors in the Bay are expected from residual petroleum at the Site. PAHs and BTEX are typically considered the primary toxic components of TPHd. BTEX have not been detected in monitoring wells located closest to the Bay (MW-1, MW-5, MW-6, MW-7, and MW-8) since February 1995. The detection limit for BTEX is 0.5 $\mu\text{g/L}$, well below the USEPA ambient water quality criteria for BTEX, which range from several hundred to several thousand $\mu\text{g/L}$ for protection of aquatic life in saltwater and freshwater. The only BTEX constituents detected in the most recent quarterly groundwater sampling event performed at the Site were in the sample collected from monitoring well MW-2, which is located approximately 400 feet upgradient from the Bay. The BTEX concentrations reported in the sample collected from monitoring well MW-2, are below ambient water quality criteria. Furthermore, the BTEX concentrations reported in monitoring well MW-2 appear to be decreasing with time.

Seven monitoring wells (MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, and MW-8) were sampled for the following 16 PAHs: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, B(a)P, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3)pyrene, naphthalene, phenanthrene, and pyrene. As indicated in Table 3-2, only two PAHs - fluorene (0.9 ug/L) and naphthalene (0.93 ug/L) were detected in the sample collected from monitoring well MW-2. None of the 16 PAHs were detected in samples collected from the other six wells. Both of the detected concentrations of PAHs are well below the lowest available chronic national AWQC value of 6.16 ug/L for a PAH (i.e., fluoranthene; Suter, 1995). In addition, any chemicals in groundwater that reach the Bay will be instantaneously diluted upon entering surface water, further lowering concentrations to which aquatic organisms may be exposed.

Given these results, it appears that the remaining constituents of TPHd present at the Site do not represent a threat to aquatic organisms in the San Francisco Bay.

5.3 Exposure Estimates

The calculation of risk estimates requires as input the environmental medium concentration (i.e., the exposure point concentration) at the point of exposure and the estimated chemical intake. The methodology used to calculate exposure point concentrations and chemical intakes for each of the COPCs for the identified complete exposure pathways and identified receptors is presented in this section.

5.3.1 Estimation of Exposure Point Concentrations

The exposure point concentration (EPC) represents the amount of a chemical to which a hypothetical human receptor may be exposed. Consistent with EPA (1989a) recommendations, when evaluating an RME scenario, the lesser of the maximum and the 95 percent UCL is selected as the appropriate EPC. The EPC for the dermal and ingestion pathways are simply the selected concentrations in a specified media (i.e., water or soil). For inhalation exposure pathways, the EPC in air is estimated using various fate and transport models that consider, for example, the likelihood a specific chemical will either volatilize or adsorb to dust particles that eventually become suspended in air. The methods used to estimate EPCs in air are presented in Appendix B and the results summarized in Tables 5-3, 5-4a, and 5-4b.

5.3.2 Estimation of Chemical Intakes

To assess the potential adverse health effects associated with Site exposure, the potential level of human exposure to the selected chemicals (i.e., chemical intake) was estimated. USEPA has published exposure algorithms for the calculation of chemical intake (USEPA, 1989a). In these algorithms, chemical intake is a function of the exposure point concentration of a chemical, the receptor-specific contact rate, exposure frequency, exposure duration, body weight, and averaging time. In general, chemical intakes are conservatively estimated using upper-bound default exposure assumptions recommended by USEPA. The majority of the exposure assumptions used are published in the following documents: *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (USEPA, 1989a), *Exposure Factors Handbook* (USEPA, 1989b, 1996b), *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors* (USEPA, 1991a). Upper-bound default exposure assumptions are chosen for these parameters such that the combination of all exposure variables results in a reasonable maximum exposure (RME) for the exposure pathway evaluated. The goal of the RME is to quantify the maximum exposure which is reasonably expected to occur at a site; not the worst possible exposure (USEPA, 1989a).

All three worker receptors evaluated in this risk assessment were assumed to work a standard 8-hour day, 5 days a week. However, both the on-site commercial worker and the on-site landscape workers were assumed to work 250 days a year for 25 years (ASTM, 1995). The on-site construction worker was assumed to work at the Site 60 days for only one year.

5.3.2.1 Incidental Ingestion of Soil

Intake of the COPC via incidental ingestion of soil is a function of the ingestion rate, the fraction of ingested soil or dust that is contaminated, and the frequency and duration of exposure. This exposure pathway is evaluated for an on-site construction worker and an on-site landscape worker, who is assumed to be exposed to subsurface soil. Chemical intake via incidental ingestion of soil by two receptors was estimated with the following algorithm

$$CI = (CS \times IR \times CF \times EF \times ED \times FI) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
CS	=	Chemical concentration in soil (mg/kg)
IR	=	Soil ingestion rate (mg/day)
CF	=	Conversion factor (10 ⁻⁶ kg soil/mg soil)
FI	=	Fraction of soil ingested from contaminated source (unit less)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days).

480 mg/kg

The on-site construction worker was assumed to ingest 50 milligrams of soil per day (USEPA, 1992a). Consistent with USEPA (1991a) estimates for a person doing yard work, an ingestion rate of 480 mg/kg was assumed for the on-site landscape worker. The fraction of soil ingested per day from the Site was conservatively assumed to be 100 percent. The exposure assumptions including the estimated chemical intake for these two receptors potentially ingesting chemically-impacted soil are presented in Table 5-5 (construction worker) and Table 5-6 (landscape worker).

5.3.2.2 Dermal Contact with Soil

Intake of COPCs via dermal contact with soil is a function of the skin surface area available for contact, the soil-to-skin adherence factor, chemical-specific absorption factors, and the frequency and duration of exposure. This exposure pathway was evaluated for the construction and landscape worker receptors, who are assumed to be exposed to subsurface soil. Chemical intake via dermal contact with soil by the on-site construction worker was estimated with the following algorithm:

$$CI = (CS \times CF \times SA \times AF \times ABS \times EF \times ED \times FI) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
CS	=	Chemical concentration in soil (mg/kg)
CF	=	Conversion factor (10 ⁻⁶ kg soil/mg soil)
SA	=	Exposed skin surface area (cm ² /day)
AF	=	Soil-to-skin adherence factor (mg/cm ²)
ABS	=	Chemical-specific absorption factor (unit less)
FI	=	Fraction of soil contacted from contaminated source (unit less)
EF	=	Exposure frequency (days/year)

ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days).

For the on-site construction and the landscape worker receptors, the exposed skin surface area was assumed to be 2,000 square centimeters (cm²). This skin surface area is based on the "typical case" adult clothing scenario for outdoor activities, which assumes that an individual wears a long sleeve shirt, pants, and shoes, and that the exposed skin surface area is limited to the head and hands (USEPA, 1989b).

The soil-to-skin adherence factor is independent of the receptor being evaluated and was assumed to be 0.5 mg/cm²-event (ASTM, 1995). The absorption factor for the PAH, B(a)P was assumed to be 0.1 (California, 1994). The fraction of soil contacted by the on-site construction and landscape worker receptors was conservatively assumed to be 100 percent. The exposure assumptions including the estimated chemical intake for the on-site construction worker potentially dermally exposed to chemically-impacted soil are presented in Table 5-7 (construction worker) and Table 5-8 (landscape worker). Construction worker receptor estimates for the proposed Grand Street Building Area are presented in Appendix C.

5.3.2.3 Inhalation of Airborne Particulates

Intake of the COPC via inhalation of airborne particulates is a function of the inhalation rate, the fraction of inhaled particles that are retained in the lung, the exposure time, and the frequency and duration of exposure. This exposure pathway was evaluated for the on-site construction and the landscape worker receptors only.

Chemical intake via inhalation of airborne particulates by the on-site construction and landscape worker receptors was estimated with the following algorithm:

$$CI = (CA \times IR \times ET \times EF \times ED) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
CA	=	Chemical concentration in outdoor air (mg/m ³)
IR	=	Inhalation rate (m ³ /hour)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days).

The outdoor inhalation rate for the on-site construction and the landscape worker receptor was assumed to be 1.32 cubic meters of air per hour (m³/hr) (USEPA, 1996b).

These exposure assumptions including the estimated chemical intake for the on-site construction and landscape worker receptors for this pathway are presented in Table 5-9 (construction worker) and Table 5-10 (landscape worker). The methods used to estimate the concentration of B(a)P adsorbed to dust-in-air are presented in Appendix B and shown in Table 5-3.

5.3.2.4 Dermal Contact with Groundwater

Intake of COPCs via dermal contact with groundwater is a function of the skin surface area available for contact, the chemical-specific dermal permeability constant, and the frequency and duration of exposure. This exposure pathway was evaluated for the on-site construction worker receptor only. Exposure via this pathway was assumed to occur during excavation activities.

Chemical intake via dermal contact with groundwater by the on-site construction worker receptor was estimated based on the following algorithm:

$$CI = (C_{gw} \times SA \times PC \times CF \times ET \times EF \times ED \times FC) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
CW	=	Chemical concentration in groundwater (mg/L)
SA	=	Exposed skin surface area (cm ² /day)
PC	=	Dermal permeability constant (2.1 x 10 ⁻² cm/hour for benzene)
CF	=	Conversion factor (10 ⁻³ L/cm ³)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
FC	=	Fraction of time contacting exposure area
BW	=	Body weight (kg)
AT	=	Averaging time (days).

The exposed skin surface area for the on-site construction and landscape worker receptor was assumed to be 2,000 cm². This skin surface area was based on the "typical case" adult clothing scenario for outdoor activities, which assumes that an individual wears a long sleeve shirt, pants, and shoes, and that the exposed skin surface area is limited to the head and hands (USEPA, 1989b)

Although highly unlikely, it was conservatively assumed that the hypothetical on-site construction worker receptor would be exposed to groundwater each of the 60 days that they might be engaged in invasive soil activities at the Site. The exposure assumptions including the estimated chemical intake for the on-site construction worker contacting chemically-impacted groundwater are presented in Table 5-11 (site-wide exposures) and Table 5-12 (office building scenario).

5.3.2.5 Inhalation of Benzene (Ambient Air) Emanating from Groundwater

Chemical intake of benzene via inhalation of ambient air is a function of the ambient air concentration, the inhalation rate, time, frequency, and duration of exposure. Intake of benzene via this exposure pathway was evaluated for the on-site construction worker receptor only and was estimated with the following algorithm:

$$CI = (Ca \times IR \times ET \times EF \times ED) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
Ca	=	Chemical concentration in indoor air (mg/m ³)
IR	=	Inhalation rate (m ³ /hour)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days).

For the on-site construction worker receptor, the inhalation rate is assumed to be 1.32 m³/hr (USEPA, 1996b). Ambient air benzene concentrations were derived in Section 5.3.2 and are shown on Table 5-4a. Modeling used to derive these concentrations is presented in Appendix B. The exposure assumptions including the estimated chemical intake for the on-site construction worker inhaling benzene volatilizing from groundwater are presented in Table 5-13 (site-wide exposure) and Table 5-14 (office building scenario).

5.3.2.6 Inhalation of Benzene (Enclosed-Space Air) Emanating from Groundwater

Inhalation of benzene in an enclosed-space air is a function of the enclosed-space air concentration, the inhalation rate, and the time, frequency, and duration of exposure. Intake of benzene via this exposure pathway was evaluated for the on-site indoor commercial worker receptor only and was estimated with the following algorithm:

$$CI = (Ca \times IR \times ET \times EF \times ED) \times (BW \times AT)^{-1}$$

Where:

CI	=	Chemical Intake (mg/kg/day)
Ca	=	Chemical concentration in indoor air (mg/m ³)
IR	=	Inhalation rate (m ³ /hour)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days).

Enclosed-space air concentrations for benzene were derived in Section 5.3.1 and are shown on Table 5-4b. Modeling used to derive these concentrations is presented in Appendix B. For the on-site indoor commercial worker receptor, the inhalation rate was assumed to be 0.83 m³/hr (ASTM, 1995). The exposure assumptions including the estimated chemical intake for the on-site commercial worker through inhalation of benzene in indoor air are presented in Table 5-15. Table 5-16 summarizes the intake assumptions used for the three different worker receptors evaluated.

6.0 TOXICITY ASSESSMENT

The purpose of the toxicity assessment was to identify the toxicity values that are used for risk characterization purposes (Section 7.0). For this assessment, the toxicity information is summarized for two categories of potential effects: noncarcinogenic and carcinogenic. These two categories were selected because of the different methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens. Carcinogenic effects result in, or are suspected to result in, the development of cancer. Noncarcinogenic or systemic effects include a variety of toxicological endpoints and may include effects on specific organs and systems, such as the kidney (nephrotoxicants), the liver (hepatotoxicants), the nervous system (neurotoxicants), the lungs (pulmonary toxicants), and the reproductive organs (toxicants).

The toxicity values used in this risk assessment were obtained from a number of sources. The primary sources of information for carcinogens are Cal-EPA's Cancer Potency Factors document (Cal-EPA, 1995) and USEPA's Integrated Risk Information System (IRIS) (USEPA, 1997). The primary source for noncarcinogens is the IRIS data base (USEPA, 1997). IRIS contains only those toxicity values that have been verified by USEPA's Reference Dose or Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Groups. In addition to IRIS and Cal-EPA, provisional toxicity information was provided by USEPA's Region IX Preliminary Remediation Goals and USEPA's Region III Risk-Based Concentration Table.

The two sections below briefly describe the methodology for deriving toxicity values for the two COPCs. Toxicity values for inhalation and oral exposure routes are presented since these routes were identified in the exposure assessment (Section 5.2.1) as potentially significant exposure routes for COPCs.

6.1 Toxicity Information for Noncarcinogenic Effects

The critical toxicity value used to describe the dose-response relationship for noncancer effects is the reference dose (RfD). A chronic RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure that can be incurred during a lifetime, without an appreciable risk of a noncarcinogenic effect being incurred in human populations, including sensitive subgroups (USEPA, 1989a). The RfD is based on the assumption that thresholds exist for noncarcinogenic toxic effects (e.g., liver or kidney damage). It is a dose operationally derived by the application of one or more order of magnitude uncertainty factors to doses thought to represent a lowest or no observed adverse effect level in humans. Thus, there should be no adverse effects associated with chronic daily intakes below the RfD value. Conversely, if chronic daily intakes exceed this threshold level, there is a potential that some adverse noncarcinogenic health effects might be observed in exposed individuals. Table 6-1 presents the chronic RfDs for each of the COPCs.

6.2 Toxicity Information for Carcinogenic Effects

The toxicity value used to describe the dose-response relationship for carcinogenic effects is called the cancer slope factor (SF). The slope factor is a plausible upper-bound estimate of the probability of a carcinogenic response per unit intake of a chemical over a lifetime. Slope factors are expressed as the inverse of milligrams of chemical per kilogram of body weight per day (mg/kg-day)⁻¹. Evidence of chemical carcinogenicity originates primarily from two sources: 1) lifetime studies with laboratory animals, and 2) human (epidemiological) studies. For most chemical carcinogens, animal data from laboratory experiments represent the primary basis for the extrapolation. Major assumptions arise from the necessity of extrapolating experimental results: across species (i.e., from laboratory animals to humans); from high-dose regions (i.e., to which laboratory animals are exposed) to low-dose regions (i.e., levels to which humans are likely to be exposed in the environment); and across routes of administration (i.e., inhalation *versus* ingestion).

For chemical carcinogens, USEPA assumes a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction. This mechanism for carcinogenesis is referred to as stochastic, which means that there is theoretically no level of exposure to a given chemical that does not pose a small, but finite, probability of generating a carcinogenic response. Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, various mathematical models have been proposed to extrapolate from high to low doses (i.e., to estimate the dose-response relationship at low doses).

Currently, regulatory decisions are based on the output of the linearized multistage model (USEPA, 1989a). The basis of the linearized multistage model is that multiple events (*versus* the single-event paradigm of the one-hit model) may be needed to yield tumor induction (Crump *et al.*, 1977). The linearized multistage model reflects the biological variability in tumor frequencies observed in animals or human studies. The dose-response relationship predicted by this model at low doses is essentially linear. It should be noted that the slope factors calculated for chemical carcinogens using the multistage model represent the 95th percentile upper confidence limit on the probability of a carcinogenic response. Consequently, risk estimates based on these slope factors are conservative estimates representing upper-bound estimates of risk.

Uncertainties in the toxicity assessment for chemical carcinogens are dealt with by classifying each chemical into one of several groups, according to the weight of evidence from epidemiological studies and animal studies, as follows:

- | | |
|---------|---|
| Group A | Human Carcinogen (sufficient evidence of carcinogenicity in humans). |
| Group B | Probable Human Carcinogen (B1—limited evidence of carcinogenicity in humans, B2—sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans). |

- Group C Possible Human Carcinogen (limited evidence of carcinogenicity in the animals and inadequate or lack of human data).
- Group D Not Classifiable as to Human Carcinogenicity (inadequate or no evidence).
- Group E Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies).

Table 6-1 presents the slope factors and the weight-of-evidence for each of the COPCs identified at the Site. Tables 6-2 and 6-3 present toxicological profiles for the COPCs - benzene and B(a)P. These profiles provide historical information, routes of exposure, chemical interactions with other chemicals, toxicological disposition, as well as information regarding the toxic effects of the chemical in humans and animals.

7.0 RISK CHARACTERIZATION

The risk characterization process compares the data from the exposure and toxicity assessments. The exposure assessment information necessary for making a reasonable risk characterization includes the estimated intakes, exposure modeling assumptions, and a list of exposure pathways that contribute to the exposure of the same individuals over the same time period (USEPA, 1989a). This information is provided for every chemical to which the receptors may be exposed.

Risk characterization combines the toxicity and exposure assessments to allow for an estimate of the risk at a site. Two methods are used to characterize cancer risk and noncancer health effects. The first method evaluates chemicals with carcinogenic effects by estimating excess lifetime cancer risk. The second method evaluates chemicals with noncarcinogenic effects (USEPA, 1989a). Spreadsheets used to estimate cancer risks and noncancer adverse health effects are presented in Appendix C.

7.1 Estimated Lifetime Excess Cancer Risk

Excess lifetime cancer risks (cancer risks) are estimated by combining the chemical-specific intake with USEPA or Cal-EPA developed cancer slope factors. A receptor and pathway-specific cancer risk is estimated based on the following equation (USEPA, 1989a).

$$CR = I \times SF$$

Where:

CR	=	Estimated excess lifetime cancer risk (unit less)
I	=	Exposure intake for chemical (mg/kg/day)
SF	=	Slope Factor for chemical (mg/kg/day) ⁻¹ .

The risks from all exposure pathways were then summed to estimate a "total" risk for a receptor. Cancer risks are typically considered acceptable if they are either within or below the range of 1×10^{-6} to 1×10^{-4} (USEPA, 1990; Cal-EPA, 1992).

7.2 Estimated Noncancer Adverse Health Effects

Noncancer effects are evaluated by estimating a hazard quotient (HQ) which is based on the following equation:

$$HQ = I \times RfD^{-1}$$

Where:

I	=	Intake for chemical (mg/kg/day)
RfD	=	Reference Dose for chemical, (mg/kg/day)

The Hazard Index (HI) for individual exposure scenarios is then estimated by summing HQs based on the following equation:

$$HI = \sum HQ_i$$

Where:

HI = Hazard Index (HI)
HQ_i = Hazard Quotient.

The HI represents the sum of all chemical-specific HQs for all exposure pathways quantitatively evaluated. EPA (1989) guidance states that, if either an HI or HQ exceeds unity (1), "...there may be a concern for potential noncancer effects." An HQ or HI of 1 or less indicates that adverse noncancer health effects are unlikely. In addition, because there is only one COPC (benzene) evaluated for noncancer effects across only one exposure pathway (inhalation), the HQ and the HI are identical (Tables 7-1 and 7-2).

7.3 Results of the Site-Wide Human Health Risk Assessment

This section presents the results of the site-wide risk characterization step described in the previous section for the hypothetical on-site construction worker and the on-site landscape worker receptors.

7.3.1 On-site Construction Worker

The site-wide estimated total excess cancer risk for the hypothetical on-site construction worker receptor was 2×10^{-9} . This estimate is well below the USEPA and Cal-EPA acceptable excess cancer risk range of 1×10^{-5} to 1×10^{-6} (Table 7-1). The estimated HI for this receptor of 4×10^{-4} is over three orders of magnitude below the USEPA and Cal-EPA threshold HI of 1.

7.3.2 On-site Landscape Worker Receptor

The site-wide total excess cancer risk for the hypothetical on-site landscape worker receptor was 5×10^{-9} . This estimate is well below the USEPA and Cal-EPA acceptable excess cancer risk range of 1×10^{-5} to 1×10^{-6} (Table 7-1). Because either other exposure pathways were incomplete or considered insignificant (Section 5.2), noncancer adverse health effects (i.e., HQs and HIs) were not estimated for this receptor.

7.4 Results of the Proposed Building Risk Assessment

This section summarizes the results of the HHRA that evaluated potential human exposure by either a hypothetical on-site construction worker receptor or an on-site commercial worker receptor at the proposed location of the two office buildings.

7.4.1 On-site Commercial Worker

The total excess cancer risk for the hypothetical on-site commercial building worker receptor was 4×10^{-6} . This estimate is within the USEPA and Cal-EPA acceptable excess cancer risk range of 1×10^{-4} to 1×10^{-6} (Table 7-2) and below the 1×10^{-5} level typically used for non-residential scenarios. The estimated HI for this receptor of 7×10^{-2} is well below the USEPA and Cal-EPA threshold HI of 1.

On-site Construction Worker. The total excess cancer risk for the hypothetical on-site construction worker receptor was 8×10^{-8} . This estimate is below the USEPA and Cal-EPA acceptable excess cancer risk range of 1×10^{-4} to 1×10^{-6} (Table 7-2). The estimated HI of 3×10^{-2} for this receptor does not exceed the USEPA and Cal-EPA threshold HI of 1.

8.0 UNCERTAINTY ANALYSIS

The uncertainty analysis characterizes the propagated uncertainty in a health risk assessment. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risks and hazards. Additionally, uncertainties are introduced in the risk assessment when exposures to multiple substances across multiple pathways are summed.

Quantifying uncertainty is an important component of the risk assessment process. According to USEPA's *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment" (USEPA, 1992d). This section presents the major sources of uncertainty associated with the risk assessment. The following four stages of the risk assessment process can introduce uncertainties:

1. Data Collection and Evaluation
2. Exposure Assessment
3. Toxicity Assessment
4. Risk Characterization

Key uncertainties associated with each of these stages are described below.

8.1 Key Uncertainties Associated with Data Collection and Evaluation

The techniques used for data sampling and analysis, and methods used for selecting chemicals for evaluation in the risk assessment may result in a number of uncertainties. In addition, uncertainty is introduced through the use of estimated concentrations for B(a)P in soil in the quantitative assessment. These uncertainties are discussed below.

Systematic or random errors in the chemical analyses may yield erroneous data. These types of errors may result in a slight over- or underestimate of risk. Ninety-five percent UCL concentrations are used to represent levels of Site contaminants. Use of 95 UCL concentrations provides a conservative estimate of average Site concentrations and can compensate for potential deficiencies in sample size, or systemic or random errors in the chemical analysis.

According to diesel fuel chemical composition values (State of California, 1989), the concentration of B(a)P in diesel fuel #2 is 0.07 $\mu\text{g}/\text{gm}$. B(a)P concentrations in soil are estimated by applying this composition factor to TPHd concentrations in soil. The proportion that is B(a)P may also vary with the type of diesel fuel, therefore, there is a moderate amount of uncertainty associated with this method of estimation.

8.2 Uncertainties Associated with Exposure Assessment

A number of uncertainties are associated with the exposure assessment, such as exposure point concentrations and the assumptions used to estimate chemical intake in the exposure assessment. Major uncertainties associated with these components of the risk assessment are summarized below.

Vapor Transport Model

- The model used assumes that the soil concentration of a particular chemical beneath the foundation of a building is uniform. This assumption may result in a slight over- or underestimate of risk.
- The model used assumes that vapors enter a structure primarily through cracks and openings in the foundation floor, and only by diffusion and convection. This assumption may result in a slight over- or underestimate of risk.
- The model used assumes vapor transport arising only from source areas beneath foundations. It does not consider lateral transport of soil vapor away from or towards foundations. This assumption may result in a slight underestimate of risk.
- The model used assumes a non-diminishing and continuous source of chemicals in subsurface soil beneath buildings. For highly volatile compounds, this assumption may result in a moderate to high overestimate of risk.
- The model used assumes that soil is homogenous in the horizontal plane. This assumption may result in a slight over- or underestimate of risk.
- The model used does not assume chemical removal in soil due to biodegradation, chemical oxidation, hydrolysis, or other chemical removal processes. This assumption may result in a moderate overestimate of risk.
- The model used assumes that indoor air exchange with outside air is the only mechanism for dilution of chemicals in air in a building. This assumption may result in a slight overestimate of risk.
- Default values presented in ASTM (1995) were used to estimate vapor transport model inputs for building floor area and ventilation rates. This default value may not be representative of actual building characteristics at the Site and may result in a slight over- or underestimate of risk.
- The maximum of the range of literature-reported values (0.01 to 0.001) was used as the estimate of the fraction of cracks in the building floor. This assumption may result in a moderate overestimate of risk.

Chemical Intake

- For estimating chemical intake, there are uncertainties associated with standard exposure assumptions, such as body weight, period exposed, life expectancy, population characteristics, and lifestyle. Assumptions made for these exposure parameters may not be representative of any actual exposure situation, but likely lead to a moderate estimate of risk.
- The data from the Site were grouped to evaluate average site-wide exposure conditions and localized exposure in the area of the planned Grand Street building. Assumptions made for this grouping of data may not be representative of any actual exposure situation and may result in a slight over- or underestimate of risk.
- An assumption of the exposure assessment is that the period of chemical intake is assumed to be constant and representative of the exposed population. This assumption has the potential for overestimating exposure. Similarly, the assumption that exposure occurs on a daily basis over a lifetime may result in an overestimate of exposure.

8.3 Uncertainties Associated with Toxicity Assessment

Toxicity information for many chemicals is often limited. Consequently, there are varying degrees of uncertainty with the toxicity values calculated. These uncertainties may result in an over- or underestimate of risk. Sources of uncertainty associated with toxicity values include:

- USEPA has established a toxicity value for B(a)P, however the concentrations in soil for this risk assessment are estimated from TPHd concentrations. This method does not account for other PAHs, which may be present as much as 5 to 10 percent in marine diesel. This may result in a moderate underestimate of risk.
- An oral provisional toxicity value for TPHd was proposed in 1992 (USEPA, 1992d) based on studies of inhalation of diesel fuel by laboratory animals. USEPA notes that in addition to the usual uncertainties associated with using route-to-route extrapolation to derive an oral toxicity value from inhalation studies, there is additional uncertainty due to the differences in composition between original fuel mixtures and spilled fuel that has weathered in the environment and lost significant amounts of the volatile components. USEPA provides a soil screening value of 5,000 mg/kg, which is higher than most TPHd concentrations at the Site. Because of the great uncertainty associated with the TPHd toxicity value, and considering that Site concentrations are below the screening value, TPHd was not quantitatively evaluated. This may result in a slight underestimate of risk.

- Dose-response information from effects observed at high doses was used by USEPA to predict the adverse health effects that may occur following exposure to the low levels expected from human contact with the agent in the environment. This may result in a moderate overestimate of risk.
- Dose-response information from short-term exposures was used by USEPA to predict the effects of long-term exposures, and vice-versa. This may result in a moderate over- or underestimate of risk.
- Dose-response information from animal studies was used by USEPA to predict effects in humans. Because sensitive laboratory animals are typically used in such studies, this may result in a slight moderate overestimate of risk.
- Dose-response information from homogeneous animal populations or human populations was used to predict the effects likely to be observed in the general population consisting of individuals with a wide range of sensitivities. Due to safety factors applied in development of toxicity values, this may result in a slight overestimate of risk.

8.4 Uncertainties Associated with Risk Characterization

Potential risks were based on an assumed site-wide average exposure and a localized exposure in the area of the planned Grand Street building and may not represent actual exposure or risks. A number of limitations are associated with the risk characterization approach for carcinogens and noncarcinogens. For estimating potential excess cancer risk, the slope factor used to convert chemical intake averaged over a lifetime to incremental risk is often an 95 UCL of the probability of response. In addition, slope factors derived from animal data will be given the same weight as slope factors derived from human data. These factors may contribute to an overestimate of risk.

The noncancer risk summation approach includes the following limitations. First, hazard quotients are combined for substances with reference doses based on varying toxicological significance, uncertainty, and modifying factors. Because reference doses do not have equal accuracy of precision and are not based on the same severity of effects, this has the effect of skewing the level of concern associated with approaching a HI of unity so that it is not linear.

8.5 Summary of Risk Assessment Uncertainties

An analysis of the uncertainties associated with the risk assessment indicates that cancer and noncancer health risk and hazard estimates are likely to overestimate actual risks posed by Site COPC. Although many factors can contribute to the potential for over- or underestimating risk, as outlined in the sections above, in general a mixture of conservative and upper-bound input values were selected to estimate potential exposures. Compounding conservative and upper-bound input values in the risk calculations results in reasonable maximum, health-protective risk estimates. Actual risks are likely to be less than those estimated using the assumptions considered in this evaluation.

9.0 SUMMARY AND CONCLUSIONS

The risk assessment is based on a receptor and exposure pathway analysis presented in a preliminary CSM discussed with ACHCS during a meeting on January 19, 1996. Exposure was evaluated for the most likely human receptors: an on-site commercial worker receptor, an on-site construction worker receptor, and an on-site landscape worker receptor. The risk assessment also considered two areas of exposure, one assuming exposure randomly across the Site, and the other assuming exposure near the proposed location of an office building at the corner of Grand Street and Fortmann Way.

With only one exception, cancer risk estimates for the three hypothetical on-site worker receptors were well below the USEPA and Cal-EPA acceptable carcinogenic risk range of 1×10^{-4} to 1×10^{-6} .

Only the estimated cancer risk for the on-site commercial worker exceeded the lower bound (1×10^{-6}) agency level of concern for carcinogens. It was, however, below the typical level of 1×10^{-5} targeted for nonresidential land use scenarios. In addition, estimated HIs for all three receptors were well below the agency threshold level of concern (unity).

Based on this risk assessment, the Site qualifies as a low risk soil and groundwater site (as defined by the RWQCB, San Francisco Bay Region [State of California, 1996]) and we therefore recommend closure with no further remedial action required.

10.0 REFERENCES

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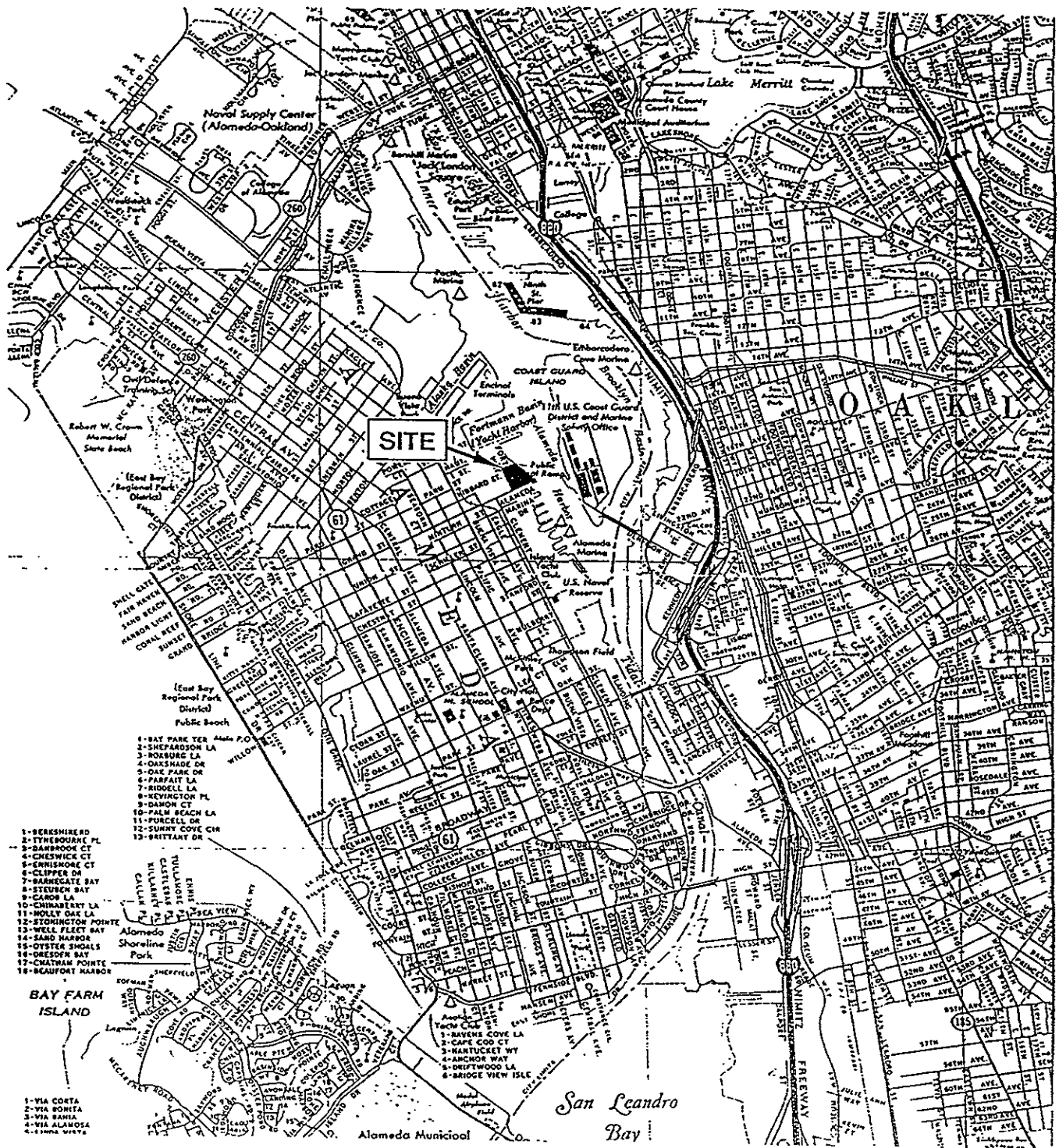
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FIGURES



SOURCE: BASE MAP FROM H.M. GOUSHA, 1988,
OAKLAND AND EAST BAY CITIES.



NORTH

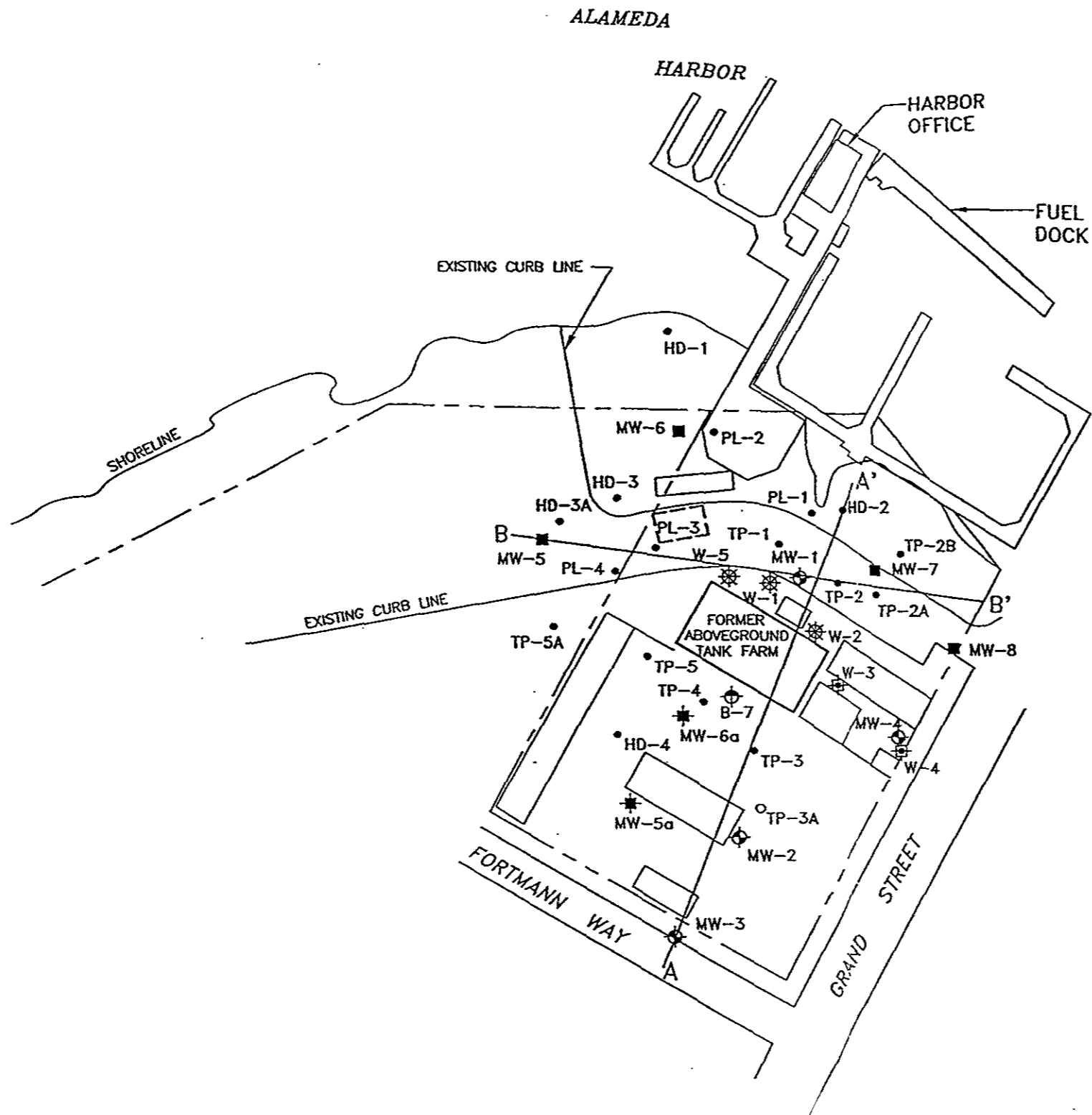


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INTERNATIONAL
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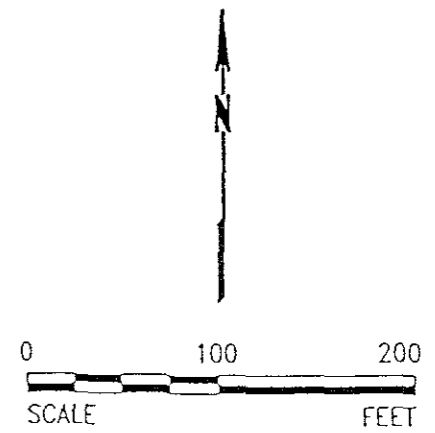
FIGURE 1
GRAND MARINA FACILITY
ALAMEDA, CALIFORNIA
SITE LOCATION MAP

SECOR 1055



LEGEND

- MW-5a * MONITORING WELL (ACC, 10/94)
- MW-8 ■ MONITORING WELL (SECOR, 10/94)
- TP-3A ○ BORING (SECOR, 10/94)
- PL-2 ● BORING (SECOR, 10/93)
- MW-1 ⊕ MONITORING WELL (ZACCOR, 5/92)
- B-7 ⊕ MONITORING WELL (HARDING-LAWSON, 6/87)
- W-3 ⊗ ABANDONED MONITORING WELL (CROWLEY ENVIRONMENTAL SERVICES, 4/87)
- W-4 ⊕ MONITORING WELL (CROWLEY, 4/87)
- PROPERTY LINE
- B———B' LINE OF CROSS SECTIONS



SOURCE: BASED ON SURVEY BY RON ARCHER, CML ENGINEER INC., NOVEMBER 1994

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FIGURE 2
GRAND MARINA FACILITY
ALAMEDA, CALIFORNIA

SITE PLAN

199501.131731 1110081WARIANA181TEPL1

TABLES

TABLE 3-1
Site-Wide Statistical Summary
Soil and Groundwater
Grand Street and Fortmann Way Property
Alameda, California

Detected Chemical ^a	Units	Number of Analyses	Number of Detects	Frequency of Detection	Minimum Detected Groundwater Concentration	Maximum Detected Groundwater Concentration	95% Upper Confidence Limit (95 UCL) of the Mean ^b
Soil							
Benzene	mg/kg ^b	65	4	6%	0.006	0.24	0.017
Toluene	mg/kg	65	13	20%	0.005	1.2	0.12
Ethylbenzene	mg/kg	65	16	25%	0.01	1.0	0
Total Xylenes	mg/kg	65	28	43%	0.009	15	1.1
Benzo(a)pyrene (B(a)P)	mg/kg	62	54	87%	0.00000091 ^c	0.0015 ^c	0.00020
Groundwater							
Benzene	mg/L ^d	55	7	13%	0.5	4.0	0.26
Toluene	mg/L	55	9	16%	0.8	11	0.63
Ethylbenzene	mg/L	55	6	11%	6.4	0.50	0.030
Total Xylenes	mg/L	55	9	16%	1.3	2.9	0.17
Fluorene	mg/L	7	1	14%	0.0009	0.0009	0.006
Napthalene	mg/L	7	1	14%	0.0093	0.0093	0.0071

Footnotes:

^aFor analytes not detected (ND) above the method reporting limit (MRL), one-half of the MRL was used to represent the soil concentration for statistical purposes.

^bmg/kg = milligrams per kilogram.

^cAs recommended by the State of California (California, 1989), the B(a)P concentration was estimated by multiplying the detected concentration of total petroleum hydrocarbons as diesel (TPHd) by a factor of 7×10^{-8} .

^dmg/L = milligrams per liter.

References:

California, 1989. State of California Leaking Underground Fuel Tank Field Manual.

Table 3-2
Summary of Groundwater Analytical Results
Polycyclic Aromatic Hydrocarbons (PAHs)
March 1996 Data
Grand Street and Fortmann Way Property
Alameda, California

CHEMICAL	MW-1			MW-2			MW-4			MW-5			MW-6			MW-7			MW-8					
	Detection Limit (mg/L) ^a	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)			
Acenaphthene	0.01	ND ^b	0.005	0.002	ND	0.001	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Acenaphthylene	0.01	ND	0.005	0.002	ND	0.001	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Anthracene	0.01	ND	0.005	0.0005	ND	0.00025	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Benzo(a)anthracene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Benzo(a)pyrene	0.01	ND	0.005	0.00005	ND	0.000025	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Benzo(b)fluoranthene	0.01	ND	0.005	0.00005	ND	0.000025	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Benzo(g,h,i)perylene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Benzo(k)fluoranthene	0.01	ND	0.005	0.00005	ND	0.000025	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Chrysene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Dibenzo(a,h)anthracene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Fluoranthene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Fluorene	0.01	ND	0.005	-- ^c	0.0009	0.0009	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Indene(1,2,3)pyrene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Naphthalene	0.01	ND	0.005	--	0.0093	0.0093	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Phenanthrene	0.01	ND	0.005	0.0005	ND	0.00025	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005
Pyrene	0.01	ND	0.005	0.0001	ND	0.00005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005	0.01	ND	0.005

Footnotes

^amg/L = milligrams per liter

^bND = not detected above the method detection limit.

^c-- indicates result is not available.

TABLE 4-1
Tier 1 - Comparison of Maximum Groundwater and Soil Concentrations and
Risk-Based Screening Levels
Grand Street and Fortmann Way Property
Alameda, California

Detected Chemical	Units	Maximum Detected Concentration	Risk-Based Screening Level (RBSL) ^a	Does Maximum Concentration Exceed RBSL?	Chemical is Retained as a COPC ^b
Exposure Pathway: Incidental Ingestion, Dermal Contact, and Dust Inhalation from Soil					
Benzene	mg/kg ^f	0.24	29	No	No
Toluene	mg/kg	1.2	18,700	No	No
Ethylbenzene	mg/kg	1.0	11,500	No	No
Total Xylenes	mg/kg	15	208,000	No	No
Benzo(a)pyrene (B(a)P)	mg/kg	0.0015 ^g	3.04	No ^h	Yes ^h
Exposure Pathway: Groundwater Volatilization to Indoor Air					
Benzene	mg/L ^c	4.0	0.214	Yes ✓	Yes
Toluene	mg/L	11	85	No	No
Ethylbenzene	mg/L	0.50	>S ^d	No	No
Total Xylenes	mg/L	2.9	>S	No	No
Fluorene	mg/L	0.0009	0.240 ^e	No	No
Napthalene	mg/L	0.0093	12.3	No	No
Exposure Pathway: Groundwater Volatilization to Outdoor Air					
Benzene	mg/L	4.0	5.34	No	No
Toluene	mg/L	11	>S	No	No
Ethylbenzene	mg/L	0.50	>S	No	No
Total Xylenes	mg/L	2.9	>S	No	No
Fluorene	mg/L	0.0009	0.240 ^e	No	No
Napthalene	mg/L	0.0093	>S	No	No

Footnotes:

^aUnless otherwise specified, the risk-based screening levels (RBSLs) were obtained from ASTM (1995).

^bCOPC = Chemical of Potential Concern.

^cmg/L = milligrams per liter.

^d">S" indicates that the selected risk level cannot be exceeded for any possible dissolved levels of a chemical.

^eIn the absence of an ASTM (1995) reported RBSL for fluorene, the EPA Region IX Preliminary Remediation Goal (PRG) of 0.240 mg/L, assuming domestic use of groundwater, was used as an RBSL (USEPA, 1996).

^fmg/kg = milligrams per kilogram.

^gAs recommended by the State of California (California, 1989), the B(a)P concentration was estimated by multiplying the maximum detected concentration of total petroleum hydrocarbons as diesel (TPHd) (21,000 mg/kg) by a factor of 7×10^{-4} .

^hAlthough the estimated soil concentration of B(a)P does not exceed the RBSL, as an added measure of conservatism B(a)P was selected as a COPC.

References:

- ASTM, 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.
 California, 1989. State of California Leaking Underground Fuel Tank Field Manual.
 USEPA, 1996. Region IX Preliminary Remediation Goals 1996. August.

TABLE 5-1
Groundwater Monitoring Wells MW-2 and MW-4 Statistical Summary
Building Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California

Detected Chemical	Units	Number of Analyses	Number of Detects	Frequency of Detection	Minimum Detected Groundwater Concentration	Maximum Detected Groundwater Concentration	95% Upper Confidence Limit (95 UCL) of the Mean ^a
Groundwater							
Benzene	mg/L ^b	14	6	43%	0.19	4.0	1.0
Toluene	mg/L	14	6	43%	0.035	11	2.6
Ethylbenzene	mg/L	14	6	43%	0.0064	0.5	0.12
Total Xylenes	mg/L	14	6	43%	0.016	2.9	0.69
Fluorene	mg/L	2	1	50%	0.0009	0.0009	0.029
Napthalene	mg/L	2	1	50%	0.0093	0.0093	0.034

Footnotes:

^aFor analytes not detected (ND) above the method reporting limit (MRL), one-half of the MRL was used to represent the soil concentration for statistical purposes.

^bmg/L = milligrams per liter.

Table 5-2
Summary of Potentially Complete Exposure Pathways
Grand Street and Fortmann Way Property
Alameda, California

Exposure Pathway ^a	RECEPTOR		
	On-Site Construction Worker	On-Site Commercial Worker	On-Site Landscape Worker
SOIL PATHWAYS			
COPC^b: Benzo(a)pyrene			
Incidental Soil Ingestion	x ^c	-- ^d	x
Dermal Contact with Soil	x	--	x
Inhalation of Airborne Soil Particulates	x	--	x
GROUNDWATER PATHWAYS			
COPCs: Benzene and Fluorene			
Dermal Contact with Groundwater	x	--	--
Inhalation of VOCs Emanating from Groundwater to Indoor Air	--	x	--
Inhalation of VOCs Emanating from Groundwater to Ambient Outdoor Air	x	--	--

Footnotes:

^aRefer to Section 5.2.1 for additional information regarding exposure pathways.

^bCOPC = Chemical of Potential Concern.

^c"x" = Indicates that the pathway is considered complete and therefore quantitatively evaluated for this receptor.

^d"--" = Indicates that the pathway is not considered complete and therefore not quantitatively evaluated for this receptor.

Table 5-3
Site-Wide Exposure Point Concentrations for Benzo(a)pyrene [B(a)P] in Soil
Grand Street and Fortmann Way Property
Alameda, California

Receptor Evaluated	Estimated Concentration of B(a)P in Soil ^a (mg/kg) ^c	Estimated Concentration of B(a)P in Air ^b (mg/m ³) ^d
Construction Worker	0.00020	1.99E-10
Landscape Worker	0.00020	5.40E-11

Footnotes:

^aRepresents the lesser of the maximum detected concentration and the 95 percent upper confidence limit (Table 3-1).

^bValues obtained from Table B-2.

^cmg/kg = milligrams per kilogram.

^dmg/m³ = milligrams per cubic meter.

Table 5-4a
Site-Wide Exposure Point Concentrations for Benzene in Groundwater
Grand Street and Fortmann Way Property
Alameda, California

.26

Receptor	Groundwater Concentration ^a (mg/L) ^c	Ambient Air Concentration Outdoors ^b (mg/m ³) ^d
Onsite Construction Worker	2.60E-01 <i>0.26</i>	3.05E-05
Onsite Landscape Worker	2.60E-01 <i>0.26</i>	7.62E-06

Footnotes:

^aRepresents the lesser of the maximum detected concentration and the 95 percent upper confidence limit (Table 3-1).

^bAmbient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM-based volatilization factor (VF_{wamb}) [mg/m³-air]/(mg/L-H₂O)] (See Appendix B).

^cmg/kg = milligrams per kilogram.

^dmg/m³ = milligrams per cubic meter.

Table 5-4b
Exposure Point Concentrations for Benzene in Groundwater
Office Building Scenario
Grand Street and Fortmann Way Property
Alameda, California

Receptor	Groundwater Concentration (mg/L) ^c	Enclosed Air Concentration ^a (mg/m ³) ^d	Ambient Air Concentration Outdoors ^b (mg/m ³) ^d
Onsite Commercial Worker	1.03E+00	1.77E-03	--
Onsite Construction Worker	1.03E+00	--	2.14E-03

Footnotes:

^aEnclosed air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM-based volatilization factor (VFWesp) [mg/m³-air]/(mg/L-H₂O)] (See Appendix B).

^bAmbient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM-based volatilization factor (VFWamb) [mg/m³-air]/(mg/L-H₂O)] (See Appendix B).

^cmg/kg = milligrams per kilogram.

^dmg/m³ = milligrams per cubic meter.

1.1.1.1

Table 5-5
Site-Wide Chemical Intake Exposure Estimates -- Incidental Soil Ingestion
Onsite Construction Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

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

Intake Parameter	Construction Worker Value
CS = Concentration of B(a)P in soil (mg/kg)	0.0002
IR = Soil ingestion rate (mg/day)	50
CF = Conversion factor (kg/mg)	1E-06
EF = Exposure frequency (days/year)	60
ED = Exposure duration (years)	1
FI = Fraction from contaminated source (unitless)	1
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	365
Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)	2.35E-11
Intake for carcinogens (mg/kg-day)	3.35E-13

Footnotes:

¹ All of the soil contacted is assumed to be site-related.

Table 5-6
Site-Wide Chemical Intake Exposure Estimates – Incidental Soil Ingestion
Onsite Landscape Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

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

Intake Parameter	Landscape Worker Value
CS = Concentration of B(a)P in soil (mg/kg)	0.0002
IR = Soil ingestion rate (mg/day)	480
CF = Conversion factor (kg/mg)	1E-06
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
FI = Fraction from contaminated source (unitless)	1
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	6,250
Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)	1.37E-09
Intake for carcinogens (mg/kg-day)	3.35E-10

Footnotes:

^aAll of the soil contacted is assumed to be site-related.

Table 5-7
Site-Wide Chemical Intake Exposure Estimates -- Dermal Contact with Soil
Onsite Construction Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$\text{Intake (mg/kg-day)} = [CS \times CF \times SA \times AF \times ABS \times EF \times ED \times FI] / [BW \times AT]$$

Intake Parameter	Landscape Worker
	Value
CS = Concentration of B(a)P in soil (mg/kg)	0.0002
CF = Conversion factor (kg/mg)	1E-06
SA = Skin Surface Area (cm ² /day)	2,000
AF = Soil/skin adherence factor (mg/cm ²)	0.5
ABS = Absorption factor (unitless)	0.10
ABS = Absorption factor-inorganics (unitless)	
EF = Exposure frequency (days/year)	60
ED = Exposure duration (years)	1
FI = Fraction from contaminated source (unitless)	1
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	365
Carcinogens	25,550
Intake for Noncarcinogens (mg/kg-day)	4.70E-11
Intake for Carcinogens (mg/kg-day)	6.71E-13

Footnotes:

^aAll of the soil contacted is assumed to be site-related.

Table 5-8
Site-Wide Chemical Intake Exposure Estimates -- Dermal Contact with Soil
Onsite Landscape Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$\text{Intake (mg/kg-day)} = [CS \times CF \times SA \times AF \times ABS \times EF \times ED \times FI] / [BW \times AT]$$

Intake Parameter	Landscape Worker
	Value
CS = Concentration of B(a)P in soil (mg/kg)	0.0002
CF = Conversion factor (kg/mg)	1E-06
SA = Skin Surface Area (cm ² /day)	2,000
AF = Soil/skin adherence factor (mg/cm ²)	0.5
ABS = Absorption factor (unitless)	0.10
ABS = Absorption factor-inorganics (unitless)	0.001
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
FI = Fraction from contaminated source (unitless)	1
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	6,250
Carcinogens	25,550
Intake for Noncarcinogens (mg/kg-day)	2.86E-10
Intake for Carcinogens (mg/kg-day)	6.99E-11

Footnotes:

^aAll of the soil contacted is assumed to be site-related.

Table 5-9
Site-Wide Chemical Intake Exposure Estimates – Inhalation of Airborne Particulates
Onsite Construction Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$Intake (mg/kg-day) = [CA \times IR \times ET \times EF \times ED] / [BW \times AT]$$

Intake Parameter	Construction Worker Value
CA = Concentration of B(a)P in air (mg/m ³)	1.99E-10
IR = Inhalation rate, outdoor (m ³ /hr)	1.32
ET = Exposure time (hr/day)	8
EF = Exposure frequency (days/year)	60
ED = Exposure duration (years)	1
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	365
Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)	4.93E-12
Intake for carcinogens (mg/kg-day)	7.04E-14

Footnotes:

^aAll of the soil contacted is assumed to be site-related.

Table 5-10
Site-Wide Chemical Intake Exposure Estimates – Inhalation of Airborne Particulates
Onsite Landscape Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

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

Intake Parameter	Landscape Worker
	Value
CA = Concentration of B(a)P in air (mg/m ³)	5.40E-11
IR = Inhalation rate, outdoor (m ³ /hr)	1.32
ET = Exposure time (hr/day)	8
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	6,250
Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)	8.14E-12
Intake for carcinogens (mg/kg-day)	1.99E-12

Footnotes:

^aAll of the soil contacted is assumed to be site-related.

Table 5-11
Site-Wide Chemical Intake Exposure Estimates -- Dermal Contact with Groundwater
Onsite Construction Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$\text{Intake (mg/kg-day)} = [C_{gw} \times SA \times PC \times CF \times ET \times EF \times ED \times FC] / [BW \times AT]$$

Intake Parameter	Construction Worker	
	Value	
C _{gw} = Concentration of Benzene in groundwater (mg/L)	0.26	
SA = Skin surface area (cm ² /day)	2,000	
PC = Dermal permeability constant (cm/hr) ^b		
for Benzene	2.10E-02	
CF = Conversion factor (L/cm ³)	1E-03	
ET = Exposure time (hr/day)	8	
EF = Exposure frequency (days/year)	60	
ED = Exposure duration (years)	1	
FC = Fraction of time contacting exposure area	1	
BW = Body weight (kg)	70	
AT = Averaging time (days)		
Noncarcinogens	365	
Carcinogens	25,550	
Intake for noncarcinogens (mg/kg-day)	2.05E-07	
Intake for carcinogens (mg/kg-day)	2.93E-09	

Footnotes:

^aAll contact with groundwater is assumed to be site related.

^bUSEPA, 1992.

References:

U.S. Environmental Protection Agency (USEPA). 1992. Table 5-7, Dermal Exposure ' Assessment Principles and Applications, Interim Report. Office of Health and ' Environmental Assessment, Washington, D.C. EPA/600/8-91/011B. January.

Table 5-12
Site-Wide Chemical Intake Exposure Estimates – Inhalation of Ambient Air VOCs Emanating from Groundwater
Onsite Construction Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$\text{Intake (mg/kg-day)} = [C_A \times IR \times ET \times EF \times ED] / [BW \times AT]$$

Intake Parameter		Construction Worker Value
C _A	= Concentration of Benzene in air (mg/m ³)	3.05E-05
IR	= Inhalation rate (m ³ /hr)	1.32
ET	= Exposure time (hr/day)	8
EF	= Exposure frequency (days/year)	60
ED	= Exposure duration (years)	1
BW	= Body weight (kg)	70
AT	= Averaging time (days)	
	Noncarcinogens	365
	Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)		7.56E-07
Intake for carcinogens (mg/kg-day)		1.08E-08

Footnotes:

^aAll contact with groundwater is assumed to be site related.

Table 5-13
Chemical Intake Exposure Estimates – Inhalation of Indoor Air VOCs Emanating from Groundwater
Office Building Scenario
Onsite Commercial Worker Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$Intake (mg/kg-day) = [C_A \times IR \times ET \times EF \times ED] / [BW \times AT]$$

Intake Parameter	Commercial Worker Value
C _A = Concentration of Benzene in air (mg/m ³)	1.77E-03
IR = Inhalation rate (m ³ /hr)	0.83
ET = Exposure time (hr/day)	8
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogens	9,125
Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)	1.15E-04
Intake for carcinogens (mg/kg-day)	4.11E-05

Footnotes:

^aAll contact with groundwater is assumed to be site related.

Table 5-14
Chemical Intake Exposure Estimates – Dermal Contact with Groundwater
Onsite Construction Worker Exposure Scenario
Office Building Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$Intake (mg/kg-day) = [C_{gw} \times SA \times PC \times CF \times ET \times EF \times ED \times FC] / [BW \times AT]$$

Intake Parameter	Construction Worker	
	Value	
C _{gw} = Concentration of Benzene in groundwater (mg/L)	1.028	
SA = Skin surface area (cm ²)	2,000	
PC = Dermal permeability constant (cm/hr) of benzene ^b	2.10E-02	
CF = Conversion factor (L/cm ³)	1E-03	
ET = Exposure time (hr/event)	8	
EF = Exposure frequency (events/year)	60	
ED = Exposure duration (years)	1	
FC = Fraction of time contacting exposure area	1	
BW = Body weight (kg)	70	
AT = Averaging time (days)		
Noncarcinogens	365	
Carcinogens	25,550	
Intake for noncarcinogens (mg/kg-day)	8.11E-07	
Intake for carcinogens (mg/kg-day)	1.16E-08	

Footnotes:

^aAll contact with groundwater is assumed to be site related.

^bUSEPA, 1992.

References:

U.S. Environmental Protection Agency (USEPA). 1992. Table 5-7, Dermal Exposure Assessment: Principles and Applications, Interim Report. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-91/011B. January.

Table 5-15
Chemical Intake Exposure Estimates – Inhalation of Ambient Air VOCs Emanating from Groundwater
Onsite Construction Worker Exposure Scenario
Office Building Scenario
Grand Street and Fortmann Way Property
Alameda, California^a

$$\text{Intake (mg/kg-day)} = [C_A \times IR \times ET \times EF \times ED] / [BW \times AT]$$

Intake Parameter		Construction Worker
		Value
C _A	= Concentration of Benzene in air (mg/m ³)	2.14E-03
IR	= Inhalation rate (m ³ /hr)	1.32
ET	= Exposure time (hr/day)	8
EF	= Exposure frequency (days/year)	60
ED	= Exposure duration (years)	1
BW	= Body weight (kg)	70
AT	= Averaging time (days)	
	Noncarcinogens	365
	Carcinogens	25,550
Intake for noncarcinogens (mg/kg-day)		5.31E-05
Intake for carcinogens (mg/kg-day)		7.58E-07

Footnotes:

^aAll contact with groundwater is assumed to be site related.

Table 5-16
Summary of Exposure Assumptions
Occupational Exposure Scenario
Grand Street and Fortmann Way Property
Alameda, California

EXPOSURE PARAMETER	Onsite Commercial Worker		Onsite Construction Worker		Onsite Landscape Worker	
	Value	Source	Value	Source	Value	Source
<u>Contact Rate Assumptions</u>						
Inhalation rate (indoors) (m ³ /hr)	0.83	ASTM, 1995	--	--	--	--
Inhalation rate (outdoors) (m ³ /hr)	-- ^a	--	1.32	USEPA, 1996	1.32	USEPA, 1996
Soil ingestion rate (mg/day)	--	--	50	ASTM, 1995	480	USEPA, 1991
Skin surface area (cm ² /day)	--	--	2,000	USEPA, 1989b ^b	2,000	USEPA, 1989b ^b
Soil-to-skin adherence factor (mg/cm ²)	--	--	0.5	ASTM, 1995	0.5	ASTM, 1995
Absorption factor-organics (unitless)	--	--	0.1	Cal/EPA, 1994	0.1	Cal/EPA, 1994
<u>General Assumptions</u>						
Exposure time (hr/day)	8	Standard Work Practice	8	Standard Work Practice	8	Standard Work Practice
Exposure time to groundwater (hr/day)	--	--	8	Conservative Assumption	--	--
Exposure frequency (days/year)	250	ASTM, 1995	60	Professional Judgment	250	ASTM, 1995
Exposure duration (years)	25	ASTM, 1995	1	Professional Judgment	25	ASTM, 1995
Conversion factor (kg/mg)	--	--	1E-06	--	1E-06	--
Conversion factor (L/cm ³)	--	--	1E-03	--	1E-03	--
Fraction of time contacting exposure area (unitless)	1	Conservative Assumption	1	Conservative Assumption	1	Conservative Assumption
Body weight (kg)	70	ASTM, 1995	70	ASTM, 1995	70	ASTM, 1995
Averaging time (days)						
Noncarcinogens	9,125	USEPA, 1989a	365	USEPA, 1989a	6,250	USEPA, 1989a
Carcinogens	25,550	USEPA, 1989a	25,550	USEPA, 1989a	25,550	USEPA, 1989a

Footnotes:

^a "--" indicates pathway is incomplete and intake factors were not selected for this receptor.

^b Skin surface area assumes exposure to hands and face.

References:

American Society for Testing and Materials (ASTM). 1995. Emergency Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM Designation E 1739-95. November.

CalTPA. 1994. Preliminary Endangerment Assessment Guidance Manual. January.

U.S. Environmental Protection Agency (USEPA). 1989a. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA-540/1-89/002. December.

U.S. Environmental Protection Agency (USEPA). 1989b. Exposure Factors Handbook. Office of Health and Environmental Assessment. Washington, D.C. EPA 600/8-89/043. July.

U.S. Environmental Protection Agency (USEPA). 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual: Supplemental Guidance. "Standard Default Exposure Factors" Interim Final. March 25. 9285.6-03.

U.S. Environmental Protection Agency (USEPA). 1992. New Interim Region IV Guidance. Region IV, Atlanta, GA. February.

**Table 6-1
Toxicity Values
Grand Street and Fortmann Way Property
Alameda, California**

Chemical Name	Carcinogenic Weight-of-Evidence	Oral/Dermal Slope Factor (SF) (mg/kg-day) ⁻¹		Inhalation Slope Factor (SF) (mg/kg-day) ⁻¹		Oral/Dermal Reference Dose (RfD) (mg/kg-day)		Inhalation Reference Dose (RfD) ^b (mg/kg-day)	
		Value	Source	Value	Source	Value	Source	Value	Source
Benzene	A	1.00E-01	Cal/EPA,1995	1.00E-01	Cal/EPA,1995	-- ^a	--	1.71E-03	USEPA, 1995a
Benzo(a)pyrene	B2	1.20E+01	Cal/EPA, 1995	3.90E+00	Cal/EPA,1995	--	--	--	--

Footnotes:

^a "--" No toxicity value available. Chemical either does not exhibit toxicity via this route or sufficient evidence is not available to derive a toxicity value.

^bInhalation reference dose for benzene. Provisional toxicity values have not received consensus judgment by USEPA's Reference Dose Work Groups and/or Carcinogenic Risk Assessment Verification Endeavor Work Group.

Reference:

California Environmental Protection Agency (CalEPA). 1995. California Cancer Potency Factors: Update. Office of Environmental Health Hazard Assessment. April 10.

U.S. Environmental Protection Agency (USEPA). 1995. Risk-Based Concentration Table. USEPA Region III. October 20.

**Table 6-2
Toxicological Profile for Benzene
Grand Street and Fortmann Way Property
Alameda, California**

Benzene

Chemical Properties

CAS #	71-43-2
Chemical Formula	C ₆ H ₆
Chemical Characteristic	Aromatic hydrocarbon
Synonyms	benzol, coal naphtha, phenyl hydride, and pyrobenzol
Weight of Evidence (WOE)	IARC=Group I (carcinogenic to humans), NTP=Clear evidence, EPA=Group A (human carcinogen)

Chemical Use, Fate and Transport

What is chemical used for?	In past, widely used as a solvent, but due to known adverse health effects, uses are now minimal. Mostly used as starting material for various organic compound synthesis and minor uses as substance in gasoline (0.8 - 2.0 %)
Where does chemical occur?	Mobile in soil/gw systems with sandy/low organic content soils Volatilization important in surface soil or soil-air compartments. Hydrolysis and biodegradation not expected in natural soils, but acclimated microbial populations can biodegrade benzene.
What type of chemical fate and transport to human exposure point?	Primary pathway from a soil-water system is migration to gw drinking supplies (historically common). Inhalation from volatilization from surface soils possibly important.

Chemical Disposition

Absorption	Inhalation, ingestion, dermal contact (lesser absorption)
Distribution	Ingestion: to bile, blood, brain, fat (abdominal), kidney, liver and mammary glands. Dermal: to kidney, liver and skin
Metabolism	Mainly by liver's cytochrome P-450 system
Excretion	Exhalation and urinary excretion

Chemical Toxicity

Slope Factor (SF) (mg/kg-day) ⁻¹	Oral: 1.0 E-1 (CalEPA, 1995); Dermal: 1.0 E-1 (Cal/EPA, 1995); Inhalation: 1.0 E-1 (CalEPA, 1995)
Reference Dose (RfD) (mg/kg-day)	Oral: -- ; Dermal: -- ; Inhalation: 1.71 E-3 (USEPA, 1995)
Unit Risk Value (ug/m ³) ⁻¹	Oral: -- ; Dermal: -- ; Inhalation: 2.9 E-5 (Cal/EPA, 1995)
Level of Confidence	
Modifying Factor (MF)	
Uncertainty Factor (UF)	
Short Term Exposure	

Signs and Symptoms from Human Exposure	Inhalation and ingestion primarily affects the CNS with following symptoms: headache, dizziness, drowsiness, and nausea progressing to convulsions, respiratory paralysis and death due to high vapor concentrations. Eye and skin irritant
Long-Term Exposure	Pancytopenia, leukemia Pregnancy/neonate data: embryotoxicity and fetotoxicity at maternally toxic doses. Genotoxicity data: mixed results.

Footnotes:

^a Cal/EPA, 1995. California Environmental Protection Agency.

^b USEPA, 1995. United States Environmental Protection Agency.

References:

Cal/EPA, 1995 = California Environmental Protection Agency (CalEPA) 1995. California Cancer Potency Factors: Update. Office of Environmental Health Hazard Assessment. April 10.
USEPA, 1995a = U.S. Environmental Protection Agency (USEPA) 1995. Risk-Based Concentration Table. USEPA Region III. October 20.

**Table 6-3
Toxicological Profile for Benzo(a)Pyrene
Grand Street and Fortmann Way Property
Alameda, California**

Benzo(a)Pyrene	
Chemical Properties	
CAS #	50-32-8
Chemical Formula	C ₂₀ H ₁₂
Chemical Characteristic	Polycyclic aromatic hydrocarbon (PAH)
Synonyms	B(a)P; benzo(d,e,f)chrysene; 3,4-benzopyrene; 6,7-benzopyrene; BP; and 3,4-BP
Weight of Evidence (WOE)	EPA=B2 (probable human carcinogen)
Chemical Use, Fate and Transport	

What is chemical used for? No known uses for Benzo(a)pyrene, except regarding research purposes.

Where does chemical occur? PAHs are a group of chemicals formed during incomplete combustion of hydrocarbons. They are formed naturally and anthropogenically. They occur throughout the environment in soil, sediment, air and water.

What type of chemical fate and transport to human exposure point? Benzo(a)pyrene tends to sorb strongly to soil and sediment, where it remains fixed. In addition, volatilization is not substantial due to low Henry's constant.

Chemical Disposition

Absorption	Ingestion, inhalation and dermal contact
Distribution	Distributed to: lungs, liver, kidney, gastrointestinal tract, blood and brain
Metabolism	Metabolism occurs in all tissues to produce a metabolite which is more hydrophilic and excretable
Excretion	Respired by lungs and excreted in urine and feces

Chemical Toxicity

Slope Factor (SF) (mg/kg-day)⁻¹ Oral: 1.2 E +1 (Cal/EPA, 1995); Dermal: 1.2 E +1 (Cal/EPA, 1995); Inhalation: 3.9 E +0 (Cal/EPA, 1995)

Reference Dose (RfD) (mg/kg-day) Oral: -- ; Dermal: -- ; Inhalation: --

Unit Risk Value (URV) (mg/m³)⁻¹ Oral: -- ; Dermal: -- ; Inhalation: 1.1 E -3 (Cal/EPA, 1995)

Level of Confidence

Modifying Factor (MF)

Uncertainty Factor (UF)

Short Term Exposure

Signs and Symptoms from Human Exposure

Animals

Humans

Long-Term Exposure Pregnancy/neonate data: reproductive difficulty in mice studies. Genotoxicity data: positive.

Animals Sufficient carcinogenicity data (increased incidences of tumors) exists via ingestion, inhalation, and dermal contact animal studies.

Humans Although human carcinogenicity data are inadequate, lung cancer has been shown to be induced in humans by various PAH mixtures known to contain B(a)P including cigarette smoke, roofing tar and coke oven emissions.

Footnotes:

* Cal/EPA, 1995. California Environmental Protection Agency.

References:

Cal/EPA, 1995 = California Environmental Protection Agency (CalEPA). 1995 California Cancer Potency Factors: Update. Office of Environmental Health Hazard Assessment. April 10.

Table 7-1
Site-Wide: Summary of Excess Cancer Risks and Noncancer Adverse Health Effects
Grand Street and Fortmann Way Property
Alameda, California

Exposure Pathway	Construction Worker		Landscape Worker	
	Excess Cancer	Hazard Index	Excess Cancer Risk	Hazard Index
Incidental Ingestion of Soil	4.03E-12	--	4.03E-09	--
Dermal Contact with Soil	8.05E-12	--	8.39E-10	--
Inhalation of Airborne Particulates	2.74E-13	--	7.77E-12	--
Dermal Contact with Groundwater	2.93E-10	--	--	--
Inhalation of Indoor Air Concentrations of Benzene Emanating from Groundwater	-- ^a	--	--	--
Inhalation of Ambient Air Concentrations of Benzene Emanating from Groundwater	1.08E-09	4.42E-04	--	--

SUM TOTAL ACROSS ALL QUANTIFIED PATHWAYS^b:

1E-09

4E-04

5E-09

--

Footnotes:

^a Pathway not quantitatively evaluated. Refer to risk assessment text for additional information.

^b Values rounded to one significant figure.

Table 7-2
Summary of Excess Cancer Risks and Noncancer Adverse Health Effects
Location of Proposed Office Building
Grand Street and Fortmann Way Property
Alameda, California

Exposure Pathway	Commercial Worker		Construction Worker	
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Hazard Index
Incidental Ingestion of Soil	-- ^a	--	4.03E-12	--
Dermal Contact with Soil	--	--	8.05E-12	--
Inhalation of Airborne Particulates	--	--	2.74E-13	--
Dermal Contact with Groundwater	--	--	1.16E-09	--
Inhalation of Indoor Air Concentrations of Benzene Emanating from Groundwater	4.11E-06	6.73E-02	--	--
Inhalation of Ambient Air Concentrations of Benzene Emanating from Groundwater	--	--	7.58E-08	3.10E-02

SUM TOTAL ACROSS ALL QUANTIFIED PATHWAYS^b:

4E-06

7E-02

8E-08

3E-02

Footnotes:

^a Pathway not quantitatively evaluated. Refer to risk assessment text for additional information.

^b Values rounded to one significant figure.

APPENDIX A

Results of Soil and Groundwater Sampling Analyses

Table A-1.
Results of Soil Sampling and Analyses
Grand Street and Fortmann Way Property
Alameda, California

Sample Identification	Depth of Sample (feet)	Sample Date	Chemical																				
			IPIH as Diesel			Total Oil and Grease			Benzene			Toluene			Ethylbenzene			Total Xylenes			Benzo(a)pyrene		
			Detection Limit (mg/kg) ¹	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)	Detection Limit (mg/kg)	Reported Value (mg/kg)	Statistical Value (mg/kg)
TP-1	1.0 - 4.5	5/1/92	50	660	660	30	2000	2000	0.005	ND	0.0025	0.005	0.87	0.87	0.005	1.0	1	0.005	2.1	2.1	--	4.62E-05	4.62E-05
TP-2	1.0 - 4.5	5/1/92	NA	NA	NA	30	350	350	0.005	ND	0.0025	0.005	0.54	0.54	0.005	0.34	0.34	0.005	0.59	0.59	NA	NA	NA
TP-3	1.0 - 4.5	5/1/92	NA	NA	NA	30	4400	4400	0.005	0.15	0.15	0.005	0.18	0.18	0.005	0.131	0.131	0.005	0.40	0.4	NA	NA	NA
TP-5	4.0 - 4.5	5/1/92	NA	NA	NA	30	12000	12000	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	NA	NA	NA
TP-6	1.0 - 4.5	5/1/92	NA	NA	NA	30	7500	7500	0.005	ND	0.0025	0.005	0.088	0.088	0.005	0.20	0.2	0.005	0.64	0.64	NA	NA	NA
TP-7	1.0 - 4.5	5/1/92	NA	NA	NA	30	480	480	0.005	ND	0.0025	0.005	0.013	0.013	0.005	0.059	0.059	0.005	0.15	0.15	NA	NA	NA
TP-8	4.0 - 4.5	5/1/92	10	82	82	30	410	410	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	--	5.74E-06	5.74E-06
TP-9	1.0 - 4.5	5/1/92	100	4700	4700	30	3100	3100	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	5.8	5.8	--	3.29E-04	3.29E-04
PL-12	1.0 - 4.5	5/1/92	10	21	21	30	37	37	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	--	1.47E-06	1.47E-06
25-28	1.0 - 4.5	5/1/92	10	ND	5	30	310	310	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	7.00E-07	ND	3.50E-07
29, 30, 32B	1.0 - 4.5	5/1/92	10	13	13	30	43	43	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	--	9.10E-07	9.10E-07
MB-1	4.0 - 4.5	5/1/92	10	ND	5	30	180	180	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.00E-07	ND	3.50E-07
MW-1	1.0 - 4.5	5/4/92	200	970	970	30	2400	2400	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	--	6.79E-05	6.79E-05
MW-2	4.0 - 4.5	5/4/92	20	150	150	30	57	57	0.005	0.24	0.24	0.005	0.62	0.62	0.005	0.050	0.050	0.005	0.26	0.26	--	1.05E-05	1.05E-05
MW-3	6.0 - 6.5	5/1/92	10	ND	5	30	170	170	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	0.005	ND	0.0025	7.00E-07	ND	3.50E-07
IP3A-2		Oct-94	--	1,400	1,400	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	--	9.80E-05	9.80E-05
MW-5-2-5		Oct-94	--	23	23	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	--	1.61E-06	1.61E-06
MW-5-5		Oct-94	--	27	27	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	--	1.89E-06	1.89E-06
MW-5A-6		Oct-94	1,000	ND	0.5	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	7.00E-08	ND	3.50E-08
MS-6-2-5		Oct-94	--	28	--	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	--	1.96E-06	1.96E-06
MW-7-2		Oct-94	--	240	240	--	--	--	0.0025	ND	0.00125	0.0025	ND	0.00125	0.0025	ND	0.00125	--	15	15	--	1.68E-05	1.68E-05
MW-8-3-5		Oct-94	--	97	97	--	--	--	0.005	ND	0.0025	--	0.0057	0.0057	0.005	0.01	0.01	--	0.084	0.084	--	6.79E-06	6.79E-06

Footnotes

- ¹ mg/kg = milligrams per kilogram
- ND = not detected above the method detection limit. Consistent with USEPA (1989) guidelines, half of the method detection limit was used to represent a non-detect value, if the chemical was detected at least once
- = not available
- NA = not analyzed

References

USEPA 1989. Risk Assessment Guidance for Superfund. Human Health Evaluation Manual Part A, Interim Final. July.

Table A-2.
Results of Groundwater Sampling and Analyses
Grand Street and Fortmann Way Property
Alameda, California

Handwritten: sheet 400-PPB

Sample Identification	Sample Date	Chemicals																							
		TPH as Gasoline			TPH as Diesel			Total Oil and Grease			Benzene			Toluene			Ethylbenzene			Total Xylenes					
		Detection Limit (mg/L) ¹	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (mg/L)	Reported Value (mg/L)	Statistical Value (mg/L)	Detection Limit (ug/L) ²	Reported Value (ug/L)	Statistical Value (ug/L)	Detection Limit (ug/L)	Reported Value (ug/L)	Statistical Value (ug/L)	Detection Limit (ug/L)	Reported Value (ug/L)	Statistical Value (ug/L)	Detection Limit (ug/L)	Reported Value (ug/L)	Statistical Value (ug/L)			
MW-1	05/12/92	0.05	ND ³	0.025	0.05	ND	0.025	5.0	ND	2.5	0.5	ND	0.25	0.5	0.8	0.8	0.5	ND	0.25	0.5	ND	0.25	0.5	1.3	1.3
MW-1	11/01/91	0.05	0.08	0.08	--	0.4	0.4	5.0	ND	2.5	--	0.5	0.5	--	1.1	1.1	0.05	ND	0.025	--	1.4	1.4	--	1.4	1.4
MW-1	02/06/95	0.05	ND	0.025	--	1.3	1.3	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-1	05/09/95	NS ⁴	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-1	08/22/95	0.05	ND	0.025	--* ⁶	1.1	1.1	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-1	11/08/95	0.05	ND	0.025	--*	0.33	0.33	NA	NA	NA	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-1	02/28/96	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-1	06/24/96	5.0	ND	25	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-2	05/12/92	0.05	29	29	0.25	1.2	1.2	5.0	ND	2.5	0.5	4000	4000	0.5	11000	11000	0.5	500	500	0.5	2900	2900	0.5	2900	2900
MW-2	11/01/91	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	510	510	--	670	670	--	65	65	--	320	320	--	320	320
MW-2	02/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	360	360	--	230	230	--	20	20	--	100	100	--	100	100
MW-2	05/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	550	550	--	350	350	--	28	28	--	120	120	--	120	120
MW-2	08/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	290	290	--	120	120	--	11	11	--	37	37	--	37	37
MW-2	11/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	190	190	--	35	35	--	6.4	6.4	--	16	16	--	16	16
MW-2	02/28/96	NS	NS	NS	--	1.1	1.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-3	05/12/92	0.05	ND	0.025	0.05	0.12	0.12	5.0	ND	2.5	0.5	ND	0.25	0.5	1	1	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	05/12/92	0.05	ND	0.025	0.05	0.15	0.15	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	11/01/91	0.05	ND	0.025	--	0.24	0.24	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	02/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	05/09/95	0.05	ND	0.025	0.05	ND	0.025	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	08/22/95	0.05	ND	0.025	--	0.41	0.41	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	11/08/95	0.05	ND	0.025	--*	0.46	0.46	NA	NA	NA	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	02/28/96	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-4	06/24/96	5.0	ND	25	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	11/01/91	0.05	ND	0.025	--	0.560	0.560	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	02/06/95	--	1.0	1.0	--	0.460	0.460	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	05/09/95	0.05	ND	0.025	0.05	ND	0.025	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	08/22/95	0.05	ND	0.025	--	0.910	0.910	5	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	11/08/95	0.05	ND	0.025	--	0.260	0.260	NA	NA	NA	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	02/28/96	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-5	06/24/96	5.0	ND	25	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	11/01/91	0.05	ND	0.025	--	0.5	0.5	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	02/06/95	0.05	ND	0.025	--	0.57	0.57	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	05/09/95	0.05	ND	0.025	0.05	ND	0.025	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	08/22/95	0.05	ND	0.025	--	0.79	0.79	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	11/08/95	0.05	ND	0.025	--*	0.33	0.33	NA	NA	NA	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	02/28/96	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6	06/24/96	5.0	ND	25	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6a	11/01/91	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6a	02/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	--	2.5	2.5	--	2.5	2.5
MW-6a	05/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6a	08/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-6a	12/01/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25

Table A-2.
Results of Groundwater Sampling and Analyses
Grand Street and Fortmann Way Property
Alameda, California

Sample Identification	Sample Date	Chemicals																				
		TPH as Gasoline			TPH as Diesel			Total Oil and Grease			Benzene			Toluene			Ethylbenzene			Total Xylenes		
		Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value	Detection Limit	Reported Value	Statistical Value
		(mg/L) ¹	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L) ²	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
MW-7	11/01/94	0.05	ND	0.025	--	0.97	0.97	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	02/06/95	0.05	ND	0.025	--	1.3	1.3	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	05/09/95	0.05	ND	0.025	0.05	ND	0.025	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	08/22/95	0.05	ND	0.025	--	2.2	2.2	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	11/08/95	0.05	NS	0.025	--*	0.7	0.7	NA	NA		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	02/28/96	NS	NS		NS	NS		NS	NS		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-7	06/24/96	50	ND	25	NS	NS		NS	NS		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	11/01/94	0.05	ND	0.025	--	1.0	1.0	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	02/06/95	0.05	ND	0.025	--	0.93 (0.47) ³	0.7	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	05/09/95	0.05	ND	0.025	0.05	<0.05 (<0.05)	0.025	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	08/22/95	0.05	ND	0.025	--	1.5	1.5	5.0	ND	2.5	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	11/08/95	0.05	ND	0.025	--*	0.57	0.57	NA	NA		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	02/28/96	NS	NS		NS	NS		NS	NS		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25
MW-8	06/24/96	50	ND	25	NS	NS		NS	NS		0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25	0.5	ND	0.25

Footnotes

- ¹ mg/L = milligrams per liter
- ² ug/L = micrograms per liter
- ³ ND = not detected above the method detection limit. Consistent with USEPA (1989) guidelines, half of the method detection limit was used to represent a non-detect value, if the chemical was detected at least once
- = not available
- NS = not sampled/well inaccessible
- * = Hydrocarbons found in the diesel range do not satisfy the diesel fingerprint (9.47) Duplicate sample result

References

USEPA. 1989. Risk Assessment Guidance for Superfund. Human Health Evaluation Manual Part A, Interim Final. July

APPENDIX B

Methods Used to Estimate Chemical Concentrations in Air

APPENDIX B

METHODS USED TO ESTIMATE CHEMICAL CONCENTRATIONS IN AIR

This appendix describes the methods used to estimate chemical concentrations in air from either soil or groundwater.

B1.0 BENZENE IN GROUNDWATER

Groundwater concentrations for benzene, the only COPC in groundwater, are used in vapor-phase migration models to estimate the concentration of COPC vapors in enclosed-space (i.e., "indoor") air and ambient (i.e., "outdoor") air. The models and methodology used are presented below.

B1.1 Exposure Point Concentrations in an Office Building

To estimate the concentration of benzene vapors in enclosed-space air, a mass balance approach was used, based on the conservative assumption that all available chemical (benzene) mass present in Site groundwater is emitted as vapors at the soil surface over the exposure duration for the office worker receptor. A chemical vapor flux was computed based on this approach, which was then input into an indoor air dispersion model to estimate an indoor air concentration of chemical vapors for this receptor. These methods, and the results obtained from them, are presented in the following section.

B1.1.1 Computation of the Theoretical Maximum Benzene Vapor Flux

The dimensions of the groundwater benzene plume, taken as the distance between MW-2 and MW-4 (140 feet) and a default plume thickness of 2 meters (ASTM, 1995), were used in conjunction with a default soil porosity (0.38; ASTM, 1995) and a groundwater benzene concentration of 1,028 ug/L to compute the available mass of benzene in Site groundwater potentially available for volatilization. This mass was divided by the emissions area and the exposure duration for the office worker receptor to compute a maximum possible flux, 9.91×10^{-7} mg/m²-sec. Table ___ shows this computation.

B1.1.2 Estimation of the Air Concentration of Benzene Vapors in an Office Building

The maximum flux obtained from the mass balance computation described above was input into a one-compartment indoor air model (ASTM, 1995) to estimate an air concentration of benzene vapors inside an office building planned for construction in the future at the corner of Grand Street and Fortmann Way. Using a conservative default air exchange rate of 0.00023 sec⁻¹ (ASTM, 1995), an indoor air concentration of 1.77×10^{-3} milligrams per cubic meter (mg/m³) was obtained. In computing this value, the attenuating effect of a concrete slab-on-grade building foundation, likely to be used for the planned office building, was conservatively ignored, based on the relatively high permeability of the sandy vadose soils present at the Site (Johnson and Ettinger, 1991).

B1.2 Exposure Point Concentrations in Outdoor Air

To estimate the concentration of benzene vapors in ambient air, two approaches were used. For the construction worker receptor who may excavate down to groundwater, a conservative mass balance approach was again used, since adequate models accounting for increased vapor emissions from the potential physical disturbance of exposed shallow groundwater were not readily available. For the landscape worker receptor who is not expected to encounter exposed groundwater, the vapor-phase groundwater volatilization model presented in ASTM (1995) was used (i.e., "VF_{w,amb}"). The groundwater volatilization model uses closed-form analytical solutions for convective and diffusive transport of vapor phase chemicals in groundwater.

B1.2.1 Ambient Air Concentrations for the Construction Worker Receptor

The emission rate, or flux, of benzene was estimated using a mass balance approach identical to that used for the indoor office worker receptor, with the exception of the exposure duration. Table ___ shows this computation. The air dispersion element of the calculations was estimated with a simple "box model" (California, 1994; USEPA, 1991; ASTM; 1995), using conservative agency-recommended default input values, with the exception of the box model mixing length, which was set equal to 64 meters based on the longest diagonal distance across the footprint of the planned office building at the corner of Fortmann Way and Grand Street (Figure ___). Table ___ shows these box model computations, and the resulting estimated outdoor benzene vapor concentration of $2.14 \times 10^{-3} \text{ mg/m}^3$.

B1.2.2 Volatilization Factor for the Landscape Worker Receptor

Because the landscape worker receptor is not assumed to contact groundwater, a chemical-specific groundwater volatilization factor was used to estimate ambient air concentrations of benzene vapors. The VF_{wamb} model (i.e., volatilization from groundwater into ambient air) presented by ASTM (1995) was used. All models inputs are conservative ASTM (1995) default values for a commercial receptor, except for the box model length dimension, which was set at a value of 11 meters, based on an assumption of 25 percent of the construction worker receptor dimension (43 meters).

The VF_{wamb} model contains the following assumptions:

- A constant dissolved chemical concentration in groundwater;
- Linear equilibrium partitioning within the soil matrix between dissolved chemicals in groundwater and chemical vapors at the groundwater table;
- Steady-state vapor- and liquid-phase diffusion through the capillary fringe and vadose zones to ground surface;
- No loss of chemical as it diffuses toward ground surface (i.e., no biodegradation); and,
- Steady well-mixed atmospheric dispersion of the emanating vapors within the breathing zone as modeled by a "box model" for air dispersion.

A VF_{wamb} value of $1.97 \times 10^{-5} \text{ mg/m}^3\text{-air//mg/L-water}$ was obtained.

B1.2.3 Resulting Outdoor Air Concentrations

Using the calculated volatilization factor for benzene, ambient air concentrations are estimated using the following equation:

$$C_{\text{groundwater}} \times VF_{\text{wamb}} = C_{\text{ambient air}}$$

Where:

$C_{\text{ambient air}}$	=	Chemical concentration in ambient air (mg/m ³)
$C_{\text{groundwater}}$	=	Chemical concentration in groundwater (mg/L)
VF_{wamb}	=	Chemical-specific groundwater-to-air volatilization factor (mg/m ³ -air)/(mg/L-H ₂ O)

Estimated ambient air concentrations for this site are as follows:

Using site-wide benzene groundwater concentration of 0.026 mg/L: 5.1×10^{-7} mg/m³

- Using Grand Street benzene groundwater concentration of 1,028 ug/L: 2×10^{-5} mg/m³

A2.0 BENZENE IN SOIL

Airborne particulate concentrations of B(a)P, the only COPC in soil, were derived from surface soil concentrations using a soil particle emission rate for soil agitation activities and a conservative box model. Because dust emissions during construction or landscaping involve mechanical disturbances which will increase emissions relative to ambient conditions, a particulate flux developed by USEPA (1974, 1985) based on actual measured airborne particulate levels during heavy construction in a hot, arid climate was used to estimate airborne particulate concentrations during construction and landscaping. This flux, after unit conversion, was input into a conservative box model (California, 1994; USEPA, 1991) with agency-recommended default mixing height and windspeed values (California, 1994; USEPA, 1991). The box model dimension parameter was estimated from site dimensions. A distance of 43 meters was measured for the longest diagonal distance of the footprint of the proposed office building at the corner of Grand Street and Fortmann Way (Figure ___). This distance was used for the construction worker receptor. One-quarter of this distance, resulting in lower estimated airborne particulate levels, was assumed for the landscape worker receptor. The resulting air concentrations of B(a)P-in-airborne dust are presented in Table B-2, along with all model inputs and equations.

Table B-1

Estimation of Indoor Air Concentration of Benzene Vapors from Groundwater Volatilization
for the Onsite Commercial Worker Receptor
Grand Street and Fortmann Way Property
Alameda, California

Parameter definition	Units	Symbol	Value
Length of plume ²	ft	L	140
Unit conversion factor	cm/ft	CF1	30.48
Length of plume ³	cm	Lc	4267
Width of plume ⁴	cm	Wc	4267
Plume thickness ⁵	cm	Tc	200
Total soil porosity ⁶	--	Pt	0.38
Chemical concentration in groundwater ⁷	mg/L	Cg	1.028
Unit conversion factor	L/cm ³	CF2	0.001
Exposure duration ⁸	days	ED	9125
Unit conversion factor	sec/d	CF3	86400
Unit conversion factor	m ² /cm ²	CF4	1.00E-04
Maximum chemical vapor flux at the soil surface ⁹	mg/m ² -sec	Fm	9.91E-07
Maximum chemical vapor flux at the soil surface	mg/m ² -sec	Fm	9.91E-07
Ceiling height ¹⁰	ft	h	8.00
Unit conversion factor	m/ft	CF5	0.31
Indoor volume related to unit area ¹¹	m ³	v	2.44
Indoor air exchange rate ¹²	sec ⁻¹	x	0.00023
Volumetric flow rate for infiltration air per unit area ¹³	m ³ /sec-m ²	q	5.61E-04
Indoor air concentration of chemical ¹⁴	mg/m ³	C(i)	1.77E-03

Notes:

ft = feet, cm = centimeters, mg = milligrams, L = liters, cm³ = centimeters cubed, sec = seconds
d = day, m² = meters squared, cm² = centimeters squared, m = meters, m³ = meters cubed.

Footnotes:

¹ Mass balance emissions model conservatively assumes that all volatile chemical mass is emitted over the exposure duration. A one-compartment indoor air model (ASTM, 1995; Johnson and Etting) is used to estimate indoor air concentrations of chemical vapors for the office worker receptor.

² Distance between MW-2 and MW-4.

³ L x CF1.

⁴ The width of the plume is assumed equal to the length of the plume.

⁵ Default value from ASTM RBCA (ASTM, 1995).

⁶ Default value from ASTM RBCA (ASTM, 1995).

⁷ From Table 5-4a.

⁸ From Table 5-16.

⁹ $(Lc \times Wc \times Tc \times Pt \times Cg \times CF2) / (L \times W \times ED \times CF3 \times CF4)$

¹⁰ Assumed value for standard construction

¹¹ $(1 \text{ m}^2) \times h \times CF5$

¹² ASTM (1995) default value for commercial enclosed space

¹³ $x \times v$

¹⁴ $Fm \times q$

QC needs final QC

Table B-2

Estimation of Outdoor Air Concentration of Benzene Vapors from Groundwater Volatilization
for the Onsite Construction Worker Receptor
Grand Street and Fortmann Way Property
Alameda, California

Parameter definition	Units	Symbol	Value
Length of plume ²	ft	L	140
Unit conversion factor	cm/ft	CF1	30.48
Length of plume ³	cm	Lc	4267
Width of plume ⁴	cm	Wc	4267
Plume thickness ⁵	cm	Tc	200
Total soil porosity ⁶	-	Pt	0.38
Chemical concentration in groundwater ⁷	mg/L	Cg	1.028
Unit conversion factor	L/cm ³	CF2	0.001
Exposure duration ⁸	days	ED	60
Unit conversion factor	sec/d	CF3	86400
Unit conversion factor	m ² /cm ²	CF4	1.00E-04
Maximum chemical vapor flux at the soil surface ⁹	mg/m ² -sec	Fm	1.51E-04
Maximum chemical vapor flux at the soil surface	mg/m ² -sec	Fm	1.51E-04
Emission area width ²	ft	W	140
Unit conversion factor	m/ft	CF5	3.05E-01
Emission area width ¹⁰	m	Wm	64
Wind speed ¹¹	m/sec	u	2.25
Mixing height ¹¹	m	h	2
Air concentration of chemical ¹²	mg/m ³	Ca	2.14E-03

Notes:

ft = feet, cm = centimeters, mg = milligrams, L = liters, cm³ = centimeters cubed, sec = seconds, d = day, m² = meters squared, cm² = centimeters squared, m = meters, m³ = meters cubed.

Footnotes:

¹ Mass balance emissions model conservatively assumes that all volatile chemical mass is emitted the exposure duration. A box model (CAL/EPA, 1994; USEPA, 1991b) is used to estimate outdoor air concentrations of chemical vapors for the construction worker receptor.

² Distance between MW-2 and MW-4.

³ L x CF1.

⁴ The width of the plume is assumed equal to the length of the plume.

⁵ Default value from ASTM RBCA (ASTM, 1995).

⁶ Default value from ASTM RBCA (ASTM, 1995).

⁷ From Table 5-4a.

⁸ From Table 5-16

⁹ (Lc x Wc x Tc x Pt x Cg x CF2) / (Lc x Wc x ED x CF3 x CF4)

¹⁰ Conservatively assumed to be equal to the longest diagonal distance across the footprint of the office building at the corner of Fortmann Way and Grand Street (Figure ___)

¹¹ Default values from CAL/EPA, 1994 and ASTM, 1995

¹² (Fm x Wm) / (u x h)

QC needs final QC

Table B-3
Dust-in-Air Estimates for Onsite Construction Workers and Landscape Workers
Grand Street and Fortmann Way Property
Alameda, California

Parameter definition	Units	Symbol	Value
Particulate flux rate during heavy soil handling ¹	T/ac-mo	AP-42	1.2
Unit conversion factor	lbs/ton	UCF1	2000
Unit conversion factor	kg/lb	UCF2	0.4545
Unit conversion factor	ac/m ²	UCF3	2.47E-04
Unit conversion factor	d/mo	UCF4	30
Unit conversion factor	hr/d	UCF5	24
Unit conversion factor	sec/hr	UCF6	3600
Unit conversion factor	mg/kg	UCF7	1.00E+06
Particulate flux rate during heavy soil handling ²	mg/sec-m ²	AP-42'	0.104
Construction Worker Receptor			
			Benzo(a)pyrene
Soil chemical concentration ³	mg/kg	S	2.00E-04
Soil chemical concentration as weight fraction ⁴	-	Sw	2.00E-10
Air concentration of chemical ⁵	mg/m ³	Ca	1.99E-10
Particulate flux rate during heavy soil handling	mg/sec-m ²	AP-42'	0.104
Distance across emission area parallel to wind direction ⁶	m	d	43
Wind speed ⁷	m/sec	u	2.25
Mixing height ⁷	m	h	2
Landscape Worker Receptor			
			Benzo(a)pyrene
Soil chemical concentration ³	mg/kg	S	2.00E-04
Soil chemical concentration as weight fraction ⁴	--	Sw	2.00E-10
Air concentration of chemical ⁵	mg/m ³	Ca	5.40E-11
Particulate flux rate during heavy soil handling	mg/sec-m ²	AP-42'	1.13E-01
Distance across emission area parallel to wind direction ⁶	m	d	11
Wind speed ⁷	m/sec	u	2.25
Mixing height ⁷	m	h	2

Notes:

T/ac-mo = tons per acre per month, lbs/ton = pounds per ton, kg/lb = kilograms per pound, ac/m² = acres per square meter, d/mo = days per month, hr/d = day, sec/hr = seconds per hour, mg/kg = milligrams per kilogram, mg/sec-m² = milligrams per second per square meter, mg/m³ = milligrams per cubic meter. m = meters, m/sec = meters per second.

Footnotes:

¹From USEPA (1985 ["AP-42"]).

²(AP-42 x UCF1 x UCF2 x UCF3)/(UCF4 x UCF5 x UCF6).

³From Table 3-1.

⁴S/1E+06.

⁵Box model (CAL/EPA, 1994; ASTM, 1995; USEPA, 1991b; Dobbins, 1979) used to estimate outdoor airborne dust chemical concentration = SwAP-42'/d

⁶Based on longest diagonal distance of footprint of proposed office building at the corner of Grand Street and Fortmann Way.

⁷Default value from California (1994) ASTM (1995)

⁸Assumed equal to 25% of the distance for the construction worker

APPENDIX C

***Spreadsheets Used to Estimate Cancer Risk and
Noncancer Adverse Health Effects***

Table C-1
Estimates of Site-Wide Cancer Risk and Noncancer Adverse Health Effects
Onsite Construction Worker, Incidental Soil Ingestion
Grand Street and Fortmann Way Property
Alameda, California

Chemical	Exposure Assumptions										DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _s (mg/kg)	IR (mg/day)	CF (kg/mg)	EF (day/yr)	ED (yr)	FI (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Oral				
												SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)			
Benzo(a)Pyrene	2.00E-04	50	1E-06	60	1	1	70	25,550	365	3.35E-13	2.35E-11	1.20E+01	--	4.03E-12	--	

Total 4.03E-12 --

- Notes*
 C_s Exposure Point Concentration, Soil
 IR Soil Ingestion Rate
 CF Conversion Factor
 EF Exposure Frequency
 ED Exposure Duration
 FI Fraction Ingested from contaminated source
 BW Body Weight
 AT-C Averaging Time, carcinogens
 AT-NC Averaging Time, noncarcinogens
 D_{OSI} (cancer) [(C × IR × CF × EF × ED × FI) / (BW × AT-C)]
 D_{OSI} (non-cancer) [(C × IR × CF × EF × ED × FI) / (BW × AT-NC)]
 SF Slope Factor
 RfD Reference Dose
 Cancer Risk DOSE × SF
 Hazard Quotient DOSE / RfD
 - if Available

Table C-2
Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
Onsite Landscape Worker, Incidental Soil Ingestion
Grand Street and Fortmann Way Property
Alameda, California

Chemical	Exposure Assumptions									DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _s (mg/kg)	IR (mg/day)	CF (kg/mg)	EF (day/yr)	ED (yr)	FI (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Oral			
												SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzo(a)Pyrene	2.00E-04	480	1E-06	250	25	1	70	25,550	6,250	3.35E-10	1.37E-09	1.20E+01	--	4.03E-09	--

Notes

C_s - Exposure Point Concentration, Soil

IR - Soil Ingestion Rate

CF - Conversion Factor

EF - Exposure Frequency

ED - Exposure Duration

FI - Fraction Ingested from contaminated source

BW - Body Weight

AT-C - Averaging Time, carcinogens

AT-NC - Averaging Time, noncarcinogens

DOSE (cancer) - $[C_s \times IR \times CF \times EF \times ED \times FI] / [BW \times AT-C]$

DOSE (non-cancer) - $[C_s \times IR \times CF \times EF \times ED \times FI] / [BW \times AT-NC]$

SF - Slope Factor

RfD - Reference Dose

Cancer Risk - DOSE x SF

Hazard Quotient - DOSE / RfD

-- Available

Total 4.03E-09 --

Table C-3
 Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Construction Worker, Dermal Contact with Soil
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions											DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _s (mg/kg)	CF (kg/mg)	SA (cm ² /day)	AF (mg/cm ²)	ABS (-)	EF (days/yr)	ED (yr)	FI (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Dermal			
														SF (mg/kg-day) ¹	RfD (mg/kg-day)		
Benzo(a)Pyrene	2.00E-04	1E-6	2,000	0.5	0.10	60	1	1	70	25,550	365	6.71E-13	4.70E-11	1.20E+01	--	8.05E-12	--

Notes

- C_s - Exposure Point Concentration, Soil
- CF - Conversion Factor
- SA - Skin Surface Area
- AF - Soil/Skin Adherence Factor
- ABS - Absorption factor
- EF - Exposure Frequency
- ED - Exposure Duration
- FI - Fraction from Contaminated Source
- BW - Body Weight
- AT-C - Averaging Time, carcinogens
- AT-NC - Averaging Time, noncarcinogens
- DOSE (cancer) $[CS \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-C]$
- DOSE (non-cancer) $[CS \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-NC]$
- SF - Slope Factor
- RfD - Reference Dose
- Cancer Risk - DOSE x SF
- Hazard Quotient - DOSE / RfD
- - Not Available

Total 8.05E-12 --

Table C-4
 Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Landscape Worker, Dermal Contact with Soil
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions											DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _s (mg/kg)	CF (kg/mg)	SA (cm ² /day)	AF (mg/cm ²)	ABS (-)	EF (day/yr)	ED (yr)	FI (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Dermal			
														SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzo(a)Pyrene	2.00E-04	1E-6	2,000	0.5	0.10	250	25	1	70	25,550	6,250	6.99E-11	2.86E-10	1.20E+01	--	8.39E-10	--

- Notes
- C_s = Exposure Point Concentration, Soil
 - CF = Conversion Factor
 - SA = Skin Surface Area
 - AF = Soil/Skin Adherence Factor
 - ABS = Absorption factor
 - EF = Exposure Frequency
 - ED = Exposure Duration
 - FI = Fraction from Contaminated Source
 - BW = Body Weight
 - AT-C = Averaging Time, carcinogens
 - AT-NC = Averaging Time, noncarcinogens
 - DOSE (cancer) = $[CS \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-C]$
 - DOSE (non-cancer) = $[CS \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-NC]$
 - SF = Slope Factor
 - RfD = Reference Dose
 - Cancer Risk = DOSE x SF
 - Hazard Quotient = DOSE / RfD
 - Not Available

Table C-5
 Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Construction Worker, Inhalation of Airborne Particulates
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _A (mg/m ³)	IR (m ³ /hr)	ET (hr/day)	EF (day/yr)	ED (yr)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer	Non-Cancer	Inhalation			
									(mg/kg-day)	(mg/kg-day)	SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzo(a)Pyrene	1.99E-10	1.32	8	60	1	70	25,550	365	7.04E-14	4.93E-12	3.90E+00	--	2.74E-13	--

Notes:

- C_A = Exposure Point Concentration, Airborne Particulates
- IR = Inhalation Rate
- ET = Exposure Time
- EF = Exposure Frequency
- ED = Exposure Duration
- BW = Body Weight
- AT-C = Averaging Time, carcinogens
- AT-NC = Averaging Time, noncarcinogens
- DOSL (cancer) = $[C_A \times IR \times EF \times ED] / [BW \times AT-C]$
- DOSL (non-cancer) = $[C_A \times IR \times EF \times ED] / [BW \times AT-NC]$
- SF = Slope Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Hazard Quotient = DOSE / RfD
- = Not Available

Total 2.74E-13 --

Table C-6
 Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Landscape Worker, Inhalation of Airborne Particulates
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _A (mg/m ³)	IR (m ³ /hr)	ET (hr/day)	EF (day/yr)	ED (yr)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer	Non-Cancer	Inhalation			
									(mg/kg-day)	(mg/kg-day)	SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzo(a)Pyrene	5.40E-11	1.32	8	250	25	70	25,550	6,250	1.99E-12	8.14E-12	3.90E+00	--	7.77E-12	--

Notes:

- C_A = Exposure Point Concentration, Airborne Particulates
- IR = Inhalation Rate
- ET = Exposure Time
- EF = Exposure Frequency
- ED = Exposure Duration
- BW = Body Weight
- AT-C = Averaging Time, carcinogens
- AT-NC = Averaging Time, noncarcinogens
- DOSE (cancer) = $[C_A \times IR \times EF \times ED] / [BW \times AT-C]$
- DOSE (non-cancer) = $[C_A \times IR \times EF \times ED] / [BW \times AT-NC]$
- SF = Slope Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Hazard Quotient = DOSE / RfD
- = Not Available

Total 7.77E-12 --

Table C-7
 Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Construction Worker, Dermal Contact with Groundwater
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions											DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C (w) (mg/L)	SA (cm ² /day)	PC (cm/hr)	CF (L/cm ²)	ET (hr/day)	EF (days/yr)	ED (yr)	FC (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Dermal			
														SF (mg/kg-day) ¹	RfD (mg/kg-day)		
Benzene	2.60E-01	2,000	2.10E-02	1E-03	8	60	1	1	70	25,550	365	2.93E-09	2.05E-07	1.00E-01	--	2.93E-10	--

Notes

- C (w) = Exposure Point Concentration, Groundwater
- SA = Skin Surface Area
- PC = Dermal Permeability Constant
- CF = Conversion Factor
- ET = Exposure Time
- EF = Exposure Frequency
- ED = Exposure Duration
- FC = Fraction of Time Contacting Exposure Area
- BW = Body Weight
- AT-C = Averaging Time, carcinogens
- AT-NC = Averaging Time, noncarcinogens
- DOSE (cancer) = $[C(w) \times SA \times PC \times CF \times ET \times EF \times ED \times FC] / [BW \times AT-C]$
- DOSE (non-cancer) = $[C(w) \times SA \times PC \times CF \times ET \times EF \times ED \times FC] / [BW \times AT-NC]$
- SF = Safety Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Hazard Quotient = DOSE / RfD
- = Not Available

Total 2.93E-10 --

Table C-8
Site-Wide Estimates of Cancer Risk and Noncancer Adverse Health Effects
Onsite Construction Worker, Inhalation of Ambient Air VOCs Emanating from Groundwater
Grand Street and Fortmann Way Property
Alameda, California

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _A (µg/m ³)	IR (m ³ /hr)	ET (hr/day)	EF (day/yr)	ED (yr)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Inhalation			
											SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzene	3.05E-05	1.32	8	60	1	70	25,550	365	1.08E-08	7.56E-07	1.00E-01	1.71E-03	1.08E-09	4.42E-04

Notes

- C_A = Exposure Point Concentration, Ambient Air
- IR = Inhalation Rate
- ET = Exposure Time
- EF = Exposure Frequency
- ED = Exposure Duration
- BW = Body Weight
- AT-C = Averaging Time, carcinogens
- AT-NC = Averaging Time, noncarcinogens
- DOSE (cancer) = $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-C]$
- DOSE (non-cancer) = $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-NC]$
- SF = Slope Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Hazard Quotient = DOSE / RfD
- = Not Available

Total 1.08E-09 4.42E-04

Table C-9
Estimates of Cancer Risk and Noncancer Adverse Health Effects
Onsite Indoor Commercial Worker, Inhalation of Indoor Air VOCs Emanating from Groundwater
Office Building Scenario
Grand Street and Fortmann Way Property
Alameda, California

Chemical Name	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _A	IR	ET	EF	ED	BW	AT-C	AT-NC	Cancer	Non-Cancer	Inhalation			
											SF	RfD		
Chemical	(mg/m ³)	(m ³ /hr)	(hr/day)	(day/yr)	(yr)	(kg)	(day)	(day)	(mg/kg-day)	(mg/kg-day)	(mg/kg-day) ⁻¹	(mg/kg-day)		
Benzene	1.77E-03	0.83	8	250	25	70	25,550	9,125	4.11E-05	1.15E-04	1.00E-01	1.71E-03	4.11E-06	6.73E-02

Notes:

C_A = Exposure Point Concentration, Enclosed-Space Air

IR = Inhalation Rate

ET = Exposure Time

EF = Exposure Frequency

ED = Exposure Duration

BW = Body Weight

AT-C = Averaging Time, carcinogens

AT-NC = Averaging Time, noncarcinogens

DOSE (cancer) = $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-C]$

DOSE (non-cancer) = $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-NC]$

SF = Slope Factor

RfD = Reference Dose

Cancer Risk = DOSE x SF

Hazard Quotient = DOSE / RfD

-- = Not Available

Total 4.11E-06 6.73E-02

Table C-9
 Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Construction Worker, Dermal Contact with Groundwater
 Office Building Scenario
 Grand Street and Fortmann Way Property
 Alameda, California

Chemical	Exposure Assumptions											DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _{GW} (mg/L)	SA (cm ² /day)	PC (cm/hr)	CF (L/cm ²)	ET (hr/day)	EF (day/yr)	ED (yr)	FC (-)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer (mg/kg-day)	Non-Cancer (mg/kg-day)	Dermal			
														SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzene	1.03E+00	2,000	2.10E-02	1E-03	8	60	1	1	70	25,550	365	1.16E-08	8.11E-07	1.00E-01	--	1.16E-09	--
Total														1.16E-09	--		

Notes

- C_{GW} = Exposure Point Concentration, Groundwater
- SA = Skin Surface Area
- PC = Dermal Permeability Constant
- CF = Conversion Factor
- ET = Exposure Time
- EF = Exposure Frequency
- ED = Exposure Duration
- FC = Fraction of Time Contacting Exposure Area
- BW = Body Weight
- AT-C = Averaging Time, carcinogens
- AT-NC = Averaging Time, noncarcinogens
- DOSE (carcinogens) = (C_{GW} x SA x PC x CF x ET x EF x ED x FC) / (BW x AT-C)
- DOSE (non-carcinogens) = (C_{GW} x SA x PC x CF x ET x EF x ED x FC) / (BW x AT-NC)
- SF = Slope Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Haz. and Quotient = DOSE / RfD
- = Not Available

Table C-10
 Estimates of Cancer Risk and Noncancer Adverse Health Effects
 Onsite Construction Worker, Inhalation of Ambient Air VOCs Emanating from Groundwater
 Office Building Scenario
 Grand Street and Fortmann Way Property
 Alameda, California^a

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C _A (mg/m ³)	IR (m ³ /hr)	ET (hr/day)	EF (day/yr)	ED (yr)	BW (kg)	AT-C (day)	AT-NC (day)	Cancer	Non-Cancer	Inhalation			
									(mg/kg-day)	(mg/kg-day)	SF (mg/kg-day) ⁻¹	RfD (mg/kg-day)		
Benzene	1.41E-03	1.32	8	60	1	70	25,550	365	7.58E-07	5.31E-05	1.00E-01	1.71E-03	7.58E-08	3.10E-02

Notes

- C_A - Exposure Point Concentration, Ambient Air
- IR - Inhalation Rate
- ET - Exposure Time
- EF - Exposure Frequency
- ED - Exposure Duration
- BW - Body Weight
- AT-C - Averaging Time, carcinogens
- AT-NC - Averaging Time, noncarcinogens
- DOSE (cancer) - $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-C]$
- DOSE (non-cancer) - $[C_A \times IR \times ET \times EF \times ED] / [BW \times AT-NC]$
- SF - Slope Factor
- RfD - Reference Dose
- Cancer Risk - DOSE x SF
- Hazard Quotient - DOSE / RfD
- - Not Available

Total 7.58E-08 3.10E-02

Footnotes.

^aAll contact with groundwater is assumed to be site related.