

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

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## 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
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 I, Human Health Evaluation Manual* (USEPA, 1989a) are 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 at the Site since 1987.

### 1.2 PURPOSE

The purpose of this risk assessment is to

- Provide an analysis of potential human health risks to both current and future potential receptors under a range of land use scenarios to help determine the need, if any, for action at the Site.

- Provide a basis for determining levels of chemicals that can remain on-site and still be adequately protective of human health.
- Provide a basis for identifying which contaminants 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 that may 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). In general, this risk assessment is conducted using RME default assumptions provided in ASTM (1995) and USEPA (1989a).

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 is 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, presents a description of the Site and summarizes the Site investigation history.
- Section 3.0 Chemicals of Potential Concern (COPCs), presents the Site data used for risk assessment and identifies the chemicals that are quantitatively evaluated for potential risks in the risk assessment.
- Section 4.0 Exposure Assessment, includes a detailed analysis of potential exposure pathways and presents estimates of chemical intakes from exposure to Site chemicals.
- Section 5.0 Toxicological Assessment, presents toxicity values for each of the Site chemicals identified for evaluation.

- Section 6.0 Risk Characterization, provides a characterization of the potential cancer and noncancer risks associated with exposure to Site chemicals.
- Section 7.0 Uncertainty Analysis, identifies major uncertainties associated with each component of the risk assessment.
- Section 8.0 Summary and Conclusions, briefly summarizes the risk assessment with general conclusions.
- Section 9.0 References, provides citations of the information sources used in the report.

Appendix A contains groundwater volatilization factor calculations. Appendices B and C contain risk calculations for Site-wide and Grand Street office building scenarios, respectively.



## 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 are under water. The land portion was created with fill which took place 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) describes the following Site history. An AGT farm was previously operated on Site and was used until 1989. According to the documentation provided by Unocal (1994), gasoline, diesel fuel, lube oil, aviation fuel, 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.

Other historic Site uses may have included the following.

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 a dog pound.
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 within the AGTs.
1953 to 1959	W. D. McElwain, dba 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 1989	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 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 five 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.

In June 1990, Versar, Inc. 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 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, 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.

In general, the Site investigations revealed the greatest hydrocarbon concentrations in soils at depths to two feet beneath the AGT farm floor and beneath the former pump house. Samples collected from depths of three to seven feet 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 well MW-2 near the former UST. Groundwater samples collected from wells W-1, W-2, W-3, and MW-4 indicated significantly lower concentrations of total petroleum hydrocarbons as gasoline (TPHg), as diesel (TPHd), and as 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 pipeline integrity test results indicated that the three lines previously used to convey petroleum liquids and bilge/sludge to and from the former AGT farm are competent in their existing configuration and did not show evidence of having leaked. The former AGT farm constructed in 1930 by Unocal (then Union Oil Company) stored and distributed various hydrocarbon compounds until approximately 1952. The contents stored in the AGTs, as reported by Unocal, included gasoline, fuel oil, diesel fuel, kerosene, ethyl, aviation fuel, stove oil, and an unknown solvent (S-76 solvent). 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 Weyerhaeuser (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.

The Subsurface Investigation conducted by *SECOR* confirmed that fill composes the upper one to six feet of Site soils. The fill is locally underlain by a fine-grained sand with varying amounts of gravel and clay, but is primarily underlain by the dark gray silty clay comprising Bay Mud. The Bay Mud contains sandy and peat-rich horizons. Samples collected from locations south of the AGT farm (TP3 with TPHd and TPHg at 800 and 13 milligrams per kilogram or mg/kg, respectively) and northeast of the pump house adjacent to the northern wall of the AGT farm (TPHd at 300 mg/kg) contained the greatest reported hydrocarbon concentrations. Samples collected from the northern portion of the area of investigation (HD1 with TPHd at 15 mg/kg), north of the pump house (TP1 with TPHd at 29 mg/kg), and near the joint in the diesel fuel pipeline north of the AGT farm (PL3 with TPHd at 5.0 mg/kg) contained lesser hydrocarbon concentrations. The vadose zone soils beneath and surrounding the AGT farm to a distance of approximately 40 feet contain concentrations of TPHg, TPHd, and oil and grease (*SECOR*, 1995).

Groundwater grab samples collected immediately north and northeast of the AGT farm pump house contained elevated TPHd concentrations. The extent of impacted groundwater appeared to be limited to the vicinity of borings TP2 and TP2A, although a confirmatory sample collected southeast of boring TP2A was not obtained. In addition, pipeline-vicinity groundwater grab samples collected north of the AGT farm (PL2 and PL4) contained elevated TPHd concentrations. The borings surrounding PL4 yielded data which indicated the TPHd extent was limited; however, groundwater grab samples were not collected bayward of PL2, due to refusal met by the drilling rig (*SECOR*, 1995). With the exception of low toluene, ethylbenzene, and xylenes concentrations reported in one water sample, gasoline-range hydrocarbons were not reported in groundwater samples analyzed for TPHg and benzene, toluene, ethylbenzene, and xylenes (BTEX) constituents.

An additional subsurface investigation, which included installing four additional groundwater monitoring wells (MW-5 through MW-8) and conducting quarterly monitoring, was conducted by *SECOR* according to the October 1994 Work Plan Addendum. During the installation of the monitoring wells, subsurface soil samples were collected on October 27 and 28, 1994 for BTEX and TPHs (*SECOR*, 1995). Although benzene was not detected in any of the samples, toluene, ethylbenzene and total xylenes were all detected once (for toluene and

ethylbenzene) or twice (for total xylenes). TPHd was detected at six of the seven sampling locations (boring TP3A-2, and wells MW-5-2.5, MW-5-5, MW-6-2.5, MW-7-2, and MW-8-3.5).

The groundwater samples were collected quarterly from November 1994 to March 1996 from wells MW-1, and MW-4 through MW-8. Quarterly monitoring was also conducted by ACC for wells MW-2, MW-4, and MW-6a. Samples were routinely analyzed for BTEX and TPHd, and once for polycyclic aromatic hydrocarbons (PAHs) in March 1996 (SECOR, 1995). The resulting data contained few detections of BTEX except for the well MW-2 area. TPHd was detected in wells MW-1 through MW-8, but not sampled at well MW-6A. There were only two PAHs detected amongst all the data. These PAHs (fluorene and naphthalene) were only detected at well MW-2.

### 3.0 CHEMICALS OF POTENTIAL CONCERN

This section presents the data used for risk assessment, and identifies the chemicals of potential concern (COPCs) at the Site.

#### 3.1 SUMMARY OF RISK ASSESSMENT DATA

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. This risk assessment assumes that the most recent Site investigation data provides the most accurate representation of current conditions at the Site. Therefore, this risk assessment focuses on results of recent subsurface soil and groundwater sampling rounds (*i. e.*, the October 1994 subsurface soil sampling round and the November 1994 to March 1996 groundwater sampling rounds) to evaluate potential health risks from exposure to current levels of residual petroleum hydrocarbons present in Site subsurface soils and groundwater. why?

ASTM observes that it is not practicable to evaluate every compound present in a petroleum product to assess the human health risk from a spill of that product. Recognizing that a significant fraction of the impact from all chemicals is due to a select group of chemicals, "indicator" compounds are identified based on exposure routes, mobility, and toxicity (ASTM, 1995). ASTM identifies BTEX and polycyclic aromatic hydrocarbons (PAHs) as indicator compounds for gasoline and diesel, respectively. 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.

The data used for risk assessment from the October 1994 subsurface soil and November 1994 to March 1996 groundwater investigations is described below.

##### 3.1.1 Soil Investigation Results

Results of the Site subsurface soil analyses for BTEX are presented in Table 3-1. Seven samples were collected during October 26 and 27, 1994, and analyzed for BTEX, TPHd, TPHg, and total petroleum hydrocarbons as oil (TPHo). Detections of toluene and ethylbenzene were limited to wellbore location MW-8 at 3.5 feet bgs. Detections occurred at 5.7 mg/kg and 10 mg/kg, respectively. Total xylenes were detected in two of the seven samples at 15 mg/kg and 84 mg/kg. The maximum detection of total xylenes occurred at wellbore location MW-8 at 3.5 feet bgs.

Because of the ASTM recommendation to consider PAHs as indicator compounds when diesel is present at petroleum release sites, concentrations for the carcinogenic PAH with the highest EPA toxicity value, benzo(a)pyrene, are estimated from TPHd. According to diesel fuel chemical composition values provided by ACHCS from the *State of California Leaking Underground Fuel Tank Field Manual* (State of California

1989), the concentration of benzo(a)pyrene in diesel fuel #2 is 0.07 micrograms per gram ( $\mu\text{g}/\text{gm}$ ). Benzo(a)pyrene concentrations in soil are estimated by applying this composition factor to TPHd concentrations in soil. The proportion that is benzo(a)pyrene may also vary with the type of diesel fuel, resulting in uncertainty associated with this method of estimation.

As presented in Table 3-1, TPHd was detected in six samples, at 23 mg/kg to 1,400 mg/kg. The maximum detection of TPHd occurred at boring TP3A at a depth of 2 feet bgs. Table 3-1 also shows the surrogate concentrations of benzo(a)pyrene estimated from each measured concentration of TPHd.

As discussed in Section 2.2, soil samples were collected during the May 1992 Zaccor investigation from the vicinity of the AGT farm, the former 1,000-gallon UST, and the product lines. The 1992 data provides information about the shallow soil in the vicinity of the former AGT farm. Because the contamination is at shallow depths, the concentrations are expected to have decreased since 1992 due to volatilization, biodegradation, and photolysis. The 1992 Zaccor report does not provide detection limits for analytes that are reported as non-detects, so standard EPA methods for using detection limits for non-detect data cannot be applied. Because this data may not be representative of current Site conditions, and because it cannot be summarized statistically in a consistent manner with the 1994 data, it is not used for quantitative evaluation of risk in this assessment. The uncertainty introduced by not including this data in the quantitative evaluation is discussed in Section 7.1 of the qualitative uncertainty analysis.

### 3.1.2 Groundwater Investigation Results

Results of the Site groundwater analyses for BTEX are presented in Table 3-2. Seven monitoring wells were sampled during six sampling events from the period of November 1994 to March 1996. With the exception of a 2.5 micrograms per liter ( $\mu\text{g}/\text{L}$ ) detection of total xylenes at well MW-6a during the February 1995 sampling round, detections of BTEX were limited to well MW-1 during the November 1994 sampling round and to well MW-2, which yielded reportable BTEX concentrations during all five sampling rounds from November 1994 to November 1995.

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 3-3. Seven monitoring wells were sampled during March 1996. The analytes included: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, 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.

Those analytes detected in at least one groundwater sample were fluorene and naphthalene. Fluorene and naphthalene were detected at concentrations of 0.9 and 9.3  $\mu\text{g}/\text{L}$ , respectively in the samples collected from well MW-2. No other PAH compounds were detected in the sample from well MW-2. No PAHs or other

semivolatile organic compounds were detected in samples collected from wells MW-1, MW-4, MW-5, MW-6, MW-7, or MW-8 using EPA method 8270.

### 3.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

The preliminary CSM discussed between the ACHCS and SECOR identified potentially complete and significant pathways at the Site. The indicator chemicals discussed in Section 3.1 are compared to Risk-Based Screening Levels (RBSLs) to determine which indicator chemicals to retain and evaluate quantitatively in the risk assessment. The purpose of identifying COPCs is to focus the risk assessment on chemicals that contribute most significantly to potential risks posed by the Site, and to eliminate from further evaluation, chemicals that may distract from the dominant risks presented by the Site.

Maximum detected concentrations of fluorene, naphthalene, and BTEX in subsurface soil and groundwater are screened against Tier 1 RBSLs provided in ASTM's *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (ASTM, 1995) to identify COPCs at the Site. If the maximum detected concentration of a Site chemical exceeds the Tier 1 RBSL, then that chemical is selected as a Site COPC and retained for quantitative evaluation in the risk assessment.

Tier 1 RBSLs represent chemical concentrations in source media that are not expected to pose a health risk, even under long-term exposure. Tier 1 RBSLs are developed based on an acceptable target risk level and standard exposure scenarios, USEPA RME default exposure assumptions, and current toxicological parameters recommended by USEPA. For direct exposure pathways, e.g., soil ingestion, standard exposure assumptions are used to derive RBSLs. For indirect exposure pathways, e.g., inhalation of vapor from soil, fate and transport models are used with standard assumptions to derive RBSLs.

#### 3.2.1 Subsurface Soil Chemicals of Potential Concern

Tier 1 soil RBSLs have been calculated by ASTM for the following potential single and/or combined routes of exposure from chemicals in subsurface soil:

- Indoor inhalation of vapor originating from soil beneath the 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 3-4 presents a comparison of maximum detected concentrations of BTEX in vadose zone subsurface soil against Tier 1 soil RBSLs for the identified exposure pathways. None of the concentrations of BTEX exceed the Tier 1 RBSLs, which indicates that potential risks are below acceptable risk levels and these indicator chemicals do not warrant further evaluation. Due to the uncertainty involved in estimating concentrations for

benzo(a)pyrene from TPHd, the estimated concentrations are not screened using RBSLs. Therefore, benzo(a)pyrene is identified as a soil COPC and quantitatively evaluated in the risk assessment.

### 3.2.2 Groundwater Chemicals of Potential Concern

Tier 1 groundwater RBSLs have been calculated by ASTM for the following potential routes of exposure from chemicals in groundwater.

- Indoor inhalation of vapor originating from groundwater
- Outdoor inhalation of vapor originating from groundwater
- Ingestion of groundwater

Table 3-4 presents a comparison of maximum detected concentrations of BTEX, naphthalenes, fluorene, and benzo(a)pyrene in groundwater against Tier 1 groundwater RBSLs for these three exposure pathways. As shown on Table 3-4, the maximum detected groundwater concentration of benzene exceeds the groundwater RBSL for the exposure routes involving indoor and outdoor inhalation of vapor originating from groundwater. RBSLs are not available in ASTM for fluorene so it is conservatively retained as a COPC. Tier 1 groundwater RBSLs for toluene, ethylbenzene, naphthalenes, and total xylenes are not exceeded for any of the three potential exposure pathways. Therefore, benzene and fluorene are identified as groundwater COPCs and quantitatively evaluated in the risk assessment.

### 3.2.3 Summary of Chemicals of Potential Concern

In summary, due to the uncertainty involved in estimating concentrations for benzo(a)pyrene from TPHd, the estimated benzo(a)pyrene concentrations were not screened using RBSLs. Therefore, benzo(a)pyrene is identified as a soil COPC to be quantitatively evaluated in the risk assessment. Benzene and fluorene were identified as a groundwater COPCs and are quantitatively evaluated in the risk assessment.

Summary statistics for these COPCs are presented in Tables 3-5 and 3-6 for subsurface soil and groundwater, respectively, to provide information on the range and central tendency of investigation results for the COPCs that are quantitatively evaluated in the risk assessment. These summary statistics include the maximum and minimum concentrations, the mean, and the 95 percent upper confidence limit (UCL) of the mean. The subsurface soil summary statistics presented for benzo(a)pyrene are based on concentrations estimated from TPHd. The groundwater summary statistics are based on measured concentrations. Further discussion on the use of summary statistics in risk assessment is provided in Section 4.3.1.



## 4.0 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of exposures to current and future potential receptors from the COPCs that are present at or migrating from the Site. This section outlines the methodologies and assumptions that are used to calculate the potential daily exposure to each Site COPC. These methodologies and assumptions are discussed by USEPA (1989a; 1989b; 1991; 1992a). The results of the exposure assessment are combined with chemical-specific toxicity information (Section 5.0) to characterize potential risks (Section 6.0).

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; and,
- Quantitatively determine the extent of exposure.

These three components are described below.

### 4.1 CHARACTERIZATION OF POTENTIALLY EXPOSED HUMAN RECEPTORS

Potentially exposed human receptors are 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 is evaluated and considered representative of future conditions.

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

- An on-site indoor commercial worker; and,
- An on-site outdoor construction worker.

The construction worker and on-site worker scenarios are based on different assumptions to provide two distinctly different scenarios and risk estimates. The construction worker is assumed to be exposed only during the construction period which involves direct contact with petroleum impacted soil. The on-site worker is assumed to work indoors at the same location for their entire career. After the construction period, it is assumed that the site is landscaped and/or paved and that the on-site worker does not have direct contact with petroleum impacted soil.

Another potential commercial/industrial receptor is a landscape worker. This receptor may have short periods of contact with petroleum impacted surficial soil during initial soil preparation and planting. Groundskeeping activities after planting, e.g., watering, pruning, and mowing, are not expected to involve contact with petroleum impacted soil. Furthermore, petroleum in soil is expected to biodegrade, and concentrations will decrease with each planting season. Compared to the construction worker, the landscape worker is expected to be exposed to petroleum impacted soils for a much shorter period. Because exposure to the landscape worker is expected to be bounded by the exposure to the construction worker, exposure to the landscape worker is not quantitatively evaluated.

Potential risks are conservatively estimated for these two receptors assuming current detected levels of Site COPCs remain at a steady-state (*i.e.*, biodegradation will not be considered) in the future. It is assumed that these potential occupational receptors will have free access to the entire Site and could potentially receive exposure to Site COPCs at any location. Therefore, average exposure across the Site is calculated using the Site-wide data presented in Tables 3-2 through 3-6.

It is currently planned that the two office/commercial buildings will be constructed on the Southeast portion of the Site, with one building located on the corner of Grand Street and Fortmann Way. The restaurant/commercial building will be constructed north of the office buildings, on the waterfront of the marina/harbor.

The proposed Grand Street office building will be adjacent to 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 is conducted. In this scenario, it is assumed that the on-site construction and indoor commercial workers are exposed to COPC concentrations representative of the Grand Street office building area. This building is selected because it represents exposure closest to the COPC source. Since this scenario does not involve Site-wide exposure, additional summary statistics are calculated using only data from sampling locations near the proposed Grand Street office building (wells MW-2 and MW-4). These groundwater summary statistics are presented in Table 4-1. Due to the small number of subsurface soil samples from the proposed Grand Street building area, analysis of risk from exposure to subsurface soil will use the same data used for the Site-wide statistics (Table 3-5). Because earth-moving activities associated with building construction and Site preparation may not be limited to the area of the foundation, use of Site-wide data for the localized risk analysis is conservative.

#### 4.2 IDENTIFICATION OF EXPOSURE PATHWAYS

An exposure pathway describes a specific environmental pathway by which a receptor can be exposed to COPCs present at the Site. Five elements comprise an exposure pathway. These elements, shown below, are identified to determine potential exposure pathways at the Site.

- A chemical source
- 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 five of these elements must be met 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 outlined schematically in a CSM, shown in Figure 4-1. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures that target significant contaminant sources and exposure pathways.

In the CSM, potentially complete and significant exposure pathways are designated with a closed circle. Potentially complete but relatively insignificant exposure pathways are designated with an open circle. Insignificant exposure pathways are those that are expected, based on risk assessment experience, to contribute only a small percentage of exposure in comparison to significant exposure pathways. Incomplete exposure pathways are designated by an "I". In this analysis, quantitative evaluation (*i.e.*, the calculation of numerical cancer and noncancer risk estimates) is limited to potentially complete and significant 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 is used to guide the scope of this risk assessment.

#### **4.2.1 Potentially Complete and Significant Exposure Pathways**

The CSM indicates that the following exposure pathways are potentially complete and significant for the on-site indoor commercial and construction worker receptors selected for evaluation. These pathways are evaluated quantitatively in the risk assessment.

##### **4.2.1.1 Identified Exposure Pathways for the On-Site Indoor Commercial Worker**

The CSM indicates that the on-site indoor commercial worker may be exposed to Site COPCs via the following 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 are identified in subsurface soil. Benzo(a)pyrene is evaluated as a subsurface soil COPC, but according to ASTM (1995), the solubility, Henry's constant, and log  $K_{oc}$  for benzo(a)pyrene all indicate that it sorbs strongly to soils and is not subject to rapid volatilization. Therefore, volatilization of benzo(a)pyrene from Site subsurface soil to indoor air is not expected and this pathway is not quantitatively evaluated.

- **Inhalation of VOCs that emanate from Site groundwater to indoor air.** Volatile COPCs (BTEX) are present in groundwater. These 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 is quantitatively evaluated in the risk assessment.

#### 4.2.1.2. Identified Exposure Pathways for the On-Site Construction Worker

The CSM indicates that the on-site construction worker may be exposed to Site COPCs via the following exposure pathway.

- **Incidental ingestion of soil.** Incidental ingestion of soil containing Site COPCs may occur during construction activities involving soil excavation. Therefore, exposure via this pathway is quantitatively evaluated.
- **Dermal contact with soil.** Dermal contact with soil containing Site COPCs may occur during construction activities involving soil excavation. Therefore, exposure via this pathway is 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 Site COPCs. Therefore, exposure via this pathway is 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 is 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 are identified in subsurface soil. Benzo(a)pyrene is evaluated as a subsurface soil COPC, but according to ASTM(1995), the solubility, Henry's constant, and log  $K_{oc}$  for benzo(a)pyrene all indicate that it sorbs strongly to soils and is not subject to rapid volatilization. Therefore, volatilization of benzo(a)pyrene from Site subsurface soil to ambient air is not expected and this pathway is not quantitatively evaluated.

- **Inhalation of VOCs that emanate from Site groundwater to ambient air.** Volatile COPCs (BTEX) are present in groundwater. These may volatilize and the vapor may migrate upward through the soil/air interface to ambient air. Therefore, exposure via this pathway is quantitatively evaluated in the risk assessment.

#### 4.2.2 Incomplete Exposure Pathways

The CSM indicates that the following exposure pathways are incomplete. These incomplete exposure pathways are not 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 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 that emanate from Site subsurface soil to indoor air by the on-site construction worker.** It is assumed that all construction activities occur outdoors; therefore, exposure via this pathway is incomplete.
- **Inhalation of VOCs that emanate from Site groundwater to indoor air by 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 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 groundwater for the on-site construction worker.** Although the on-site construction worker may come in contact with groundwater during excavation activities, the volume of ingested groundwater would be negligible.

- **Inhalation of VOCs volatilized from indoor groundwater use.** Areas on-site are currently using a public water supply; therefore, inhalation of VOCs volatilized from indoor groundwater use is not expected.

The exposure pathway analysis also indicates that no impacts to the Bay are expected from residual petroleum at the Site. The most mobile chemicals at the Site, 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 aquatic life in saltwater and freshwater. The only BTEX detected in the last several quarterly samples at the Site is at well MW-2, which is located further from the Bay. BTEX concentrations at Well MW-2 are below ambient water quality criteria and concentrations are decreasing.

### 4.3 QUANTIFICATION OF EXPOSURE

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

#### 4.3.1 Estimation of Exposure Point Concentrations

The exposure point concentration (EPC) is one of several parameters required to estimate the intake of chemicals by a human receptor. The EPC generally used in an intake calculation is the arithmetic average concentration for a chemical in the medium being evaluated. Because this average is derived from a limited data set, it is uncertain how accurately it represents the true average concentration at the Site. USEPA guidance recommends using the 95 percent UCL as the exposure point concentration for intake calculations. In the calculation of the 95 percent UCL, all data are assumed to be normally distributed (USEPA, 1992a).

USEPA risk assessment guidance recommends consideration of the positively detected results together with the non-detected results (*i.e.*, the sample quantitation limits) (USEPA, 1989a). Following this guidance, for all results reported as "non-detect," one-half of the sample quantitation limit is assumed as a conservative proxy concentration for each sample with a non-detect result.

If the calculated 95 percent UCL of a chemical in a medium-specific data set exceeds the maximum concentration detected in that data set, USEPA recommends that the maximum detected concentration be selected as the EPC (USEPA, 1989a). Exceedance of the maximum concentration typically occurs when dilution effects have resulted in reporting of very high sample quantitation limits (*i.e.*, non-detect values) or if there is a limited (*i.e.*, less than ten) number of samples.

EPCs for Site COPCs in groundwater are used in vapor-phase migration models to estimate the concentration of Site COPCs in enclosed-space air and ambient air. The models and methodology used are presented below.

#### 4.3.1.1 Enclosed-Space Air Exposure Point Concentrations

To estimate the concentration of benzene and fluorene in enclosed-space air, the vapor-phase migration model presented in ASTM (1995) are used. The model uses closed-form analytical solutions for convective and diffusive transport of vapor phase chemicals in groundwater. The calculation of enclosed-space air concentrations is performed in two steps: (1) deriving a Site- and chemical-specific volatilization factor (VF) that describes the relationship between enclosed-space air and groundwater concentrations; and (2) estimating enclosed-space air concentrations from the calculated VF and groundwater concentrations.

##### Volatilization Factor Derivation

Chemical-specific volatilization factors were determined using the following model presented by ASTM (1995).

$$VF_{wesp} \left[ \frac{(mg/m^3-air)}{(mg/L-H_2O)} \right] = \frac{H \times \left[ \frac{Deff_{ws} L_{GW}}{ER \times L_B} \right]}{1 + \left[ \frac{Deff_{ws} L_{GW}}{ER \times L_B} \right] + \left[ \frac{Deff_{ws} L_{GW}}{(Deff_{crack} L_{crack}) \times n} \right]} \times 10^3 \frac{L}{m^3}$$

where:

$VF_{wesp}$	=	volatilization factor for groundwater to enclosed space vapors [(mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)]
H	=	Henry's law constant (unitless)
$Deff_{ws}$	=	effective diffusion coefficient between groundwater and soil surface
$L_{GW}$	=	depth to groundwater (cm)
ER	=	enclosed-space air exchange rate (1/s)
$L_B$	=	enclosed-space volume/infiltration area ratio (cm)
$Deff_{crack}$	=	effective diffusion coefficient through foundation cracks
L	=	enclosed-space foundation or wall thickness (cm)
n	=	areal fraction of cracks in foundation/walls (cm <sup>2</sup> -cracks/cm <sup>2</sup> -total area)

The model is based on the following assumptions

- A constant dissolved chemical concentration in groundwater;
- Equilibrium partitioning between dissolved chemicals in groundwater and chemical vapors at the groundwater table;
- Steady-state vapor- and liquid-phase diffusion through the capillary fringe, vadose zone, and foundation cracks;
- 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 enclosed space.

#### Enclosed-Space Air Concentrations

Using the calculated volatilization factors for benzene and fluorene, enclosed-space air concentrations are estimated with the following algorithm:

$$C_{\text{enclosed-space air}} = C_{\text{groundwater}} \times VF_{\text{wesp}}$$

where:

$C_{\text{enclosed-space air}}$	=	Chemical concentration in enclosed-space air (mg/m <sup>3</sup> )
$C_{\text{groundwater}}$	=	Chemical concentration in groundwater (mg/L)
$VF_{\text{wesp}}$	=	Chemical-specific groundwater-to-enclosed-space air volatilization factor (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)

Calculated enclosed-space concentrations of benzene and fluorene in air for average exposure Site-wide are presented in Table 4-2. The enclosed-space air concentrations of benzene and fluorene calculated for the office building are presented in Table 4-3.

#### 4.3.1.2. Ambient Air Exposure Point Concentrations

To estimate the concentration of benzene and fluorene in ambient air, the vapor-phase migration model presented in ASTM (1995) is used. The model uses closed-form analytical solutions for convective and diffusive transport of vapor phase chemicals in groundwater. The calculation of ambient air concentrations is performed in two steps: (1) deriving a Site- and chemical-specific volatilization factor (VF) that describes the relationship between ambient air and groundwater concentrations, and (2) estimating ambient air concentrations from the calculated VF and groundwater concentrations.



### Volatilization Factor Derivation

Chemical-specific volatilization factors are determined using the following model presented by ASTM (1995).

$$VF_{wamb} \left[ \frac{(mg/m^3-air)}{mg/L-H_2O} \right] = \frac{H}{1 + \left[ \frac{U_{air} \times \delta_{air} \times L_{GW}}{W \times Deff_{ws}} \right]} \times 10^3 \frac{L}{m^3}$$

where:

$VF_{wamb}$	=	volatilization factor for groundwater to enclosed space vapors [(mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)]
H	=	Henry's law constant (unitless)
$U_{air}$	=	wind speed above ground surface in ambient mixing zone (cm/s)
$\delta_{air}$	=	ambient air mixing zone height (cm)
$L_{GW}$	=	depth to groundwater (cm)
W	=	width of source area parallel to wind, or groundwater flow direction (cm)
$Deff_{ws}$	=	effective diffusion coefficient between groundwater and soil surface

The 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.

### Ambient Air Concentrations

Using the calculated volatilization factors for benzene and fluorene, ambient air concentrations are estimated with the following algorithm

$$C_{air} = C_{GW} \times VF_{wamb}$$

where:

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

Calculated ambient air concentrations of benzene and fluorene for average Site-wide exposure are presented in Table 4-2. In addition, the calculated ambient air concentrations of benzene and fluorene for the office building area are presented in Table 4-3.

#### 4.3.2 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) must be determined. 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), *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance*, and *Standard Default Exposure Factors* (USEPA, 1991). 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).

##### 4.3.2.1 Incidental Ingestion of Soil

Intake of chemicals of potential concern 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 a on-site construction worker, who is assumed to be exposed to subsurface soil.

Chemical intake via incidental ingestion of soil by the on-site construction worker is estimated with the following algorithm:

$$Intake \text{ (mg} \cdot \text{g}^{-1} \cdot \text{d}^{-1}) = \frac{CS \times IR \times CF \times FI \times FF \times ED}{BW \times AT}$$

where:

CS	=	Chemical concentration in soil (mg/kg)
IR	=	Soil ingestion rate (mg/day)
CF	=	Conversion factor (10 <sup>-6</sup> kg soil/mg soil)
FI	=	Fraction of soil ingested from contaminated source (unitless)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The chemical concentration for benzo(a)pyrene in soil [CS] is equal to its estimated exposure point concentration. Exposure point concentrations for subsurface soil are presented in Table 4-4.

The on-site construction worker is assumed to ingest 50 mg/day of soil (USEPA, 1992a). The fraction of soil ingested per day from the Site is conservatively assumed to be 100 percent. It is assumed that exposure to the on-site construction worker occurs eight hours per day, 60 days per year, for one year. These exposure assumptions and the calculated chemical intake for the on-site construction worker via ingestion of soil are presented in Table 4-5.

#### 4.3.2.2 Dermal Contact with Soil

Intake of chemicals of potential concern 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 is evaluated for the current on-site construction worker, who is assumed to be exposed to subsurface soil.

Chemical intake via dermal contact with soil by the on-site construction worker is estimated with the following algorithm.

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

where

CS	=	Chemical concentration in soil (mg/kg)
CF	=	Conversion factor (10 <sup>-6</sup> kg soil/mg soil)
SA	=	Exposed skin surface area (cm <sup>2</sup> /event)

AF	=	Soil-to-skin adherence factor (mg/cm <sup>2</sup> -event)
ABS	=	Chemical-specific absorption factor (unitless)
FI	=	Fraction of soil contacted from contaminated source (unitless)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The chemical concentration for benzo(a)pyrene in soil [CS] is equal to its exposure point concentration. Exposure point concentrations for subsurface soil are presented in Table 4-4.

For the on-site construction worker, the exposed skin surface area is assumed to be 2,000 cm<sup>2</sup>. 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 is assumed to be 0.5 mg/cm<sup>2</sup>-event (ASTM, 1995).

It is assumed that exposure to the on-site construction worker occurs eight hours per day, 60 days per year, for one year. The absorption factor for benzo(a)pyrene (a PAH) is assumed to be 0.01 (USEPA, 1992b). The fraction of soil contacted by the on-site construction worker is conservatively assumed to be 100 percent.

These exposure assumptions and the calculated chemical intake for the on-site construction worker via dermal contact with soil are presented in Table 4-6.

#### 4.3.2.3 Inhalation of Airborne Particulates

Intake of chemicals of potential concern 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 is evaluated for the on-site construction worker.

Chemical intake via inhalation of airborne particulates by the on-site construction worker is estimated with the following algorithm

$$Intake (mg \cdot kg^{-1} \cdot day^{-1}) = \frac{(A \times IR \times EF \times ED)}{BW \times AT}$$

where:

CA	=	Chemical concentration in outdoor air (mg/m <sup>3</sup> )
IR	=	Inhalation rate (m <sup>3</sup> /day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The outdoor airborne particulate concentration [CA] was derived from the estimated exposure point concentration for benzo(a)pyrene. This derivation is shown below in "Calculation of Airborne Particulate Concentrations".

The outdoor inhalation rate for the on-site construction worker is assumed to be 1.35 m<sup>3</sup>/hr (USEPA, 1989a). This inhalation rate assumes a moderate activity level. Fifty percent of the time and a light activity level the remaining 50 percent of the time.

It is assumed that exposure to the on-site construction worker occurs eight hours per day, 60 days per year, for one year.

These exposure assumptions and calculated chemical intake for the on-site construction worker via inhalation of airborne particulates are presented in Table 4-7.

#### Calculation of Airborne Particulate Concentrations

Airborne particulate concentrations are derived from surface soil exposure point concentrations using a particulate emission factor. The particulate emission factor (PEF) relates the chemical concentration in surface soil with the concentration of respirable particles (PM<sub>10</sub>) in the air due to fugitive dust emissions from surface soil. The model used is presented in USEPA (1989b) and is based on the relationship derived by Cowherd *et al.* (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface soil provides a relatively continuous and constant potential of emission over an extended period of time (*e.g.*, years). This model, along with the corresponding inputs to the model, is presented in Table 4-8.

#### 4.3.2.4 Dermal Contact with Groundwater

Intake of chemicals of potential concern 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 is evaluated for the on-site construction worker. Exposure via this pathway is assumed to occur during excavation activities.

Chemical intake via dermal contact with groundwater by the on-site construction worker is estimated with the following algorithm.

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

where:

CW	=	Chemical concentration in groundwater (mg/L)
SA	=	Exposed skin surface area (cm <sup>2</sup> /event)
PC	=	Dermal permeability constant (cm/hour)
CF	=	Conversion factor (10 <sup>-3</sup> L/cm <sup>3</sup> )
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 chemical concentration for each COPC in groundwater [CW] is equal to its exposure point concentration, presented in Tables 4-2 and 4-3.

The exposed skin surface area for the on-site construction worker is assumed to be 2,000 cm<sup>2</sup>. 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)

Dermal permeability constants for groundwater COPCs were based on calculate measurements in aqueous media (USEPA, 1992b). These values are summarized in Table 4-9.

The groundwater exposure time for the on-site construction worker is assumed to be two hours per day. It is assumed that exposure to the on-site construction worker occurs eight hours per day, 60 days per year, for one year

These exposure assumptions and calculated chemical intake for the on-site construction worker via dermal contact with groundwater are presented in Table 4-10

#### 4.3.2.5 Inhalation of Benzene and Fluorene (Enclosed-Space Air) Emanating from Groundwater

Inhalation of benzene and fluorene 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 and fluorene via this exposure pathway is evaluated for the on-site indoor commercial worker and is estimated with the following algorithm.

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

where:

CA	=	Chemical concentration in indoor air (mg/m <sup>3</sup> )
IR	=	Inhalation rate (m <sup>3</sup> /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 and fluorene are derived in Section 4.3.1.1. For the on-site indoor commercial worker, the inhalation rate is assumed to be 0.83 m<sup>3</sup>/hr (ASTM, 1995).

It is assumed that exposure to the on-site commercial worker occurs 8 hours per day, 250 days per year, for 25 years (ASTM, 1995).

For the on-site commercial worker, the averaging time for noncarcinogens and carcinogens is 9,125 and 25,550 days, respectively.

These exposure assumptions and the calculated chemical intake for the on-site commercial worker via inhalation of benzene and fluorene in enclosed-space are presented in Table 4-11.

#### 4.3.2.6 Inhalation of Benzene and Fluorene (Ambient Air) Emanating from Groundwater

Chemical intake of benzene and fluorene via inhalation of ambient air is a function of the ambient air concentration, the inhalation rate, the time, frequency, and duration of exposure. Intake of benzene and

fluorene via this exposure pathway is evaluated for the on-site construction worker and is estimated with the following algorithm.

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

where:

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

Ambient air concentrations for benzene and fluorene are derived in Section 4.3.1.2. For the on-site construction worker, the inhalation rate is assumed to be 1.35 m<sup>3</sup>/hr. This inhalation rate assumes a moderate activity level 50 percent of the time and the light activity level the remaining 50 percent of the time (USEPA, 1989b).

It is assumed that exposure to the on-site construction worker occurs eight hours per day, 60 days per year, for one year.

The averaging time for exposure to noncarcinogens is equivalent to the exposure duration expressed in days (USEPA, 1989a). For the on-site construction worker, the averaging time for noncarcinogens is 365 days. The averaging time for exposure to carcinogens is equivalent to the average lifetime (*i.e.*, 70 years [USEPA, 1991]), expressed in days (*i.e.*, 25,550 days), regardless of the age of the receptor evaluated.

These exposure assumptions and the calculated chemical intake for the on-site construction worker via inhalation of benzene and fluorene in ambient are presented in Table 4-12.



## 5.0 TOXICOLOGICAL ASSESSMENT

The purpose of the toxicity assessment is to identify the toxicity values that will be used for risk characterization purposes (Section 6). For this assessment, the toxicity information will be 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 end points 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 are obtained from several sources. The primary sources of information for carcinogens are California EPA's Cancer Potency Factors document (CalEPA, 1995) and USEPA's Integrated Risk Information System (IRIS) (USEPA, 1996). The primary source for noncarcinogens is the IRIS data base (USEPA, 1996). 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 CalEPA, 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 three Site COPCs. Toxicity values for inhalation exposure routes are presented since these routes were identified in the exposure assessment (Section 4.2.1) as potentially significant exposure routes for Site COPCs.

### 5.1 TOXICITY INFORMATION FOR NONCARCINOGENIC EFFECTS

The critical toxicity value used to describe the dose-response relationship for systemic 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 benchmark 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 5-1 presents the chronic RfDs for each of the Site COPCs.

## 5.2 TOXICITY INFORMATION FOR CARCINOGENIC EFFECTS

The toxicity value used to describe the dose-response relationship for carcinogenic effects is called the cancer slope factor (CSF). 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)<sup>-1</sup>. 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, EPA 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 where there is only a 5 percent probability that the actual risk is greater than the estimated 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 5-1 presents the slope factors and the weight-of-evidence for each of the COPCs identified at the Site. Tables 5-2 through 5-4 present toxicological profiles for each of the Site COPCs (benzene, benzo(a)pyrene, and fluorene), which provide historical information, routes of exposure, chemical interactions with other chemicals, toxicological disposition, and toxic effects in humans and animals.

## 6.0 RISK CHARACTERIZATION

The risk characterization process begins with a review of 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 risk. The first method evaluates chemicals with carcinogenic effects by estimating excess lifetime cancer risk. The second method evaluates chemicals with noncarcinogenic effects (USEPA, 1989a).

### 6.1 ESTIMATED LIFETIME EXCESS CANCER RISK

The calculated cancer risks represent excess cancer risks that may be experienced in a lifetime under a given exposure scenario. The term "excess" refers to levels above the background cancer risk. For example, national cancer statistics indicate that each person has approximately a one-in-three chance, or 333,333 chances in one million, of developing cancer during his lifetime (ACS, 1986). An individual with an excess cancer risk of one in a million (denoted as either  $1E-06$  or  $1 \times 10^{-6}$ ) has a total cancer risk of 333,334 in one million of developing cancer: 333,333 chances per million from background exposures plus 1 chance per million from exposure to the Site.

Risk from chemicals with potential carcinogenic effects are estimated using the following equation (USEPA, 1989a).

$$\text{Lifetime Excess Cancer Risk} = I_i \times SF_i$$

Where:

$I_i$  - Exposure intake for chemical  $i$ , (mg·kg/day)

$SF_i$  - Slope Factor for chemical  $i$ , (mg/kg/day)<sup>-1</sup>

The exposure intake is estimated in the exposure assessment step of the risk assessment and may be adjusted to ensure that it relates to the route of administration used to determine the CSF. For example, some CSFs are determined using an administered dose while others are determined using an absorbed dose.

CSFs are used to determine the potential risk associated with exposure to individual COPCs. The CSF is multiplied by the chronic daily intake averaged over 70 years to estimate the risk excess lifetime cancer incidence. This averaging is consistent with USEPA risk assessment guidelines (EPA 1989a).

Based on regulatory guidelines, it is appropriate to combine risk estimates across exposure pathways if the exposure to particular pathways is not exclusive of other pathways. Excess lifetime cancer risks are summed by exposure pathway. In addition, the total excess lifetime cancer risk is estimated by summing all the risks from all exposure pathways (USEPA, 1989a).

## 6.2 ESTIMATED NONCANCER RISK

Non-carcinogenic effects are determined by comparing an exposure level over a specified time period, the exposure duration, with a RfD of similar duration. To calculate the hazard quotient, the intake is divided by the RfD. If the hazard quotient is greater than unity, there is a potential for harmful effects to occur (USEPA, 1989a). The following equation is used.

$$\text{Hazard Quotient} = \left( \frac{I_i}{RFD_i} \right)$$

Where:

- I = Intake for chemical  $_i$  (mg/kg/day)  
RfD = Reference Dose for chemical  $_i$  (mg/kg/day)

There are several exposure durations that are considered when estimating the noncarcinogenic effects. They are chronic, subchronic, and shorter-term or acute exposures. Chronic exposures account for the duration of seven years up to a lifetime; subchronic exposures range in duration from two weeks to seven years; and shorter-term (acute) exposures are those less than two weeks in duration (USEPA, 1989a).

The Hazard Index (HI) for individual exposure scenarios is estimated by summing hazard quotients for multiple chemicals using the following equation.

$$HI = \sum HQ_i$$

where

- HI = Hazard Index  
HQ = Hazard Quotient for chemical

The hazard index is used to determine if potential noncancer effects may be of concern; it does not predict the incidence or severity of potential health effects. A hazard index greater than unity (*i.e.*, greater than 1) indicates that there may be concern for potential noncancer health effects; however, it does not necessarily mean that health effects will occur. As a general rule, the greater the HI is above unity, the greater the level of concern.

It is important to note that the level of concern does not increase linearly as the threshold level of 1 is approached or exceeded because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects (*i.e.*, the slopes of the dose-response curves in excess of the RfD can range widely depending on the substance). To provide conservative estimates of risk, individual hazard quotients are assumed to be additive, regardless of toxic effects or mechanisms of action.

### **6.3 SUMMARY OF POTENTIAL EXCESS CANCER RISK**

This section summarizes the excess cancer risk estimates for the hypothetical on-site indoor commercial and construction workers.

#### **6.3.1 On-Site Indoor Commercial Worker**

Table 6-1 presents the excess cancer risks estimated for the hypothetical on-site indoor commercial worker. The total excess cancer risk for the current and future on-site indoor commercial worker from average Site-wide exposure is  $2E-7$ . This risk level is below the USEPA and California EPA acceptable excess cancer risk range of  $1E-6$  to  $1E-4$ .

#### **6.3.2 On-Site Construction Worker**

Table 6-1 presents the excess cancer risks estimated for the hypothetical on-site construction worker. The total excess cancer risk for the current and future on-site construction worker from average Site-wide exposure is  $2E-8$ . This risk level is below the USEPA and California EPA acceptable excess cancer risk range of  $1E-6$  to  $1E-4$ .

#### **6.3.3 On-Site Indoor Commercial Worker (Grand Street Office Building Scenario)**

Table 6-2 presents the excess cancer risks estimated for the hypothetical indoor commercial worker at the proposed Grand Street building. The total excess cancer risk for the current and future on-site indoor commercial worker from Site-wide exposure is  $6E-7$ . This risk level is below USEPA and California EPA acceptable excess cancer risk range of  $1E-6$  to  $1E-4$ .

#### 6.3.4 On-Site Construction Worker (Grand Street Office Building Scenario)

Table 6-2 presents the excess cancer risks estimated for the hypothetical construction worker in the area of the proposed Grand Street building. The total excess cancer risk for the construction worker is  $8E-8$ . This risk level is below USEPA and California EPA acceptable excess cancer risk range of  $1E-6$  to  $1E-4$ .

### 6.4 SUMMARY OF POTENTIAL NONCANCER RISK

This section summarizes the noncancer risk estimates for the hypothetical on-site indoor commercial workers and construction workers.

#### 6.4.1 On-Site Indoor Commercial Worker

Table 6-3 presents the noncancer risks estimated for the hypothetical on-site indoor commercial worker. The total hazard index for the current and future on-site indoor commercial worker from average Site-wide exposure is  $3E-3$ . The calculated HI for this receptor does not exceed the USEPA and California EPA threshold HI of 1, and indicates that adverse noncancer health effects are not expected to occur to this receptor population from exposure to current concentrations of noncarcinogens detected at the Site.

#### 6.4.2 On-Site Construction Worker

Table 6-3 presents the noncancer risks estimated for the hypothetical on-site construction worker. The total hazard index for the current and future on-site construction worker from average Site-wide exposure is  $1E-4$ . The calculated HI for this receptor does not exceed the USEPA and California EPA threshold HI of 1, and indicates that adverse noncancer health effects are not expected to occur to this receptor population from exposure to current concentrations of noncarcinogens detected at the Site.

#### 6.4.3 On-Site Indoor Commercial Worker (Grand Street Office Building)

Table 6-4 presents the noncancer risks estimated for the hypothetical indoor commercial worker at the proposed Grand Street building. The total hazard index for the current and future on-site indoor commercial worker from indoor exposure at this portion of the Site is  $1E-2$ . The calculated HI for this receptor does not exceed the USEPA and California EPA threshold HI of 1, and indicates that adverse noncancer health effects are not expected to occur to this receptor population from exposure to current concentrations of noncarcinogens detected at the Site.

#### 6.4.4 On-Site Construction Worker (Grand Street Office Building)

Table 6-4 presents the noncancer risks estimated for the hypothetical construction worker in the area of the proposed Grand Street building. The total hazard index for the current and future on-site construction worker from exposure at this point of the Site is  $2E-4$ . The calculated HI for this receptor does not exceed the USEPA and California EPA threshold HI of 1, and indicates that adverse noncancer health effects are not expected to occur to this receptor population from exposure to current concentrations of noncarcinogens detected at the Site.



## 7.0 UNCERTAINTY ANALYSIS

The uncertainty analysis characterizes the propagated uncertainty in public health risk assessments. 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 risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several 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 these stages are described below.

### 7.1 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 benzo(a)pyrene in soil and the absence of 1992 soil data 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.

Because of the ASTM recommendation to consider PAHs as indicator compounds when diesel is present at petroleum release Sites, concentrations for the most toxic PAH, benzo(a)pyrene, are estimated from TPHd. According to diesel fuel chemical composition values (State of California, 1989) the concentration of benzo(a)pyrene in diesel fuel #2 is 0.07  $\mu\text{g/gm}$ . Benzo(a)pyrene concentrations in soil are estimated by

applying this composition factor to TPHd concentrations in soil. The proportion that is benzo(a)pyrene may also vary with the type of diesel fuel, therefore, there is a moderate amount of uncertainty associated with this method of estimation.

As discussed in Section 3.1.1, soil samples were collected during the May 1992 Zaccor investigation from the vicinity of the AGT farm, the former 1,000-gallon UST, and the product lines. The samples were collected from the vadose zone over the 0 to 0.5-foot depth interval, and in the saturated or capillary zone at depths generally greater than 4 feet. This data is examined for useability for risk assessment.

The 1992 saturated zone data is several years older than the more recent (November 1994 to March 1996) quarterly monitoring well data presented in the next section, and does not represent recent Site conditions. Therefore, the saturated zone soil samples are not used in risk assessment.

The 1992 vadose zone soil results (0 to 0.5 feet bgs) range from non-detect to 0.88 mg/kg for ethylbenzene, from non-detect to 0.55 mg/kg for toluene, from non-detect to 3.0 mg/kg for total xylenes, and from non-detect to 21,000 mg/kg for TPHd. *But Zaccor investigation found benzene*  
Benzene was not detected in the 1992 vadose zone soil samples. The report does not provide detection limits for data reported as non-detected. The 1992 vadose zone sampling locations were focused in the vicinity of the former AGT farm and generally indicates higher levels of TPHd than the October 1994 soil data, which was generally collected more towards the perimeter of the Site. Since the samples were collected from shallow depths, the low detections of BTEX are expected to have volatilized and undergone biodegradation in the four years since measurement. This is also expected, to a lesser extent to the lighter components of TPHd. The less volatile and less biodegradable components of TPHd, e.g., benzo(a)pyrene, have probably undergone photolysis to some extent.

In summary, the 1992 data provides information about the shallow soil in the vicinity of the former AGT farm. Because the contamination is at shallow depths, the concentrations are expected to have decreased since 1992 due to volatilization, biodegradation, and photolysis. The 1992 Zaccor report does not provide detection limits for analytes that are reported as non-detects, so standard EPA methods for using detection limits for non-detect data cannot be applied. Because this data may not be representative of current Site conditions, and because it cannot be summarized statistically in a consistent manner with the 1994 data, it is not used for quantitative evaluation of risk in this assessment.

The uncertainty introduced by not including the 1992 soil data is that greater levels of TPHd, and estimated benzo(a)pyrene, may remain in some areas of the central portion of the Site than are represented by the 1994 data. Consequently, the estimated risk from exposure to benzo(a)pyrene may be underestimated. Because the estimated risks from benzo(a)pyrene presented in Section 6 are extremely low, the impacts of not including the 1992 soil data in the quantitative evaluation are expected to be insignificant.

## 7.2 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 over- or 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 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 determine vapor transport model inputs for building floor area and ventilation rates. These default values may not be representative of actual building characteristics at the Site and may result in a moderate 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 and may result in either an over- or underestimate 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.

### 7.3 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 benzo(a)pyrene, 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 over- or 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 is 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.
- Dose-response information from short-term exposures is used by USEPA to predict the effects of long-term exposures, and *vice-versa*.
- Dose-response information from animal studies is used by USEPA to predict effects in humans.
- Dose-response information from homogeneous animal populations or human populations is used to predict the effects likely to be observed in the general population consisting of individuals with a wide range of sensitivities.

#### 7.4 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 to 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 upper 95<sup>th</sup> percentile confidence limit 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 hazard index of unity so that it is not linear.

Another limitation of the hazard index approach is that the assumption of dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action. Consequently, application of the hazard index equation to a number of compounds that are not expected to include the same type of effects or that do not act by the same mechanisms could overestimate the potential for effects, although this approach is appropriate for screening level purposes.

## 7.5 SUMMARY OF RISK ASSESSMENT UNCERTAINTIES

An analysis of the uncertainties associated with the risk assessment indicates that cancer and noncancer health risk estimates are likely to overestimate actual risks posed by Site COPCS. 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.

## 8.0 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 is evaluated for the most likely human receptors: an on-site commercial worker and an on-site construction worker. The risk assessment also considers two areas of exposure, one assuming average exposure randomly across the Site, and the other assuming exposure near the proposed location of the building at the corner of Grand Street and Fortmann Way.

The calculated risks for these hypothetical receptors are based on conservative (*i.e.*, health protective) assumptions and are below the USEPA and California EPA acceptable carcinogenic risk range of  $1E-04$  to  $1E-06$  and non-carcinogenic hazard index of 1.0. Due to the low health risk, and other evidence from site remediation and characterization activities, the Site appears to meet the definition for a low risk soil and groundwater site, as defined by the RWQCB, San Francisco Bay Region (State of California, 1996). Based on this, the Site appears to be a candidate for clean closure with no further action.

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**Table 3-1**  
**Summary of Subsurface Soil Analytical Results (ug/kg)**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Sampling Location	Sampling Date	CHEMICAL					
		Benzene	Toluene	Ethylbenzene	Xylenes (total)	TPHd	Benzo(a)pyrene [1]
TP3-A-2	Oct-94	2.5 U	2.5 U	2.5 U	2.5 U	1,400,000	9.80E-02
MW-5-2-S	Oct-94	2.5 U	2.5 U	2.5 U	2.5 U	23,000	1.61E-03
MW-5-S	Oct-94	2.5 U	2.5 U	2.5 U	2.5 U	27,000	1.89E-03
MW-5-A-1	Oct-94	2.5 U	2.5 U	2.5 U	2.5 U	1,000 U <sup>1</sup>	7.00E-05 U <sup>1</sup>
MS-6-2-S	Oct-94	2.5 U	2.5 U	2.5 U	2.5 U	28,000	1.96E-03
MW-7-2	Oct-94	2.5 U	2.5 U	2.5 U	15	240,000	1.68E-02
MW-8-3-S	Oct-94	5 U	5.7	10	84	97,000	6.79E-03

*Notes*

*1. U = amount not detected. Value shown represents the sample quantitation limit.*

*TPHd = Total Petroleum Hydrocarbons as diesel*

*2. Samples were not analyzed for benzo(a)pyrene. TPHd was used to estimate a surrogate concentration for benzo(a)pyrene. Benzo(a)pyrene concentrations were calculated by taking 0.01 mg of TPHd concentrations in soil (Guerin et al., 1984).*

*Source: M.R. et al. 1984. "Comparative Toxicological and Chemical Properties of Fuels Developed from Coal, Shale, or Petroleum." Oak Ridge National Laboratory*

**Table 3-2**  
**Summary of Groundwater Analytical Results (ug/L)**  
**BTEX and TPHd**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Sampling Location	Sampling Date	CHEMICAL				
		Benzene	Toluene	Ethylbenzene	Xylenes (total)	TPHd
MW-1	Nov-94	0.5	1.1	0.05	1.4	400
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	1,300
	May-95	--	--	--	--	--
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	1,100
	Nov-95	0.5 U	0.5 U	0.5 U	0.5 U	330
	Mar-96	0.5 U	0.5 U	0.5 U	0.5 U	--
MW-2	Nov-94	510	670	65	320	--
	Feb-95	360	230	20	100	--
	May-95	550	350	28	120	--
	Aug-95	290	120	11	37	--
	Dec-95	190	35	6.4	16	--
	Mar-96	--	--	--	--	1,100
MW-4	Nov-94	--	--	--	--	--
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	May-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	Dec-95	0.5 U	0.5 U	0.5 U	0.5 U	--
MW-4	Nov-94	0.5 U	0.5 U	0.5 U	0.5 U	240
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	660
	May-95	0.5 U	0.5 U	0.5 U	0.5 U	50 U
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	410
	Nov-95	0.5 U	0.5 U	0.5 U	0.5 U	460
	Mar-96	0.5 U	0.5 U	0.5 U	0.5 U	--
MW-5	Nov-94	0.5 U	0.5 U	0.5 U	0.5 U	560
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	460
	May-95	0.5 U	0.5 U	0.5 U	0.5 U	50 U
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	910
	Nov-95	0.5 U	0.5 U	0.5 U	0.5 U	260
	Mar-96	0.5 U	0.5 U	0.5 U	0.5 U	--
MW-6	Nov-94	0.5 U	0.5 U	0.5 U	0.5 U	500
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	570
	May-95	0.5 U	0.5 U	0.5 U	0.5 U	50 U
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	790
	Nov-95	0.5 U	0.5 U	0.5 U	0.5 U	330
	Mar-96	0.5 U	0.5 U	0.5 U	0.5 U	--
MW-6	Nov-94	0.5 U	0.5 U	0.5 U	0.5 U	--
	Feb-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	May-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	Aug-95	0.5 U	0.5 U	0.5 U	0.5 U	--
	Nov-95	0.5 U	0.5 U	0.5 U	0.5 U	--



**Table 3-3**  
**Summary of Groundwater Analytical Results (ug/L)**  
**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
Acenaphthene	10 U	2 U	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	2 U	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	0.5 U	10 U	10 U	10 U	10 U	10 U
Benzo(a)anthracene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Benzo(a)pyrene	10 U	0.05 U	10 U	10 U	10 U	10 U	10 U
Benzo(b)fluoranthene	10 U	0.05 U	10 U	10 U	10 U	10 U	10 U
Benzo(k)fluoranthene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Benzo(k)fluoranthene	10 U	0.05 U	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Dibenzo(a,h)anthracene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	0.9	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3)pyrene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	9.3	10 U	10 U	10 U	10 U	10 U
Phenanthrene	10 U	0.5 U	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	0.1 U	10 U	10 U	10 U	10 U	10 U

*Notes*

*U = Undetectable. Value shown represents the sample quantitation limit.*

*N = Not sampled.*

Table 3-4

Comparison of Maximum Detected Site Subsurface Soil and Groundwater Concentrations Against ASTM RBCA Tier 1 RBSLs  
Grand Street and Fortmann Way Property  
Alameda, California

Chemical	SUBSURFACE SOIL ( $\mu\text{g}/\text{kg}$ ) [a]				GROUNDWATER ( $\mu\text{g}/\text{L}$ ) [b]			
	Maximum Detected Concentration	ASTM RBCA Tier 1 RBSL [c][d]	Maximum Detected Exceeds RBSL?	Chemical of Potential Concern (COPC)?	Maximum Detected Concentration	ASTM RBCA Tier 1 RBSL [e][d]	Maximum Detected Exceeds RBSL?	Chemical of Potential Concern (COPC)?
<u>Indoor Inhalation of Vapor</u>								
Benzene	nd	1.09E+01	no	no	5.50E+02	7.39E+01	YES	YES
Ethylbenzene	1.00E+01	1.10E+06	no	no	6.50E+01	>S	no	no
Toluene	5.70E+00	5.45E+04	no	no	6.70E+02	8.50E+04	no	no
Xylenes	8.40E+01	RES	no	no	3.20E+02	>S	no	no
Naphthalenes	NA	1.07E+05	no	no	9.30E+00	1.23E+04	no	no
Fluorene	NA	NA	NA	no	9.00E-01	NA	NA	YES
Benzo(a)pyrene	NA	RES	no	no	nd	>S	no	no
<u>Outdoor Inhalation of Vapor</u>								
Benzene	nd	4.57E+02	no	no	5.50E+02	1.84E+04	no	no
Ethylbenzene	1.00E+01	RES	no	no	6.50E+01	>S	no	no
Toluene	5.70E+00	RES	no	no	6.70E+02	>S	no	no
Xylenes	8.40E+01	RES	no	no	3.20E+02	>S	no	no
Naphthalenes	NA	RES	no	no	9.30E+00	>S	no	no
Fluorene	NA	NA	NA	no	9.00E-01	NA	NA	YES
Benzo(a)pyrene	NA	RES	no	no	nd	>S	no	no
<u>Ingestion [e]</u>								
Benzene	nd	1.00E+04	no	no	5.50E+02	9.87E+00	YES	YES
Ethylbenzene	1.00E+01	1.15E+07	no	no	6.50E+01	1.02E+04	no	no
Toluene	5.70E+00	1.87E+07	no	no	6.70E+02	2.04E+04	no	no
Xylenes	8.40E+01	2.08E+08	no	no	3.20E+02	>S	no	no
Naphthalenes	NA	1.90E+06	no	no	9.30E+00	4.09E+02	no	no
Fluorene	NA	NA	NA	no	9.00E-01	NA	NA	YES
Benzo(a)pyrene	NA [f]	3.04E+02	NA	YES [g]	nd	1.17E-02	no	no

## Notes

[a] See Table 3-1.

[b] See Table 3-2.

[c] Site-specific RBSL concentrations shown represent data from the October 1994 sampling round.

[d] Site-specific RBSL concentrations shown represent data from November 1994 to March 1996.

[e] The Tier 1 RBSLs (and site-specific RBSLs) shown are for a commercial industrial land use scenario. The RBSL for carcinogens (i.e., benzene and benzo(a)pyrene) is based on an excess cancer risk of  $1 \times 10^{-6}$ . The RBSLs for noncarcinogens (i.e., ethylbenzene, toluene, xylenes, and naphthalenes) is based on a hazard index of 1.0.

[f] American Society for Testing and Materials (ASTM), 1995. Standard Guide for Risk-Based Corrective Action (RBCA) Applied at Petroleum Release Sites. E 1739-95. November.

[g] See Appendix B.2.3.5. Ingestion does consider dermal contact and inhalation of vapors and particulates.

[h] ASTM commonly uses benzo(a)pyrene as an indicator compound for diesel, however benzo(a)pyrene was not analyzed. Due to the uncertainty involved with estimating benzo(a)pyrene concentrations from diesel, the screening process is not applied and benzo(a)pyrene is retained as a COPC.

[i] X - Selected risk level is not exceeded for pure compound present at any concentration (ASTM, 1995).

[j] S - Selected risk level is not exceeded for all possible dissolved levels (less than or equal to pure component solubility) (ASTM).

**Table 3-5**  
**Statistical Analysis of Subsurface Soil Data for COPCs**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Units	Number Detected [a]	Number of Samples [a]	Detection Frequency	Minimum Estimated [a]	Maximum Estimated [a]	Arithmetic Mean [a,b]	Normal 95 UCL [a,c]
Benzo(a)pyrene	mg/kg	6	7	86%	1.61E-06	9.80E-05	1.82E-05	4.44E-05

*Notes*

[a] - If not detected, concentration shown represents a surrogate concentration based on Guerin et al., 1984, which estimates a benzo(a)pyrene concentration to be approximately 0.07 mg/kg of diesel.

[b] - Standard deviation calculated assuming one-half the sample quantitation limit for nondetected data.

[c] - 95% Upper Confidence Limit (UCL) on the arithmetic mean assuming a normal distribution.

**Table 3-6**  
**Statistical Analysis of Groundwater Data for COPCs**  
**(Site-Wide)**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Units	Number Detected	Number of Samples	Detection Frequency	Minimum Detected	Maximum Detected	Arithmetic Mean [a]	Normal 95 UCL [b]
Benzene	ug/L	6	45	13%	5.00E-01	5.50E+02	4.25E+01	7.51E+01
Fluorene	ug/L	1	7	14%	9.00E-01	9.00E-01	4.41E+00	

*Notes*

[a] Statistics calculated assuming one-half the sample quantitation limit for nondetected data.

[b] 95% Upper Confidence Limit (UCL) on the arithmetic mean assuming a normal distribution



**Table 4-1**  
**Statistical Analysis of Groundwater COPC Data for Wells MW-2 and MW-4**  
**(Grand Street Office Building)**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Data group	Units	Number Detected	Number of Samples	Detection Frequency	Minimum Detected	Maximum Detected	Arithmetic Mean [a]	Normal 95 UCL [b]
Benzene	Bldg	ug/L	5	11	45%	1.90E+02	5.50E+02	1.73E+02	2.93E+02
Fluorene	Bldg	ug/L	1	2	50%	9.00E-01	9.00E-01	2.95E+00	

*Notes*

[a] - Statistics calculated assuming one-half the sample quantitation limit for nondetected data.

[b] - 95% Upper Confidence Limit (UCL) on the arithmetic mean assuming a normal distribution.

Table 4-2  
 Exposure Point Concentrations for Groundwater COPCs  
 (Site-Wide)  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical Name	Direct Groundwater Contact (mg/L)	VF <sub>wesp</sub> (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Enclosed Air Concentration (mg/m <sup>3</sup> ) [1]	VF <sub>wamb</sub> (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Ambient Air Concentration (mg/m <sup>3</sup> ) [2]
Benzene	7.51E-02	9.02E-04	6.77E-05	2.76E-05	2.07E-06
Fluorene	9.00E-04	1.05E-05	9.44E-09	2.26E-06	2.03E-09

*Notes:*

[1] Enclosed air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor (VF<sub>wesp</sub>) [(mg·m<sup>3</sup>-air)/(mg·L-H<sub>2</sub>O)]

[2] Ambient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor (VF<sub>wamb</sub>) [(mg·m<sup>3</sup>-air)/(mg·L-H<sub>2</sub>O)]

Table 4-3  
 Exposure Point Concentrations for Groundwater COPCs  
 (Office Building Scenario)  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical Name	Direct Groundwater Contact (mg/L)	VFwesp (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Enclosed Air Concentration (mg/m <sup>3</sup> ) [1]	VFwamb (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Ambient Air Concentration (mg/m <sup>3</sup> ) [2]
Benzene	2.93E-01	9.02E-04	2.64E-04	2.76E-05	8.08E-06
Fluorene	9.00E-04	1.05E-05	9.44E-09	2.26E-06	2.03E-09

Notes.

[1] Enclosed air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor ( $VF_{wesp}$ ) [(mg·m<sup>3</sup>-air)/(mg·L-H<sub>2</sub>O)]

[2] Ambient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor ( $VF_{wamb}$ ) [(mg·m<sup>3</sup>-air)/(mg·L-H<sub>2</sub>O)]

Table 4-4  
 Exposure Point Concentrations for Soil COPCs  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical Name	Direct Soil Contact (mg/kg)	Particulate Emission Factor (m <sup>3</sup> /kg)	Airborne Soil Particulates (mg/m <sup>3</sup> ) [1]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

*Notes*

[1] Airborne soil particulate concentration calculated by dividing the soil concentration with the Particulate Emission Factor (PEF) of 4.63 E + 09 m<sup>3</sup> kg.

Table 4-5  
**Chemical Intake Exposure Assumptions -- Incidental Soil Ingestion  
 On-Site Construction Worker Exposure Scenario  
 Grand Street and Fortmann Way Property  
 Alameda, California**

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

Intake Parameter	On-Site Construction Worker
	Value
CS = Chemical concentration in soil (mg/kg)	See Table 4-4
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

*Notes:*

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

**Table 4-6**  
**Chemical Intake Exposure Assumptions -- Dermal Contact with Soil**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	On-Site Construction Worker Value
CS = Chemical concentration in surface soil (mg/kg)	See Table 4-4
CF = Conversion factor (kg/mg)	1E-06
SA = Skin Surface Area (cm <sup>2</sup> /day)	2,000
AF = Soil/skin adherence factor (mg/cm <sup>2</sup> )	0.5
ABS = Absorption factor-organics (unitless)	0.01
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

*Notes:*

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

**Table 4-7**  
**Chemical Intake Exposure Assumptions -- Inhalation of Airborne Particulates**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	On-Site Construction Worker
	Value
CA = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 4-4
IR = Inhalation rate, outdoor (m <sup>3</sup> /hr)	1.35
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

**Table 4-8**  
**Air Concentrations Calculated from Soil Particulate Emissions**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

**Particulate Emissions Model (USEPA, 1991)**

The particulate emission factor (PEF) relates the chemical concentration in soil with the concentration of respirable particles (PM<sub>10</sub>) in the air due to fugitive dust emissions from surface soil. This model is a conservative estimate for particulate emissions from surface soils and is taken from USEPA, 1991. This relationship is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface soil provides a relatively continuous and constant potential of emission over an extended period of time (e.g., years).

The particulate emissions are assumed due to wind erosion and, therefore, depend on the erodibility of the surface material. The equation is representative of a surface with unlimited erosion potential, which is characterized by bare surfaces of finely divided material such as sandy agricultural soil with a large number (unlimited reservoir) of erodible particles. Such surfaces erode at low wind speeds, and particulate emission rates are relatively time independent at a given wind speed.

$$PEF = [(LS \times V \times DH \times CF_{one})/A] \times [CF_{two} / (RF \times (1-G) \times (U_m/U_t)^3 \times F(x))]$$

Parameter	Value	Units	Reference
PEF = Particulate Emission Factor	4.63E+09	m <sup>3</sup> /kg	
LS = Width of contaminated area	45	m	USEPA, 1991
V = Wind speed in mixing zone	2.25	m/s	USEPA, 1991
DH = Diffusion height	2	m	USEPA, 1991
A = Area of contamination	2.025	m <sup>2</sup>	USEPA, 1991
RF = Respirable fraction	0.036	g/m <sup>2</sup> -hr	USEPA, 1991
G = Fraction of vegetative cover	0	[unitless]	USEPA, 1991
U <sub>m</sub> = Mean annual wind speed	4.5	m/s	USEPA, 1991
U <sub>t</sub> = Equivalent threshold value of wind speed at 10 m	12.8	m/s	USEPA, 1991
F(x) = Function dependent on U <sub>m</sub> /U <sub>t</sub>	0.0497	[unitless]	Cowherd, 1985
CF <sub>one</sub> = Conversion Factor 1	3.600	s/hr	--
CF <sub>two</sub> = Conversion Factor 2	1.000	g/kg	--

**Air Concentration (C<sub>A</sub>) = C / PEF**

Chemical	UCL95 Soil Concentration (C) [mg/kg]	Particulate Emission Factor (PEF) [m <sup>3</sup> /kg]	Air Concentration (C <sub>A</sub> ) (C/PEF) [mg/m <sup>3</sup> ]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

**Notes:**

Cowherd, C., Muleska, G., Engelhart, P., and D. Gillette. 1985. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*. EPA Office of Health and Environmental Assessment. EPA/600/8-85/002.

USEPA. 1991. *Method 19.1-1991. Rapid Assessment Guidelines for Surface Soil. Method 19.1-1991. Method 19.1-1991. Particulate Emissions from Surface Soil. EPA/600/8-85/002. EPA/600/8-85/002.*



Table 4-9  
Dermal Permeability Constants for Groundwater COPCs  
Grand Street and Fortmann Way Property  
Alameda, California

Chemical	Dermal permeability constant (cm/hr) [1]
Benzene	2.10E-02
Fluorene [2]	3.60E-01

*Notes:*

[1] 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 600/5-91/011B, January.

[2] The dermal permeability constant for fluorene is not available. The value shown represents the dermal permeability constant for fluoranthene.

**Table 4-10**  
**Chemical Intake Exposure Assumptions – Dermal Contact with Groundwater**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	On-Site Construction Worker Value
C <sub>gw</sub> = Chemical concentration in groundwater (mg/L)	See Tables 4-2 and 4-3
SA = Skin surface area (cm <sup>2</sup> )	2,000
PC = Dermal permeability constant (cm/hr) [1]	
Benzene	2.10E-02
Fluorene [2]	3.60E-01
CF = Conversion factor (L/cm <sup>3</sup> )	1E-03
ET = Exposure time (hr/event)	2
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

*Notes:*

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

[2] The dermal permeability constant for fluorene is not available. The value shown represents the dermal permeability constant for fluoranthene.

**Table 4-11**  
**Chemical Intake Exposure Assumptions – Inhalation of Indoor Air VOCs Emanating from Groundwater**  
**On-Site Commercial Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	On-Site Commercial Worker Value
$C_A$ = Chemical concentration in air (mg/m <sup>3</sup> )	See Tables 4-2 and 4-3
IR = Inhalation rate (m <sup>3</sup> /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

**Table 4-12**  
**Chemical Intake Exposure Assumptions – Inhalation of Ambient Air VOCs Emanating from Groundwater**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	On-Site Construction Worker
	Value
C <sub>A</sub> = Chemical concentration in air (mg/m <sup>3</sup> )	See Tables 4-2 and 4-3
IR = Inhalation rate (m <sup>3</sup> /hr)	1.35
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

**Table 5-1  
Toxicity Values  
Grand Street and Fortmann Way Property  
Alameda, California**

Chemical Name	Carcinogenic Weight-of-Evidence	Oral/Dermal Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Inhalation Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Oral/Dermal Reference Dose (RfD) (mg/kg-day)		Inhalation Reference Dose (RfD) (mg/kg-day)	
		Value	Source	Value	Source	Value	Source	Value	Source
Benzene	A	1.00E-01	CalEPA, 1995	1.00E-01	CalEPA, 1995	--		1.71E-03	USEPA, 1995a
Benzopyrenes	B2	1.20E+01	CalEPA, 1995	3.90E+00	CalEPA, 1995	--		--	
Fluorene	D	--		--		4.00E-02	USEPA, 1995b	4.00E-02	USEPA, 1995c

**Notes:**

1. Chemicals with a weight-of-evidence of "D" do not exhibit toxicity via this route or sufficient evidence is not available to derive a toxicity value.

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

3. USEPA is the United States Environmental Protection Agency (USEPA), 1995a. Risk-Based Concentration Table. USEPA Region III. October 20

4. USEPA is the United States Environmental Protection Agency (USEPA), 1995b. Integrated Risk Information System. On-line data base. Office of Research and Development. Cincinnati, Ohio.

5. USEPA is the United States Environmental Protection Agency (USEPA), 1995c. Preliminary Remediation Goals. USEPA Region IX. February 1.

6. Some toxicity values are provisional. Provisional toxicity values have not received consensus judgment by USEPA's Reference Dose Work Groups and or Carcinogenic Risk Assessment Verification Endeavor Work Group. These values are included in this analysis to provide more conservative risk estimates.

**Table 5-2  
Toxicological Profile for Benzene  
Grand Street and Fortmann Way Property  
Alameda, California**

<b>Benzene</b>	
<b>Chemical Properties</b>	
CAS #	71-43-2
Chemical Formula	C <sub>6</sub> H <sub>6</sub>
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)
<b>Chemical Use, Fate and Transport</b>	
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.
<b>Chemical Disposition</b>	
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
<b>Chemical Toxicity</b>	
Slope Factor (SF) (mg/kg-day) <sup>-1</sup>	Oral: 1.0 E-1 (CalEPA, 1995); Dermal: 1.0 E-1 (CalEPA, 1995); Inhalation: 1.0 E-1 (CalEPA, 1995)
Reference Dose (RfD) (mg/kg-day)	Oral: -- ; Dermal: -- ; Inhalation: 1.71 E -3 (USEPA, 1995a)
Unit Risk Value (ug/m <sup>3</sup> ) <sup>-1</sup>	Oral: -- ; Dermal: -- ; Inhalation: 2.9 E -5 (CalEPA, 1995)
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.

*Notes*

CalEPA, 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 5-3**  
**Toxicological Profile for Benzo(a)Pyrene**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

<b>Benzo(a)Pyrene</b>	
<b>Chemical Properties</b>	
CAS #	50-32-8
Chemical Formula	C <sub>20</sub> H <sub>12</sub>
Chemical Characteristic	Polycyclic aromatic hydrocarbon (PAH)
Synonyms	BaP; benzo(d,e,f)chrysenes; 3,4-benzopyrene; 6,7-benzopyrene; BP; and 3,4-BP
Weight of Evidence (WOE)	EPA=B2 (probable human carcinogen)
<b>Chemical Use, Fate and Transport</b>	
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 strongly sorb to soil and sediment, where they remain fixed. In addition, volatilization is not common due to low Henry's constant.
<b>Chemical Disposition</b>	
Absorption	Ingestion, inhalation and dermal contact
Distribution	Distributed to: lungs, liver, kidney, gastrointestinal tract, carcass, 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
<b>Chemical Toxicity</b>	
Slope Factor (SF) (mg/kg-day) <sup>-1</sup>	Oral: 1.2 E +1 (CalEPA, 1995); Dermal: 1.2 E +1 (CalEPA, 1995); Inhalation: 3.9 E +0 (CalEPA, 1995)
Reference Dose (RfD) (mg/kg-day)	Oral: --; Dermal: --; Inhalation: --
Unit Risk Value (ug/m <sup>3</sup> ) <sup>-1</sup>	Oral: --; Dermal: --; Inhalation: 1.1 E -3 (CalEPA, 1995)
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 is inadequate, lung cancer has been shown to be induced in humans by various PAH mixtures known to contain BaP including cigarette smoke, roofing tar and coke oven emissions.

*Notes:*

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

**Table 5-4**  
**Toxicological Profile for Fluorene**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

<b>Fluorene</b>	
<b>Chemical Properties</b>	
CAS #	86-73-7
Chemical Formula	C <sub>13</sub> H <sub>10</sub>
Chemical Characteristic	Polycyclic aromatic hydrocarbon (PAH)
Synonyms	ortho-biphenylene methane; diphenylenemethane; 2,2-methylene biphenyl; and 2,3-benzidene
Weight of Evidence (WOE)	EPA=Group D (not classifiable as to human carcinogenicity)
<b>Chemical Use, Fate and Transport</b>	
What is chemical used for?	Fluorene is used as a chemical intermediate in chemical processes and in polyradical formation.
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?	Some PAHs tends to strongly sorb to soil and sediment, where they remain fixed.
<b>Chemical Disposition</b>	
Absorption	Ingestion, inhalation and dermal contact
Distribution	Distributed to: lungs, liver, kidney, gastrointestinal tract, carcass, 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
<b>Chemical Toxicity</b>	
Slope Factor (SF) (mg/kg-day) <sup>-1</sup>	Oral: -- ; Dermal: -- ; Inhalation: --
Reference Dose (RfD) (mg/kg-day)	Oral: 4.00E-2 (USEPA, 1995b); Dermal: 4.00E-2 (USEPA, 1995b); Inhalation: 4.00E-2 (USEPA, 1995c)
Uncertainty Factor (UF)	3000 (oral RfD)
Short Term Exposure	Chronic studies indicate hypoactivity, a decreased red blood cell count, and increased liver and spleen weights are all dose-related.
Animals	

*Notes:*

CalEPA, 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

USEPA, 1995b = U.S. Environmental Protection Agency (USEPA), 1995. Integrated Risk Information System. On-line data base. Office of Research and Development. Cincinnati, Ohio

USEPA, 1995c = U.S. Environmental Protection Agency (USEPA), 1995. Preliminary Remediation Goals. USEPA Region IX. February 1.



**Table 6-1**  
**Excess Cancer Risk Summary**  
**Site-Wide Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	EXCESS CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	8.94E-13	--
Dermal Contact with Soil	1.79E-13	--
Inhalation of Airborne Particulates	1.35E-17	--
Dermal Contact with Groundwater	2.12E-08	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	1.57E-07
Inhalation of Ambient Air VOCs Emanating from Groundwater	7.50E-11	--
<b>TOTAL EXCESS CANCER RISK</b>	<b>2E-08</b>	<b>2E-07</b>

**Table 6-2**  
**Excess Cancer Risk Summary**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

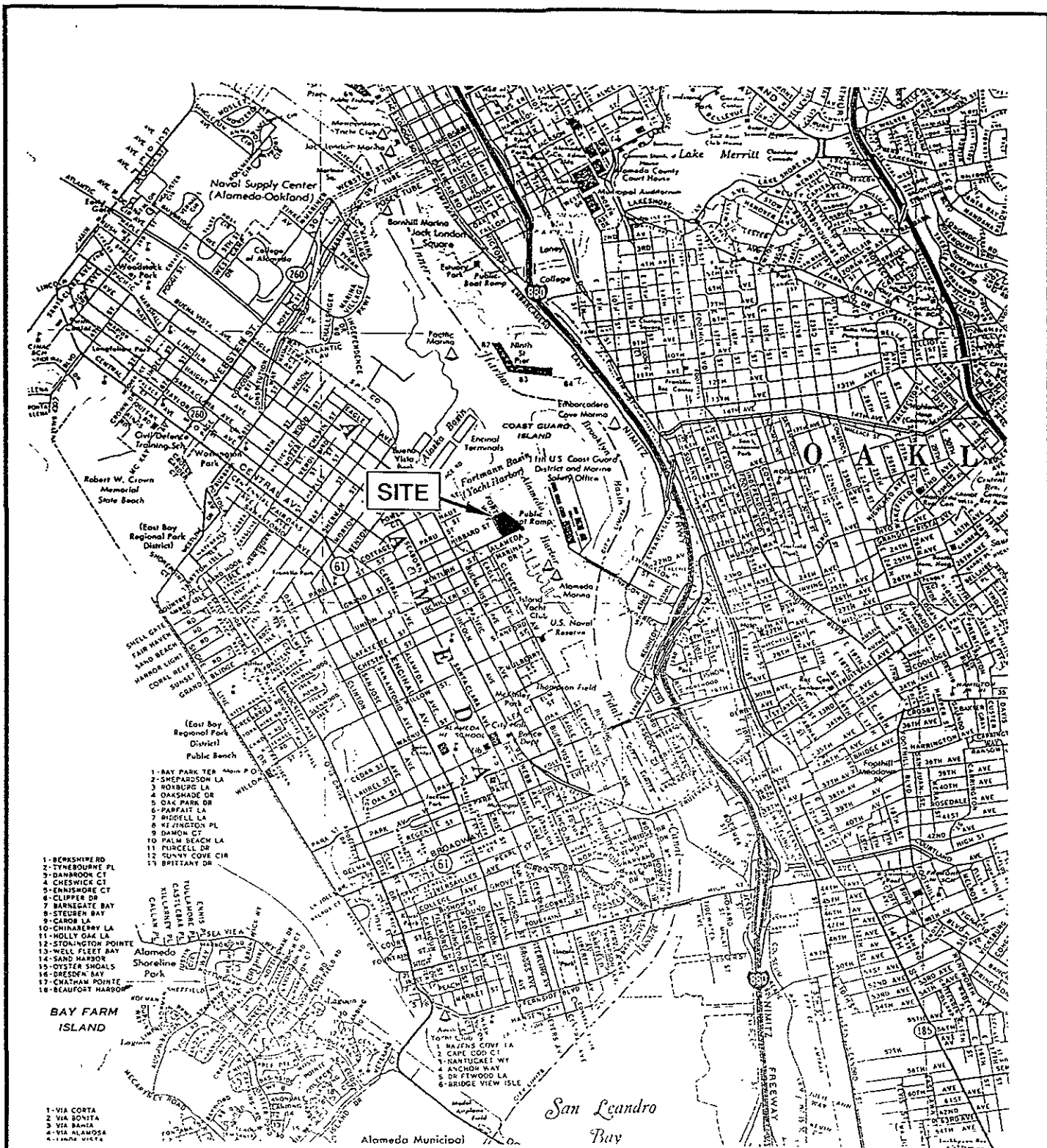
Exposure Pathway	EXCESS CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	8.94E-13	--
Dermal Contact with Soil	1.79E-13	--
Inhalation of Airborne Particulates	1.35E-17	--
Dermal Contact with Groundwater	8.26E-08	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	6.13E-07
Inhalation of Ambient Air VOCs Emanating from Groundwater	2.93E-10	--
<b>TOTAL EXCESS CANCER RISK</b>	<b>8E-08</b>	<b>6E-07</b>

**Table 6-3**  
**Non-Cancer Risk Summary**  
**Site-Wide Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	NON-CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	--	--
Dermal Contact with Soil	--	--
Inhalation of Airborne Particulates	--	--
Dermal Contact with Groundwater	7.61E-05	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	2.57E-03
Inhalation of Ambient Air VOCs Emanating from Groundwater	3.07E-05	--
<b>TOTAL NON-CANCER RISK</b>	<b>1E-04</b>	<b>3E-03</b>

**Table 6-4**  
**Non-Cancer Risk Summary**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	NON-CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	--	--
Dermal Contact with Soil	--	--
Inhalation of Airborne Particulates	--	--
Dermal Contact with Groundwater	7.61E-05	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	1.00E-02
Inhalation of Ambient Air VOCs Emanating from Groundwater	1.20E-04	--
<b>TOTAL NON-CANCER RISK</b>	<b>2E-04</b>	<b>1E-02</b>



SOURCE: BASE MAP FROM U.S. G.O.S.H.A., 1988.  
 OAKLAND AND EAST BAY CITIES



NORTH

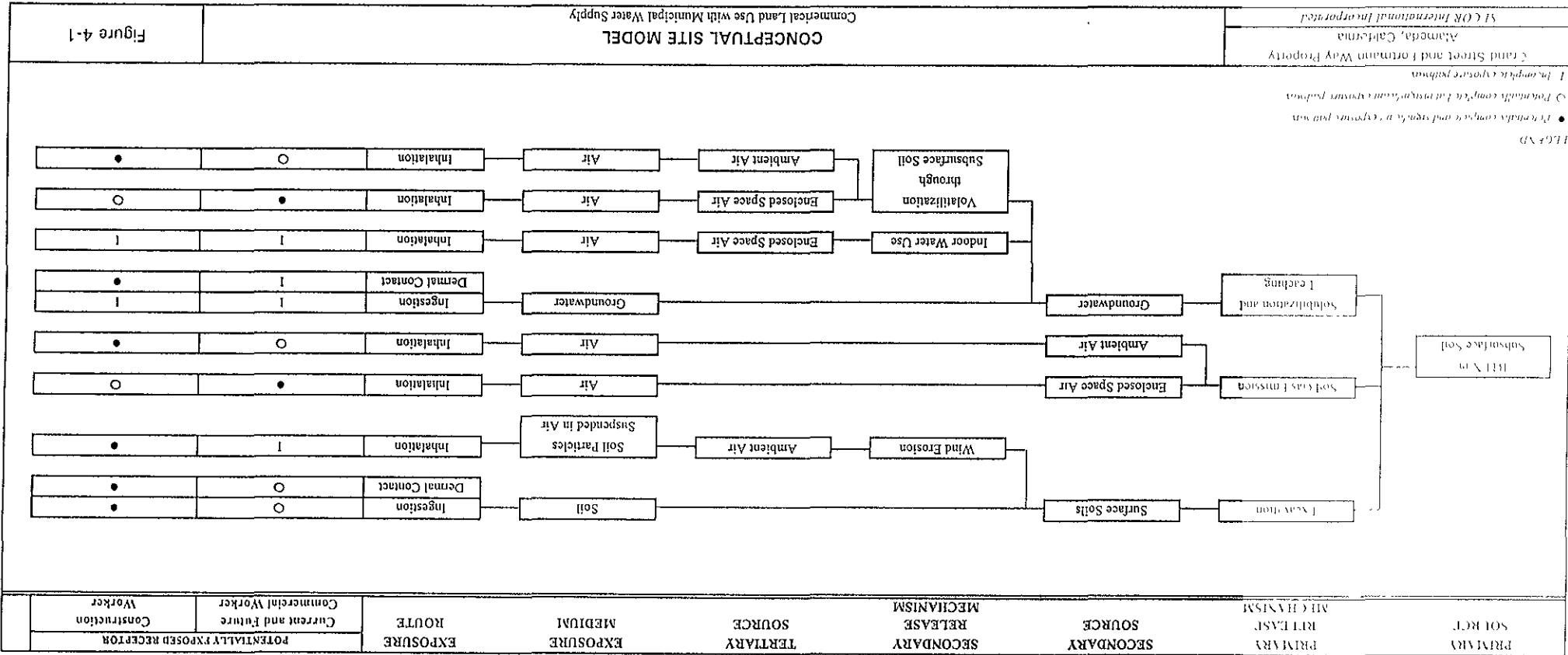


**SECOR**  
 INTERNATIONAL  
 INCORPORATED

FIGURE 1-1  
 GRAND STREET AND FORTMANN WAY PROPERTY  
 ALAMEDA, CALIFORNIA

**SITE LOCATION MAP**





PRIMARY SOURCE	PRIMARY RELEASE MECHANISM	SECONDARY SOURCE	SECONDARY RELEASE MECHANISM	TERTIARY SOURCE	EXPOSURE MEDIUM	EXPOSURE ROUTE	EXPOSURE RECEPTOR
Commercial Worker	Current and Future	Commercial Worker	Construction	Construction	Construction	Construction	POTENTIALLY EXPOSED RECEPTOR
							POTENTIALLY EXPOSED RECEPTOR

Figure 4-1  
 CONCEPTUAL SITE MODEL  
 Commercial Land Use with Municipal Water Supply

SLCOR International Incorporated  
 Alameda, California  
 2 Sand Street and Formann Way Property  
 1 Incomplete exposure pathway  
 ● Potentially complete future exposure pathway  
 ○ Potentially complete future exposure pathway

LEGEND  
 ● Potentially complete future exposure pathway  
 ○ Potentially complete future exposure pathway  
 I Incomplete exposure pathway

Appendix A  
 Volatilization Factor Calculations for an Occupational Scenario  
 Grand Street and Fortmann Way Property  
 Alameda, California

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**Notes:**

*Volatilization Factor (VF) calculations are based on ASTM E 1739-95 Risk-Based Corrective Action Applied at Petroleum Release Sites. November, 1995.*



Table A-1  
**Chemical-Specific Properties**  
**Volatilization Factor Calculation for an Occupational Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	$D_{air}$ ( $cm^2/s$ ) [a]	$D_{wat}$ ( $cm^2/s$ ) Source	$D_{wat}$ ( $cm^2/s$ ) Source	H ( $cm^3-H_2O/cm^3-air$ ) [a]	$k_{oc}$ ( $g-H_2O/g-C$ ) [a]	S ( $mg/L-H_2O$ ) [a]	$k_s$ ( $g-H_2O/g-soil$ ) [d]
Benzene	8.70E-02	9.80E-06	[a]	2.20E-01	5.70E+01	1.78E+03	5.70E-01
Fluorene	3.63E-02	8.36E-06	[b]	3.00E-03	7.93E+03	1.86E+00	7.93E+01

Notes.

[a] U.S. Environmental Protection Agency. 1994. *Technical Background Document for Soil Screening Guidance. Review draft. Office of Solid Waste and Emergency Response, Washington, D.C. EPA540/R-94/106. November.*

[b]  $D_{wat}$  was not available for fluorene. A value of  $8.36 E -06$  was assumed based upon another chemical (2,4,6-Trichlorophenol) with a  $D_{air}$  value which is similar to fluorene.

[d]  $k_s = k_{oc} \times f_{oc}$ . Value for  $f_{oc}$  is presented in Table 2.

$D_{air}$  Diffusion coefficient in air

$D_{wat}$  Diffusion coefficient in water

H Henry's law constant

$k_{oc}$  Carbon-water sorption coefficient

S Pure component solubility in water

Unknown values are shaded.

**Table A-2**  
**Nonchemical-Specific Properties**  
**Volatilization Factor Calculations for an Occupational Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Parameter	Definition	Units	Results	Source
<b>d</b>	Lower depth of surficial soil zone	cm	100	ASTM, 1995
<b>ER</b>	Enclosed-space air exchange rate	1/s	0.00167	Burton, 1990
<b>f<sub>oc</sub></b>	Fraction of organic carbon in soil	g-C/ g-soil	0.01	ASTM, 1995
<b>h<sub>cap</sub></b>	Thickness of capillary fringe	cm	5	ASTM, 1995
<b>h<sub>v</sub></b>	Thickness of vadose zone	cm	100	Site-Specific
<b>I</b>	Infiltration rate of water through soil	cm/year	30	ASTM, 1995
<b>k<sub>s</sub></b>	Soil-water sorption coefficient (f <sub>oc</sub> x k <sub>oc</sub> )	g-H <sub>2</sub> O/g-soil	see table 1	ASTM, 1995
<b>L<sub>B</sub></b>	Enclosed-space volume/infiltration area ratio	cm	300	ASTM, 1995
<b>L<sub>crack</sub></b>	Enclosed-space foundation or wall thickness	cm	15	ASTM, 1995
<b>L<sub>GW</sub></b>	Depth to groundwater (h <sub>cap</sub> + h <sub>v</sub> )	cm	105	ASTM, 1995
<b>L<sub>S</sub></b>	Depth to subsurface soil sources	cm	100	ASTM, 1995
<b>P<sub>e</sub></b>	Particulate emission rate	g/cm <sup>2</sup> -s	6.9E-14	ASTM, 1995
<b>U<sub>air</sub></b>	Wind speed above ground surface in ambient mixing zone	cm/s	225	ASTM, 1995
<b>U<sub>gw</sub></b>	Ground water Darcy velocity	cm/year	2.50E+03	ASTM, 1995
<b>W</b>	Width of source area parallel to wind, or groundwater flow direction	cm	1500	ASTM, 1995
<b>δ<sub>air</sub></b>	Ambient air mixing zone height	cm	200	ASTM, 1995
<b>δ<sub>gw</sub></b>	Ground water mixing zone thickness	cm	200	ASTM, 1995
<b>η</b>	Areal fraction of cracks in foundation/walls	cm <sup>2</sup> -cracks/cm <sup>2</sup> -total area	0.01	ASTM, 1995
<b>Θ<sub>acap</sub></b>	Volumetric air content in capillary fringe soils	cm <sup>3</sup> -air/cm <sup>3</sup> -soil	0.038	ASTM, 1995
<b>Θ<sub>acrack</sub></b>	Volumetric air content in foundation/wall cracks	cm <sup>3</sup> -air/cm <sup>3</sup> -total volume	0.26	ASTM, 1995
<b>Θ<sub>as</sub></b>	Volumetric air content in vadose zone soils	cm <sup>3</sup> -air/cm <sup>3</sup> -soil	0.26	ASTM, 1995
<b>Θ<sub>T</sub></b>	Total soil porosity	cm <sup>3</sup> /cm <sup>3</sup> -soil	0.38	ASTM, 1995
<b>Θ<sub>wcap</sub></b>	Volumetric water content in capillary fringe soils	cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -soil	0.342	ASTM, 1995
<b>Θ<sub>wcrack</sub></b>	Volumetric water content in foundation/wall cracks	cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -total volume	0.12	ASTM, 1995
<b>Θ<sub>ws</sub></b>	Volumetric water content in vadose zone soils	cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -soil	0.12	ASTM, 1995
<b>ρ<sub>s</sub></b>	Soil bulk density	g-soil/cm <sup>3</sup> -soil	1.7	ASTM, 1995
<b>T</b>	Averaging time for vapor flux	s	7.58E+08	ASTM, 1995

*Notes*

*American Society for Testing and Materials (ASTM) 1995. Standard Guide for Risk-Based Corrective Action for Soil Contamination Release. Nov. 1, 1995. November.*

Table A-3

Effective Diffusion Coefficient in Soil Based on Vapor-Phase Concentration ( $Deff_s$ )  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$Deff_s [cm^2/s] = [D_{air} \times (\Theta_{as}^{3.33} / \Theta_T^2)] + [(D_{wat} / H) \times (\Theta_{ws}^{3.33} / \Theta_T^2)]$$

Chemical	$D_{air}$ ( $cm^2/s$ )	$\Theta_{as}$ ( $cm^3$ -air/ $cm^3$ - soil)	$\Theta_T$ ( $cm^3$ / $cm^3$ -soil)	$D_{wat}$ ( $cm^2/s$ )	H ( $cm^3$ - $H_2O$ / $cm^3$ -air)	$\Theta_{ws}$ ( $cm^3$ - $H_2O$ / $cm^3$ -soil)	$Deff_s$ ( $cm^2/s$ )
Benzene	0.087	0.26	0.38	9.80E-06	0.22	0.12	6.79E-03
Fluorene	0.0363	0.26	0.38	8.36E-06	0.003	0.12	2.85E-03

Table A-4

Effective Diffusion Coefficient through Foundation ( $Deff_{crack}$ )  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$Deff_{crack} [cm^2/s] = [D_{air} \times (\Theta_{acrack}^{3.33} / \Theta_T^2)] + [(D_{wat} / H) \times (\Theta_{wcrack}^{3.33} / \Theta_T^2)]$$

Chemical	$D_{air}$ ( $cm^2/s$ )	$\Theta_{acrack}$ ( $cm^3\text{-air} / cm^3\text{-total volume}$ )	$\Theta_T$ ( $cm^3 / cm^3\text{-soil}$ )	$D_{wat}$ ( $cm^2/s$ )	H ( $cm^3\text{-H}_2\text{O} / cm^3\text{-air}$ )	$\Theta_{wcrack}$ ( $cm^3\text{-H}_2\text{O} / cm^3\text{-total}$ )	$Deff_{crack}$ ( $cm^2/s$ )
Benzene	0.087	0.26	0.38	9.80E-06	0.22	0.12	6.79E-03
Fluorene	0.0363	0.26	0.38	8.36E-06	0.003	0.12	2.85E-03

Table A-5

Effective Diffusion Coefficient through Capillary Fringe ( $D_{eff, cap}$ )  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$D_{eff, cap} [cm^2/s] = [D_{air} \times (\Theta_{acap}^{3.33} / \Theta_T^2)] + [(D_{wat} / H) \times (\Theta_{wcap}^{3.33} / \Theta_T^2)]$$

Chemical	$D_{air}$ ( $cm^2/s$ )	$\Theta_{acap}$ ( $cm^3\text{-air} / cm^3\text{-soil}$ )	$\Theta_T$ ( $cm^3 / cm^3\text{-soil}$ )	$D_{wat}$ ( $cm^2/s$ )	H ( $cm^3\text{-H}_2O / cm^3\text{-air}$ )	$\Theta_{wcap}$ ( $cm^3\text{-H}_2O / cm^3\text{-soil}$ )	$D_{eff, cap}$ ( $cm^2/s$ )
Benzene	0.087	0.038	0.38	9.80E-06	0.22	0.342	1.99E-05
Fluorene	0.0363	0.038	0.38	8.36E-06	0.003	0.342	5.46E-04

Table A-6

Effective Diffusion Coefficient between Groundwater and Soil Surface ( $Deff_{ws}$ )  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$Deff_{ws} [cm^2/s] = (h_{cap} + h_v) \times [(h_{cap}/Deff_{cap}) + (h_v/Deff_s)]^{-1}$$

Chemical	$h_{cap}$ (cm)	$h_v$ (cm)	$Deff_{cap}$ (cm <sup>2</sup> /s)	$Deff_s$ (cm <sup>2</sup> /s)	$Deff_{ws}$ (cm <sup>2</sup> /s)
Benzene	5	100	1.99E-05	6.79E-03	3.95E-04
Fluorene	5	100	5.46E-04	2.85E-03	2.37E-03

Table A-7

Volatilization Factor: Groundwater to Enclosed-Space Vapors (VF<sub>wesp</sub>)  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$VF_{wesp} [(mg/m^3 \text{ air}) / (mg/L H_2O)] = [H((Deff_{ws}/L_{GW}) / (ER \times L_B)) / (1 + ((Deff_{ws}/L_{GW}) / (ER \times L_B)) + ((Deff_{ws}/L_{GW}) / (Deff_{crack}/L_{crack})n))] \times 10^3 L/m^3$$

Chemical	H (cm <sup>3</sup> -H <sub>2</sub> O / cm <sup>3</sup> - air)	Deff <sub>ws</sub> (cm <sup>2</sup> /s)	L <sub>GW</sub> (cm)	Deff <sub>crack</sub> (cm <sup>2</sup> /s)	ER (L/s)	L <sub>B</sub> (cm)	η (cm <sup>2</sup> -cracks / cm <sup>2</sup> total area)	L <sub>crack</sub> (cm)	VF <sub>wesp</sub> (mg/m <sup>3</sup> air) / (mg/L H <sub>2</sub> O)
Benzene	0.22	3.95E-04	105	6.79E-03	0.00167	300	1.00E-02	1.50E+01	9.02E-04
Fluorene	0.003	2.37E-03	105	2.85E-03	0.00167	300	1.00E-02	1.50E+01	1.05E-05

Table A-8

Volatilization Factor: Groundwater to Ambient Air (Vapors) (VF<sub>wamb</sub>)  
 Grand Street and Fortmann Way Property  
 Alameda, California

$$VF_{wamb} [(mg/m^3 \text{ air})/(mg/L H_2O)] = H/[1 + (U_{air} \times \delta_{air} \times L_{GW})]/(W \times Deff_{ws})] \times 10^3 L/m^3$$

Chemical	H (cm <sup>3</sup> -H <sub>2</sub> O / cm <sup>3</sup> - air)	U <sub>air</sub> (cm/s)	δ <sub>air</sub> (cm)	L <sub>GW</sub> (cm)	W (cm)	Deff <sub>ws</sub> (cm <sup>2</sup> /s)	VF <sub>wamb</sub> (mg/m <sup>3</sup> air)/(mg/L H <sub>2</sub> O)
Benzene	0.22	225	200	105	1500	3.95E-04	2.76E-05
Fluorene	0.003	225	200	105	1500	2.37E-03	2.26E-06



Table A-9

Groundwater-Ambient Air Concentration Calculation  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical	Groundwater Concentration	Volatilization Factor	Ambient Air Concentration (Site-Wide)
	(mg/L)	$VF_{wamb} [(mg/m^3\text{-air})/(mg/L\ H_2O)]$	(mg/m <sup>3</sup> )
Benzene	7.51E-02	2.76E-05	2.07E-06
Fluorene	9.00E-04	2.26E-06	2.03E-09

Table A-10  
 Groundwater-Enclosed Space Air Concentration Calculation  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical	Groundwater Concentration	Volatilization Factor	Enclosed-Space Air Concentration (Site-Wide)
	(mg/L)	$VF_{wesp} [(mg/m^3\text{-air})/(mg/L\ H_2O)]$	(mg/m <sup>3</sup> )
Benzene	7.51E-02	9.02E-04	6.77E-05
Fluorene	9.00E-04	1.05E-05	9.44E-09

Table A-11

**Groundwater-Ambient Air Concentration Calculation  
Office Building Scenario  
Grand Street and Fortmann Way Property  
Alameda, California**

Chemical	Groundwater Concentration  (mg/L)	Volatilization Factor  $VF_{wamb} [(mg/m^3\text{-air})/(mg/L\ H_2O)]$	Ambient Air Concentration (Office Building)  (mg/m <sup>3</sup> )
Benzene	2.93E-01	2.76E-05	8.08E-06
Fluorene	9.00E-04	2.26E-06	2.03E-09

Table A-12

Groundwater-Enclosed Space Air Concentration Calculation  
Office Building Scenario  
Grand Street and Fortmann Way Property  
Alameda, California

Chemical	Groundwater Concentration	Volatilization Factor	Enclosed-Space Air Concentration (Office Building)
	(mg/L)	$VF_{wesp} [(mg/m^3\text{-air})/(mg/L\ H_2O)]$	(mg/m <sup>3</sup> )
Benzene	2.93E-01	9.02E-04	2.64E-04
Fluorene	9.00E-04	1.05E-05	9.44E-09

**Appendix B  
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Risk Calculations  
Site-Wide Occupational Exposure Scenario  
Grand Street and Fortmann Way Property  
Alameda, California**

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**Summary of Potentially Complete Exposure Pathways  
Grand Street and Fortmann Way Property  
Alameda, California**

Exposure Pathway/Route [1]	RECEPTOR	
	On-Site Construction Worker	On-Site Commercial Worker
<b>SOIL PATHWAYS</b>		
<b>COC: Benzo(a)pyrene</b>		
Incidental Soil Ingestion	x	
Dermal Contact with Soil	x	
Inhalation of Airborne Soil Particulates	x	
<b>GROUNDWATER PATHWAYS</b>		
<b>COCs: Benzene and Fluorene</b>		
Dermal Contact with Groundwater	x	
Inhalation of VOCs Emanating from Groundwater to Indoor Air		x
Inhalation of VOCs Emanating from Groundwater to Ambient Air	x	

*Notes:*

[1] See the Conceptual Site Model for additional information regarding exposure pathways.

x Pathway is quantitatively evaluated for this receptor.

Table 2

**Summary of Exposure Assumptions  
Occupational Exposure Scenario  
Grand Street and Fortmann Way Property  
Alameda, California**

EXPOSURE PARAMETER	On-Site Commercial Worker		On-Site Construction Worker	
	Value	Source	Value	Source
<b>Contact Rate Assumptions</b>				
Inhalation rate (indoors) (m <sup>3</sup> /hr)	0.83	ASTM, 1995	--	
Inhalation rate (outdoors) (m <sup>3</sup> /hr)	--		1.35	USEPA, 1989a [1]
Soil ingestion rate (mg/day)	--		50	ASTM, 1995
Skin surface area (cm <sup>2</sup> /day)	--		2,000	USEPA, 1989a [2]
Soil-to-skin adherence factor (mg/cm <sup>2</sup> )	--		0.5	ASTM, 1995
Absorption factor-organics (unitless)	--		0.01	USEPA, 1992
<b>General Assumptions</b>				
Exposure time (hr/day)	8	Professional Judgment	8	Professional Judgment
Exposure time to groundwater (hr/day)	--		2	Professional Judgment
Exposure frequency (days/year)	250	ASTM, 1995	60	Professional Judgment
Exposure duration (years)	25	ASTM, 1995	1	Professional Judgment
Conversion factor (kg/mg)	--		1E-06	
Conversion factor (L/cm <sup>3</sup> )	--		1E-03	
Fraction of time contacting exposure area (unitless)	1		1	
Body weight (kg)	70	ASTM, 1995	70	ASTM, 1995
Averaging time (days)				
Noncarcinogens	9,125	Professional Judgment	365	Professional Judgment
Carcinogens	25,550	USEPA, 1989b	25,550	USEPA, 1989b

## Notes

-- Not applicable

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.

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

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

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

[1] Inhalation rate assumes a moderate activity level 50 percent of the time (2.1 m<sup>3</sup>/hr) and a light activity level the remaining 50 percent of the time (0.6 m<sup>3</sup>/hr).

[2] Skin surface area assumes exposure to hands and face.

**Table 3**  
**Chemical Intake Exposure Assumptions – Incidental Soil Ingestion**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker	
	Value	
CS = Chemical concentration in soil (mg/kg)	See Table 11	
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

*Notes:*

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



**Table 4**  
**Chemical Intake Exposure Assumptions -- Dermal Contact with Soil**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker	
	Value	
CS = Chemical concentration in surface soil (mg/kg)	See Table 11	
CF = Conversion factor (kg/mg)	1E-06	
SA = Skin Surface Area (cm <sup>2</sup> /day)	2,000	
AF = Soil/skin adherence factor (mg/cm <sup>2</sup> )	0.5	
ABS = Absorption factor-organics (unitless)	0.01	
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

*Notes:*

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

**Table 5**  
**Chemical Intake Exposure Assumptions -- Inhalation of Airborne Particulates**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker Value
CA = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 11
IR = Inhalation rate, outdoor (m <sup>3</sup> /hr)	1.35
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

**Table 6**  
**Air Concentrations Calculated from Soil Particulate Emissions**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

**Particulate Emissions Model (USEPA, 1991)**

The particulate emission factor (PEF) relates the chemical concentration in soil with the concentration of respirable particles (PM<sub>10</sub>) in the air due to fugitive dust emissions from surface soil. This model is a conservative estimate for particulate emissions from surface soils and is taken from USEPA, 1991. This relationship is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface soil provides a relatively continuous and constant potential of emission over an extended period of time (e.g., years).

The particulate emissions are assumed due to wind erosion and, therefore, depend on the erodibility of the surface material. The equation is representative of a surface with unlimited erosion potential, which is characterized by bare surfaces of finely divided material such as sandy agricultural soil with a large number (unlimited reservoir) of erodible particles. Such surfaces erode at low wind speeds, and particulate emission rates are relatively time independent at a given wind speed.

$$PEF = [(LS \times V \times DH \times CF_{one})/A] \times [CF_{two} / (RF \times (1-G) \times (U_m/U_t)^3 \times F(x))]$$

Parameter	Value	Units	Reference
PEF = Particulate Emission Factor	4.63E+09	m <sup>3</sup> /kg	
LS = Width of contaminated area	45	m	USEPA, 1991
V = Wind speed in mixing zone	2.25	m/s	USEPA, 1991
DH = Diffusion height	2	m	USEPA, 1991
A = Area of contamination	2,025	m <sup>2</sup>	USEPA, 1991
RF = Respirable fraction	0.036	g/m <sup>2</sup> -hr	USEPA, 1991
G = Fraction of vegetative cover	0	[unitless]	USEPA, 1991
U <sub>m</sub> = Mean annual wind speed	4.5	m/s	USEPA, 1991
U <sub>t</sub> = Equivalent threshold value of wind speed at 10 m	12.8	m/s	USEPA, 1991
F(x) = Function dependent on U <sub>m</sub> /U <sub>t</sub>	0.0497	[unitless]	Cowherd, 1985
CF <sub>one</sub> = Conversion Factor 1	3,600	s/hr	--
CF <sub>two</sub> = Conversion Factor 2	1,000	g/kg	--

Air Concentration (C<sub>A</sub>) = C / PEF

Chemical	UCL95 Soil Concentration (C) [mg/kg]	Particulate Emission Factor (PEF) [m <sup>3</sup> /kg]	Air Concentration (C <sub>A</sub> ) (C/PEF) [mg/m <sup>3</sup> ]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

**Notes:**

Cowherd, C., Muleski, G., Engelhart, P., and D. Gillete. 1985. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*. EPA Office of Health and Environmental Assessment EPA/600/R-85/002

U.S. Environmental Protection Agency. 1991. *Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (Part B: Development of Risk-based Priority Remediation Goals)*. Publication 9285-7-01-B, December

**Table 7**  
**Chemical Intake Exposure Assumptions – Dermal Contact with Groundwater**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker	
	Value	
Cgw = Chemical concentration in groundwater (mg/L)	See Table 12	
SA = Skin surface area (cm <sup>2</sup> )	2,000	
PC = Dermal permeability constant (cm/hr) [1]		
Benzene	2.10E-02	
Fluorene [2]	3.60E-01	
CF = Conversion factor (L/cm <sup>3</sup> )	1E-03	
ET = Exposure time (hr/event)	2	
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	

*Notes:*

[1] 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.

[2] The dermal permeability constant for fluorene is not available. The value shown represents the dermal permeability constant for fluoranthene.

**Table 8**  
**Chemical Intake Exposure Assumptions – Inhalation of Indoor Air VOCs Emanating from Groundwater**  
**On-Site Commercial Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Commercial Worker	
	Value	
C <sub>A</sub> = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 12	
IR = Inhalation rate (m <sup>3</sup> /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	

**Table 9**  
**Chemical Intake Exposure Assumptions -- Inhalation of Ambient Air VOCs Emanating from Groundwater**  
**On-Site Construction Worker Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker Value
$C_A$ = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 12
IR = Inhalation rate (m <sup>3</sup> /hr)	1.35
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

**Table 10**  
**Toxicity Values**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical Name	Carcinogenic Weight-of-Evidence	Oral/Dermal Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Inhalation Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Oral/Dermal Reference Dose (RfD) (mg/kg-day)		Inhalation Reference Dose (RfD) (mg/kg-day)	
		Value	Source	Value	Source	Value	Source	Value	Source
Benzene	A	1.00E-01	CalEPA, 1995	1.00E-01	CalEPA, 1995	--		1.71E-03	USEPA, 1995a
Benzo(a)pyrene	B2	1.20E+01	CalEPA, 1995	3.90E+00	CalEPA, 1995	--		--	
Fluorene	D	--		--		4.00E-02	USEPA, 1995b	4.00E-02	USEPA, 1995c

*Notes:*

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

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

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

USEPA: U.S. Environmental Protection Agency (USEPA). 1995b. Integrated Risk Information System. On-line data base. Office of Research and Development. Cincinnati, Ohio.

USEPA: U.S. Environmental Protection Agency (USEPA). 1995c. Preliminary Remediation Goals. USEPA Region IX. February 1.

Shaded values represent provisional toxicity values. Provisional toxicity values have not received consensus judgment by USEPA's Reference Dose Work Groups and/or Carcinogenic Risk Assessment Verification Endeavor Work Group. The values are used in this analysis to provide more conservative risk estimates.

**Table 11**  
**Exposure Point Concentrations for Soil COCs**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical Name	Direct Soil Contact (mg/kg)	Particulate Emission Factor (m <sup>3</sup> /kg)	Airborne Soil Particulates (mg/m <sup>3</sup> ) [1]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

*Notes*

[1] Airborne soil particulate concentration calculated by dividing the soil concentration with the Particulate Emission Factor (PEF) of  $4.63 \times 10^9 \text{ m}^3/\text{kg}$ .



Table 12  
 Exposure Point Concentrations for Groundwater COCs  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical Name	Direct Groundwater Contact (mg/L)	VF <sub>wesp</sub> (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Enclosed Air Concentration (mg/m <sup>3</sup> ) [1]	VF <sub>wamb</sub> (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Ambient Air Concentration (mg/m <sup>3</sup> ) [2]
Benzene	7.51E-02	9.02E-04	6.77E-05	2.76E-05	2.07E-06
Fluorene	9.00E-04	1.05E-05	9.44E-09	2.26E-06	2.03E-09

Notes:

[1] Enclosed air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor (VF<sub>wesp</sub>) [(mg/m<sup>3</sup>-air)/(mg/L-H<sub>2</sub>O)]

[2] Ambient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor (VF<sub>wamb</sub>) [(mg/m<sup>3</sup>-air)/(mg/L-H<sub>2</sub>O)]

**Table 13**  
**Risk Calculations**  
**On-Site Construction Worker, Incidental Soil Ingestion**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions										DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>s</sub> (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) <sup>-1</sup>	RfD (mg/kg-day)			
Benzotoluene	1.41E-05	50	1E-06	60	1	1	70	25,550	365	7.45E-14	5.21E-12	1.20E+01	--	8.94E-13	--	

Notes:

- Exposure Point Concentration, Soil*
- Soil Ingestion Rate*
- Conversion Factor*
- Exposure Frequency*
- Exposure Duration*
- Fraction Ingested from contaminated source*
- Body Weight*
- Ingestion Time, carcinogens*
- Ingestion Time, noncarcinogens*
- $[C_s] \times IR \times CF \times EF \times ED \times FI / [BW \times AT-C]$
- $[C_s] \times IR \times CF \times EF \times ED \times FI / [BW \times AT-NC]$
- Slope Factor*
- Reference Dose*
- $DOSE \times SF$
- $DOSE / RfD$
- Not Available*

**Total**      **8.94E-13**      **--**

**Table 14**  
**Risk Calculations**  
**Current On-Site 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 <sub>s</sub> (mg/kg)	CF (kg/mg)	SA (cm <sup>2</sup> /day)	AF (mg/cm <sup>2</sup> )	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) <sup>-1</sup>	RfD (mg/kg-day)		
BenzotaPyrene	1.11E-05	1E-6	2,000	0.5	0.01	60	1	1	70	25,550	365	1.49E-14	1.04E-12	1.20E+01	--	1.79E-13	--

- Notes
- C<sub>s</sub> 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<sub>cancer</sub>  $[C_s \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-C]$
  - DOSE<sub>non-cancer</sub>  $[C_s \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-NC]$
  - SF Slope Factor
  - RfD Reference Dose
  - Cancer Risk DOSE<sub>cancer</sub> x SF
  - Hazard Quotient DOSE<sub>non-cancer</sub> / RfD
  - Not available

<b>Total</b>	<b>1.79E-13</b>	<b>--</b>
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**Table 15**  
**Risk Calculations**  
**On-Site 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 <sub>A</sub> (mg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzo(a)Pyrene	9.59E-15	1.35	8	60	1	70	25,550	365	3.47E-18	2.43E-16	3.90E+00	--	1.35E-17	--

Notes

- C<sub>A</sub> 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**      **1.35E-17**      **--**

Table 16  
**Risk Calculations**  
**On-Site 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 <sub>GW</sub> (mg/L)	SA (cm <sup>2</sup> /day)	PC (cm/hr)	CF (L/cm <sup>3</sup> )	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) <sup>1</sup>	RfD (mg/kg-day)		
Benzene	7.51E-02	2,000	2.10E-02	1E-03	2	60	1	1	70	25,550	365	2.12E-07	1.48E-05	1.00E-01	--	2.12E-08	--
1,1-Dichloroethene	9.00E-04	2,000	3.60E-01	1E-03	2	60	1	1	70	25,550	365	4.35E-08	3.04E-06	--	4.00E-02	--	7.61E-05

- Notes:
- C<sub>GW</sub> = 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<sub>C</sub> = [C<sub>GW</sub> x SA x PC x CF x ET x EF x ED x FC] / (BW x AT-C)
  - DOSE<sub>NC</sub> = [C<sub>GW</sub> x SA x PC x CF x ET x EF x ED x FC] / (BW x AT-NC)
  - SF = Slope Factor
  - RfD = Reference Dose
  - DOSE x SF = DOSE x SF
  - DOSE / RfD = DOSE / RfD
  - = Not Available

**Total**      2.12E-08      7.61E-05

Table 17

**Risk Calculations**  
**On-Site Indoor Commercial Worker, Inhalation of Indoor Air VOCs Emanating from Groundwater**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>A</sub> (µg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzene	6.77E-05	0.83	8	250	25	70	25,550	9,125	1.57E-06	4.40E-06	1.00E-01	1.71E-03	1.57E-07	2.57E-03
Fluorene	9.11E-09	0.83	8	250	25	70	25,550	9,125	2.19E-10	6.14E-10	--	4.00E-02	--	1.53E-08

Notes

- C<sub>A</sub> = 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<sub>A</sub> x IR x ET x EF x ED] / [BW x AT-C]
- DOSE (non-cancer) = [C<sub>A</sub> x IR x ET x EF x ED] / [BW x AT-NC]
- SF = Slope Factor
- RfD = Reference Dose
- Cancer Risk = DOSE x SF
- Hazard Quotient = DOSE / RfD
- Not Available

Total                      1.57E-07    2.57E-03

Table 18

Risk Calculations

On-Site 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 <sub>a</sub> (mg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzene	2.0E-06	1.35	8	60	1	70	25,550	365	7.50E-10	5.25E-08	1.00E-01	1.71E-03	7.50E-11	3.07E-05
Ethylene	2.0E-09	1.35	8	60	1	70	25,550	365	7.37E-13	5.16E-11	--	4.00E-02	--	1.29E-09

Notes

- C<sub>a</sub> 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**      **7.50E-11**      **3.07E-05**

**Table 19**  
**Excess Cancer Risk Summary**  
**Occupational Exposure**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	EXCESS CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	8.94E-13	--
Dermal Contact with Soil	1.79E-13	--
Inhalation of Airborne Particulates	1.35E-17	--
Dermal Contact with Groundwater	2.12E-08	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	1.57E-07
Inhalation of Ambient Air VOCs Emanating from Groundwater	7.50E-11	--
<b>TOTAL EXCESS CANCER RISK</b>	<b>2E-08</b>	<b>2E-07</b>



**Table 20**  
**Non-Cancer Risk Summary**  
**Occupational Exposure**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	NON-CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	--	--
Dermal Contact with Soil	--	--
Inhalation of Airborne Particulates	--	--
Dermal Contact with Groundwater	7.61E-05	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	2.57E-03
Inhalation of Ambient Air VOCs Emanating from Groundwater	3.07E-05	--
<b>TOTAL NON-CANCER RISK</b>	<b>1E-04</b>	<b>3E-03</b>

**Appendix C**  
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**Risk Calculations**  
**Occupational Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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**Table 1**  
**Summary of Potentially Complete Exposure Pathways**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway/Route [1]	RECEPTOR	
	On-Site Construction Worker	On-Site Commercial Worker
<b>SOIL PATHWAYS</b>		
<b>COC: Benzo(a)pyrene</b>		
Incidental Soil Ingestion	x	
Dermal Contact with Soil	x	
Inhalation of Airborne Soil Particulates	x	
<b>GROUNDWATER PATHWAYS</b>		
<b>COCs: Benzene and Fluorene</b>		
Dermal Contact with Groundwater	x	
Inhalation of VOCs Emanating from Groundwater to Indoor Air		x
Inhalation of VOCs Emanating from Groundwater to Ambient Air	x	

*Notes:*

[1] See the Conceptual Site Model for additional information regarding exposure pathways.

x Pathway is quantitatively evaluated for this receptor.

Table 2

**Summary of Exposure Assumptions  
Occupational Office Building Exposure Scenario  
Grand Street and Fortmann Way Property  
Alameda, California**

EXPOSURE PARAMETER	On-Site Commercial Worker		On-Site Construction Worker	
	Value	Source	Value	Source
<b>Contact Rate Assumptions</b>				
Inhalation rate (indoors) (m <sup>3</sup> /hr)	0.83	ASTM, 1995	--	
Inhalation rate (outdoors) (m <sup>3</sup> /hr)	--		1.35	USEPA, 1989a [1]
Soil ingestion rate (mg/day)	--		50	ASTM, 1995
Skin surface area (cm <sup>2</sup> /day)	--		2,000	USEPA, 1989 [2]
Soil-to-skin adherence factor (mg/cm <sup>2</sup> )	--		0.5	ASTM, 1995
Absorption factor-organics (unitless)	--		0.01	USEPA, 1992
<b>General Assumptions</b>				
Exposure time (hr/day)	8	Professional Judgment	8	Professional Judgment
Exposure time to groundwater (hr/day)	--		2	Professional Judgment
Exposure frequency (days/year)	250	ASTM, 1995	60	Professional Judgment
Exposure duration (years)	25	ASTM, 1995	1	Professional Judgment
Conversion factor (kg/mg)	--		1E-06	--
Conversion factor (L/cm <sup>3</sup> )	--		1E-03	
Fraction of time contacting exposure area (unitless)	1		1	
Body weight (kg)	70	ASTM, 1995	70	ASTM, 1995
Averaging time (days)				
Noncarcinogens	9,125	Professional Judgment	365	Professional Judgment
Carcinogens	25,550	USEPA, 1989b	25,550	USEPA, 1989b

**Notes**

-- Not applicable

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.

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

U.S. Environmental Protection Agency (USEPA). 1989b. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final*. Office of Emergency and Remedial Response, Washington, D.C. EPA-510/1-89/002. December.

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

[1] Inhalation rate assumes a moderate activity level 50 percent of the time (2.1 m<sup>3</sup>/hr) and a light activity level for the remaining 50 percent of the time (0.6 m<sup>3</sup>/hr).

[2] Skin surface area assumes exposure to hands and face.

**Table 3**  
**Chemical Intake Exposure Assumptions – Incidental Soil Ingestion**  
**On-Site Construction Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker Value
CS = Chemical concentration in soil (mg/kg)	See Table 11
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

**Notes:**

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

**Table 4**  
**Chemical Intake Exposure Assumptions – Dermal Contact with Soil**  
**On-Site Construction Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker
	Value
CS = Chemical concentration in surface soil (mg/kg)	See Table 11
CF = Conversion factor (kg/mg)	1E-06
SA = Skin Surface Area (cm <sup>2</sup> /day)	2,000
AF = Soil/skin adherence factor (mg/cm <sup>2</sup> )	0.5
ABS = Absorption factor-organics (unitless)	0.01
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

*Notes:*

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

**Table 5**  
**Chemical Intake Exposure Assumptions – Inhalation of Airborne Particulates**  
**On-Site Construction Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker Value
CA = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 11
IR = Inhalation rate, outdoor (m <sup>3</sup> /hr)	1.35
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

**Table 6**  
**Air Concentrations Calculated from Soil Particulate Emissions**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

**Particulate Emissions Model (USEPA, 1991)**

The particulate emission factor (PEF) relates the chemical concentration in soil with the concentration of respirable particles (PM<sub>10</sub>) in the air due to fugitive dust emissions from surface soil. This model is a conservative estimate for particulate emissions from surface soils and is taken from USEPA, 1991. This relationship is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface soil provides a relatively continuous and constant potential of emission over an extended period of time (e.g., years).

The particulate emissions are assumed due to wind erosion and, therefore, depend on the erodibility of the surface material. The equation is representative of a surface with unlimited erosion potential, which is characterized by bare surfaces of finely divided material such as sandy agricultural soil with a large number (unlimited reservoir) of erodible particles. Such surfaces erode at low wind speeds, and particulate emission rates are relatively time independent at a given wind speed.

$$PEF = [(LS \times V \times DH \times CF_{onc})/A] \times [CF_{two} / (RF \times (1-G) \times (U_m/U_t)^3 \times F(x))]$$

Parameter	Value	Units	Reference
<b>PEF = Particulate Emission Factor</b>	<b>4.63E+09</b>	<b>m<sup>3</sup>/kg</b>	
LS = Width of contaminated area	45	m	USEPA, 1991
V = Wind speed in mixing zone	2.25	m/s	USEPA, 1991
DH = Diffusion height	2	m	USEPA, 1991
A = Area of contamination	2,025	m <sup>2</sup>	USEPA, 1991
RF = Respirable fraction	0.036	g/m <sup>2</sup> -hr	USEPA, 1991
G = Fraction of vegetative cover	0	[unitless]	USEPA, 1991
U <sub>m</sub> = Mean annual wind speed	4.5	m/s	USEPA, 1991
U <sub>t</sub> = Equivalent threshold value of wind speed at 10 m	12.8	m/s	USEPA, 1991
F(x) = Function dependent on U <sub>m</sub> /U <sub>t</sub>	0.0497	[unitless]	Cowherd, 1985
CF <sub>onc</sub> = Conversion Factor 1	3,600	s/hr	--
CF <sub>two</sub> = Conversion Factor 2	1,000	g/kg	--

**Air Concentration (C<sub>A</sub>) = C/PEF**

Chemical	UCL95 Soil Concentration (C) [mg/kg]	Particulate Emission Factor (PEF) [m <sup>3</sup> /kg]	Air Concentration (C <sub>A</sub> ) (C/PEF) [mg/m <sup>3</sup> ]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

**Notes:**

1. Cowherd, G. M. "Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination." EPA Office of Health and Environmental Assessment, EPA-600/8-85-002.

2. U.S. Environmental Protection Agency, 1991. "Rapid Assessment Guidance for Superfund Volume 1 - Human Health Evaluation Manual." EPA-823 Development of Revised Human Health Remediation Goals, Publication 9285-7-01P, 2, 2nd ed.



**Table 7**  
**Chemical Intake Exposure Assumptions – Dermal Contact with Groundwater**  
**On-Site Construction Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker	
	Value	
C <sub>gw</sub> = Chemical concentration in groundwater (mg/L)	See Table 12	
SA = Skin surface area (cm <sup>2</sup> )	2,000	
PC = Dermal permeability constant (cm/hr) [1]		
Benzene	2.10E-02	
Fluorene [2]	3.60E-01	
CF = Conversion factor (L/cm <sup>3</sup> )	1E-03	
ET = Exposure time (hr/event)	2	
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	

*Notes:*

[1] 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.*

[2] The dermal permeability constant for fluorene is not available. The value shown represents the dermal permeability constant for fluoranthene.

**Table 8**  
**Chemical Intake Exposure Assumptions -- Inhalation of Indoor Air VOCs Emanating from Groundwater**  
**On-Site Commercial Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Commercial Worker Value
C <sub>A</sub> = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 12
IR = Inhalation rate (m <sup>3</sup> /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

**Table 9**  
**Chemical Intake Exposure Assumptions -- Inhalation of Ambient Air VOCs Emanating from Groundwater**  
**On-Site Construction Worker**  
**Office Building Exposure Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

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

Intake Parameter	Construction Worker Value
C <sub>A</sub> = Chemical concentration in air (mg/m <sup>3</sup> )	See Table 12
IR = Inhalation rate (m <sup>3</sup> /hr)	1.35
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

**Table 10**  
**Toxicity Values**  
**Grand Street and Fortmann Way Property**  
**Office Building Scenario**  
**Alameda, California**

Chemical Name	Carcinogenic Weight-of-Evidence	Oral/Dermal Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Inhalation Slope Factor (SF) (mg/kg-day) <sup>-1</sup>		Oral/Dermal Reference Dose (RfD) (mg/kg-day)		Inhalation Reference Dose (RfD) (mg/kg-day)	
		Value	Source	Value	Source	Value	Source	Value	Source
Benzene	A	1.00E-01	CalEPA, 1995	1.00E-01	CalEPA, 1995	--		1.71E-03	USEPA, 1995a
Benzo(a)pyrene	B2	1.20E+01	CalEPA, 1995	3.90E+00	CalEPA, 1995	--		--	
1,1-Dichloroethene	D	--		--		4.00E-02	USEPA, 1995b	4.00E-02	USEPA, 1995c

*Notes:*

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

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). 1995a. *Risk-Based Concentration Table. USEPA Region III. October 20*

U.S. Environmental Protection Agency (USEPA). 1995b. *Integrated Risk Information System. On-line data base. Office of Research and Development. Cincinnati, Ohio*

U.S. Environmental Protection Agency (USEPA). 1995c. *Preliminary Remediation Goals. USEPA Region IX. February 1.*

Shaded values represent provisional toxicity values. Provisional toxicity values have not received consensus judgment by USEPA's Reference Dose Work Groups and/or Carcinogenic Risk Assessment Verification Endeavor Work Group. The values are used in this analysis to provide more conservative risk estimates.

**Table 11**  
**Exposure Point Concentrations for Soil COCs**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical Name	Direct Soil Contact (mg/kg)	Particulate Emission Factor (m <sup>3</sup> /kg)	Airborne Soil Particulates (mg/m <sup>3</sup> ) [1]
Benzo(a)pyrene	4.44E-05	4.63E+09	9.59E-15

*Notes*

[1] Airborne soil particulate concentration calculated by dividing the soil concentration with the Particulate Emission Factor (PEF) of  $4.63 \text{ E} + 09 \text{ m}^3/\text{kg}$ .

Table 12  
 Exposure Point Concentrations for Groundwater COCs  
 Office Building Scenario  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical Name	Direct Groundwater Contact (mg/L)	VFwesp (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Enclosed Air Concentration (mg/m <sup>3</sup> ) [1]	VFwamb (mg/m <sup>3</sup> -air)/(mg/L-H <sub>2</sub> O)	Ambient Air Concentration (mg/m <sup>3</sup> ) [2]
Benzene	2.93E-01	9.02E-04	2.64E-04	2.76E-05	8.08E-06
Fluorene	9.00E-04	1.05E-05	9.44E-09	2.26E-06	2.03E-09

Notes:

[1] Enclosed air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor ( $VF_{wesp}$ ) [(mg/m<sup>3</sup>-air)/(mg/L-H<sub>2</sub>O)]

[2] Ambient air concentration calculated by multiplying groundwater concentration (mg/L) by appropriate ASTM volatilization factor ( $VF_{wamb}$ ) [(mg/m<sup>3</sup>-air)/(mg/L-H<sub>2</sub>O)]

**Table 13**  
**Risk Calculations**  
**On-Site Construction Worker, Incidental Soil Ingestion**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions										DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>s</sub> (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) <sup>1</sup>	RfD (mg/kg-day)			
Benzo(a)Pyrene	1.44E-05	50	1E-06	60	1	1	70	25,550	365	7.45E-14	5.21E-12	1.20E+01	--	8.94E-13	--	

Notes:

- C<sub>s</sub> 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
- SF  $[C_s \times IR \times CF \times EF \times ED \times FI] / [BW \times AT-C]$
- RfD  $[C_s \times IR \times CF \times EF \times ED \times FI] / [BW \times AT-NC]$
- 1 Nephelometer
- 2 Reference Dose
- 3 Dose via SF
- 4 Dose via RfD
- 5 Not Available

**Total**      **8.94E-13**      **--**

Table 14  
 Risk Calculations  
 Current On-Site Construction Worker, Dermal Contact with Soil  
 Office Building Scenario  
 Grand Street and Fortmann Way Property  
 Alameda, California

Chemical	Exposure Assumptions											DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>s</sub> (mg/kg)	CF (kg/mg)	SA (cm <sup>2</sup> /day)	AF (mg/cm <sup>2</sup> )	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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzofluoranthene	1.1E-05	1E-6	2,000	0.5	0.01	60	1	1	70	25,550	365	1.49E-14	1.04E-12	1.20E+01	--	1.79E-13	--

- Notes
- C<sub>s</sub> 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
  - DOSI (cancer)  $[C_s \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-C]$
  - DOSI (non cancer)  $[C_s \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT-NC]$
  - SF Slope Factor
  - RfD Reference Dose
  - Cancer Risk DOSI x SF
  - Hazard Quotient DOSI / RfD
  - Not Available

**Total**      **1.79E-13**      **--**



Table 15  
**Risk Calculations**  
**On-Site Construction Worker, Inhalation of Airborne Particulates**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>A</sub> (mg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzo(a)Pyrene	9.59E-15	1.35	8	60	1	70	25,550	365	3.47E-18	2.43E-16	3.90E+00	--	1.35E-17	--

*Notes*

- C<sub>A</sub> - 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**      **1.35E-17**      **--**

Table 16

**Risk Calculations  
On-Site 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
	CGW (mg/L)	SA (cm <sup>2</sup> /day)	PC (cm/hr)	CF (L/cm <sup>3</sup> )	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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzene	3.93E-01	2,000	2.10E-02	1E-03	2	60	1	1	70	25,550	365	8.26E-07	5.78E-05	1.00E-01	--	8.26E-08	--
Fluorene	9.00E-01	2,000	3.60E-01	1E-03	2	60	1	1	70	25,550	365	4.35E-08	3.04E-06	--	4.00E-02	--	7.61E-05

Notes:  
CGW = Groundwater Concentration  
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<sub>C</sub> = [CGW x SA x PC x CF x ET x EF x ED x FC] / [BW x AT-C]  
DOSE<sub>NC</sub> = [CGW x SA x PC x CF x ET x EF x ED x FC] / [BW x AT-NC]  
SF = Slope Factor  
RfD = Reference Dose  
DOSE x SF = DOSE x SF  
DOSE / RfD = DOSE / RfD

CGW = 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<sub>C</sub> = [CGW x SA x PC x CF x ET x EF x ED x FC] / [BW x AT-C]  
DOSE<sub>NC</sub> = [CGW x SA x PC x CF x ET x EF x ED x FC] / [BW x AT-NC]  
SF = Slope Factor  
RfD = Reference Dose  
DOSE x SF = DOSE x SF  
DOSE / RfD = DOSE / RfD  
Not Available

**Total**      8.26E-08      7.61E-05

Table 17

**Risk Calculations**  
**On-Site Indoor Commercial Worker, Inhalation of Indoor Air VOCs Emanating from Groundwater**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>A</sub> (mg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzene	2.61E-04	0.83	8	250	25	70	25,550	9,125	6.13E-06	1.72E-05	1.00E-01	1.71E-03	6.13E-07	1.00E-02
Fluorene	9.11E-09	0.83	8	250	25	70	25,550	9,125	2.19E-10	6.14E-10	--	4.00E-02	--	1.53E-08

## Notes

C <sub>A</sub>	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**      **6.13E-07**      **1.00E-02**

Table 18

**Risk Calculations**  
**On-Site Construction Worker, Inhalation of Ambient Air VOCs Emanating from Groundwater**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Chemical	Exposure Assumptions								DOSE		TOXICITY VALUE		Cancer Risk	Hazard Quotient
	C <sub>a</sub> (mg/m <sup>3</sup> )	IR (m <sup>3</sup> /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) <sup>-1</sup>	RfD (mg/kg-day)		
Benzene	8.08E-06	1.35	8	60	1	70	25,550	365	2.93E-09	2.05E-07	1.00E-01	1.71E-03	2.93E-10	1.20E-04
Fluorene	2.03E-09	1.35	8	60	1	70	25,550	365	7.37E-13	5.16E-11	--	4.00E-02	--	1.29E-09

Notes

- C<sub>a</sub> 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<sub>Cancer</sub> [C<sub>a</sub> x IR x ET x EF x ED] / [BW x AT-C]
- DOSE<sub>Non-Cancer</sub> [C<sub>a</sub> x IR x ET x EF x ED] / [BW x AT-NC]
- SF Slope Factor
- RfD Reference Dose
- Cancer Risk DOSE x SF
- Hazard Quotient DOSE / RfD
- Not Available

**Total**      **2.93E-10**      **1.20E-04**

**Table 19**  
**Excess Cancer Risk Summary**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	EXCESS CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	8.94E-13	--
Dermal Contact with Soil	1.79E-13	--
Inhalation of Airborne Particulates	1.35E-17	--
Dermal Contact with Groundwater	8.26E-08	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	6.13E-07
Inhalation of Ambient Air VOCs Emanating from Groundwater	2.93E-10	--
<b>TOTAL EXCESS CANCER RISK</b>	<b>8E-08</b>	<b>6E-07</b>

**Table 20**  
**Non-Cancer Risk Summary**  
**Office Building Scenario**  
**Grand Street and Fortmann Way Property**  
**Alameda, California**

Exposure Pathway	NON-CANCER RISK	
	Construction Worker	Commercial Worker
Incidental Ingestion of Soil	--	--
Dermal Contact with Soil	--	--
Inhalation of Airborne Particulates	--	--
Dermal Contact with Groundwater	7.61E-05	--
Inhalation of Indoor Air VOCs Emanating from Groundwater	--	1.00E-02
Inhalation of Ambient Air VOCs Emanating from Groundwater	1.20E-04	--
<b>TOTAL NON-CANCER RISK</b>	<b>2E-04</b>	<b>1E-02</b>