Draft Final Report

Human Health Risk Assessment

AMCO Chemical Superfund Site

Prepared for

United States Environmental Protection Agency, Region 9

October 2010

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Executive Summary

This report presents the methodology, findings, and conclusions of a human health risk assessment (HHRA) prepared as part of the Remedial Investigation (RI) for the AMCO Chemical Superfund Site (the Site). This HHRA includes a quantitative evaluation of the potential adverse health effects to people resulting from exposure to hazardous chemicals in soil at the former AMCO facility and adjacent parcels (on- and off-facility locations) and in groundwater at the Site. In addition, a vapor intrusion evaluation was performed on residential homes near the former AMCO facility as well as the office building on the Site. Screening level evaluations were performed to assess potential exposure to residential contaminated soil and homegrown produce prior to the soil remediation activities. Results from this HHRA will be one of the factors that the EPA uses to determine if cleanup actions are warranted at the Site.

An ecological risk assessment (ERA) was not performed for the Site. Due to the residential and industrial land use in the vicinity of the former AMCO facility, there are no significant populations of ecological receptors or individuals of special status species on the Site. In addition, there are no reasonable and unambiguous pathways for contaminant transport from the Site to any wildlife or sensitive habitats, including Oakland harbor (EPA 2004d). Under current conditions, birds and small mammals may be exposed to site-related chemicals that have been taken up by homegrown produce. This pathway, while potentially complete, was not quantitatively evaluated in this HHRA and is considered to be insignificant compared to exposure by other receptors (humans) and pathways.

ES.1 Study Area

Four separate industrial/commercial exposure areas within the AMCO study area are evaluated as part of this HHRA. These areas are referred to as follows: former AMCO facility, parking lot, small vacant lot, and large vacant lot. Each of these areas is currently paved with concrete ranging from 0.5 foot to more than 3.7 feet in thickness. However, for this assessment it was assumed that no pavement would be present to preclude direct contact with soil.

The groundwater underneath the Site is not being used for drinking or other potable uses. It is extremely unlikely that residents would drink groundwater underneath the Site in the future; however, in accordance with input from the community and regulatory agencies, the potential risk of using groundwater underneath the Site as drinking water is evaluated.

To assess the potential human health risks associated with VOCs migrating from the groundwater into the office at the Site and into nearby residences; crawlspace and ambient air sampling was performed over nine sampling events from September 2004 through June 2009. Soil gas and crawlspace air samples were collected to determine preferential migration pathways and the potential for vapor intrusion. In addition to the crawlspace and ambient air sampling, the June 2009 sampling event included indoor air sampling at some of the nearby residences. Because indoor air was only sampled once, this data represents a snapshot in time and risks and hazards were not calculated using the indoor air data. Crawl

space air was used in this evaluation because it is thought to be less affected by the lifestyle choices, such as household product use and smoking, of the building's occupants than indoor air. The evaluation of the results of crawl space air sampling is considered easier to interpret than indoor air sampling results (DTSC 2004).

Prior to the soil removal action, soil was sampled at six residential parcels in the immediate vicinity of the facility. Produce samples were collected from four residences that have gardens and fruit trees to evaluate the potential for chemical exposure through ingestion of this produce.

ES.2 Risk Assessment Methodology

This HHRA was prepared in a manner consistent with EPA's *Risk Assessment Guidance for Superfund, Part A* (EPA 1989), *Part B* (EPA 1991b), *Part E* (EPA 2004b) and *Part F* (EPA 2009), as well as guidelines published by the California Environmental Protection Agency (CalEPA). The assumptions provided for the general public by EPA and incorporated into this HHRA are conservative (i.e., representative highest exposure that is reasonably expected to occur at a site) and thus, health-protective.

This HHRA including both the quantitative and screening level assessments is a baseline evaluation which assumes exposure to contaminated media under baseline conditions without consideration of future remediation or natural attenuation of chemicals.

Data Collection and Data Evaluation

Data were evaluated separately for each of the different industrial and residential site locations. In addition to the data collected for the RI, data from previous investigations were reviewed to gain a better understanding of the site characteristics.

For the industrial areas, soil data collected from depths of 0 to 7 feet below the bottom of the concrete was evaluated. Soil deeper than 7 feet was below the water table. The groundwater evaluation was based on six quarters of groundwater monitoring data. Exposure point concentrations (EPCs) were calculated for soil, groundwater, crawlspace air, and ambient air data. For soil and groundwater the EPC was either the 95 percent upper confidence limit on the mean (95 UCL) or the maximum detected concentration for chemicals with the 95 UCL exceeding the maximum concentration.

All chemicals reported in at least one sample at concentrations greater than the sample detection limit were included as constituents of potential concern (COPCs). Chemicals were not excluded based on comparison to background concentrations. The approach used to evaluate COPCs is appropriate for a conservative baseline HHRA.

Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to COPCs that are present at or migrating from a site. An exposure-based conceptual site model (CSM) was prepared to identify potential exposure media, exposed populations, and exposure pathways (Figure 1). The exposed populations included on-facility and off-facility adult and child residents, outdoor commercial/industrial workers, construction workers, and excavation/trench workers.

The exposure pathways evaluated included direct contact (incidental ingestion, dermal contact) with soil and groundwater, as well as inhalation of dusts and vapors in ambient air from soil and groundwater. In addition, direct contact with groundwater and outdoor inhalation of vapors from groundwater was evaluated for excavation/trench workers. For residents, ingestion of chemicals in homegrown produce was evaluated by comparing the concentrations detected in the produce collected from backyards occupying the same city block as the former facility to background levels and soil screening levels.

Toxicity Assessment

The objective of the toxicity assessment is to evaluate evidence regarding the potential for COPCs to cause adverse effects in exposed individuals. Toxicity values published in EPA's Integrated Risk Information System (IRIS) were used for the toxicity assessment. Other sources, including those provided in the EPA Regional Screening Levels (RSL) table (EPA 2010b) were used for chemicals not found in IRIS. Slope factors developed by California EPA's Office of Environmental Health Hazard Assessment (OEHHA) and reference exposure levels developed by Air Toxics and Epidemiology Section of OEHHA were used if they were more health-protective than the federal toxicity values.

Residential exposure to lead in soil for residents was evaluated using OEHHA's California Human Health Screening Level (CHHSL) for lead calculated using the California Department of Toxic Substances Control's (DTSC) Lead Risk Assessment Spreadsheet Version 7, LeadSpread 7. The Leadspread model considers exposure to lead in soil by three pathways: ingestion, re-suspension and inhalation, and dermal contact. The Leadspread model was queried for the soil lead concentrations that would produce a 90th percentile estimate of increase in blood lead of 1 µg/dL. Exposure to lead in soil for residents was evaluated using the updated CHHSL of 80 mg/kg (CalEPA 2009).

OEHHA uses EPA's Adult Lead Model (EPA 2005) to estimate CHHSLs for an industrial setting. This CHHSL is intended to protect a fetus that may be carried by a pregnant female worker. It is assumed that a cleanup goal that is protective of a fetus will also afford protection for male or female adult workers. The model was queried directly for the soil lead concentration that would produce a 90th percentile estimate of change in blood lead of 1 µg/deciliter. The updated CHHSL for soil lead at commercial/industrial (i.e. nonresidential) sites is 320 mg/kg (CalEPA 2009).

Risk Characterization

Excess lifetime cancer risk (ELCR) and non-cancer hazard index (HI) were calculated for both residents and industrial/commercial workers for each soil exposure area, site-wide for groundwater. For the vapor intrusion evaluation, ELCRs and HIs were calculated for the office on the former AMCO facility and several residences located on the same block as the facility. Human health risks are compared against EPA's target risk range of 10^{-6} to 10^{-4} for cancer risks and the HI benchmark of 1 for non-cancer hazards (EPA 1991b). Exposure areas with ELCRs less than 10^{-6} or HI less than 1 are characterized as not posing a threat to human health for the evaluated exposed populations and pathways. Because the neighborhood surrounding the site is a vulnerable community, EPA has elected to use an excess lifetime cancer risk of 10^{-6} as the point at which action will be required at this site.

Ambient air and crawlspace air sample results were compared to acute reference exposure levels (RELs) developed by OEHHA and the Agency for Toxic Substances and Disease Registry's (ATSDR) acute minimal risk level (MRLs) for hazardous substances to confirm that contaminant levels would not pose an immediate health threat to residents.

Data from residential soil were compared against background levels and EPA residential RSLs for soil. Results from the homegrown produce samples were compared against background levels based on an evaluation of relevant scientific literature.

ES.3 Results of Quantitative Risk Evaluation

Soil

The ELCRs and HIs for on- and off-facility soil exposure areas are calculated based on all detected compounds except lead. Exposures to lead are evaluated by calculating a lead EPC and comparing it to the CHHSLs (residential or industrial. As a result, in the following sections, the health effects associated with lead are discussed separately from the cancer risks and non-cancer hazards for all other contaminants.

Former AMCO Facility

The chemicals that contribute the most to the cancer risk and non-cancer hazards in this area are vinyl chloride, naphthalene, xylenes, cadmium, manganese, 2-methylnaphthalene, aluminum, aldrin and dieldrin.

For the industrial worker RME scenario, the ELCR is $1x10^{-4}$ for exposure to shallow soil and $1x10^{-4}$ for exposure to deep soil. HIs for exposure to both the shallow soil and deep soil are 1.

For the construction worker RME scenario, the ELCR is $1x10^{-5}$ for exposure to shallow soil and $1x10^{-5}$ for exposure to deep soil. The HI for exposure to shallow soil is 23 and the HI for exposure to deep soil is 20.

For the future on-site residential RME scenario, for both shallow and deep soil the ELCR is $3x10^{-4}$ The HI for the child is 10 for exposure to shallow soil and 11 for exposure to deep soil. For the adult, the HIs for exposure to the shallow soil is 1 and exposure to deep soil is 2.

The lead EPC for shallow soil is 640 mg/kg and for deep soil 605 mg/kg; both of these concentrations exceed the residential CHHSL for lead of 80 mg/kg. These lead concentrations also exceed the CHHSL for an industrial scenario (320 mg/kg).

Parking Lot

The chemicals that contribute the most to the risk in the parking lot are lead, arsenic, cadmium, benzo(a)pyrene and antimony. Although arsenic is a risk driver, concentrations of arsenic detected in this exposure area are similar to arsenic levels found in the background data set; therefore, the risk contributions from arsenic may not be site-related.

For the industrial worker RME scenario, the ELCR is $5x10^{-5}$ for exposure to shallow soil and $1x10^{-4}$ for exposure to deep soil. HIs are 1 for both exposure to both shallow and deep soil.

For the construction worker RME scenario, the ELCR is $9x10^{-6}$ for exposure to shallow soil and $2x10^{-5}$ for exposure to deep soil. HIs for exposure to both the shallow and deep soil HIs are 30 and 25, respectively.

For the future on-site residential RME scenario, the ELCR is $2x10^{-4}$ for exposure to shallow soil and $4x10^{-4}$ for exposure to deep soil. The HI for the child is 26 for exposure to shallow soil and 25 for exposure to deep soil. For the adult, HIs for exposure to both the shallow and deep soil are 1.

The lead EPC for shallow soil is 2,170 mg/kg and for deep soil 1,450 mg/kg; both of these concentrations exceed the CHHSLs for both residential industrial scenarios.

Large Vacant Lot

The chemicals that contribute the most to the risks and hazards at the large vacant lot are lead, arsenic, cadmium, DDT and benzo(a)pyrene. Although arsenic is a risk driver, concentrations of arsenic detected in this exposure area are similar to arsenic levels found in background; therefore, the risk contributions from arsenic may not be site-related.

For the industrial worker RME scenario, the ELCR is $6x10^{-5}$ for exposure to shallow soil and $4x10^{-5}$ for exposure to deep soil. HIs for exposure to both the shallow and deep soil HIs are less than 1.

For the construction worker RME scenario, the ELCR is $1x10^{-5}$ for exposure to shallow soil and $7x10^{-6}$ for exposure to deep soil. The HI for exposure to shallow soil is 12, and the HI for exposure to deep soil HI is 10.

For the future on-site residential RME scenario, the ELCR is $2x10^{-}$ for exposure to shallow soil and $1x10^{-4}$ for exposure to deep soil. The HI for the child is 10 for exposure to shallow soil and 7 for exposure to deep soil. For the adult, the HIs for exposure to both the shallow and deep soil are less than 1.

The lead EPC for shallow soil is 4,360 mg/kg and for deep soil 2,750 mg/kg; both of these concentrations exceed the CHHSLs for lead for residential and industrial scenarios.

Small Vacant Lot

Due to the shallow water table at this exposure area, only shallow soil samples were collected. The chemicals that contribute the most to the risks and hazards at the small vacant lot are arsenic, cadmium, aluminum, dieldrin, and DDT. Although arsenic is a risk driver, concentrations of arsenic detected in this exposure area are similar to arsenic levels found in background; therefore, the risk contributions from arsenic may not be site-related.

For the industrial worker RME scenario, the ELCR is $4x10^{-5}$ for exposure to shallow soil. The HI is less than 1.

For the construction worker RME scenario, the ELCR for exposure to shallow soil is $7x10^{-6}$. The HI for exposure to shallow soil is 3.

For the potential on-site residential RME scenario, the ELCR for exposure to shallow soil is $3x10^{-4}$. The HI for exposure to shallow soil for the child is 12. For the adult the HI is less than 1.

The lead EPC for shallow soil is 386 mg/kg, which exceeds both the residential and industrial CHHSL for lead.

Groundwater

The chemicals that contribute the most to the risk through exposure to groundwater are vinyl chloride, arsenic, cis-1, 2-dichloroethene, benzo(a)pyrene, and aroclor-1260.

For the potential residential RME scenario, the ELCR is $7x10^{-2}$ for exposure to groundwater. The HI for the child is 628; and the HI for the adult is 262.

In addition, at the request of the community's technical advisor, a trench worker's risk from dermal contact with groundwater and inhalation of vapors from groundwater at the Site was evaluated. For the trench worker RME scenario, the ELCR is $1x10^{-4}$ and the HI is 34 for exposure to groundwater.

Vapor Intrusion

To assess the potential human health risks and hazards associated with VOCs migrating from the groundwater into the office at the former AMCO facility and into nearby residences; crawlspace and ambient air sampling was performed over nine sampling events from September 2004 through June 2009. Ambient air and crawlspace air sample results were compared to acute reference exposure levels (RELs) developed by OEHHA and the Agency for Toxic Substances and Disease Registry's (ATSDR) acute minimal risk level (MRLs) for hazardous substances to confirm that contaminant levels would not pose an immediate health threat to residents.

In addition to the crawlspace and ambient air sampling, the June 2009 sampling event included indoor air sampling at some of the nearby residences and the office located on the Site. Because indoor air data was collected only once, it represents a snapshot in time, therefore it is compared to the crawlspace and ambient air data, as well as screening levels. ELCRs and hazards were not calculated using the indoor air data. Crawl space air was used in this evaluation because it is thought to be less affected by the lifestyle choices, such as household product use and smoking, of the building's occupants than indoor air. The evaluation of the results of crawl space air sampling is considered easier to interpret than indoor air sampling results (DTSC 2004).

Industrial Exposure Evaluation

Potential cancer risks and non-cancer hazards were calculated using industrial worker exposure assumptions for the 1414 3rd Street office. Crawlspace air is used to represent the air that could potentially be inhaled by the workers in their offices. Potential cancer risk from exposure to VOCs in crawlspace air at the office building is 6×10^{-5}, which is within the risk management range of 10^{-6} to 10^{-4}. The main contributors to the cancer risk are carbon tetrachloride (35%) and vinyl chloride (18%). The non-cancer HI is below 1 for exposure by an indoor worker.

Residential Exposure Evaluation

All non-facility locations (residential parcels, South Prescott Park, background) were evaluated using residential exposure assumptions. Crawlspace and ambient air is used to represent the air that could potentially be inhaled by the residents inside and outside the

living spaces of their homes. Potential cancer risks are within the risk management range at all residences for crawlspace and ambient air with the exception of two of the residential properties for crawlspace (1428 3rd Street and 1432 3rd Street) and one for ambient air (1428 3rd Street). These are also the only locations having non-cancer HIs greater than 1.

Potential cancer risks from inhalation of crawlspace air ranged from 5×10^{-5} to 3×10^{-4}. The primary chemical contributors to risk from inhalation of crawlspace air are vinyl chloride, benzene, 1,2-dichloroethane, carbon tetrachloride, and 1,4-dichlorobenzene at the four residences where crawlspace air and ambient air were collected. Crawlspace air HIs range from 0.5 to 8. The primary contributors to the HI in crawlspace air at the two locations that have HIs that exceed 1 are 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene.

Potential cancer risks from inhalation of ambient air ranged from 2×10^{-5} to 2×10^{-4}. The primary contributors to risk from inhalation of ambient air are naphthalene, benzene, carbon tetrachloride, and vinyl chloride. Vinyl chloride is only a primary contributor at one property - 1436 3rd Street. The HI from exposure to ambient air exceeds 1 at 1428 3rd Street (HI=4). Naphthalene (47%), 1,2,4-trimethylbenzene (18%), and 1,3,5-trimethyl-benzene (18%) are the primary contributors to the ambient air HI.

The background cancer risk estimated using the Lewis Street ambient air data is 3×10^{-5}. The primary contributors to the background cancer risk estimate include benzene (31%), carbon tetrachloride (29%) and naphthalene (17%). The background non-cancer HI (0.5) is less than the non-cancer threshold of 1.

Future Buildings

Potential risks and hazards from vapor intrusion into future buildings from VOCs in groundwater may be as high as when residential use of the groundwater is considered, which are exceedingly high. The cancer risks estimated for future residents using the groundwater as tap water in the home is approximately 7×10^{-2}, which is significantly above the risk management range. Hazard indices for an adult (262) and child (628) resident are also significantly above the non-cancer threshold of 1.

Evaluation of potential vapor intrusion for future buildings using soil gas data at the parking lot, small vacant lot, and large vacant lot was not conducted because of the following uncertainties:

a) Subslab soil gas samples were not collected – only exterior soil gas was collected in residential yards.
b) Exterior soil gas samples may underestimate the concentrations found beneath a building because there is no floor covering the ground surface.
c) Soil gas samples could not be collected at the DTSC recommended depth because the groundwater is less than 5 feet from the ground surface.
d) Use of a generic attenuation factor may over/underestimate the VOC concentrations in indoor air.

If future buildings are constructed in these areas, vapor mitigation systems are recommended.

ES.4 Results for Screening Level Risk Evaluation

Residential Soil

All residential soil borings were completed in areas where there was no concrete or asphalt surface cover. Shallow samples were collected from 0.5 to 1 foot bgs; deeper samples were generally collected from between 2.5 and 3 feet bgs, although one sample was collected from between 2 and 2.5 feet bgs due to obstructions. Subsequent to the collection of the residential soil samples, a soil removal action to address high concentrations of lead was performed at residential properties adjacent to and near the former AMCO facility. These properties include 1428, 1432, and 1436 3rd Street, and 320, 326, 356, 360, and 366/368 Center Street. The soil was excavated until the confirmation sampling indicated that the remaining soil was below the EPA residential screening level of 400 mg/kg, or to a 3-foot maximum depth. The excavation depth was generally between one and three feet. Small areas were excavated to a depth of less than 1 foot in locations where valuable trees or plants might have been damaged by deeper excavation. As a result, the samples collected during the RI are no longer representative of the soil conditions at these properties. The following discussion explains samples results **before** the removal action.

Before the removal action, several chemicals exceeded screening levels in residential soil samples. Lead exceeded the site-specific screening level for soil at each of the residential properties. Polynuclear aromatic hydrocarbons (PAHs), pesticides (DDT, DDE, dieldrin, and heptachlor epoxide), antimony, and iron also exceed soil screening levels in at least one property.

In 2009, soil samples were collected during installation of additional monitoring wells. Tables showing the results of this soil sampling compared with screening levels are presented in Attachment 4.

Homegrown Produce

To evaluate the ingestion of homegrown produce pathway, 15 fruits and vegetables from four gardens were collected and analyzed for selected metals (arsenic, chromium, and lead) and VOCs. Analytical results may reflect soil and dust deposited on the plant surface and possible uptake from soil into the edible portions of the plants.

Of the 47 VOCs analyzed, only methyl acetate and styrene were detected. Methyl acetate was detected in figs, mint, and red chili peppers. Styrene was detected only in cactus. Both methyl acetate and styrene have been detected in ripening produce in concentrations ranging from 0.04 to 0.24 mg/kg (Heikes et al. 1995). Volatile organic compounds like methyl acetate are naturally produced by ripening fruits at less than 1 mg/kg (Fountain et al. 1984).

Produce was also analyzed for selected inorganic compounds of concern: arsenic, chromium, and lead. Concentrations of lead in produce range from 0.16 to 8.47 mg/kg. Lead naturally occurs in all plants at concentrations ranging from 0.1 to 10 mg/kg (Kabata-Pendias and Pendias 2001). The maximum arsenic concentration was detected in the pomegranate sample at 0.08 mg/kg and chromium concentrations in produce range from 0.39 to 1.07 mg/kg. Both arsenic and chromium are found in plants at concentrations

ranging from 0.009 to 1.5 mg/kg and 0.02 to 1.5 mg/kg respectively (Kabata-Pendias and Pendias 2001).

ES.5 Uncertainty Evaluation

Uncertainties, which arise at every step in the risk assessment process, are evaluated to provide an indication of the relative degree of conservatism associated with a risk estimate. The uncertainties in this risk assessment can be grouped into three main categories as listed below.

Environmental Sampling and Analysis

Errors in sampling results can arise from the field sampling, laboratory analyses, and data analyses. Errors in laboratory analysis procedures are possible, although the impacts of these sorts of errors on the risk estimates are likely to be low. The environmental sampling at a site is one source of uncertainty in the evaluation. The number and location of samples at each exposure area are considered adequate for the calculation of EPCs at most of the industrial areas and for groundwater. However, the number of samples collected from shallow soil at the small vacant lot and the parking lot are less than what is generally needed to calculate a 95 UCL; therefore, the maximum concentration was used to represent the EPC in these areas. A larger sample size would allow for the calculation of a more representative EPC, and thus decrease uncertainty regarding chemical concentrations used for risk assessment at these locations.

Because of the long history of industrial use at the Site and the associated history of construction and filling, all primary sources may not have been identified. Hot spots and localized areas of contamination in soil or soil vapor that were not sampled may remain unknown in on-facility and off-facility areas. The existence of unknown contamination could lead to an increase in the health risks beyond what has been reported in this document. Data collected from known hot spots have been included in the risk assessment.

Soil gas samples collected in the yards of the homes sampled could not be collected at DTSC's recommended depth of at least 5 feet below ground surface because of the shallow groundwater in the area. Soil gas collected at less than 5 feet below ground surface may be influenced by outdoor air being pulled in by the sample collection pump. This outdoor air would cause the sample to not accurately represent the levels of VOCs in the soil gas. In addition, the soil gas samples were collected in the backyards, in some cases several feet away from the structures. Therefore, there is uncertainty associated with the relationship between the soil gas and crawlspace air or indoor air data presented.

Indoor air sampling was conducted only once in June 2009. Although multiple indoor air samples were collected within each home/office, the indoor air sampling data represents a snapshot in time. As shown by the crawlspace air and ambient air data, the VOC concentrations vary widely from sampling event to sampling event. In addition, it was unusually warm (for the Bay Area) on the days that the sampling was conducted, and many homes had open windows. This condition may not accurately represent VOC concentrations when the windows are closed.

Exposure Pathways and Assumptions

Uncertainties can arise from the types of exposures examined, the points of potential human exposure, the concentrations of COPCs at the points of human exposure, and the intake assumptions. For instance, exposure parameters (e.g., exposure frequency, exposure duration, soil ingestion rates, and skin surface areas) are selected as reasonable maximum exposure (RME) assumptions, resulting in the likely overestimation of risk for most potential exposed populations.

The exposure pathways selected are another source of uncertainty. Exposure routes which were not considered in this evaluation could exist for a particular activity. Such exposures, however, are expected to be lower than the risks and hazards associated with the pathways considered. Dermal exposure has greater uncertainty resulting from uncertainty in several of the inputs including the amount of skin surface area available for exposure and the degree to which soil adheres to skin. Uncertainty in the inhalation route results from the method used for estimating resuspended dust from soil concentrations.

The vapor intrusion pathway is complex and data are variable (i.e., volatile chemicals are detected in one crawlspace sampling event but not in others) causing uncertainty in the evaluation of this pathway.

Characteristics of the COPCs can also present a source of uncertainty. For instance, the amount that each of the COPCs might be absorbed into the body may be quite different from the amount of chemical that is actually contacted (i.e., bioavailability).

Toxicity Criteria and Factors

The availability and quality of toxicological data is another source of uncertainty in the risk assessment. Uncertainties associated with animal and human studies could influence the toxicity criteria. Carcinogenic criteria are classified according to the amount of evidence available that suggests human carcinogenicity. In the establishment of the non-carcinogenic criteria, conservative multipliers, known as uncertainty and modifying factors, are used.

For a number of chemicals detected in the Site media, toxicity values have not been established by EPA or California EPA. Toxicity values based on surrogate chemicals with similar structural and behavioral properties were used where appropriate. If a surrogate chemical was not available, these chemicals were not evaluated quantitatively.

There is uncertainty with the toxicity values used to evaluate trichloroethylene (TCE). EPA has proposed more stringent TCE toxicity values which are pending review (EPA 2009d). This compound is a contaminant of concern in the groundwater at the site but is not a major contributor to risk through the vapor intrusion pathway. Therefore, revising the toxicity values for TCE will not significantly affect the conclusions of the vapor intrusion evaluation presented in this assessment.

ES.6 Summary and Conclusions

This HHRA evaluates potential health risks to workers, as well as future adult and child residents, from exposure to COPCs in soil, groundwater, crawlspace air, and ambient air at the former AMCO facility. Because this is a baseline evaluation which assumes exposure to contaminated media under current conditions without consideration of future remediation

or natural attenuation of chemicals, estimated risks and hazards to current and future workers is the same. A screening level risk evaluation was conducted on the soil and homegrown produce in the surrounding residential neighborhood.

Consistent with the CSM, the predominant exposure pathways for workers at the Site are incidental ingestion of soil, inhalation of particulates and vapors, and dermal contact with soil. Current and future residents in the vicinity may be exposed to contaminants through the same pathways described for workers. Groundwater at the Site is not currently used as a potable water source, nor is it likely to be in the future. Oakland residents have their drinking water supplied by the East Bay Municipal Utility District. However, should groundwater be used as a potable water source, residents could be exposed to contaminants through ingestion of groundwater and dermal contact with groundwater while showering or bathing.

Quantitative Soil Risk Estimates

Soil samples were divided into the following four exposure areas: former AMCO facility, parking lot, large vacant lot, and small vacant lot. Risk and hazard estimates for each receptor and exposure area are discussed below.

Industrial Worker: Estimated cancer risks are at the upper end of the risk range for exposure to either shallow or deep soil at each of the four exposure areas. HIs exceed the non-cancer threshold of 1 only at the former AMCO facility.

Construction Worker: Estimated cancer risks are within the risk range of 10^{-6} to 10^{-4} for exposure to shallow or deep soil at each of the four exposure areas. HIs exceeds the non-cancer threshold of 1 at the former AMCO facility, parking lot, and large vacant lot.

Future Residents: Estimated cancer risks are within the risk range for exposure to shallow or deep soil at all four of the exposure areas. HIs also exceed the non-cancer threshold of 1 at all four exposure areas.

In addition, lead levels at all four exposure areas exceed both the residential and industrial CHHSLs.

Groundwater Risk Estimates

The cancer risks and non-cancer HIs significantly exceed the risk range and non-cancer threshold of 1 when residential use of groundwater is considered. However, it is unlikely that groundwater will be used as a source of drinking water in the future.

An evaluation of vapor intrusion using groundwater data was not conducted, however, it is acknowledged that in a worst case scenario, the risks and hazards may be as high as when residential use of the groundwater is considered. As noted above, the cancer risks estimated for future residents using the groundwater as tap water in the home is significantly above the risk management range and clearly unacceptable. Hazard indices for an adult and child resident are also significantly above the non-cancer threshold of 1.

Vapor Intrusion - Ambient Air and Crawlspace Air Risk Estimates

Several VOCs, including PCE, TCE, vinyl chloride, carbon tetrachloride, chloroform, benzene, and naphthalene were detected above screening levels in the soil gas, ambient air,

crawlspace air, and indoor air samples which indicates vapor intrusion is occurring at the homes near the site. Potential cancer risks and non-cancer hazards were calculated using industrial worker exposure assumptions for the 1414 3rd Street office. Crawlspace air is used to represent the air that could potentially be inhaled by the workers in their offices. Potential cancer risk from exposure to VOCs in crawlspace air at the office building is 6×10^{-5}, which is within the risk management range of 10^{-6} to 10^{-4}. The main contributors to cancer risk are carbon tetrachloride (35%) and vinyl chloride (18%). The non-cancer HI was below 1 for exposure by an indoor worker.

All non-facility locations (residential parcels, South Prescott Park, background) were evaluated using residential exposure assumptions. Crawlspace air and ambient air data is used to represent the air that could potentially be inhaled by the residents in the living spaces of their homes. Potential cancer risks are within the risk management range at all residences for crawlspace air and ambient air with the exception of two of the residential properties for crawlspace air (1428 3rd Street and 1432 3rd Street) and one for ambient air (1428 3rd Street). These were also the only locations having non-cancer HIs greater than 1.

Potential cancer risks from inhalation of crawlspace air ranged from 5×10^{-5} to 3×10^{-4}. The primary chemical contributors to risk from inhalation of crawlspace air are vinyl chloride, benzene, 1,2-dichloroethane, carbon tetrachloride, and 1,4-dichlorobenzene at the four residences where crawlspace air and ambient air were collected. Crawlspace air HIs range from 0.5 to 8. The primary contributors to the HI in crawlspace air at the two locations that have HIs that exceed 1 are 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene.

Potential cancer risks from inhalation of ambient air ranged from 2×10^{-5} to 2×10^{-4}. The primary contributors to risk from inhalation of ambient air are naphthalene, benzene, carbon tetrachloride, and vinyl chloride. Vinyl chloride was only a primary contributor at one property - 1436 3rd Street. The HI from exposure to ambient air exceeds 1 at 1428 3rd Street (HI=4). Naphthalene (47%), 1,2,4-trimethylbenzene (18%), and 1,3,5-trimethyl-benzene (18%) are the primary contributors to the ambient air HI.

The background cancer risk estimated using the Lewis Street ambient air data is 3×10^{-5}. The primary contributors to the background cancer risk estimate include benzene (31%), carbon tetrachloride (29%) and naphthalene (17%). The background non-cancer HI (0.5) is less than the non-cancer threshold of 1. The similarity between the risks and hazards for background and the risks and hazards near the site indicates that air quality is poor in the whole area due to other sources of contamination than the site.

Screening Level Evaluation

The screening level risk evaluation was performed for the current or future off-facility resident or park user. Potential pathways include:

- Soil (incidental ingestion, direct contact, outdoor dust and vapor inhalation, indoor vapor inhalation)
- Homegrown Produce (ingestion of homegrown produce)

Subsequent to the collection of the residential soil samples during the RI investigation, a soil removal action was performed at residential properties adjacent to and near the former AMCO facility in August/September 2007. These properties include 1428, 1432, and 1436 3rd

Street, and 320, 326, 356, 360, and 366/368 Center Street. The soil was excavated until the confirmation sampling indicated that the remaining soil was below the EPA residential screening level of 400 mg/kg, or to a 3-foot maximum depth. The excavation depth was generally between one and three feet. Small areas were excavated to a depth of less than 1 foot in locations where valuable trees or plants might have been damaged by deeper excavation. As a result, the samples collected during the RI are no longer representative of the soil or produce conditions at these properties.

Residential Soil

At each of the residential properties, lead exceeds the site-specific screening level for soil based on residential exposure. PAHs, pesticides (DDT, DDE, dieldrin, and heptachlor epoxide), antimony, and iron also exceed soil screening levels in at least one property.

All residential soil borings were completed in areas where there was no concrete or asphalt surface cover. Shallow samples were collected from 0.5 to 1 foot bgs; deeper samples were generally collected from between 2.5 and 3 feet bgs, although one sample was collected from between 2 and 2.5 feet bgs due to obstructions.

In 2009, soil samples were collected during installation of additional monitoring wells. Tables showing the results of this soil sampling compared with screening levels are presented in Attachment 4.

Homegrown Produce

To evaluate the ingestion of homegrown produce pathway, 15 fruits and vegetables from four gardens were collected and analyzed for selected metals (arsenic, chromium, and lead) and VOCs. Analytical results may reflect soil and dust deposited on the plant surface and possible uptake from soil into the edible portions of the plants.

Of the 47 VOCs analyzed, only methyl acetate and styrene were detected. Methyl acetate was detected in figs, mint, and red chili peppers. Styrene was detected only in cactus. Both methyl acetate and styrene have been detected in ripening produce in concentrations ranging from 0.04 to 0.24 mg/kg (Heikes et al. 1995). Volatile organic compounds like methyl acetate are naturally produced by ripening fruits at less than 1 mg/kg (Fountain et al. 1984).

Produce was also analyzed for selected inorganic compounds of concern: arsenic, chromium, and lead. Concentrations of lead in produce range from 0.16 to 8.47 mg/kg. Lead naturally occurs in all plants at concentrations ranging from 0.1 to 10 mg/kg (Kabata-Pendias and Pendias 2001). The maximum arsenic concentration was detected in the pomegranate sample at 0.08 mg/kg and chromium concentrations in produce range from 0.39 to 1.07 mg/kg. Both arsenic and chromium are found in plants at concentrations ranging from 0.009 to 1.5 mg/kg and 0.02 to 1.5 mg/kg respectively (Kabata-Pendias and Pendias 2001).

Because produce samples were analyzed for VOCs as well as metals, none of the produce samples were rinsed or washed before analysis. As a result, the metals concentrations could reflect dust or soil deposited on the plant surfaces in addition to metals that were taken up through the root system.

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Abbreviations and Acronyms

µg	micrograms
ADD	average daily dose
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BaP	Benzo(a)Pyrene
BART	Bay Area Rapid Transit
bgs	below ground surface
CalEPA	California Environmental Protection Agency
CalTrans	California Department of Transportation
CDC	Centers for Disease Control and Prevention
CDHS	California Department of Health Services
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHHSL	California Human Health Screening Level
COPC	constituent of potential concern
CSBCA	Chester Street Block Club Association
CSF	cancer slope factor
CSM	conceptual site model
DHHS	U.S. Department of Health and Human Services
dL	deciliter
DTSC	California Department of Toxic Substances Control
ELCR	excess lifetime cancer risk
EPA	Environmental Protection Agency
EPC	exposure point concentration
ft	feet
HERO	Human and Ecological Risk Office
HHRA	human health risk assessment

HI	hazard index
HQ	hazard quotient
hr	hour
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
kg	kilogram
L	liter
LADD	lifetime average daily dose
LMS	linearized multistage
LOAEL	Lowest Observed Adverse Effect Level
m	meter
m^3	cubic meter
MCL	maximum contaminant level
mg	milligram
min	minute
MRL	Minimal Risk Level
NAPL	non-aqueous phase liquids
NATA	National Air Toxics Assessment
NCEA	National Center for Environmental Assessment
NCHS	National Center for Health Statistics
NCP	National Contingency Plan
NEI	National Emissions Inventory
NOAEL	No Observed Adverse Effect Level
OEHHA	California EPA's Office of Environmental Health Hazard Assessment
PA/SI	Preliminary Assessment and Site Investigation
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PEA	Preliminary Endangerment Assessment

PEF	particulate-emission factor
PG&E	Pacific Gas & Electric
PHA	public health assessment
PPRTV	provisional peer reviewed toxicity values
PTTIL	Provisional Total Tolerable Intake Levels
ppm	parts per million
REL	reference exposure level
RfC	reference concentration
RfD	reference dose
RfDi	inhalation reference doses
RfDo	oral reference doses
RI	remediation investigation
RME	reasonable maximum exposure
RSL	Regional Screening Levels
RWQCB	Regional Water Quality Control Board
s	second
SES	socioeconomic status
Site	AMCO Chemical Superfund Site
SPNA	South Prescott Street Neighborhood Association
SVOC	semivolatile organic compounds
SWDS	Solid Waste Disposal Site
TAG	Technical Advisor Grant
TCE	trichloroethylene
TDS	total dissolved solids
UCL	upper confidence level
VF	volatilization factor
VOC	volatile organic compound
WOA	West Oakland Alliance

1.0 Introduction

The Human Health Risk Assessment (HHRA) described in this appendix was prepared as part of the Remedial Investigation (RI) for the AMCO Chemical Superfund Site (the Site). This HHRA includes a quantitative evaluation of the potential adverse health effects to people from exposure to hazardous chemicals in soil at the former AMCO facility and adjacent parcels and in groundwater at the Site. In addition, a vapor intrusion evaluation of exposure to air (ambient and crawlspace) which has been impacted by contaminants in groundwater, was performed on residential parcels adjacent to the former AMCO facility and South Prescott Park as well as the office at the former AMCO facility. Screening level evaluations were performed to assess potential exposure to contaminated soil and homegrown produce at the residential properties. Results from the HHRA will be one of the factors that EPA uses to determine if cleanup actions are warranted at the Site.

This HHRA was prepared in a manner consistent with EPA's *Risk Assessment Guidance for Superfund, Part A* (EPA 1989), *Part B* (EPA 1991b), *Part E* (EPA 2004b), and *Part F* (EPA 2009) and supporting documents and guidelines published by the California Environmental Protection Agency (CalEPA). The assumptions provided for the general public by EPA and incorporated into this HHRA are conservative (i.e., representative highest exposure that is reasonably expected to occur at a site) and thus, health-protective.

As part of this HHRA, a conceptual site model (CSM) a schematic diagram that identifies the primary source of contamination in the environment (e.g. releases from leaking storage tank or waste material poured onto the ground) and shows how chemicals at the original point of release move in the environment (e.g. a chemical in soil might percolate into groundwater or might volatilize into air) and identifies the different types of human populations (e.g., residents and workers) who might come in contact with contaminated media. The models also lists the potential exposure pathways (e.g., ingestion of contaminated water) The CSM for the former AMCO facility is presented in Figure 1. The risk assessment will assist EPA in the following areas

- Evaluating the need for a comprehensive remedial action to address contaminated groundwater and soil.
- Provide a basis for performing a remedial action, including a no-action alternative
- Determine what exposure pathways need to be remediated.

The overall goals of the RI are to characterize site conditions, collect sufficient data to determine the nature and extent of contamination, and to support informed risk management decisions regarding human health and the environment.

In order to meet these objectives, six separate evaluations specific to each of these environmental media were conducted in this HHRA:

1. On-facility soil from the former AMCO facility and off-facility soil from the surrounding large vacant lot, small vacant lot, and parking lot

2. Groundwater beneath the former AMCO facility and surrounding areas
3. Soil gas, ambient air, and crawlspace air at the office on the former AMCO site and at eight adjacent residential properties
4. Soil gas and ambient air at South Prescott Park
5. Off-facility soil at six adjacent residential properties
6. Homegrown produce at four adjacent residential properties

A description of the Site, as well as operational history, can be found in Section 1 of the RI report.

1.1 Previous Health Studies

The primary objective of this HHRA is to evaluate the extent to which exposure to hazardous chemicals increases the likelihood of adverse effects occurring in adult and child residents, industrial workers, construction workers, and trench workers at the former AMCO facility. Several previous studies have evaluated potential health issues associated with the Site, as described below. A brief summary of previous health studies conducted at the Site is presented in the following sections to provide relevant background and site history.

1.1.1 Public Health Assessment

The California Department of Health Services (CDHS) prepared a Public Health Assessment (PHA) for the AMCO Chemical Superfund Site under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) (CDHS 2005). ATSDR is a federal agency within the U.S. Department of Health and Human Services (DHHS) and is authorized by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) to conduct PHAs at hazardous waste sites.

A PHA is conducted to evaluate potential adverse health impacts to people coming into contact with chemicals at hazardous waste sites. A health assessor derives an estimated dose of the substances that people in the community might be exposed to; this dose is compared to regulatory standards. A PHA may consider information from citizens about actual exposures, including any health data that might be available. CDHS collected community health concerns as part of the PHA process from a variety of sources including the South Prescott Street Neighborhood Association (SPNA), the Chester Street Block Club Association (CSBCA), and the West Oakland Alliance (WOA). The community expressed concerns including breathing problems, miscarriages, and cancer.

Using available data, CDHS concluded that the Site has four complete exposure pathways, two potentially complete exposure pathways, and four pathways that can be eliminated from consideration**.** The breathing of vapors from subsurface excavations by utility workers is considered a public health hazard. The potential present and future exposure to soil gas contamination at the facility office and abutting residences are considered indeterminate public health hazards. The potential future exposure to subsurface soil contamination at the Site is also considered an indeterminate public health hazard. On the basis of CDHS review of the site data and understanding of the neighborhood, CDHS is concerned that people

may have already, or could potentially in the future, come into contact with chemicals at the Site at levels that could result in adverse health effects. The concentrations of chemicals that remain at the Site could pose health risks to utility workers, on-facility workers, and neighboring residents in the future. Findings from the PHA helped define sampling areas of the RI and HHRA.

1.1.2 National Air Toxics Assessment

In June 2009, EPA released the results of its national-scale assessment of 2002 air toxics emissions (http://www.epa.gov/ttn/atw/nata2002/). The purpose of the National Air Toxics Assessment (NATA) is to identify and prioritize air toxics, emission source types, and locations which are of greatest concern in terms of contributing to population-wide health risks. A subset of 2002 NATA results for census tract 06001401900, which includes the vicinity of the former AMCO facility (Oakland, CA), is presented in Table 1 (note that all tables are located at the end of this report).

The national-scale assessment includes 180 air pollutants (a subset of the air toxics on the Clean Air Act's list of 187 air toxics plus diesel particulate matter). This study provides an indication of the background level for some chemicals of concern. Attribution of air pollution sources can be challenging in industrial areas such as West Oakland which have multiple potential release points. Despite this limitation, the NATA study provides an indication of the background level for some chemicals of relevance for the Site study area.

NATA is a screening level assessment, and is therefore most appropriately used as a relative indicator of air toxics concerns. NATA results are most accurate when comparing between census tracts and over large geographic areas. The NATA assessment includes the following four objectives:

1. Compiling a national emissions inventory of air toxics emissions from outdoor sources,
2. Estimating ambient concentrations of air toxics,
3. Estimating population exposures,
4. Characterizing potential public health risk due to inhalation of air toxics including both cancer and non-cancer effects.

EPA generally updates air toxics emissions inventories every 3 years. The data evaluated as part of this HHRA are from 2002 since these data are the most complete and up-to-date available. The next national-scale assessment, likely to be available in 2010, will focus on the 2005 emissions inventory. The presentation of results for a single census tract is meant only to illustrate the magnitude of concentrations that may be expected in ambient air in the vicinity of the former AMCO facility, and the types of sources that may be contributing to those concentrations including potential sources coming from the facility.

Selected information from the 2002 National Emissions Inventory (NEI) for Alameda County is presented in Table 2. The NEI is a national database of air emissions prepared by EPA, based on input from State and local air agencies, tribes, and industry. The database includes estimates of annual emissions, by source, for every county in all 50 States, the District of Columbia, Puerto Rico, and the Virgin Islands.

With respect to the information presented below, it is important to note the following:

- Carbon tetrachloride is a global pollutant, with an atmospheric lifetime in excess of 50 years and minimal local sources throughout the United States. While sometimes considered a chemical of potential concern from a health perspective, the main contribution to ambient concentrations of carbon tetrachloride is global transport and nearly never local.
- Two other chemicals of potential concern, benzene and ethylbenzene, are emitted primarily by mobile sources, including on-road cars and trucks and non-road sources, such as aircraft, commercial marine, trains, lawn and garden, and construction equipment. While there could be impacts from local, stationary sources of these pollutants, the largest contribution to the widespread concentrations of these pollutants is likely to be mobile sources, especially in West Oakland, where there are several major freeways as well as truck, rail, and commercial marine vessels operating around the Port.
- Three of the chemicals of potential concern—chloroform, trichloroethylene (TCE), and vinyl chloride—are emitted nearly entirely by stationary sources, including both local contributions and long-range transport. Further information on the potential sources of these pollutants may be found in EPA's NEI (using EPA's Air Data web site, http://www.epa.gov/oar/data/) or California's state inventory (http://www.arb.ca.gov/ei/emissiondata.htm).

  The top five stationary sources for vinyl chloride in Alameda County in 2002 (EPA 2002) include:

  - Crow Canyon Solid Waste Disposal Site (SWDS) (Hayward)
  - Galbraith Golf Course (Oakland)
  - Fiberboard Emeryville
  - Tri-Cities Recycling (Fremont)
  - Republic Services Vasco Rd. (Livermore)

1.1.3 Preliminary Endangerment Assessment

In September 2001, the 7th Street McClymonds Corridor Neighborhood Improvement Initiative prepared a Preliminary Endangerment Assessment (PEA) for the Site (7th Street 2001). The objectives of the PEA included identification of potential pathways for human exposure, calculations of cancer risk and non-cancer health hazard for each of the contaminated media, and recommendations for further remedial action.

Based on the PEA results, exposure to contaminated groundwater represents nearly all the cancer risk and over 90% of the non-cancer hazard. The primary contributor to risk is vinyl chloride. The potential excess cancer risk for the Site calculated using the California EPA Department of Toxic Substances Control (DTSC) PEA methodology is 2.7×10^{-1}, or nearly three cancers per ten persons with lifetime exposure to the Site. This is thousands of times higher than the target risk level of 1×10^{-6} (one per million persons with lifetime exposure). Similarly, the non-cancer HI for the Site is calculated to be 940, nearly 1000 times higher than the non-cancer threshold of 1.

1.1.4 Preliminary Assessment and Site Investigation Report

Community interest in the former AMCO facility began in 1996, when DTSC presented information on hazardous materials found on property related to the California Department of Transportation (Caltrans) Cypress Construction Project. Pacific Gas and Electric Company (PG&E) employees who had worked on the construction of a utility trench on Center Street in June of 1995 expressed concern over possible chemical exposure. Investigations conducted on behalf of PG&E and Caltrans in 1996 documented the presence of vinyl chloride and other chlorinated solvents in soil and groundwater at sample locations on 3rd Street, south of the former AMCO facility. Sampling conducted in 1996 on behalf of DC Metals documented the presence of vinyl chloride on the property (E&E 2001).

EPA Region 9 first became aware of the former AMCO facility in 1996, when DTSC requested assistance. To ensure that people living near the Site were protected, the EPA took immediate action under its Emergency Response program. The EPA conducted a Removal Assessment in October 1996 and initiated an Emergency Response action in December 1996, installing a groundwater and soil vapor treatment system that operated until July 1998. The treatment system was shut down in response to community concern over potential exposure to contaminants from the system's exhaust stack.

Following the shutdown of the treatment system, EPA conducted groundwater, soil, and air sampling in December 1998, September 1999, and April 2000 to verify that residents near the property were not at risk from contamination. The results of the investigation are presented in the Preliminary Assessment and Site Investigation [PA/SI] Report (E&E 2001). Additional sampling of groundwater, soil gas, and crawlspace air was conducted in August 2002 following the PA/SI.

The following are the most significant findings from EPA's investigation of the Site:

- Significant concentrations of chemicals have been found in soil on the on- and off-facility properties. However, the majority of the ground surface at these properties is covered with concrete. Therefore, the potential for current workers and residents to come into direct contact with contaminated soil is minimized.
- Significant concentrations of vinyl chloride and other chemicals have been found in groundwater monitoring wells on and near the former AMCO facility that establish a release of chemicals to the regional groundwater. However, the regional groundwater is not used for drinking water, and there are no drinking water wells within 4 miles of the Site.
- A release to air of hazardous substances was observed in 1996, during the excavation of a trench for an on-facility treatment system. A sample collected at the time of the observed release documented that vinyl chloride, trichloroethene, and other volatile organic compounds (VOCs) were present in the vapor observed emanating from the trench.
- Sampling at nearby homes documented the presence of very low levels of vinyl chloride in crawlspace air and soil gas in September 1999. However, vinyl chloride was not detected in either soil gas or crawlspace air in sampling conducted in April 2000. The

EPA does not expect that the very low levels of vinyl chloride found in 1999 could affect the health of people living in the homes where samples were collected.

1.1.5 The West Oakland Environmental Indicators Project

The former AMCO facility is located in West Oakland, approximately one block south of the West Oakland BART Station. In 2002, a collaboration of grassroots advocacy groups, community residents, and a research organization released an independent report, "Neighborhood Knowledge for Change: The West Oakland Environmental Indicators Project". After in-depth discussion with a neighborhood-based steering committee, the Pacific Institute created a set of 17 indicators to track environmental conditions in West Oakland (Pacific Institute 2002).

The indicators look at issues ranging from air pollution and toxic contamination to gentrification and voting. The 17 indicators include: amount of air pollution released by large polluters, air pollution health risks to neighborhood residents, asthma rates, voting power, vulnerability to displacement/housing affordability, community stability/market trends, subsidized housing supply, new business development, illegal dumping, land use conflict, neighborhood toxic volumes, resident toxic exposure sensitive area toxic hazard exposure, lead poisoning, lead abatement, transit mobility, and bike-able streets.

The report states that residents of West Oakland face five times more toxic pollution per person than residents of the city of Oakland with nearly 82 percent living within 1/8 mile of an industrial area. Children in West Oakland were reportedly seven times more likely to be hospitalized for asthma than the average child in the state of California. In addition, only 31 percent of area residents can afford the median rent on available housing units.

1.1.6 Other Relevant Studies: Vulnerable Communities

In discussing the population near the Site, it is important to note that the socioeconomic profile for the surrounding community of West Oakland is characterized by low socioeconomic status and racial diversity (SES) (Census 2000). Characteristics of low SES include low income and associated conditions including poor housing and inadequate health care and education systems.

Research in the area of environmental justice suggests that chemical facilities that pose increased environmental health hazards are disproportionately located in communities characterized by low SES such as West Oakland (Arista et al. 2004). A proposed explanation for this discrepancy is the "diminished response capacity" among low-income and minority communities to resist toxic exposure or to participate in pollution production decisions (Heiman 1996). Based on exposure to chemical concentrations evaluated in the Preliminary Endangerment Assessment, the potential cancer risk for residents living near the Site is several orders of magnitude greater than the levels acceptable to the EPA.

In addition to having more exposure to toxic chemicals, it has been suggested that individuals in such communities are potentially more vulnerable to the effects of exposure to hazardous chemicals due to impaired body defenses. A recent study by deFur et al. (2007) evaluated factors that could hinder an individual's ability to resist adverse impacts associated with chemical exposures. Characteristics of an individual's household, their community and local institutions (e.g. schools and medical facilities) can impact an

individual's vulnerability to toxic agents. Typical stress factors associated with low SES neighborhoods include increased levels of family instability, crowding and incidents of violence and crime. Higher rates of disease and increased mortality among individuals living in low SES neighborhoods support the concept of increased vulnerability among these populations.

1.2 Methodology and Organization of the Risk Assessment

This HHRA was prepared in a manner consistent with EPA's *Risk Assessment Guidance for Superfund, Part A* (EPA 1989), *Part B* (EPA 1991), *Part E* (EPA 2004c), and *Part F* (EPA 2009) and supporting documents and guidelines published by the California Environmental Protection Agency. The assumptions provided by EPA guidance documents and incorporated into this HHRA are conservative and thus, health-protective.

Risk assessments are typically performed in following four steps:

1. Data collection and data evaluation
2. Exposure assessment
3. Toxicity assessment
4. Risk characterization

A summary of the four steps is presented below.

1.2.1 Data Collection and Data Evaluation

Samples of environmental media such as soil, water, air, and homegrown produce are collected in order to characterize the nature and extent of contamination at a site. The data evaluation step consists of reviewing and evaluating available data. Data evaluation allows for the identification of constituents of potential concern (COPCs). In addition to data collected for the RI, data from previous investigations were reviewed to gain a better understanding of the site characteristics. With the exception of residential soil sampling, homegrown produce sampling, and facility office crawlspace sampling, which were not included the original scope of the field investigation, the sampling activities were performed in accordance with the methods and rationale described in the SAP. EPA added sampling of residential soil, homegrown produce, and facility crawlspace air to the RI based on information collected during the course of the RI.

Soil data were evaluated separately for each of the on- and off-facility exposure area. A quantitative evaluation was performed using groundwater data and a vapor intrusion evaluation was performed using crawlspace air and ambient air data evaluated separately for each residential property. A screening level risk evaluation was performed for residential soil and homegrown produce data prior to the soil removal action.

All chemicals reported in at least one sample at concentrations greater than the sample detection limit were included as COPCs. Chemicals were not excluded based on comparison to background concentrations. The approach used to evaluate COPCs is appropriate for a conservative baseline HHRA.

1.2.2 Exposure Assessment

In the exposure assessment step, the potential exposure pathways for COPCs and the potential human populations that could be exposed to these constituents, either now or in the future are identified. Exposure point concentrations (EPCs) are estimated from measured or modeled concentrations, and pathway-specific intake (doses) are estimated for use in the subsequent risk calculations. People who might be exposed and how they are exposed to each chemical are identified in this step. For the former AMCO facility, potential exposed populations included both current and future residents and workers.

1.2.3 Toxicity Assessment

The purpose of the toxicity assessment is to evaluate the potential for COPCs to cause adverse health effects. The derivation of toxicity values is a complex process which must evaluate many factors relating to toxicological data including the type of exposure route, duration of exposure, dose administered, physiology of the species tested, and the type of adverse health effect observed. In the toxicity assessment step, toxicity values are compiled that characterize potential adverse health effects from exposure to COPCs.

1.2.4 Risk Characterization

Risk characterization is the final step in the risk assessment process. It combines the results of the previous three steps to quantitatively characterize potential risks to human health associated with exposure to COPCs. Potential cancer risk, adverse non-cancer health effects, and an evaluation of potential effects from exposure to lead are estimated. Uncertainties associated with or inherent to risk assessments are also evaluated as part of the HHRA process. Section 6.0 presents a review of these uncertainties to provide context for interpreting the results of the HHRA.

In the risk characterization, theoretical non-cancer hazards and theoretical lifetime excess cancer risks (ELCR) associated with exposure to chemicals are estimated. Theoretical hazard for non-carcinogenic (i.e., not cancer causing) chemicals at a site are evaluated by comparison to a target-hazard index of 1 (unity). To evaluate cancer effects, EPA considers a target risk range of 10^{-6} to 10^{-4} to be "safe and protective of public health" (56 F.R. 3535), although EPA has discretion to take action in this range depending on site-specific circumstances. Even risks slightly greater than 1×10^{-4} may be considered adequately protective based on site-specific conditions, including any uncertainties about the nature and extent of contaminants and associated risks. The lifetime theoretical cancer excess cancer risk represents the additional, or excess, risk compared to the actual incidence of cancer that is unrelated to a site. The observed incidence of cancer cases in the United States is approximately 1-in-2 for men and 1-in-3 for women and is due to factors such as smoking, poor nutrition, excessive exposure to sunlight, and other causes including a person's genetics (American Cancer Society 2007). Because the surrounding neighborhoods are a vulnerable community, EPA has decided to use an excess lifetime cancer risk of 10^{-6} as the point at which action will be required at this site.

1.2.5 Organization of the HHRA

Attachments to this document include the following:

- Attachment 1: Detailed Risk and Hazard Results for Exposure to Soil

- Attachment 2: Detailed Risk and Hazard Results for Exposure to Groundwater
- Attachment 3: Detailed Risk and Hazard Results for Vapor Intrusion Evaluation
- Attachment 4: Residential Neighborhood Screening Tables
- Attachment 5: ATSDR Toxicity Profiles for Compounds that Contribute the Most Risk/Hazard
- Attachment 6: Outputs from proUCL
- Attachment 7: Response to DTSC Comments on the HHRA
- Attachment 8: Response to TAG Advisor Comments on the HHRA
- Attachment 9: Comments on the HHRA from the California Department of Public Health
- Attachment 10: Handouts Provided at the October 16, 2010 Public Meeting
- Attachment 11: Updated Section 7.0 from the RI Report

2.0 Data Collection and Data Evaluation

Samples of environmental media such as soil, water, air, and homegrown produce are collected during the remedial investigation of a site in order to characterize the nature and extent of contamination. The data evaluation step consists of reviewing and evaluating available data.

This section describes the data collected to identify contaminant distribution at the former AMCO facility. A detailed discussion of the data collected for the site and used in this HHRA is presented in the RI Report. The analytical data were reviewed according to the data evaluation procedures specified in EPA guidance documents, including *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual, Part A* (EPA 1989) and *Guidance for Data Usability in Risk Assessment* (EPA 1990b). These procedures include the evaluation of analytical methods, quantitation limits, qualified data, blank contamination, and background concentrations.

2.1 Chemicals of Potential Concern

All chemicals reported in at least one sample at concentrations greater than the sample detection limit were included as COPCs. Chemicals were not excluded based on comparison to background soil concentrations. Potential risks associated with ambient levels of metals in soil were also calculated to provide an understanding of the total risks at the Site (i.e., potential risks from site-related COPCs and ambient levels of metals). Screening criteria were used to focus on chemicals that would contribute the most to the risk and were not used to eliminate or screen out chemicals. The approach used to evaluate COPCs is appropriate for a conservative baseline HHRA. Section 5.1 of the RI Report, Screening Level Determination, provides the rationale for the screening criteria selected for this Site. Table 3 presents the COPCs for each media.

All chemicals reported in at least one sample from the data sets compiled for this risk assessment were included as COPCs, except calcium, magnesium, potassium, and sodium, which are known to be essential human nutrients. Elements considered to be essential human nutrients were eliminated as COPCs. EPA and DTSC guidance state that these elements can be deleted from the list of COPCs because of their low toxicity when detected at ambient concentrations (EPA 1989; DTSC 1992). Even if these constituents are present at concentrations slightly above naturally-occurring levels, they are eliminated as COPCs because they are toxic only at very high doses.

2.1.1 Soil

A non-engineered concrete cap exists over the majority of the former AMCO facility and varies from 6 to more than 40 inches thick. In accordance with the SAP, shallow soil samples were generally collected from between 1 and 2 feet below the concrete or below ground surface in unpaved areas. Soil sampling was completed using a slide hammer to drive a sampling “shoe” containing a 2-inch diameter, 6-inch long stainless steel sleeve. In accordance with EPA method 5035, immediately after retrieval of the sample, three

Encore™ sample containers were used to collect soil for VOC analysis from "undisturbed" soil core remaining in the sampling "shoe". For more detail on the sampling procedures, refer to Appendix C, Section C.1.8.2.

For this HHRA, soil samples were divided into the following four exposure areas:

- Former AMCO facility (includes 21 shallow and 11 deep samples),
- Parking lot (includes 3 shallow and 3 deep samples),
- Large vacant lot (includes 14 shallow and 9 deep samples),
- Small vacant lot (includes 2 shallow samples).

Sampling locations were approved by EPA prior to sample collection and were based on a 50-foot grid and historical aerial photographs. If contaminant concentrations greater than screening levels were detected, additional samples were collected to define the extent of contamination. The soil sampling locations for these four exposure areas are shown on Figure 2. Background concentrations for soil were obtained for naturally occurring metals from the city of Oakland (City of Oakland Urban Land Redevelopment Program 1995).

2.1.2 Groundwater

Groundwater samples were collected directly from the discharge line into the sample container using standard procedures for filling VOAs. For more detail on the sampling procedures, refer to Appendix C, Sections C.1.1.2 and C.1.6. The groundwater sample results used for this HHRA are from first, third, and fourth quarters of 2005, and the first, second, and third quarters of 2006, and the grab groundwater samples (September 2004). VOC data from groundwater samples collected from second quarter 2005 were not used in the risk assessment data set due to quality issues (EPA 2006b). Groundwater samples were not collected from monitoring wells with floating non-aqueous phase liquids (NAPL) (MW-13 and MW-14). Evidence of NAPL was observed in the soil during the construction of on-facility wells in the central and south-central portion of the facility. Results of groundwater samples collected from locations with suspected NAPL were included in the data set that was used to calculate the exposure point concentrations used in the groundwater risk calculations. Groundwater sample locations used in the risk assessment are shown on Figure 3.

During the RI, the shallow water table fluctuated from approximately 2.5 to 6.5 feet below ground surface (bgs). In the dry season (May through October), flow generally appears to be toward the southwest; in the wet season (November through April), flow is generally to the south. The highest concentration of contaminants is observed in shallow groundwater (less than 25 feet bgs) in the central and south-central areas of the former AMCO facility, west of the warehouse and office. Contaminant concentrations beneath the central and south-central portions of the former facility decrease rapidly with increasing depth.

2.1.3 Residential Crawlspace Air and Ambient Air

Crawlspace and/or ambient air sampling was conducted between September 2004 and June 2009. Samples were collected from the office located at the former AMCO facility located at 1414 3rd Street, as well as at residential properties occupying the same block as the facility, including 320 Center Street, 326 Center Street, 360 Center Street, 1428 3rd Street, 1432 3rd Street, and 1436 3rd Street. Ambient air sampling was also conducted at 337 Center St., 356

Center St., 360 Center St., 366 Center St., South Prescott Park and from nearby "background locations" measured at 322, 323, and 329 Lewis Street.

Crawlspace and ambient air samples were collected as described below:

- 1414 3rd Street – Crawlspace air samples were collected in the office crawlspace beginning in November 2006. The office has been sampled eight times at two locations during each sampling event.
- 320 Center Street—Ambient air and crawlspace air samples were collected at this residence beginning in August 2008. Sampling at one crawlspace location and one ambient air location have occurred during five sampling events except during the June 2009 sampling, the crawlspace was sampled in two locations.
- 326 Center Street—Crawlspace air samples were collected during nine sampling events. Ambient air samples were collected during eight events (access was not granted during the June 2009 sampling event).
- 360 Center Street— The foundation of this residence consists of a slab-on-grade; therefore, no crawlspace air samples were collected. Ambient air samples were collected during six sampling events from September 2004 to June 2009.
- 1428 3rd Street—During each sampling event, two crawlspace air samples were collected at this residence. Due to remodeling of the house, the initial crawlspace locations were no longer accessible so alternate sampling locations were used. Figure 6 indicates the sampling locations and number of sampling events at each location. Ten sampling events have been conducted at this residence both at crawlspace and at ambient air locations.
- 1432 3rd Street—One ambient air and one crawlspace air sample were collected during the ten sampling events occurring at this residence except during the June sampling, two crawlspace and two ambient air locations were sampled.
- 1436 3rd Street—The foundation of this residence consists of a slab-on-grade; therefore, no crawlspace air samples were collected. Ambient air samples were collected during six sampling events from September 2004 to October 2008.

During the June 2009 sampling event, 3 additional residences were sampled for soil gas, indoor air, and ambient air.

- 337 Center Street
- 356 Center Street
- 366 Center Street

Crawlspaces were not present at these homes. Figure 4a shows the locations of the soil gas sampling.

2.1.4 Residential Soil and Homegrown Produce

Soil sampling was conducted at six residential properties adjacent to or near the facility. Soil sampling locations were sited either along the property boundary or in areas where produce was grown. Produce samples were collected from four of the residences with gardens.

Figure 4b shows the produce and soil sampling locations at the six residential properties. Produce samples were collected from backyards at 356 and 360 Center Street, and 1428 and 1432 3rd Street. No produce was present at 326 Center Street and 1428 3rd Street. At the time of the RI sampling, access had not been granted at 320 Center Street, therefore, no produce sampling was performed at this property. At each of the four residences where produce samples were collected, one sample was collected for each type of produce grown.

3.0 Exposure Assessment

Exposure assessment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure. Exposure assessments may consider past, present, and future exposures, using varying assessment techniques for each phase. The objective of the exposure assessment is to estimate the type and magnitude of exposures to COPCs that are present at or migrating from a site.

The three primary steps in exposure assessment are site characterization, exposure pathway identification and quantification of exposure. A CSM is a tool used to assist with the identification of potential exposure media, human receptors, and exposure pathways.

3.1 Identification of People and Exposure Pathways

Exposure pathways are the different ways that a receptor may contact a chemical. Each of the following components must be present for an exposure pathway to be complete (EPA 1989):

- A potential source of a toxic substance in an environmental media, such as soil or air
- A potential receptor, such as a resident living near or on the potential source
- A contact point, such as a resident planting a garden in soil contaminated with some substance
- A route for the substance to enter the body, such as the inhalations of dust particles or the ingestion of soil particles by a resident working in a garden.

The exposure routes and pathways considered in this HHRA are described below. Figure 1 presents a CSM illustrating these exposure routes and pathways.

3.1.1 Exposed Populations

Potential exposed populations are members of a community who may be exposed to contaminated media during the course of daily living and working in the area of concern. The exposed populations evaluated in the HHRA were identified based on current land use and input from the South Prescott community via Spanish and English focus groups, the Technical Advisor Grant (TAG) recipient, and the technical advisor. Receptors evaluated quantitatively in the HHRA include adult and child residents who currently live immediately adjacent to the facility or may in the future live within the boundaries of the facility.

For the Site, use of a CSM (Figure 1) resulted in the identification of the following potential receptors:

- Future on-facility adult and child residents and current and future off-facility adult and child residents,
- Outdoor commercial/industrial workers,

- Construction workers, and
- Excavation/trench workers.

Potential exposure to workers is over a shorter period of time than residents. The assumed exposure for a worker is 250 days per year over 25 years, while a resident is assumed to be exposed for 350 days per year over 30 years. Based on the common assumption that workers take two weeks of vacation per year, EPA assumes that a resident will be away from home approximately 15 days per year.

Industrial, construction, and trench workers may be exposed to the same chemical concentrations as a resident (by the same pathways), but for a much shorter duration. Thus, the cumulative risk faced by workers from all exposure pathways might be significantly lower than residents for all exposure pathways and routes of exposure evaluated. Exposure assumptions for both future residents and workers are presented in Table 4 for exposure by workers and future residents to soil, Table 5 for exposure by future residents to groundwater, and Table 6 for exposure by trench workers to groundwater. Table 7 presents the exposure assumptions for workers and residents exposed to crawlspace air and ambient air.

3.1.2 Exposure Pathways

An exposure pathway represents how a chemical moves through the environment from the source to a receptor. Exposure pathways are identified by analysis of the distribution of COPCs in the environment and the physical and chemical properties of each COPC. The following exposure pathways for residential, occupational, construction and trench worker scenarios at the Site are considered complete for this risk assessment:

- **Residential**: Current residents (adults and children) that are immediately adjacent to the former AMCO facility may be exposed to groundwater, soil, air, and produce that have been impacted by site-related chemicals. For future residents, this HHRA conservatively assumes that residential development would consist of single-family dwellings within the facility boundaries. This assumption is health-protective and yields conservative risk estimates that are greater than the risk estimates for multi-family dwellings such as apartments or condominiums.
- **Recreational**: Recreational exposure may occur in Prescott Park which is across the street from the former AMCO facility. Both adults and children visiting the park may be exposed to site-related chemicals by outdoor inhalation of VOCs that may emanate from groundwater and soil gas at the park.
- **Industrial**: Current commercial and industrial workers (non-construction) at the former AMCO facility may be exposed to site-related chemicals primarily through inhalation of VOCs emanating from soil, groundwater, and soil gas.
- **Construction/Trench worker**: Under current and future conditions, construction and excavation workers are assumed to be engaged in subsurface disturbance activities that may extend to 10 ft below ground surface (bgs). Such activities may include utility work, repairs, maintenance and construction. This is potentially the most significant exposure pathway for subsurface workers.

- **Ecological:** Under current conditions, birds and small mammals may be exposed to site-related chemicals that have been taken up by homegrown produce. This pathway, while potentially complete, was not quantitatively evaluated in this HHRA and is considered to be insignificant compared to exposure by other pathways.

In addition, risks for unrestricted residential use of groundwater were also evaluated in accordance with input from the regulatory agencies and the community.

Residents/Workers could be exposed to COPCs through any of the following pathways:

- Incidental soil ingestion
- Dermal absorption due to direct soil contact
- Inhalation of airborne suspended soil particulates
- Inhalation of VOCs from soil or groundwater
- Ingestion of homegrown produce
- Dermal absorption due to direct groundwater contact (trench worker only)
- Inhalation of VOCs in indoor air from vapor intrusion

Incidental soil ingestion by adults and children primarily occurs through hand-to-mouth contact as a result of hands and fingers being placed in the mouth after contact with soil while gardening or playing. This scenario assumes that adults ingest 100 milligrams of soil per day (mg/day), 350 days per year (EPA 1991a). A child resident that plays in the soil may ingest twice as much as the average adult (200 mg/day). Based on the common assumption that workers take two weeks of vacation per year, EPA assumes that a resident will be away from home approximately 15 days per year (EPA 1991a).

Dermal absorption of COPCs is a result of chemicals being absorbed into the body from soil particles after any direct skin contact with contaminated soil. Hands and fingers are typically the primary body parts in contact with soil. Chemicals absorbed through the skin are absorbed into the bloodstream. The soil adherence factor is based on gardening and play activities.

Inhalation of airborne suspended soil particles occurs when soil grains are picked up by the wind and dispersed into the air. Once these soil particles are airborne, people in the vicinity can inhale them. Particles typically less than 10 microns in size are inhaled. Once inhaled into the lungs, chemicals are absorbed from the soil particle and absorbed into the bloodstream. Larger particles do not reach the lungs but are coughed up and swallowed.

Inhalation of VOCs which volatilize from soil or groundwater into air (outdoor and indoor air) can be absorbed into the bloodstream after being inhaled.

Residents may be exposed to COPCs through **ingestion of homegrown produce.** Various types of produce are grown and consumed in the neighborhood adjacent to the former AMCO facility. Produce grown in the residential gardens include mint, figs, guava, cilantro, and grapes. Produce may take up COPCs into roots or have soil deposited on aboveground plant parts.

Oakland residents have their drinking water supplied by the East Bay Municipal Utility District. It is unlikely that residents would drink groundwater in the future; however, in accordance with input from the regulatory agencies and the community, groundwater use

for drinking water and household use is included in the evaluation of future residential use of the AMCO property.

3.2 Exposure Point Concentrations

EPCs are representative of the concentration of the chemical of potential concern to which receptors may be exposed over a period of time. EPCs were calculated for on-facility soil, groundwater, and crawlspace and ambient air for each residential property and the office at 1414 3rd Street. Because a screening level risk evaluation was conducted on the residential soil and homegrown produce sample results, these data were not grouped and individual sample results were compared with screening levels. Detected concentrations from each sample/media were compared to their appropriate screening levels.

Exposure point concentration estimates do not include physical, chemical, or biological processes that could result in the reduction of chemical concentrations over time. The EPCs are assumed to remain constant at levels reflected in the analytical results. This general assumption of steady state conditions also applies to sources and contaminant release mechanisms. This assumption may result in a conservative evaluation of long-term exposure conditions.

3.2.1 Soil and Groundwater

The measure of exposure appropriate for a risk assessment is the average concentration of a contaminant throughout an area to which humans are exposed. The premise is based on the assumption that over a long enough period of time a receptor would contact all parts of the exposure area. A conservative estimate of the average concentration of a chemical across an exposure area is the 95 UCL on the mean; 95% UCLs were calculated for the soil and groundwater datasets using ProUCL3 software (EPA 2004c). ProUCL outputs for each COPC in each medium are provided in Attachment 5.

ProUCL computes parametric UCLs based on normal, lognormal, or gamma distributions, and nonparametric UCLs using one of several nonparametric methods. The UCLs that are selected as the EPCs are based on the data distribution and the associated skewness. If the dataset contained four or fewer samples, the maximum sample concentration was used as the EPC because a 95% UCL could not be calculated. EPCs are the lesser of the maximum-detected concentration and the 95% UCL.

Table 8 summarizes the EPCs for each soil exposure area. Table 9 summarizes the EPCs for the groundwater dataset. Table 10 summarizes the EPCs for the crawlspace air and ambient air data.

3.2.2 Crawlspace Air and Ambient Air

95% UCLs were calculated for workers in the onsite office and each resident using the crawlspace air and ambient air data from the multiple sampling events. 95% UCLs were calculated for the crawl space air and ambient air datasets using ProUCL4 software (EPA 2010c).

At the residential locations, during the early sampling events (2004, 2005, and 2006) the crawlspace air samples were collected over a 4-hour time period. During more recent sampling events (2007 to 2009), the air samples were collected over a 24-hour time period.

At the office, during the 2006 and 2007 sampling events, the crawlspace air samples were collected over a 24-hour time period and starting in 2008, the air samples were collected over an 8-hour time period to represent a worker scenario in the office only. Concentrations measured using each of these two sampling approaches were consistent; so there were no adjustments made to the data for this evaluation.

3.3 Estimation of Chemical Intake

Exposure (or intake) is defined as contact of an organism with a chemical. Intake is normalized for time and body weight and is expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-day). Six basic factors are used to estimate intake: chemical concentration, contact rate, exposure frequency, exposure duration, body weight, and averaging time.

Intake estimates are calculated for each COPC and exposure pathway. For non-carcinogenic effects, the intake is averaged over the period of time that receptors are exposed to the COPCs and is referred to as the average daily dose (ADD). For carcinogenic effects, the intake is averaged over a receptor's lifetime (i.e., assumed to be 70 years) and is referred to as the lifetime average daily dose (LADD).

The quantification of exposure intake considers chemical EPCs, as well as general exposure assumptions or parameters. The intake assumptions are based on information that is highly conservative in nature and are intended to overestimate exposure to be protective of sensitive members of the population such as children.

EPA guidance states that actions at Superfund sites should be based on an estimate of the "reasonable maximum exposure" (RME) (EPA 1989). The RME is defined as the "highest exposure that is reasonably expected to occur at a site." The intent of the RME is to estimate a conservative exposure case (i.e., well above the average case) that is still within the range of possible values. To the extent possible, the risk assessment has selected values for the exposure factors that result in an estimate of the RME scenario.

The parameters used to assess exposure in this HHRA are summarized in the sections below and are provided in Table 4 for soil, Tables 5 and 6 for groundwater (exposure by residents and trench workers, respectively), and Table 7 for crawlspace and ambient air. The parameters based on RME exposure are recommended values from EPA's *Regional Screening Levels (RSLs)* and California Department of Toxic Substances Control (DTSC) and Human and Ecological Risk Office (HERO) recommended default exposure factors for use in risk assessment at California Military Facilities (DTSC 2005).

3.3.1 General Exposure Assumptions

General exposure assumptions are used in the intake calculations for all exposure pathways evaluated in the HHRA. General exposure assumptions include exposure frequency, exposure duration, body weight, and averaging time. These assumptions are detailed below:

- **Exposure Frequency**—It was assumed that adult and child residents would be exposed to chemicals at the site 350 days per year (EPA 1991a). For workers the assumed exposure duration is 250 days per year (EPA 1991a).

- **Exposure Duration**—A total resident exposure of 30 years is assumed (i.e., 24 years for an adult and 6 years for a child). An industrial worker exposure of 25 years at the same location is assumed (EPA 1991a). The construction worker is assumed to be exposed for a period of 1 year.
- **Body Weight**—It was assumed that the body weight for an adult (for both resident and worker) is 70 kilograms (kg). A body weight of 15 kg is used for a child.
- **Averaging Time**—Intake calculations are averaged over a period of time. For non-carcinogenic effects, the averaging time is equal to the period of time that receptors are exposed to the COPC, or 365 days per year multiplied by the exposure duration. The averaging time for non-carcinogenic effects for residential adults and children are 8,760 and 2,190 days, respectively (corresponding to 24 years for an adults and 6 years for a child). For workers, an averaging time of 1 year or 365 days, is assumed. For carcinogenic effects (for both resident and worker), the averaging time is equal to a receptor's lifetime of 365 days per year multiplied by 70 years. The averaging time for carcinogenic effects is 25,500 days.

3.3.2 Exposure Parameters and Equations for Soil Ingestion

To calculate intake by incidental ingestion of soil, soil ingestion rates were applied (Table 4). The soil ingestion rates identified for assessing a residential exposure are 100 mg/kg for an adult and 200 mg/kg for a child. Soil ingestion rates of 100 mg/kg and 330 mg/kg are assumed for the industrial worker and construction workers, respectively.

Chemical intake via ingestion of soil was estimated according to the following equation (EPA 1989):

Intake =

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
Cs	=	EPC in soil (mg/kg)
IngR	=	Ingestion Rate (mg/day)
EF	=	Exposure frequency (day/years)
ED	=	Exposure duration (years)
CF	=	Conversion factor (1×10^{-6} kg/mg)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

3.3.3 Exposure Parameters and Equations for Dermal Contact with Soil

Exposure assumptions used in the intake calculations for the dermal contact with soil exposure pathways include body surface area and soil adherence factor (Table 4). Chemical specific dermal absorption factors are also applied. These factors are detailed below:

- **Body Surface Area**—The body surface area is the total amount of skin surface that can be exposed to contaminated soil. The adult resident was assumed to wear a short-sleeved shirt, shorts, and shoes with an exposed skin surface area of 5,700 cm^2 which included head, hands, forearm, and lower legs. The surface area for a child is 2,900 cm^2

which includes exposure to the head, hands, forearms, lower legs, and feet. Both industrial and construction workers are assumed to have an exposed skin surface area of 5,700 cm^2.

- **Soil-adherence Factor—**The soil-adherence factor is a measure of the amount of soil that can adhere to an area of skin surface. EPA's (2004b) recommended soil-adherence factor for adults is 0.07 mg/cm^2. This is based on the body-part specific adherence factor presented in Kissel et al. (1996) and Holmes et al. (1999). The activity pattern selected to be representative of the average urban suburban resident is the outdoor gardener. This scenario is considered to represent the most common residential activities, since it included activities as weeding, pruning, picking fruit, digging small irrigation trenches, and cleaning up. The recommended soil-adherence factor for a child resident is 0.2 mg/cm^2 (EPA 1999a), and is used to represent a sensitive population with activity patterns that could contribute to increased exposure. The age group/activity used to determine the adherence factor is children at play. The assumed soil-adherence factor for industrial workers is 0.2 mg/cm^2; for construction workers, a soil-adherence factor of 0.8 mg/cm^2 is used.
- **Dermal–absorption Factor—**The dermal absorption factor is a chemical-specific factor that measures a chemical's ability to be absorbed into the human body. An absorption factor of 0.1 assumes that 10 percent of the chemical will be absorbed into the body and be bioavailable to cause a toxic effect. Dermal-absorption factors were obtained for all chemicals from EPA (1999). Dermal-absorption factors are compiled in Table 1-4 (located in Attachment 1).

Chemical Intake via dermal contact with soil was estimated according to the following equation (EPA 1989):

$$\text{Intake} = \frac{Cs \times SA \times EF \times ED \times AF \times ABS \times CF}{BW \times AT}$$

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
Cs	=	EPC in soil (mg/kg)
SA	=	Body Surface area (cm^2)
EF	=	Exposure frequency (day/years)
ED	=	Exposure duration (years)
AF	=	Soil-adherence factor (mg/cm^2)
ABS	=	Absorption factor
CF	=	Conversion factor (1×10^{-6} kg/mg)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

3.3.4 Exposure Parameters and Equations for Inhalation of Particulates and Volatiles from Soil

There are two types of exposure pathways evaluated in this HHRA to address inhalation of chemicals. One is inhalation of particulates in which nonvolatile chemicals of potential concern (i.e., DDT and lead) are sorbed to airborne dust and subsequently inhaled by

receptors. The other pathway evaluated is inhalation of volatile compounds that have migrated from soil to air. Exposure assumptions used in the intake calculations for the inhalation of particulates and volatiles from soil include inhalation rate and exposure time. A particulate emission factor (PEF) and chemical specific volatilization factors are also applied. These factors are detailed below and summarized in Table 4.

- **Inhalation Rate**—For adults (both workers and residents) the inhalation was assumed to be 0.83 cubic meters per hour (m^3/hr). For children 6 to 8 years of age, an inhalation rate of 0.42 m^3/hr is recommended. This is the highest recommended inhalation rate for a child within the age range of 1 through 6 years.
- **Exposure Time**—Inhalation pathways are unique in that an exposure time parameter can be applied to the intake estimates to account for the amount of time during one day that a receptor can potentially inhale chemicals. The exposure time is assumed to be 24 hours for both the adult and child resident, which is conservative given that residents are typically not exposed all day to chemicals in soil at their homes. For workers, an exposure time of 8 hours is assumed.
- **Particulate-emission and Volatilization Factors**—The inhalation pathways incorporate a PEF for nonvolatile chemicals and a chemical specific volatilization factor (VF) for volatile chemicals. These factors relate chemical concentrations in soil to chemical concentrations in air that can be inhaled by receptors. A PEF of 1.32×10^9 cubic meters per kilogram (m^3/kg) was applied to resident and industrial worker exposures. It was derived by assuming a continuous and contact emission rate over an extended period of time. This PEF was used to evaluate inhalation of the nonvolatile chemicals. A PEF of 1.0×10^6 was applied to construction worker inhalation exposures (DTSC 2005). When available for volatile chemicals, chemical-specific VFs were used.

Chemical intake via inhalation of particulates from soil is estimated according to the following equation (EPA 1989):

$$\text{Intake} = \frac{Cs \times InhR \times EF \times ET \times ED}{PEF \times BW \times AT}$$

Chemical intake via inhalation of volatiles from soil is estimated according to the following equation:

$$\text{Intake} = \frac{Cs \times InhR \times EF \times ET \times ED}{VF \times BW \times AT}$$

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
Cs	=	EPC in soil (mg/kg)
InhR	=	Inhalation Rate (m^3/day)
EF	=	Exposure frequency (day/years)
ET	=	Exposure time (hours)
ED	=	Exposure duration (years)
PEF	=	Particulate-emission factor (m^3/kg)
VF	=	Volatilization factor (m^3/kg)
BW	=	Body weight (kg)

AT = Averaging time (days)

3.3.5 Exposure Parameters and Equations for Ingestion of Groundwater

Specific equations used to estimate chemical exposures for each complete pathway are presented in Table 5 for exposure by residents and Table 6 for exposure by trench workers.

Although groundwater beneath the Site is not currently used by residents as a drinking water source, risks were calculated for a hypothetical exposure assuming that future residents might use the groundwater at the Site for drinking and for household use. The groundwater ingestion rates identified for assessing a residential exposure were 2 L/day for an adult and 1 L/day for a child.

Chemical intake from ingestion of chemicals in groundwater was calculated using the following equation (EPA 1989):

$$\text{Intake} = \frac{C_{gw} \times IngR \times EF \times ED}{BW \times AT}$$

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
Cgw	=	EPC in groundwater (mg/kg)
IngR	=	Ingestion Rate (L/day)
EF	=	Exposure frequency (day/years)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

3.3.6 Exposure Parameters and Equations for Dermal Contact with Groundwater

Dermal contact with groundwater used in the home as tap water could occur as a result of bathing or showering. Calculation of exposure through this pathway varies depending on the nature of the chemical involved as well as the length of the exposure and the amount of "lag time" assumed to occur following the exposure period.

The general chemical intake equation for dermal contact with groundwater is as follows (EPA 2004b):

$$\text{Intake} = \frac{DA_{event} \times SA \times EF \times ED}{BW \times AT}$$

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
DA_{event}	=	Absorbed dose per event per area of skin exposed (mg/cm^2-event)
SA	=	Body surface area (cm^2)
EF	=	Exposure frequency (day/years)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

DA_{event} is calculated differently for organic and inorganic chemicals.

For inorganic chemicals DA_{event} is calculated as follows:

$$DA_{event} = K_p \times C_{gw} \times t_{event}$$

For organic chemicals DA_{event} is calculated using the following equations:

If $t_{event} > t^*$

$$DA_{event} = FA \times K_p \times C_{gw} \left[\frac{t_{event}}{1+B} + 2t\tau \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

If $t_{event} \leq t^*$

$$DA_{event} = 2\,FA \times K_p \times C_{gw} \sqrt{\frac{6\tau \times t_{event}}{\Pi}}$$

Where:

C_{gw}	=	EPC concentration in groundwater (mg/L)
FA	=	Fraction absorbed (unitless)
K_p	=	Skin permeability constant for chemicals in groundwater (cm/hour)
t_{event}	=	Exposure Time (hrs)
t*	=	Time to reach steady state (hrs)
τ	=	Lag time per event
Π	=	Pi
B	=	Dimensionless coefficient (cm/hr)

3.3.7 Exposure Parameters and Equations for Inhalation of Vapors from Groundwater

Assuming that groundwater under the former AMCO facility is used in the home as tap water, volatile chemicals within this water that became airborne could be inhaled by residents within their homes during bathing or showering. Assumptions regarding exposure duration and frequency are the same as those used for the soil inhalation pathway described above with the exception that the inhalation pathway is only assumed to occur for volatile chemicals and the VF for each of these chemicals is assumed to be 0.5.

Inhalation of chemicals in groundwater was calculated using the following equation:

$$\text{Intake} = \frac{C_{gw} \times InhR \times VF \times ET \times EF \times ED}{BW \times AT}$$

Where:

Intake	=	Intake, or dose for each chemical (mg/kg-day)
C_{gw}	=	EPC in groundwater (mg/L)
InhR	=	Inhalation Rate (m^3/day)
VF	=	Volatilization factor (L/m^3)

ET	=	Exposure time (hours)
EF	=	Exposure frequency (day/years)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Since the groundwater is present at the Site at depths less than 10 feet bgs, trench workers may be exposed to groundwater under the former AMCO facility, based on the assumption of standing groundwater in the ditch during digging. For estimating steady-state concentrations of VOCs released to ambient air during trenching activity, the following equations (EPA 1988, EPA 1994, EPA 1995a) were applied:

The chemical specific gas-phase mass-transfer coefficient, k_{iG} for each groundwater COPC is derived as follows:

$$k_{iG} = (\frac{MW_{H2O}}{MW_i})^{0.335} x(\frac{T}{298})^{1,005} xk_{G,H_2O}$$

Where:

K_{iG}	=	Chemical-specific gas-phase mass-transfer coefficient (cm/s)
MW_{H2O}	=	Molecular weight of water (g/mol) 18
MW_i	=	Chemical-specific molecular weight (g/mol)
T	=	Average temperature (Kelvin)
k_{GH2O}	=	Gas phase mass transfer coefficient for water vapor at 25 degrees Centigrade (cm/s) 8.33E-01 (EPA 1995a)

The chemical-specific liquid-phase mass-transfer coefficient, K_{iL} for each groundwater COPC is derived as follows:

$$k_{iL} = \sqrt{\frac{MW_{O_2}}{MW_i}} \quad x \quad \frac{T}{298} \quad x \quad k_{L,O2}$$

Where:

K_{iL}	=	Chemical-specific liquid-phase mass-transfer coefficient, (cm/s)
MW_{O2}	=	Molecular weight of oxygen (g/mol) 32
MW_i	=	Chemical-specific molecular weight (g/mol)
T	=	Average temperature (Kelvin)
$k_{L,O2}$	=	Liquid phase mass transfer coefficient for oxygen at 25 degrees Centigrade (cm/s), 2.0E-03 (EPA 1995a)

The overall mass-transfer coefficient for each groundwater COPC is derived as follows:

$$\frac{1}{K_i} = (\frac{1}{k_{iL}}) + (\frac{RT}{H_i k_{IG}})$$

Where:

K_i	=	Chemical-specific overall mass-transfer coefficient (cm/s)
k_{iL}	=	Chemical-specific liquid-phase mass-transfer coefficient (cm/s)
R	=	Gas constant, (atm-m^3/mol-K), 8.2E-05
T	=	Average temperature (Kelvin)
H_i	=	Chemical-specific Henry's Law Constant (atm-m^3/mol)
K_{iG}	=	Chemical-specific gas-phase mass-transfer coefficient (cm/s)

For a conservative risk evaluation, assume an infinite VOC source. At steady state, the emission rate for each VOC can be calculated as below:

$$E_i = K_i \times C_w \times A_w$$

Where:

E_i	=	Emission rate of the VOC (mg/s)
K_i	=	Overall mass-transfer coefficient (cm/s)
C_w	=	Concentration of VOC in groundwater (mg/cm^3)
A_w	=	Bottom area of the trench covered with contaminated water (cm^2)

The box model was used to estimate the concentration of VOCs in the breathing zone of the construction worker using the following equation:

$$C_{air} = \frac{E_i \times CF}{u \times H \times W}$$

Where:

C_{air}	=	Concentration of VOCs in breathing zone (µg/m^3)
E_i	=	VOC emission rate within the trench (mg/s)
CF	=	Conversion factor (µg/mg)
u	=	Assumed velocity of air in the trench (m/s)
H	=	Mixing height, adult breathing zone (m)
W	=	Width of the trench perpendicular to wind direction (m)

Trench dimensions are assumed to be 10 ft (w) x 10 ft (l) with 70% water coverage in the bottom of the trench assuming dewatering. The mixing height is assumed to be 6 feet. With respect to wind speed in the trench, 0.152 m/s (30 ft/min) is a reasonable lower bound on air flow in the trench (EPA 1994).

3.3.8 Exposure Parameters and Equations for Inhalation of Vapors from Crawl space Air and Ambient Air

This HHRA evaluated COPC-specific intakes by estimating the amount of a chemical absorbed daily by the residents near the former AMCO facility and on-facility workers. The following general equation was used to estimate intake from inhalation (USEPA 2009):

$$I = \frac{C \times ET \times EF \times ED}{AT}$$

where:

I = Intake: the amount of chemical absorbed daily via inhalation (μg/m^3).

C = Chemical concentration in air (μg/m^3).

ET = Exposure time (hours/day).

EF = Exposure frequency: number of exposure occurrences per given time (e.g., 350 days per year).

EF = Exposure frequency (days/year).

ED = Exposure duration (years).

AT = Averaging time (lifetime in years x 365 days/year x 24 hours/day)

Exposure assumptions used for a industrial worker, adult, and child resident are presented in Table 7.

4.0 Toxicity Assessment

The toxicity assessment seeks to develop a reasonable association between the degree of exposure to a chemical and the possibility of adverse health effects. A chemical may not cause adverse toxic effects in biological systems unless the agent, or its metabolic byproducts, reach critical receptor sites in the body at specific levels and for a period of time sufficient to elicit a particular effect. Whether a toxic response occurs depends on the chemical and physical properties of the toxic agent, the degree of exposure to the agent, and the susceptibility of an individual to the particular effect. To characterize the toxicity of a particular chemical, the type of effects it can produce, and how much is needed to produce those effects must be known.

The toxicity assessment consists of two components:

- **Hazard Identification**—The process of determining what adverse human health effects, if any, could result from exposure to a particular chemical.
- **Dose-response Evaluation**—A quantitative examination of the relationship between the level of exposure and the probability of adverse health effects in an exposed population.

4.1 Hazard Identification

Health effects are divided into two categories—non-cancer and cancer effects. The division is based on the different mechanisms of action associated with each category. Chemicals with non-cancer effects may have cancer effects as well. These chemicals are assessed in both categories.

4.1.1 Non-cancer Effects

Non-cancer or systemic effects are assumed to occur only after a finite level of exposure (i.e., toxic threshold) is exceeded. Exposure levels below the threshold can be tolerated by the organisms without causing an adverse health effect. Non-cancer health effects include a variety of toxicological end points and may include effects on specific organs (e.g., pulmonary toxicants affect lungs) or systems (e.g., neurotoxicants affect the nervous system).

Non-cancer health effects fall in two basic categories—acute effects and chronic effects. Acute toxicological effects typically occur after a short exposure, and the effects are usually observed within 1 to 7 days. Chronic toxicological effects usually occur after repeated exposure and are observed weeks, months, or years after the initial exposure.

4.1.2 Cancer Effects

Carcinogenesis is generally thought to be a phenomenon for which risk evaluation based on presumption of a threshold is inappropriate. For carcinogens, it is assumed that a small number of molecular events can evoke changes in a single cell that can eventually lead to cancer. This hypothesized mechanism for carcinogenesis is referred to as “non-threshold,”

because there is assumed to be essentially no level of exposure that does not pose a finite probability, however small, of generating a carcinogenic response.

EPA has developed a carcinogen classification system (EPA 1989) that uses a weight-of-evidence approach to classify the likelihood of a chemical being a human carcinogen. Information considered in developing the classification includes human studies that associate cancer incidence with exposure. Also considered are long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetics properties; toxicological effects other than cancer; structure-activity relationships; and physical and chemical properties of the chemical.

EPA classifies the chemical into one of the following groups, according to the weight-of-evidence from epidemiologic and animal studies:

- Carcinogenic to Humans
- Likely to be Carcinogenic to Humans
- Suggestive Evidence of Carcinogenic Potential
- Inadequate Information to Assess Carcinogenic Potential
- Not Likely to be Carcinogenic to Humans

The CSFs for COPCs are presented in Table 11.

4.2 Dose-Response Evaluation

Toxicity values are quantitative expressions of the dose-response relationship for a chemical. These values are expressed as cancer slope factors and non-cancer reference doses, both of which are specific to the route of exposure.

4.2.1 Toxicity Values for Non-cancer Effects

The toxicity value used to describe the dose-response relationship for non-cancer health effects is the reference dose (RfD). The EPA defines the RfD as:

> ". . . an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human populations (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA 1989).

The oral RfD is generally expressed in units of milligrams per kilogram of body weight per day (mg/kg-day). RfDs for effects associated with inhalation of a particular chemical are given as a reference concentration (RfC) (mg/m^3) that can be converted to an intake (RfD in terms of mg/kg-day).

Dose-response criteria for assessing the potential for non-cancer health effects from exposure to chemicals have been developed by EPA on the principle supported by scientific data that non-cancer health effects occur only after a threshold dose is reached. A threshold dose is the dose below which most people can be exposed without adverse effects occurring. This threshold dose is usually estimated from the No Observed Adverse Effect Level (NOAEL) or the Lowest Observed Adverse Effect Level (LOAEL) determined from long-term chronic animal studies. The NOAEL is defined as the highest dose at which no adverse

effects are observed, while the LOAEL is defined as the lowest dose at which adverse effects are observed.

Uncertainty factors or safety factors are applied to the NOAEL or LOAEL determined from animal studies and sometimes enhanced with human epidemiologic information to establish RfDs. A chronic RfD represents the dose to which human populations are continuously exposed and are likely to be without significant risk of adverse health effects over a lifetime.

In most cases, the RfD is extrapolated using nontoxic exposure levels in animals to humans and reduced further using individual uncertainty factors ranging from 1 to 10. Uncertainty factors are used in an attempt to account for limitations in the quality or quantity of available dose-response data. An uncertainty factor of 1 to 10 is applied to account for the application of high-dose animal toxicity endpoints to low-dose human exposure. If the toxic endpoints are based upon animal studies, but applied to humans an additional factor of 1 to 10 is applied. Ideally, the RfD is based upon the NOAEL; in those cases where only the LOAEL is available, another factor of 1 to 10 is applied. Similarly, if only subchronic data are available, then an uncertainty factor of 1 to 10 is applied. Finally, RfDs can be adjusted using a modifying factor of 1 to 10 to account for the quality of the toxicological studies or results. The uncertainty factors and the modifying factors provide an inherently more conservative RfD. If all uncertainty and modifying factors are applied at their maximum value, then the endpoints observed in animal studies may be reduced by an overall factor of 10,000.

- For DDT, the experimental NOAEL is 0.05 milligrams per kilogram per day (mg/kg-day). A cumulative uncertainty factor of 100 was applied to this NOAEL (10 for the uncertainty of interspecies conversion and 10 for the protection of sensitive human subpopulations). This results in an RfD for DDT of 0.0005 mg/kg-day (EPA 2006a).
- For Aroclor-1254, the LOAEL is 0.005 mg/kg-day. An uncertainty factor of 300 was applied to this LOAEL, which results in an RfD of 0.00002 mg/kg-day.
- For naphthalene, the adjusted LOAEL is 71 mg/kg-day. An uncertainty factor of 3000 was applied to the NOAEL (10 for extrapolation from rats to humans, 10 for protection of sensitive humans, 10 for extrapolation from subchronic to chronic exposure, and 3 to account for database deficiencies including the lack of chronic oral exposure studies and 2-generation reproductive toxicity studies). The resulting RfD is 0.02 mg/kg-day.
- For vinyl chloride, the NOAEL reported is 0.09 mg/kg-day. An uncertainty factor of 30 was applied to this NOAEL (10 for protection of sensitive human subpopulations and 3 for animal-to-human extrapolation) resulting in an RfD of 0.003 mg/kg-day.

RfDs developed by EPA are used to evaluate non-cancer health hazards in the HHRA. The RfDs were compiled from EPA's Integrated Risk Information System (IRIS) (EPA 2010a). The non-cancer toxicity values for the chemicals of potential concern are listed in Table 11. This table also identifies the toxic endpoints observed in each investigation used to derive the RfD, as well as the cumulative uncertainty factor used to derive each RfD. Route-to-route extrapolations were frequently used when there were no toxicity values available for a given route of exposure. Oral reference doses (RfDo) were used for both oral and inhaled exposures for organic compounds lacking inhalation values. Inhalation reference doses (RfDi) were used for both inhaled and oral exposures for organic compounds lacking oral

values. Route extrapolations were not performed for inorganics due to portal of entry effects and known differences in absorption efficiency for the two routes of exposure. An additional route extrapolation is the use of oral toxicity values for evaluating dermal exposures. In general, dermal toxicity values are not listed in EPA databases and consequently must be estimated from oral toxicity information.

4.2.2 Toxicity Values for Carcinogens

The dose-response relationship for cancer effects is usually expressed as a cancer slope factor (CSF). Generally, the CSF is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The CSF is usually, but not always, the upper 95 percent confidence limit of the slope of the dose-response curve and is expressed as the inverse of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. CSFs associated with inhalation of a particular chemical are given as inhalation unit risk (IURs). IURs can be defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air.

Chemical carcinogens are generally divided into two classes based upon the mechanism by which they cause cancer. The two classes are genotoxic agents (capable of causing DNA damage) and non-genotoxic (toxic through mechanism not related to DNA damage). For genotoxic carcinogens, it is generally assumed that no threshold exists below which the agent cannot cause cancer. In other words, no matter how small the dose, there is some carcinogenic response, even if that response cannot be measured in animal experiments or in an exposed human population. In contrast, non-genotoxic carcinogens are likely to have a threshold dose, below which no adverse toxicological impact would be expected to occur.

The dose-response curve used by regulatory agencies is typically derived using the linearized multistage (LMS) model, which extrapolates the tumor response in animals exposed to high doses to a theoretical cancer risk for human exposed to low doses. EPA acknowledges that this approach likely overestimates cancer risks:

> "It should be emphasized that the linearized multistage procedure leads to a plausible upper limit to risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of the risk is unknown and may be as low as zero. The range of risks defined by the upper limit given by the chosen model and the lower limit, which may be as low as zero, should be explicitly stated. An established procedure does not yet exist for making 'most likely' or 'best' estimated of risk within a range of uncertainty defined by the upper and lower limit estimates"(EPA 1986)

The linearized multistage procedure is used to develop chemical-specific CSFs. A CSF is a measure of the carcinogenic potency of a chemical. As the slope factor increases, the toxicity of the chemical also increases.

- For example, the CSF for vinyl chloride is 1.5 $(mg/kg\text{-}day)^{-1}$ based on the assumption of continuous lifetime exposure from birth.

- For aldrin, a CSF of 17 $(mg/kg\text{-}day)^{-1}$ was selected based on the geometric mean of 3 separated studies.
- For benzo[a]pyrene, a CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ was calculated based on a geometric mean of four slope factors obtained by different modeling procedures.

There is uncertainty and conservatism built into the risk extrapolation approach. Cancer risks estimated by this method produce an estimate that provides a rough but plausible upper limit of risk (i.e., it is not likely that the true risk would be much more than the estimated risk, but could be considerably lower) (EPA 1989).

4.2.3 Toxicity Values for Lead

Intakes of lead are assessed differently than for other chemicals. Currently, EPA has not established CSFs or RfDs for lead. Much of the toxicological data collected on the effects of lead on the human body relates exposure and effect in terms of the amount of lead in blood associated with an observed effect, expressed as micrograms of lead per deciliter of blood (µg lead/dL blood). California EPA has identified childhood blood levels of 1 µg/dL as the level of concern above which significant health risks may occur (CalEPA 2009).

For workers exposed to lead in soil, the screening level is assumed to be the OEHHA CHHSL of 320 mg/kg (CalEPA 2009). DTSC uses the Adult Lead Model to estimate CHHSLs for an industrial setting. This CHHSL is intended to protect a fetus that may be carried by a pregnant female worker. It is assumed that a cleanup goal that is protective of a fetus will also afford protection for male or female adult workers. The Leadspread model was queried for the soil lead concentrations that would produce a 90th percentile estimate of increase in blood lead of 1 µg/dL.

4.2.4 Sources of Toxicity Criteria

The hierarchy of human health toxicity values used by EPA follows Directive 9.85.7-53 issued by EPA's Office of Solid Waste and Emergency Response on December 5, 2003 (EPA 2003b):

- Tier 1 – EPA's IRIS database (EPA 2010a)
- Tier 2 – EPA's Provisional Peer Reviewed Toxicity Value (PPRTV)
- Tier 3 – Health Effects Assessment Summary Tables (EPA 1997), EPA's National Center for Environmental Assessment (NCEA), CalEPA

Slope factors developed by California EPA's OEHHA and reference exposure levels developed by Air Toxics and Epidemiology Section of OEHHA were used if they were more health-protective than the federal toxicity values. In addition, where available, OEHHA child-specific reference doses are used.

For this assessment, toxicity values presented in the EPA RSL tables (EPA 2010b) were used if other toxicity values were not available.

5.0 Risk Characterization

Information presented in the exposure assessment and toxicity assessment is integrated in this section to characterize risks to workers, residents, and recreational users exposed to COPCs from the Site. Theoretical non-cancer hazards and lifetime-excess carcinogenic health risks are characterized and discussed. The critical uncertainties affecting risk calculations are discussed in Section 6.0.

In this risk characterization, numerical risk estimates calculated for each COPC and exposure pathway were combined to estimate non-cancer HIs and, for carcinogens, total ELCR. In keeping with the most recent guidance, professional judgment has been relied upon to select the most significant uncertainties (those that define and explain the risk estimates) for discussion in the risk characterization.

Under RME conditions, the calculated risks are not likely to be exceeded by any member of the exposed population because of the health-protective exposure assumptions used. A risk assessment does not measure the actual health effects that hazardous substances at a site have on people. Conservative safety margins are built into a risk assessment analysis to ensure protection of the public. Therefore, people will not necessarily be affected even if they are exposed to chemicals at higher dose levels than those estimated in the HHRA. In other words, the most vulnerable people (e.g., children) are carefully considered to make sure all members of the public will be protected.

5.1 Non-carcinogenic Hazard

Non-carcinogenic effects for each exposure route and chemical are evaluated by comparing the average dose over a specified time period. The ratio of the average daily dose to RfD is called a hazard quotient (HQ), which is calculated as follows:

$$HQ = \frac{ADD}{RfD}$$

Where:

HQ = Theoretical non-cancer hazard quotient for chemical and exposure pathway
ADD = Average Daily Dose (mg/kg-day) for chemical and exposure pathway
RfD = Reference Dose (mg/kg-day) for chemical and exposure pathway

The HQ assumes that there is a dose below which adverse health effects are unlikely (EPA 1989). If the average daily dose is below the threshold RfD (i.e., the ratio is less than 1), it is unlikely that non-carcinogenic effects would occur. To assess the overall potential for non-carcinogenic effects from a particular exposure scenario, HQ for the relevant individual soil exposure pathways (i.e., ingestion, dermal contact, and inhalation) and chemicals are summed to obtain the HI for the population evaluated:

HI = Sum of HQs for chemicals and pathways

When the total HI exceeds 1, a segregated HI analysis is used to further evaluate adverse non-cancer health hazards associated with exposure to COPCs in soil and groundwater. Segregated HIs are prepared because adverse non-cancer health effects of chemicals that affect different target organs are generally not additive (EPA 1989). Segregated HIs are the sums of chemical-specific HQs grouped according to affected target organ and corresponding to the lowest adverse-effect levels (that is, the critical effects) identified by EPA. A segregated HI that exceeds 1 indicates the potential for adverse non-cancer health effects (EPA 1989). A segregated HI that does not exceed 1 indicates that no appreciable risk exists for adverse non-cancer health effects.

For assessing non-cancer hazards for a 30-year residential exposure, the child (6 year exposure) and adult (24-year exposure) residential HI are calculated separately. A 30-year exposure scenario is consistent with EPA national guidance, as explained in the Preamble to the NCP (55 Fed. Reg. 8710). The Preamble states that Superfund remedial projects will address lifetime excess cancer risks using a reasonable maximum exposure scenario. EPA national Superfund guidance calculates lifetime risk over 70 years based on a reasonable maximum exposure scenario, which is defined as a 30-year exposure in the case of residents and 25-year exposure in the case of workers. The concept of lifetime risk does not automatically imply exposure over an entire 70 year lifetime.

A HI at or below 1 indicates that there is unlikely to be any increased health risk even for sensitive populations. At the same time a HI greater than 1 does not necessarily indicate that adverse effects will occur, because the RfD used in the calculation contains substantial measure of conservatism. The RfD is conservative because it is typically derived by applying multiple safety factors to a level at which no adverse effects have been observed or to the lowest level at which effects have been observed in the most sensitive animal species that have been tested.

5.2 Cancer Risks

The theoretical lifetime-excess cancer risks associated with the lifetime average daily doses are calculated as the product of the LADD and the CSF for each chemical and exposure pathway as shown below:

Risk = CSF x LADD

Where:

Risk = Theoretical lifetime-excess cancer risk for chemical and pathway
CSF = Slope Factor for chemical and exposure pathway
LADD = Lifetime Average Daily Dose for chemical and exposure pathway

The quantitative risk estimates for suspected carcinogens are expressed as the lifetime-theoretical-excess (or additional) risk of contracting cancer above the background incidence of cancer if no exposure to chemicals occurs. In the U.S. population, the likelihood of developing cancer over one's lifetime is approximately 1-in-2 males and 1-in-3 females (American Cancer Society 2007). The total upper-bound theoretical excess cancer risk is calculated by combining the risks across pathways and chemicals as follows:

Total lifetime-theoretical-excess risk = Sum of risks for chemicals and pathways

For assessing excess cancer risk for a 30-year residential exposure, the child (6-year exposure) and adult (24-year exposure) residential cancer risks are summed.

5.2.1 Cancer Risk Perspective

EPA has provided guidance on the role of the risk assessment in federal Superfund remedy selection (EPA 1991b). EPA considers a target lifetime-theoretical-excess risk range of 10^{-6} to 10^{-4}, to be "safe and protective of public health" (56 F.R. 3535), although EPA has discretion to take action in this range depending on site-specific circumstances.

According to EPA, where the cumulative lifetime-theoretical-excess cancer risk to an individual based on RME assumptions is less than 10^{-4}, and the theoretical non-cancer HI is less than 1, remedial action is generally not warranted unless there are other adverse environmental impacts or an applicable or relevant and appropriate requirement (ARAR) is exceeded. Even risks slightly greater than 1×10^{-4} may be considered adequately protective based on site-specific conditions, including any uncertainties about the nature and extent of contaminants and associated risks. Alternatively, on a case-by-case basis, action may be recommended for sites within the 10^{-6} to 10^{-4} risk range. Where remedial action is warranted, guidance for remedy selection is provided in the EPA directive entitled *Land Use in the CERCLA Remedy Selection Process* (EPA 1995b). The directive notes that it is not EPA's intent that acceptable risk standards be based solely on categories of land use (i.e., with residential cleanup at a 10^{-6} level or industrial at a 10^{-4} level). Rather, the risk range provides the risk manager with the necessary flexibility to address technical and cost limitations, and performance and risk uncertainties in all site remediation efforts.

When it is stated that exposure to cancer-causing chemicals results in a cancer risk of one-in-a-million, it means that each individual exposed to that chemical, at that level over his or her lifetime, has a one-in-a-million chance above the background risk of getting cancer from that particular exposure. In order to take into account the uncertainties in the science, the risk numbers are calculated using conservative assumptions, which results in conservative estimates of risk. The risk is the plausible upper limit of the true risk. In actuality, the extra risk is probably somewhat less than those calculated and presented in the following sections.

5.3 Risk Characterization Results

In this section, the quantitative evaluations of theoretical non-cancer hazards and lifetime-theoretical excess cancer risks are presented for each scenario evaluated in the HHRA. Quantitative risks and hazards were estimated under RME conditions for the soil, groundwater, crawlspace air, and ambient air datasets described in Section 2, Data Collection and Data Evaluation. In addition to the risk and hazards estimated for these datasets, a screening level risk evaluation was conducted for residential soil and produce on adjacent residential properties.

Attachment 1 (Tables 1-7 through 1-126) provides detailed risk and hazard results for exposure to soil; Attachment 2 (Tables 2-1 through 2-27) provides detailed risk and hazard results for exposure to groundwater; Attachment 3 (Tables 3-1 through 3-20) and Attachment 4 (Tables 4-1 through 4-47) summarizes the results of the residential screening

risk evaluation. Results are also summarized for soil in Table 12, for groundwater in Table 13, and crawlspace and ambient air in Table 14.

5.4 Soil Risk Evaluation

Throughout the following sections, shallow soil risk refers to risk from exposure to soil contamination in the upper 2 feet of soil. A non-engineered concrete cap exists over the majority of the former AMCO facility and varies from 6 to more than 40 inches thick. In accordance with the SAP, shallow soil samples were generally collected from between 1 and 2 feet below the concrete or below ground surface in unpaved areas. Deep soil risk or subsurface risk refers to risk from exposure to contamination from surface to the maximum sample depth of approximately 7 feet. It is important to note that the on- and off-facility properties are mostly paved so the potential for current contact with the soil is minimized. The evaluation of RME risk for both commercial/industrial and construction workers assumes no pavement. The evaluation of RME risk for the future on-facility resident assumes the on- and off-facility properties are developed for homes and are not paved.

To evaluate the on-facility soil, soil samples were divided into the following four exposure areas: former AMCO facility, parking lot, large vacant lot, and small vacant lot.

5.4.1 Former AMCO Facility

One-hundred-ten chemicals were detected in soil samples collected from the former AMCO facility, including 18 metals, 17 pesticides or polychlorinated biphenyls (PCBs), 30 semivolatile organic compounds (SVOCs) , 30 VOCs and 15 dioxins or furans (Attachment 1, Table 1-1 and Table 1-2). At present, the former AMCO facility is paved, and concrete in some areas is present to a depth of approximately 3 feet. As with the other paved soil areas, it was assumed that no pavement would be present to preclude direct contact with soil. Theoretical excess lifetime-cancer risks and non-cancer HI for all exposure scenarios are shown in Attachment 1, Table 1-109.

For the industrial worker RME scenario, the ELCR is 1×10^{-4} for the shallow soil and for deep soil is 1×10^{-4}. Both the shallow and deep soil HIs are 1.

For the construction worker RME scenario, the ELCR is 1×10^{-5} for both the shallow and deep soil. The shallow soil HI is 23 and deep soil HI is 20.

For the future on-facility residential RME scenario, for both shallow and deep soil, the ELCR is 3×10^{-4}. The HI for the child is 10 for the shallow soil and 11 for the deep soil. For the adult, both the shallow and deep soil HI is 1 and 2, respectively.

The lead exposure point concentration for shallow soil is 640 mg/kg and for deep soil 605 mg/kg (Attachment 1, Tables 1-5 and 1-6); both exceed the residential (80 mg/kg) and industrial (320 mg/kg) CHHSLs for lead.

The chemicals that contribute most to the risk include vinyl chloride, xylenes, naphthalene, 2-methylnaphthalene, manganese, aluminum, cadmium, aldrin, and dieldrin (Attachment 1, Tables 1-11, 1-12, 1-17, 1-18, 1-23, 1-24, 1-29, and 1-30).

5.4.2 Parking Lot

In soil at the parking lot, there are 67 chemicals detected in soil, including 18 metals, 8 pesticides or PCBs, 18 SVOCs, 6 VOCs, and 17 dioxins or furans (Attachment 1, Table 1-1 and Table 1-2). At present the parking lot is paved. As with the other evaluated soil areas, it was assumed that no pavement would be present to preclude direct contact with soil.

For the industrial worker RME scenario, the ELCR is 5×10^{-5} for the shallow soil. The total ELCR for deep soil was 1×10^{-4}. Both the shallow and deep soil HI is 1.

For the construction worker RME scenario, the ELCR is 9×10^{-6} for the shallow soil. The ELCR for deep soil was 2×10^{-5}. The shallow and deep soil HI values are 30 and 25, respectively.

For the future on-facility residential RME scenario, the ELCR is 2×10^{-4} for shallow soil and 4×10^{-4} for deep soil. The HI for the child is 26 for the shallow soil and 25 for deep soil. For the adult, both the shallow and deep HI is 1.

The lead exposure point concentration for shallow soil is 2,170 mg/kg and for deep soil 1,450 mg/kg; both the residential (80 mg/kg) and industrial (320 mg/kg) CHHSLs for lead(Attachment 1, Tables 1-31 and 1-32).

The chemicals that contribute most to the risk include lead, arsenic, benzo(a)pyrene and antimony (Attachment 1, Tables 1-37, 1-38, 1-43, 1-44, 1-49, 1-50, 1-55, and 1-56).

5.4.3 Large Vacant Lot

In soil at the large vacant lot, there are 73 chemicals detected in soil, including 18 metals, 18 pesticides or PCBs, 23 SVOCs, and 14 VOCs (Attachment 1, Table 1-1 and Table 1-2). At present the large vacant lot is paved. As with the other evaluated soil areas, it was assumed that no pavement would be present to preclude direct contact with soil.

For the industrial worker RME scenario, the ELCR is 6×10^{-5} for the shallow soil. The ELCR for deep soil is 4×10^{-5}. Both the shallow and deep soil HIs are less than 1.

For the construction worker RME scenario, the shallow soil ELCR is 1×10^{-5}. The ELCR for deep soil is 7×10^{-6}. The shallow soil HI is 12, and the deep soil HI is 10.

For the future on-facility residential RME scenario, the ELCR is 2×10^{-4} for shallow soil. The ELCR calculated for deep soil is 1×10^{-4}. The HI for the child is 10 for the shallow soil and 7 for the deep soil. For the adult, both the shallow and deep soil HIs are less than 1.

The lead EPC for shallow soil is 4,360 mg/kg and for deep soil 2,750 mg/kg; both the residential (80 mg/kg) and industrial (320 mg/kg) CHHSLs for lead. (Attachment 1, Tables 1-57 and 1-58).

The chemicals that contribute most to the risk estimate are lead, arsenic, DDT, cadmium and benzo(a)pyrene (Attachment 1, Tables 1-63, 1-64, 1-69, 1-70, 1-75, 1-76, 1-81, and 1-82).

5.4.4 Small Vacant Lot

In soil at the small vacant lot property, there are 23 chemicals detected in soil, including 17 metals and 6 pesticides or PCBs (Attachment 1, Table 1-1). Although arsenic is a risk driver,

concentrations of arsenic detected in this exposure area are similar to arsenic levels found in the background data set; therefore, the risk contributions from arsenic may not be site-related. At present the small vacant lot is paved. As with the other evaluated soil areas, it is assumed that in the future no pavement would be present to preclude direct contact with soil. Only shallow soil samples were collected due to the shallowness of the water table at this location.

For the industrial worker RME scenario, the ELCR is 4×10^{-5} for the shallow soil. The HI is less than 1.

For the construction worker RME scenario, for shallow soil the ELCR is 7×10^{-6}. The shallow soil HI is 7.

For the potential on-facility residential RME scenario, the ELCR is 3×10^{-4} for shallow soil. The HI for the child is 12. For the adult, the HI is less than 1.

The lead exposure point concentration for shallow soil is 386 mg/kg (Attachment 1, Table 1-1), which exceeds both the residential (80 mg/kg) and industrial (320 mg/kg) CHHSLs for lead.

The chemicals that contribute most to the risk and HI are lead, arsenic, dieldrin, aluminum, cadmium, and DDT (Attachment 1, Tables 1-88, 1-89, 1-94, 1-95).

5.4.5 Background Soil Risk Evaluation

Many substances, such as metals, are naturally occurring elements in the environment and are commonly present in all environmental samples. For these constituents, it is important to determine what fraction of the concentration detected is due to the site-related contamination, and what fraction represents background for the former AMCO facility. Background refers to the average concentration of the chemical in similar nearby reference areas that have not been impacted by the Site.

Risks and hazards from exposure to background concentrations of metals in soil were estimated using the City of Oakland *Survey of Background Metal Concentration Studies* (colluvium and fill) (City of Oakland 1995). Table 1-96 (located in Attachment 1) provides the exposure point concentrations associated with the City of Oakland's background data. For a child resident, the ELCR is 2×10^{-4}. The arsenic EPC for the background data is 14 mg/kg. Arsenic contributed over 99% of the total background risk. The HI is 10 for the child resident and 1 for the adult. Thallium contributed 89% to the total background HI.

For industrial workers the ELCR from exposure to background soil is 6×10^{-5}. The HI for industrial workers is less than 1. For construction workers the ELCR is 9×10^{-6}, and the HI is 3. As with the residential scenario, risks from exposure to background concentrations are driven by arsenic, while non-cancer hazards are driven almost entirely by thallium.

Some naturally-occurring concentrations of metals (i.e., arsenic) in Oakland soils are higher than the thresholds calculated by risk-based models. In these cases, EPA typically conducts community outreach activities to educate and advise the community about the potential risks to the public and to communicate precautions that they might take to lower the risk from arsenic exposure. Superfund cleanups are not conducted where the sole or principal threat is from natural background sources.

5.5 Groundwater Risk Evaluation

Currently, residents are using drinking water supplied by the East Bay Municipal Utility District who obtains the water from Sierra Nevada. The groundwater underneath the Site is not being used for drinking or other potable uses. It is extremely unlikely that residents would drink groundwater underneath the Site in the future; however, in accordance with input from the community and regulatory agencies the potential risk of using groundwater underneath the Site as drinking water is evaluated.

Total Dissolved Solids (TDS) is the water quality parameter typically used to determine whether groundwater is potentially of "beneficial use". TDS concentrations over 3,000 mg/L are considered too high for "beneficial use" as drinking water (RWQCB 2004). Across the RI area, TDS concentrations ranged from 730 to 53,000 mg/L. With the exception of RMW-03-15, which had a TDS concentration of 3,600 mg/L, all samples north of 3rd Street were below the drinking water threshold of 3,000 mg/L. TDS concentrations in all wells south of 3rd Street were above 3,000 mg/L.

5.5.1 Shallow Groundwater

For the potential residential RME scenario, the excess lifetime cancer risk is 7×10^{-2} for groundwater. The HI for the child was 628, and the HI for the adult was 262 (Attachment 2, Table 2-22).

In addition, at the request of the community's technical advisor, a trench worker's risk from contact with groundwater underneath the Site is evaluated. For the trench worker RME scenario, the total lifetime-excess cancer risk was 1×10^{-4} for groundwater (Table 2-14). The HI for the trench worker was 34 (Attachment 2, Table 2-15).

The chemicals that contribute most to the risk through exposure to groundwater include vinyl chloride, arsenic, cis-1, 2-dichloroethene, benzo(a)pyrene, and aroclor-1260 (Attachment 2, Tables 2-10, 2-11, 2-14 and 2-15).

An evaluation of vapor intrusion using groundwater data was not conducted, however, it is acknowledged that in a worst case scenario, the risks and hazards may be as high as when residential use of the groundwater is considered. As noted above, the cancer risks estimated for future residents using the groundwater as tap water in the home is significantly above the risk management range and clearly unacceptable. Hazard indices for an adult and child resident are also significantly above the non-cancer threshold of 1.

To confirm that the risks for vapor intrusion are similar as the risks from drinking the groundwater, selected VOCs that contribute the most to the risk and hazard estimates were modeled using the DTSC screening groundwater vapor intrusion model. Defaults were used as inputs into the model except the depth to groundwater was adjusted to 5 feet below ground surface and sand was used as the SCS soil type. Below is the table of results:

VOC	Exposure Point Concentration (μg/L)	Incremental Risk from Vapor Intrusion to Indoor Air	Hazard Quotient from Vapor Intrusion to Indoor Air
Vinyl chloride	1,627	2.2×10^{-1}	80
TCE	57	6.0×10^{-6}	0.014
PCE	12	6.2×10^{-6}	0.083
Cis-1,2-DCE	13,700	NA	22
Trans-1,2-DCE	400	NA	0.83
Totals		2×10^{-1}	103

These results show that the risks and hazards related to vapor intrusion are significantly above the risk management range and clearly unacceptable.

5.5.2 Residential Irrigation Well

One of the residents living adjacent to the facility owns a well located in his backyard shed. According to the property owner, the well is primarily used for backyard irrigation. The well is not used as a source of drinking water. The residential irrigation well was sampled on three occasions: September 2, 2004; June 24, 2005; and October 12, 2005. A summary of the results is presented in Table 13.

As indicated on this table, the only analyte that exceeds the maximum contaminant level (MCL) is lead. However, boron, manganese, mercury, and sodium are at concentrations that exceed their agricultural water quality limit (Ayers and Westcot 1985).

5.6 Ambient Air and Crawlspace Air Risk Estimates

Several VOCs have been detected in soil gas, ambient air, crawlspace air, and indoor air at the former AMCO facility and in adjacent residences indicating that vapor intrusion is occurring in crawlspaces at homes. As a precautionary measure, mitigation systems have been installed in selected homes nearest the site. Potential cancer risks and non-cancer hazards are evaluated using the ambient air and crawlspace air data. Potential cancer risks and non-cancer hazards were calculated for office workers and residents assuming that the crawlspace air concentrations are representative of indoor air. Soil gas results for each property are briefly summarized to provide information about the potential source of the VOCs found in the ambient and crawlspace air.

Because the indoor air has been sampled only during one sampling event, it represents a snapshot in time; therefore, potential chronic risks and hazards were not estimated from exposure to indoor air. Crawl space air was used in this evaluation because it is thought to be less affected by the lifestyle choices, such as household product use and smoking, of the building's occupants than indoor air. The evaluation of the results of crawl space air sampling is considered easier to interpret than indoor air sampling results (DTSC 2004). Indoor air locations and results are provided on Figures 4 through 14 for each structure where indoor air was sampled.

5.6.1 Comparison of VOC Data Between Crawlspace and Ambient Air

A comparison of EPCs for each VOC detected in both crawlspace and ambient air at the same location can provide valuable information regarding the source of crawlspace air contaminants. When crawlspace concentrations are similar to ambient air concentrations, it is difficult to associate the source of the VOCs to vapor intrusion. Only two chemicals, 1,2-dichloroethane (1,2-DCA) and TCE had concentrations in crawlspace air that were greater than the ambient air concentrations in all cases.

The VOCs which have significantly higher (greater than 5 times) EPCs in crawlspace air than the EPCs in ambient air at each residence include:

- 1428 3rd Street: 1,2-DCA, Chloroform, Chloromethane, TCE, Vinyl chloride
- 1432 3rd Street: 1,2,4-Trimethylbenzene, 1,2-DCA, 1,3,5-Trimethylbenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, Benzene, Chlorobenzene, Ethylbenzene, Styrene, Tetrachloroethene, Toluene, TCE, m&p-Xylenes, o-Xylenes
- 320 Center Street: 1,2-DCA, 1,4-Dichlorobenzene, TCE
- 326 Center Street: 1,2-DCA, Styrene, TCE

The air samples were analyzed for a list of 42 VOCs. The fact that most VOCs are at similar concentration levels in crawlspace air and ambient air suggest that some of the VOCs in crawlspace air may be coming from sources other than vapor intrusion. For the other chemicals measured in crawlspace air no obvious correlations with ambient air concentrations were observed.

5.6.2 Comparison of VOC Data Between Ambient Air and Background Air

Naphthalene and benzene have been detected above screening levels in ambient air collected from the residences sampled. Generally, the levels of these VOCs at most of the properties are consistent with levels found in the background air samples collected. For example, in the 1432 3rd Street ambient air samples (2004 through 2009), benzene was detected from 0.24 to 1.6 $\mu g/m^3$ and from 0.3 to 1.5 $\mu g/m^3$ in the background samples. Similarly, naphthalene was detected at 0.27 to 0.74 $\mu g/m^3$ in the ambient air and 0.09 to 0.7 $\mu g/m^3$ in the background samples. The exception is at 1428 3rd Street where one high detection of benzene in 5.6 $\mu g/m^3$ was found in September 2004. Since then, the benzene has ranged from 0.33 to 1.8 $\mu g/m^3$. Also at 1428 3rd Street, there was one high detection of naphthalene 16 $\mu g/m^3$ found in December 2008. The other detected concentrations of naphthalene at this residence in ambient air are 0.12 and 0.63 $\mu g/m^3$.

At 1436 3rd Street, vinyl chloride was detected above screening levels in ambient air but has not been detected in background air samples. At 360 Center Street, carbon tetrachloride was detected above screening levels in ambient air and has been detected at similar concentrations in the background samples.

The air data indicate that vinyl chloride is a primary chemical of concern in crawlspace and ambient air on the facility property and at one nearby residence. Because it was never detected in the up-wind background locations, vinyl chloride is likely a site-related chemical of concern.

5.6.3 Comparison of VOC Data Between Groundwater, Soil Gas, and Crawlspace Air

A qualitative comparison of VOCs detected in soil gas and in groundwater also provided some preliminary information regarding source contributions to the chemicals identified in crawlspace air. For example, the primary contributors to HI at 1428 3rd Street and 1432 3rd Street, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene, were contributors to the HI from inhalation of VOCs from groundwater. However, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were only detected in one of six soil gas samples, at levels below the laboratory reporting limit; and these chemicals were detected in ambient air at levels comparable to those measured in crawlspace air suggesting that these VOCs may be coming from other outdoor sources (such as local industry and traffic) and not necessarily from vapor intrusion.

Soil gas concentrations were also found to have only a limited correlation with the chemical concentrations detected in crawlspace air samples for other chemicals. For example, vinyl chloride, the primary contributor to potential cancer risk at 1428 3rd Street was only detected at a very low concentration in one of four soil gas samples collected at this residence. By contrast, vinyl chloride was one of the primary contributors to potential cancer risk from inhalation of VOCs from groundwater for the trench worker scenario and the residential scenario (inhalation of VOCs while showering). It should be noted that soil gas samples collected in the yards of the homes sampled could not be collected at DTSC's recommended depth of at least 5 feet below ground surface (DTSC 2005) because of the shallow groundwater in the area. Soil gas collected at less than 5 feet below ground surface may be influenced by outdoor air being pulled in by the sample collection pump and may not be representative of actual soil gas conditions in the subsurface below the structures. It should also be noted that the entire groundwater data set from the site was used to calculate exposure point concentrations which were used to evaluate risk from exposure to groundwater. At the time of this evaluation, there were no groundwater monitoring wells located on the residential properties. Figure 3 shows the location of the groundwater monitoring wells and the nearby residential properties where air sampling was performed. Because of these uncertainties with the groundwater and soil gas results, there are uncertainties with comparisons of chemical results between media.

5.6.4 Comparison of VOC Data Between Indoor Air and Crawlspace Air

In June 2009, the indoor air was sampled in nine homes occupying the same block as the facility. Because the indoor air has been sampled only during one sampling event, it represents a snapshot in time; therefore, potential chronic risks and hazards were not estimated from exposure to indoor air. For each property, medium-specific tables were generated showing a comparison of the 2009 data to the range of concentrations found from 2004 through 2008. Attachment 4 presents tables with these comparisons. A comparison of the crawlspace exposure point concentrations (representing data from 2004 through 2008) to the 2009 indoor air data is presented in Table 4-2 (1414 3rd St.), Table 4-5 (1428 3rd St.), Table 4-9 (1432 3rd St.), Table 4-15 (320 Center St.), and Table 4-18 (326 Center St.). As shown on these tables, most of the VOCs which exceed EPA's Regional Screening Levels (RSL) (EPA 2010b) for residential air are less than or within the range of concentrations detected in crawlspace air. This would lead to the conclusion that the risks and hazards from exposure to indoor air would be similar or less than the risks and hazards estimated from exposure to crawlspace air. There are two notable exceptions where a VOC was detected at significantly higher levels in indoor air than crawlspace air. When VOC levels are higher in indoor air than crawlspace air, it may indicate that there is a source within the residences for these VOCs. The exceptions are:

- Tetrachloroethene (PCE) was detected at 58 $\mu g/m^3$ in indoor sample collected in the center of the master bedroom at 1428 3rd Street and the crawlspace EPC is 1.73 $\mu g/m^3$ (Table 4-5). There were four other indoor air samples collected downstairs in the home and the PCE results were much lower (below 5 $\mu g/m^3$). Also, in the four samples collected upstairs in the same structure (1430 3rd Street), PCE was detected a less than 1 $\mu g/m^3$. Common sources of PCE in indoor air include dry cleaning, auto brake cleaners, suede protectors, and water repellents.
- Naphthalene was detected in indoor air sample collected in the living room area at 110 $\mu g/m^3$ and 75 $\mu g/m^3$ (in the duplicate sample) at 1432 3rd Street and the crawlspace EPC is 0.887 $\mu g/m^3$. One other sample was collected in this home and one sample was collected in the upstairs in the same structure (1434 3rd Street) and the naphthalene results were below 2 $\mu g/m^3$. Naphthalene is used in mothballs and may be produced during cooking.

A summary of the potential cancer risks and non-cancer hazards for each property is provided in Table 14. The risk calculation spreadsheets are provided in Attachment 3. The following sections provide a summary of the findings for each property.

5.6.5 1414 3rd Street

Crawlspace air was measured at two locations in the office building at 1414 3rd Street. Figure 5 presents the sampling locations and exceedances of screening levels. All estimated risks and hazards were calculated based on detected VOCs. The potential cancer risk for an office worker is 6×10^{-5}. The main contributors to potential cancer risk are carbon tetrachloride (35%) and vinyl chloride (18%). The carbon tetrachloride EPC (6.05 $\mu g/m^3$) was influenced by one high result (17 $\mu g/m^3$) measured during the September 2007 sampling event. There is uncertainty associated with this result because carbon tetrachloride was detected in the field duplicate at 0.45 $\mu g/m^3$ and all of the other carbon tetrachloride results from the office were

below 1 μg/m^3. The vinyl chloride EPC (1.62 μg/m^3) is influenced by one sample result (November 2006) where it was detected at 7.6 μg/m^3. The vinyl chloride results from the other locations and other sampling events were below 2 μg/m^3. The non-cancer HI for this office worker is 0.6, which is below the non-cancer threshold of 1.

Ambient air has not been sampled on the 1414 3rd Street property and soil gas has not been sampled since 2004 except for RSP-07. Vinyl chloride has been sporadically detected at RSP-07 but carbon tetrachloride has not been found above screening levels at this location. Carbon tetrachloride has been detected at low levels in the background samples but vinyl chloride has not been found. Both compounds have been detected in groundwater. It is unclear whether these compounds are entering the crawlspace air through vapor intrusion.

In the indoor air samples, only PCE was detected above its screening level (for an industrial worker). The PCE concentration found at air sample location CMI-IA02 is 2.2 μg/m^3 which is just above the industrial RSL of 2.1 μg/m^3. The other indoor air sample location (CMI-IA01) had a PCE concentration of 1.2 μg/m^3. PCE was also detected in the crawlspace air samples (1.2 to 19 μg/m^3) and soil gas samples collected around the warehouse indicating that vapor intrusion is a possible source.

5.6.6 1428 3rd Street

Crawlspace and ambient air data were collected and evaluated at this residence. The potential cancer risk from exposure to crawlspace air is 3×10^{-4}. The primary contributor to risk from inhalation of crawlspace air is vinyl chloride (61%). The EPC (1.58 μg/m^3) for vinyl chloride is influenced by one sampling event (November 2006) where it was detected at 10 μg/m^3 at one location and 1.5 μg/m^3 at a second crawlspace location. All other crawlspace sampling results indicated vinyl chloride was either not detected or detected at much lower concentrations.

The potential cancer risk from ambient air at this residence is 2×10^{-4}. The primary contributors to risk are naphthalene (47%) and benzene (25%). The EPC for naphthalene (5.72 μg/m^3) in ambient air is influenced by the sample result from December 2008 when it was detected at 16 μg/m^3. There is uncertainty associated with this result because all of the other ambient air results from this location were either not detected or below 1 μg/m^3 and because naphthalene was not detected in the field duplicate (<4.1 μg/m^3) of this sample.

For crawlspace air the non-cancer HI is 7. The primary non-cancer contributors to the HI are 1,2,4-trimethylbenzene (65%) and 1,3,5-trimethylbenzene (21%). The HI for exposure to ambient air is 4. The main non-cancer contributor for ambient air is naphthalene (46%).

The indoor air samples showed exceedances of screening levels for several VOCs (Figure 6), however, the concentrations are similar or less than the concentrations found in crawlspace air, with the exception of one sample with a high concentration of PCE described in Section 2.5 above. The PCE concentration found in the other eight air samples collected both downstairs and upstairs in this home is less than 5 μg/m^3. Since PCE has been found in the soil gas and crawlspace air, it's possible that PCE from the site is contributing to some of the PCE in the indoor air. However the one high detection of PCE may be coming from an indoor source since it's been detected at much lower levels in the crawlspace.

A comparison of EPCs for crawlspace air and ambient air data indicates that the primary contributor (vinyl chloride) to cancer risk in crawlspace were found at concentrations greater than 10 times levels detected in ambient air. Vinyl chloride was detected in two of six soil gas samples at very low concentrations (0.024 μg/m^3 and 0.009 μg/m^3). These results suggest vapor intrusion is occurring for vinyl chloride.

EPCs of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were less in crawlspace air than ambient air. These compounds were each detected in only one sample at levels below the laboratory reporting limit (J qualified). Naphthalene was not detected above the detection limit in any of the soil gas samples. The lines of evidence suggest that the trimethylbenzenes and naphthalene are not entering the crawlspace through vapor intrusion but may be coming from an ambient source.

5.6.7 1432 3rd Street

Crawlspace and ambient air data were collected and evaluated at this residence. The potential cancer risk from exposure to crawlspace air is 6×10^{-4}. The primary contributors to risk from inhalation of crawlspace air are vinyl chloride (54%) and benzene (34%). The vinyl chloride EPC (2.8 μg/m^3) is the maximum detected concentration from the sample collected in November 2006. The other crawlspace air samples at this location indicated vinyl chloride concentrations of less than 0.2 μg/m^3. The benzene EPC (16 μg/m^3) is the maximum detected concentration (collected in September 2004). The other crawlspace air samples collected from this location indicated benzene concentrations at less than 2 μg/m^3.

The potential cancer risk from inhalation of ambient air is 4×10^{-5}. The primary contributors to risk are benzene (27%) and naphthalene (28%). Vinyl chloride was detected in both of the June 2009 ambient air samples collected at 0.11 μg/m^3 and 0.12 μg/m^3.

Exposure to crawlspace air results in a HI of 8. The primary contributors to the HI are 1,2,4-trimethylbenzene (55%) and 1,3,5-trimethylbenzene (23%). The EPCs for both of these chemicals was influenced by elevated concentrations detected in September 2004. The HI from inhalation of ambient air is 0.8, which is less than the non-cancer threshold of 1.

The chemicals that contributed the most to risk from exposure to crawlspace air (vinyl chloride, benzene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene) were not detected at levels of concern in the indoor air. Benzene barely exceeded its screening level in one indoor air sample (detected at 0.32 μg/m^3, screening level 0.31 μg/m^3) and was found at levels consistent with the ambient and background air. As described in Section 5.2, naphthalene was detected in one air sample location at a high level. Although naphthalene has been sporadically detected in the soil gas samples collected in yard, it was found at much lower levels indicating a possible indoor source for the high level of naphthalene detected in the living room area.

Vinyl chloride was detected in soil gas at this location during three sampling events. It was detected at 1.1 μg/m^3 and at 0.014 μg/m^3 in October 2008. In November 2006, it was detected at 0.014 μg/m^3 and in June 2009, it was detected at 0.024 μg/m^3. These vinyl chloride concentrations are below soil gas screening levels. Benzene was detected in four of five sampling events at concentrations ranging from 0.32 to 1 μg/m^3, also below soil gas screening levels. 1,2,4-Trimethylbenzene was detected at least once during four of five sampling events at concentrations ranging from 0.15 to 6.5 μg/m^3. 1,3,5-Trimethylbenzene

was detected during the September 2007, October 2008, and June 2009 sampling events at concentrations of 0.13 and 6 μg/m^3. Because the levels of these compounds in soil gas are less than the concentrations found in crawlspace air, it is unlikely these compounds in the crawlspace air are solely from vapor intrusion.

5.6.8 1436 3rd Street

The foundation at 1436 3rd Street is slab on grade so crawlspace samples could not be collected at this residence. In indoor air, several VOCs were detected above their screening levels. The VOCs which exceeded their screening levels by the largest margin include chloroform and naphthalene. Chloroform levels in ambient air ranges from 0.09 to 0.39 μg/m^3. The concentrations of chloroform found in soil gas (1.6 to 7.6 μg/m^3) are much higher than the levels found in indoor air (ND to 3 μg/m^3), which indicates that vapor intrusion may be occurring for chloroform. Naphthalene levels in ambient air has ranged from 0.069 to 0.62 μg/m^3. Naphthalene concentrations in soil gas range from ND to 1.3 μg/m^3 and in indoor air from ND to 1.2 μg/m^3. It is unclear whether the naphthalene is coming from the soil gas or an indoor source.

Potential risks were calculated from exposure to ambient air at this residence. The potential cancer risk from inhalation of ambient air is 1×10^{-4}. The primary contributors to risk from inhalation of ambient air are vinyl chloride (58%) and benzene (13%). Vinyl chloride was only detected once at 0.7 μg/m^3 out of the six ambient air samples and this detected concentration was selected as the EPC. Exposure to ambient air resulted in a HI of 0.8 which is below the non-cancer threshold of 1. Vinyl chloride has never been detected in the background air samples collected from the upwind location. However, the benzene concentrations found in the ambient air samples at this residence (0.24 to 0.8 μg/m^3) are similar to the benzene concentrations in background (0.26 to 1.5 μg/m^3).

A review of soil gas data from this location indicates that vinyl chloride was detected in one of five soil samples (October 2008) at 1.1 μg/m^3. Benzene was detected in four of five soil gas samples at concentrations ranging from 0.61 to 1.2 μg/m^3.

5.6.9 320 Center Street

Crawlspace and ambient air data were collected and evaluated at this residence. Potential cancer risks from exposure to crawlspace air is 5×10^{-5}. The primary contributors to risk from inhalation of crawlspace air are benzene (29%) and 1,2-dichloroethane (23%).

Potential cancer risk from exposure to ambient air is 6×10^{-5}. The primary contributors to risk from inhalation of ambient air are naphthalene (43%) and benzene (26%). Naphthalene was only detected once out of five times at 1.9 μg/m^3 in June 2009. Exposure to crawlspace air results in an HI of 0.6 and to exposure to ambient air is 1, which do not exceed the non-cancer threshold of 1.

A comparison of EPCs in crawlspace air and ambient air indicates that benzene concentrations are similar in the two media. 1,2-Dichloroethane was detected at 15 times greater concentration in crawlspace air than in ambient air. Naphthalene has not been detected in crawlspace air. Soil gas samples indicated the presence of benzene at 1.1 μg/m^3 and 1,2-dichloroethane at 0.026 at μg/m^3 which is much lower than the concentrations found in crawlspace air (benzene at 0.3 to 2 μg/m^3 and 1,2-dichloroethane at 0.037 to 1.2

μg/m^3) which suggests that these VOCs are not coming from vapor intrusion but may be from an indoor or outdoor source.

Benzene and 1,2-dichloroethane were also detected above screening levels in the indoor air samples. The levels of benzene detected in indoor air are similar to the levels found in the outdoor air and background. The levels of 1,2-dichloroethane found in indoor air are higher than the levels found in the crawlspace samples. This may indicate that these VOCs are not coming from vapor intrusion but from an outdoor or indoor source.

5.6.10 326 Center Street

Crawlspace and ambient air data were collected and evaluated at this residence. Potential cancer risk from exposure to crawlspace air is 8×10^{-5}. The primary contributors to risk from inhalation of crawlspace air are 1,2-dichloroethane (22%), benzene (15%), and 1,4-dichlorobenzene (14%). The EPC (2.3 μg/m^3) for 1,4-dichlorobenzene is influenced by one sampling event (September 2004) when it was detected at 6 μg/m^3. For 1,2-dichloroethane and benzene, the highest concentrations were detected during the same sampling event (October 2008). Potential cancer risk from exposure to ambient air is 3×10^{-5}. The primary contributor to risk from inhalation of ambient air is benzene (37%). Exposure to crawlspace air results in a HI of 0.5; and exposure to ambient air results in a HI of 0.4. For both exposures, the HI is below the non-cancer threshold of 1.

A comparison of EPCs in crawlspace air and ambient air indicates that 1,4-dichlorobenzene and 1,2-dichloroethane were detected at approximately 9 and 15 times higher concentrations in crawlspace air than in ambient air, respectively. Benzene was detected at a similar concentration in crawlspace air and ambient air.

A review of soil gas data indicates that benzene and 1,2-dichloroethane were each detected in two of four samples. Benzene was detected at 0.46 and 0.58 μg/m^3. 1,2-dichloroethane was detected at 0.023 and 0.054 μg/m^3; both levels are below the laboratory reporting limit. Carbon tetrachloride was detected once (September 2007) at 0.46 μg/m^3. 1,4-dichloro-benzene was not detected in soil gas. The lines of evidence for these compounds (low soil gas concentrations, ambient air less than crawlspace air) indicate that vapor intrusion is not occurring into crawlspace but there may be an indoor source of VOCs at this residence.

Four indoor air samples were collected in the upstairs unit. 1,2-Dichloroethane, benzene, and 1,4-dichlorobenzene were detected in the indoor air at levels that exceed screening levels. The levels of benzene and 1,4-dichlorobenzene are consistent with the levels of these VOCs found in the outdoor air (2004 through 2008). Access to sample the outdoor air and soil gas was not obtained for the June 2009 sampling event.

5.6.11 337 Center Street

Table 4-26 presents the soil gas, downstairs indoor air, upstairs indoor air, and outdoor air sample results collected at 337 Center Street. Crawlspace samples were not collected at this residence. Concentrations of VOCs detected in the indoor air are similar to the concentrations found in the outdoor air and background air samples. Some of the VOCs that exceed screening levels include benzene and naphthalene. There is not a strong indication that these compounds are coming from vapor intrusion as the concentrations found in the soil gas sample collected from the backyard are either less than those found

indoors or not detected. Also, the highest naphthalene concentration was found in a sample collected from the upstairs unit which may indicate an indoor source. Chloroform was detected at a higher concentration in the soil gas sample than in the indoor air samples which may indicate vapor intrusion is occurring.

5.6.12 356 Center Street

Table 4-27 presents the soil gas, indoor air, and outdoor air sample results collected at 356 Center Street. Crawlspace samples were not collected at this residence. The VOCs which are most above their screening levels include benzene, naphthalene, and 1,2,4-trimethyl-benzene. Although Table 4-27 shows that these VOCs are significantly higher than the soil gas sample result, Figure 12 shows that historically, benzene was detected above screening levels in the soil gas. The levels of naphthalene and 1,2,4-trimethylbenzene in soil gas do not indicate that vapor intrusion is occurring.

5.6.13 360 Center Street

The foundation at 360 Center Street appears to be slab on grade. No crawlspace samples were collected at this residence. Risks were calculated for exposure to ambient air. The potential cancer risk from inhalation of ambient air is 4×10^{-5}. The primary contributors to risk from inhalation of ambient air are benzene (41%) and carbon tetrachloride (27%). The highest concentration for each of these chemicals was measured in October 2008. Exposure to ambient air results in a HI of 1. The primary contributor to this HI is 1,2,4-trimethyl-benzene (62%).

A review of soil gas data indicates that benzene was detected in 14 of 16 soil gas samples at concentrations ranging from 0.36 to 3.6 $\mu g/m^3$. Carbon tetrachloride was detected in 8 of 16 samples at 0.22 to 1.1 $\mu g/m^3$; and 1,2,4-trimethylbenzene was detected in 9 of 16 samples at 0.21 to 5.7 $\mu g/m^3$.

Several VOCs were detected above their screening levels in indoor air. The VOCs which exceeded their screening levels by the largest margin include benzene and naphthalene. The range of benzene concentrations detected in indoor air is 0.32 to 1.2 $\mu g/m^3$ which falls within the range of benzene concentrations detected in outdoor air is 0.28 to 2 $\mu g/m^3$. Only one of the four air samples detected naphthalene. Naphthalene was also detected at similar levels in the soil gas samples collected in the backyard of this residence. Vapor intrusion is a possible source of the naphthalene in indoor air.

5.6.14 366 Center Street

Table 4-28 presents the soil gas, indoor air, and outdoor air sample results collected at 366 Center Street. Crawlspace samples were not collected at this residence. The VOCs which are most above their screening levels are benzene and naphthalene. Naphthalene was detected in only one of the four indoor air samples and not detected in the soil gas or ambient air samples. Benzene was detected at higher concentrations in the indoor samples than the soil gas sample or ambient air sample. This indicates that these VOCs may be present in the indoor air due to an indoor source.

5.6.15 South Prescott Park

Risks and hazards were calculated for exposure to ambient air at South Prescott Park. The cancer risk from inhalation of ambient air is 3×10^{-5}. The primary contributors to the potential

cancer risk from inhalation of ambient air are benzene (34%), carbon tetrachloride (31%) and chloroform (11%). Exposure to ambient air results in a HI of 0.5, which is less than the non-cancer threshold of 1.

A review of soil gas data indicates that benzene was detected in 18 of 21 soil gas samples collected from 9 locations (Figure 15) at levels ranging from 0.4 to 14 $\mu g/m^3$. Carbon tetrachloride was detected in 12 of 21 samples at 0.064 to 0.56 $\mu g/m^3$; and chloroform was detected in 14 of 21 samples at 0.66 to 590 $\mu g/m^3$.

5.6.16 Background

Ambient air samples measured at three locations (322, 323, and 329 Lewis Street) were used to evaluate background ambient air concentrations. Sample results and locations are shown in Figure 16. Inhalation of background ambient air results in a cancer risk of 3×10^{-5} and a HI of 0.5. The primary contributors to potential cancer risk from inhalation of background ambient air are benzene (31%), carbon tetrachloride (29%) and naphthalene (17%). The similarity between the risks and hazards for background and the risks and hazards near the site indicates that air quality is poor in the whole area due to other sources of contamination than the site.

5.6.17 Future Buildings

Potential risks and hazards from vapor intrusion into future buildings from VOCs in groundwater may be as high as when residential use of the groundwater is considered, which are exceedingly high. The cancer risks estimated for future residents using the groundwater as tap water in the home is approximately 7×10^{-2}, which is significantly above the risk management range. Hazard indices for an adult (262) and child (628) resident are also significantly above the non-cancer threshold of 1.

Evaluation of potential vapor intrusion for future buildings using soil gas data at the parking lot, small vacant lot, and large vacant lot was not conducted because of the following uncertainties:

a) Subslab soil gas samples were not collected – only exterior soil gas was collected in residential yards.
b) Exterior soil gas samples may underestimate the concentrations found beneath a building because there is no floor covering the ground surface.
c) Soil gas samples could not be collected at the DTSC recommended depth because the groundwater is less than 5 feet from the ground surface.
d) Use of a generic attenuation factor may over/underestimate the VOC concentrations in indoor air.

If future buildings are constructed in these areas, vapor mitigation systems are recommended.

5.7 Residential Screening Level Soil Evaluation

Subsequent to the collection of the residential soil samples during the RI investigation, a soil removal action was performed at residential properties adjacent to and near the former AMCO facility in August/September 2007. These properties include 1428, 1432, and 1436 3rd

Street, and 320, 326, 356, 360, and 366/368 Center Street. The soil was generally excavated until the confirmation sampling indicated that the remaining soil was below the EPA residential screening level of 400 mg/kg, or to a 3-foot maximum depth. The excavation depth was generally between one and three feet. Small areas were excavated to a depth of less than 1 foot in locations where valuable trees or plants might have been damaged by deeper excavation. As a result, the soil samples collected during the RI are no longer representative of the soil conditions at these properties.

A screening level evaluation was performed on the soil data collected from the residential yards adjacent to or near the former AMCO facility. The concentrations detected in soil were compared to their respective screening levels to determine if they may pose a potential health risk. Screening levels are used to distinguish those substances that clearly do not pose a significant health threat because their concentrations in soil are low, from those that require additional evaluation for potential health risks. Screening levels selected for soil were EPA Residential RSLs.

The residential soil screening levels for arsenic are 0.39 mg/kg for cancer risks and 22 mg/kg for non-cancer hazards. The non-cancer screening level for arsenic was used in the residential screening evaluation because an arsenic level of 0.39 mg/kg is significantly less than what was found in background samples (14 mg/kg) (City of Oakland Urban Land Redevelopment Program 1995).

For mixtures of carcinogenic PAHs, the reference chemical is benzo(a)pyrene. Benzo(a)pyrene was chosen as the reference chemical because the toxicity of the chemical is well characterized. The toxicity equivalency factor for each carcinogenic PAH is an estimate of the relative toxicity (by an order of magnitude) of the congener compared to benzo(a)pyrene. A summary of PAH toxicity equivalence factors is provided below.

Toxicity Equivalence Factors for Carcinogenic PAHs

Carcinogenic PAHs	Toxicity Equivalency Factor*
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	0.4
Indeno(1,2,3-cd)pyrene	0.1

In the San Francisco Bay area, PAH cleanup levels of 0.9 mg/kg (DTSC 1998) and 1.8 mg/kg BaP Equivalents concentrations (U.S. Navy 2006) have been used for residential cleanup. These levels are considered safe for residential use.

Soil was sampled at six residential parcels in the immediate vicinity of the facility. Generally, within samples from each boring, the highest contaminant concentrations were

observed in the shallow soil. VOCs were sparsely detected at concentrations below screening levels. Below is a brief summary of the findings by parcel.

In 2009, soil samples were collected during installation of additional monitoring wells. Tables showing the results of this soil sampling are compared with screening levels and are presented in Attachment 4.

5.7.1 1428 3rd Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Five locations were sampled at this residence, four locations along the property boundary and one in the center of the yard (Figure 17). The soil sampling at 1428 3rd Street indicated lead, PAHs, antimony, iron and 4,4'-DDT at levels above screening levels (Attachment 4, Table 4-30). The lead concentrations ranged from 224 to 4,170 mg/kg which is significantly above the site-specific screening levels (194 mg/kg for lead exposure including the homegrown produce pathway and 340 mg/kg without homegrown produce). Antimony and iron only exceeded in the shallow portion of two samples collected on the eastern boundary. Arsenic exceeded the non-cancer screening level of 22 mg/kg in one sample at a concentration of 35.1 mg/kg. 4,4'-DDT slightly exceeded the screening level of 1.7 mg/kg in one shallow sample.

5.7.2 1432 3rd Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Three locations were sampled at this residence, two along the property boundary and one in the vegetable garden (Figure 18). The soil sampling at 1432 3rd Street indicated lead, PAHs, 4,4'-DDT, and iron at concentrations above screening levels (Attachment 4, Table 4-31). Lead concentrations range from 524 to 2,280 mg/kg which is significantly above the screening levels. Antimony, iron, and 4,4'-DDT slightly exceeded their screening levels in one shallow sample. BaP Equivalents exceeded its screening level in all the shallow samples.

5.7.3 1436 3rd Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Two locations were sampled at this residence, one in the vegetable garden and one next to the lemon tree (Figure 19). The soil sampling at 1436 3rd Street indicated lead, PAHs, dieldrin, and iron at levels above screening levels (Attachment 4, Table 4-32). Lead concentrations range from 216 to 3,630 mg/kg which is significantly above screening levels. Dieldrin significantly exceeds its screening level in one shallow sample and barely exceeds in the other shallow sample. Iron slightly exceeds its screening level in both shallow samples. BaP Equivalents exceeds its screening level in both shallow samples.

5.7.4 326 Center Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Five locations were sampled at this residence, four along the property

boundary with the large vacant lot and one along the property boundary with the former facility (Figure 20). The soil sampling at 326 Center Street indicated lead, PAHs Attachment 4, Table 4-33, dieldrin, 4,4'-DDT, 4,4'-DDE, iron, and arsenic at levels above screening levels . Lead was detected at concentrations ranging from 170 to 53,000 mg/kg. Three of the locations had samples with lead concentrations below the EPA residential screening level of 400 mg/kg. However two of the locations had lead concentrations that significantly exceeded the screening level. Arsenic was detected above the screening level in every soil sample collected; however, concentrations detected across the RI Study Area are generally less than or equal to background concentrations typical of the San Francisco Bay Area with the exception of the sample collected location 326SSd. Arsenic was detected at concentrations greater than background in shallow (451 mg/kg) and deeper (125 mg/kg) soil at this location. Iron is only slightly greater than its screening level in one shallow sample. 4,4'-DDE and dieldrin are slightly greater than their screening level in one shallow sample. 4,4'-DDT was detected at concentrations ranging from 0.59 to 11 mg/kg in two sample locations.

5.7.5 356 Center Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Three locations were sampled at this residence—one location was in a small yard behind the house, and two locations were in the dirt floor of a recently vacated chicken coop (Figure 21). The soil sampling at 356 Center Street indicated benzo(a)pyrene and lead at levels above screening levels (Attachment 4, Table 4-34). Lead was detected at concentrations ranging from 26.2 to 822 mg/kg. Of the six soil samples collected, five were above screening levels. Although three samples had benzo(a)pyrene that exceeded its screening level, none of the samples exceeded the BaP Equivalents criteria.

5.7.6 360 Center Street

As described above, soil was removed from this property during the August/September 2007 removal action, therefore all exceedances discussed below are no longer representative of current conditions. Two locations were sampled at this residence, one location along the northern parcel boundary, and one location in the southeastern corner (Figure 22). The soil sampling at 360 Center Street indicated lead, benzo(a)pyrene, Aroclor-1254, and heptachlor epoxide at levels above screening levels (Attachment 4, Table 4-35). Lead concentrations ranged from 193 to 2230 mg/kg which is significantly higher than the screening level. Aroclor-1254 (screening level of 0.22 mg/kg) was detected at 2.4 to 11 mg/kg at one location, and heptachlor epoxide (screening level of 0.53 mg/kg) was detected at 0.31 mg/kg in only the shallow sample at the same location.

5.7.7 Homegrown Produce Results

Four of the residents whose properties are adjacent to the former AMCO facility have gardens and fruit trees. The detection of TCE, PCE, and vinyl chloride in shallow groundwater and the potential for shallow groundwater to migrate into residential areas containing these gardens prompted concerns that contaminants from the Site could be taken up and transferred into edible fruit or vegetables. To evaluate the ingestion of the homegrown produce pathway, 15 fruits and vegetables from four gardens were collected and analyzed for selected metals (arsenic, chromium, and lead) and VOCs. Because produce

samples were analyzed for VOCs as well as metals, none of the produce were rinsed or washed before analysis. As a result, the metals concentrations could reflect soil and dust deposited on the plant surfaces and possible uptake from soil through the roots into the edible portions of the plants. Produce samples collected and analyzed include:

- Fruit: Apple (2), Cactus, Blackberries, Pomegranate, Grapes, Fig, Lemon
- Fruiting Vegetables: Tomatillo, Tomatoes (2), Red Chili Pepper, Green Chili Pepper, Bell Pepper
- Leafy Vegetables and Herbs: Mint
- Root Vegetables: Root vegetables were not collected because none were available in the gardens that were sampled.

Results of the produce analyses are presented in Attachment 4, Tables 4-43, 4-44, 4-45 and 4-46. In summary, of the 47 VOCs analyzed, only methyl acetate and styrene were detected. Methyl acetate was detected in figs, mint, and red chilies. Styrene was detected only in cactus. Both methyl acetate and styrene have been detected in ripening produce in concentrations ranging from 0.04 - 0.24 mg/kg. (Heikes et al. 1995). Volatile organic compounds like methyl acetate are naturally produced by ripening fruits at less than 1 mg/kg (Fountain et al. 1984).

Urban gardens have been assessed extensively since the 1970s and provide the foundation for evaluating metals in garden soil. Plants absorb various metals from different soils related to the metals properties, soil properties (pH, metal concentration in soil, organic matter, cation exchange capacity, and level of other metals in soil) and plant properties (plant age, species, type of crop edible portion (leafy, root or garden fruit). Some metals, like zinc, cadmium, and selenium are easily absorbed and transferred to food chain plant tissues. Some metals like lead, iron, mercury, and chromium are strongly bound or precipitated in soil or in the root fibers and are not transferred to plant foliage in unsafe amounts even when soils are greatly enriched. Other metals like copper, nickel and arsenic are easily absorbed and transferred to plant foliage but phytotoxicity to the crop may limit plant levels of the metal. (Chaney et al 1984). Important to note; plants with higher surface areas green leafy vegetables such as lettuce, collard greens and swiss chard tend to easily attach dust and soil which may remain after rinsing.

Lead concentrations in the soil samples collected in the residential garden areas adjacent to the former AMCO facility ranged from 1,060 to 2,910 mg/kg with corresponding lead produce concentrations from 0.16 to 8.47 mg/kg. These lead concentrations reflect that none of the produce samples were rinsed or washed before analysis; thus, the lead concentrations could reflect dust or soil deposited on the plant surfaces in addition to lead that was taken up through the root system.

A study by Finster et al. (2003) investigated the relationship between lead concentrations in urban garden soils and homegrown produce grown in these soils, with a focus on the levels of lead detected in the edible portion of the plants. In this study, all produce were washed with water or detergent and detection limits were 10 mg/kg.

By comparison, the homegrown produce samples were not washed and the lead detection limits were 0.06 mg/kg. The lead soil concentrations in the Finster study ranged from 27 to

4,580 mg/kg. Concentrations of lead in residential shallow soils ranged from 167 to 28,600 mg/kg. The lead concentrations in the Finster study produce ranged from non-detect (ND) at 10 mg/kg to 81 mg/kg. The lead concentrations in the residential produce ranged from 0.15 to 8.47 mg/kg.

The risk posed by eating lead containing produce depends on the frequency and the amount of consumption. U.S. Food and Drug Administration (FDA) recommends Provisional Total Tolerable Intake Levels (PTTIL) for all age groups, which are defined at 6 µg lead/day for children up to 6 years of age, 15 µg lead/day for children 7 years and older, 25 µg lead/day for pregnant women and 75 µg lead/day for other adults (FDA 1993).

The highest lead concentrations in produce were detected in mint at 8.47 mg/kg. Mint is an extremely strong herb with 1 gram of mint equal to approximately 20 leaves (U.S. Department of Agriculture [USDA] 2002). Only two leaves of fresh mint, weighing 0.1 g, are needed for tea. Consider tea made with mint - 2 leaves fresh mint weighs 0.1 g x 8.47 µg/g = 0.847 µg lead/day. Even if this mint were ingested from the garden unwashed, lead levels would be below PTTIL.

Other metals analyzed in produce include arsenic and chromium. Arsenic concentrations in produce range from 0.06 to 0.08 mg/kg, Arsenic is commonly found in most plants from 0.009 to 1.7 mg/kg dry weight. (Kabatas-Pendias et al 2001). Leafy vegetables like lettuce or spinach contain more arsenic than fruits. Mushrooms are found to be relatively high arsenic accumulators. Chromium concentrations in produce range from 0.39 to 1.07 mg/kg, Levels of chromium commonly found in plants range from 0.02 to 1.5 mg/kg dry weight (Kabatas-Pendias et al 2001). All produce collected from residential gardens adjacent to or near the former AMCO facility had chromium concentrations within this range.

6.0 Uncertainty Evaluation

A risk characterization incorporates information on the uncertainty associated with the risk assessment, including data gaps in toxicological or exposure assessment information and the conservative assumptions or scientific judgments used to bridge these data gaps (EPA 1992). These uncertainties, which are associated with every step in the risk assessment process, are evaluated to provide an indication of the relative degree of conservatism associated with a risk estimate. This section presents a qualitative discussion of the uncertainties associated with the overall assessment process.

Risk assessments are not intended to estimate actual risks to a receptor associated with exposure to chemicals in the environment. In fact, estimating actual risks is impossible because of the variability in the exposed or potentially exposed populations. Therefore, risk assessment is a means of estimating the upper bound probability that an adverse health effect (e.g., cancer) may occur in a receptor at some point in the future. The multitude of conservative assumptions used in the process ensures that the risk results are not likely to be underestimated.

Risk estimates are calculated by combining site data, assumptions about individual receptor's exposures to impacted media, and toxicity data. The uncertainties in this risk assessment can be grouped into three main categories that correspond to these steps:

- Uncertainties in environmental sampling and analysis
- Uncertainties in assumptions concerning exposure scenarios
- Uncertainties in toxicity data and dose-response extrapolations

6.1 Environmental Sampling and Analysis

This risk assessment is based on the sampling results obtained from the remedial investigations at the Site. Errors in sampling results can arise from the field sampling, laboratory analyses, and data analyses. Errors in laboratory analysis procedures are possible, although the impacts of these sorts of errors on the risk estimates are likely to be low. The environmental sampling at a site is one source of uncertainty in the evaluation. The number and location of samples at the Site are considered adequate for input in the risk assessment. The type of contaminants and exposure concentrations identified are also considered representative of site conditions.

Because of the long history of the Site's industrial use and the associated history of construction and filling, all primary sources may not have been identified. Hot spots and localized areas of contamination in soil or soil vapor that were not sampled may remain unknown in on-facility and off-facility areas. The existence of unknown contamination could lead to an increase in the health risks beyond what has been reported in this document. Data collected from known hot spots have been included in the risk assessment.

The number and location of samples at each exposure area are considered adequate for the calculation of EPCs at most of the industrial areas and for groundwater. However, for the

small vacant lot and the parking lot, the number of samples varied from 2 to 6 for each of the chemicals analyzed. This sample size is less than what is generally needed to calculate a 95 UCL; therefore, the maximum concentration was used to represent the EPCs where UCLs could not be calculated. A larger sample size would allow for the calculation of a more representative EPC and thus decrease uncertainty regarding chemical concentrations used for risk assessment at these locations.

Soil gas samples collected in the yards of the homes sampled could not be collected at DTSC's recommended depth of at least 5 feet below ground surface because of the shallow groundwater in the area. Soil gas collected at less than 5 feet below ground surface may be influenced by outdoor air being pulled in by the sample collection pump. This outdoor air would cause the sample to not accurately represent the levels of VOCs in the soil gas. In addition, the soil gas samples were collected in the backyards, in some cases several feet away from the structures. Therefore, there is uncertainty associated with the relationship between the soil gas and crawlspace air or indoor air data.

Indoor air sampling was conducted only once in June 2009. Although multiple indoor air samples were collected within each home/office, the indoor air sampling data represents a snapshot in time. As shown by the crawlspace air and ambient air data, the VOC concentrations vary widely from sampling event to sampling event. In addition, it was unusually warm (for the Bay Area) on the days that the sampling was conducted, and many homes had open windows. This condition may not accurately represent VOC concentrations when the windows are closed.

6.1.1 Laboratory and Sampling Results

Potential laboratory errors can also result in uncertainty in the chemical concentrations used in the exposure assessment. For well-designed analysis methods there should be no significant systematic error. However, uncertainty in measured concentrations due to random errors cannot be eliminated. These random errors result from:

- Precision of analytical measurements
- Random fluctuations in equipment performance
- Normal variations in analytical technique

These errors are expected to be small but nonetheless will affect the overall uncertainty in the results.

6.1.2 Reporting Limits

During the project planning phase, analytical methods are selected that provide sufficient sensitivity to meet the project screening levels. Positive results for all analytes were reported above the method detection limit. Because of the uncertainty that a specific analyte will be detected at concentrations below the reporting limit, analytes not detected are reported as not detected at the method reporting limit, generally 2 to 5 times higher than the method detection limit. In general, there are two reasons that the final analyte result is reported as not detected at a concentration above the screening limit:

1. The best available analytical methods does not provide the necessary sensitivity;

2. The sample contains high concentrations of one or more target analytes that require dilution, raising the final reporting limit for non-detected analytes above the screening level.

In both cases, some uncertainty exists whether the actual analyte concentration exceeds the screening level. The level of uncertainty is smaller in cases where the screening level is only slightly lower than the reporting limit. In addition, the level of uncertainty is mitigated in part because all positive results are reported to the method detection and in general, the method detection limit (MDL) is two to five times less than the reporting limit. As discussed in the following sections by media, this uncertainty is associated with a small number of analytes and there should be little or no effect on the final outcome of the risk assessment.

Soil

The failure to achieve the screening levels was due to both high concentrations of some target analytes in the sample that required dilution and percent moisture adjustments, raising the final reporting limit for non-detected analytes. However, three analytes were reported as not detected at a minimum reporting limit that exceeded the screening levels: benzo(a)pyrene, dibenz(a,h)anthracene, and n-nitroso-di-n-propylamine. This is a method limitation because of the low screening limit.

Groundwater

The failure to achieve the screening levels was primarily due to high concentrations of some target analytes in the sample that required dilution, thereby raising the reporting limit above the screening levels. Table 16 lists the minimum analyte reporting limits that were above the applicable groundwater screening level.

For 1,1,1,2-tetrachloroethane, 1,2,3-trichloropropane, bis(2-chloroethyl)ether, dibenz(a,h)anthracene, and n-nitroso-n-propylamine the required analytical method cannot achieve the screening levels. For the remaining analytes, dilution was required in many cases which elevated the reporting limit above the screening levels.

Air

The failure to achieve the screening levels for ambient air and crawlspace air samples was primarily due to method sensitivity limitations with respect to the very low concentration screening levels. Table 17 lists the minimum analyte reporting limits that were above the applicable ambient/crawlspace air screening level. Where the percentages are lower than 100 percent, the target analyte was detected in several of the samples.

6.2 Exposure Pathways and Assumptions

Risk assessments are designed to provide a margin of safety to protect public health and the environment by using conservative assumptions that assure risks are not underestimated. Actual human exposures and associated risks are likely to be less than those calculated for the risk assessment because each input value is conservative. Uncertainties can arise from the types of exposures examined, the points of potential human exposure, the concentrations of COPCs at the points of human exposure, and the intake assumptions.

- The exposure parameters—exposure frequency, exposure duration, soil ingestion rates, and skin surface areas—are selected as reasonable maximum exposure assumptions. To

minimize the possibility of underestimating risk, such factors are generally conservative and represent the portion of the population with the greatest potential for exposure. For example, the potential future resident at the former AMCO facility is assumed to be present for 350 days of the year over a 30 years period including the sensitive childhood period from birth to the age of six. These potential residents are assumed to play or garden daily in the soil. Few people, including children, are likely to be home and in direct contact with the soil daily for the entire 30 years. The HHRA assumes that the potential resident lives in a home that has a backyard and is unpaved. However, the degree of direct soil exposure would be reduced if the potential resident lived in a condominium with a backyard that was paved.

- The selection of exposure pathways is a process, often based on professional judgment that attempts to identify the most probable potentially harmful exposure scenarios. In an evaluation, risks are sometimes not calculated for all of the exposure scenarios that may occur, possibly causing some underestimation of risk. In this evaluation, potential risks are estimated for residential and worker exposure scenarios at the Site. Risks to potential receptors are estimated for a number of different exposure pathways (e.g., inhalation of fugitive dust). While other exposure routes could exist for a particular activity, these exposures are expected to be lower than the risks and hazards associated with the pathways considered.
- The amount that each of the COPCs might be absorbed into the body may be quite different from the amount of chemical that is actually contacted (i.e., bioavailability). In this assessment, bioavailability of ingested and inhaled chemicals is conservatively assumed to be 100 percent. Actual chemical- and site-specific values are likely to be much less than this conservative default value.
- Many factors contribute to the uncertainty of dermal contact exposure in risk assessment. There are uncertainties associated with each of the input parameters used in the equations to estimate risk. Additional uncertainties originate from factors that are not sufficiently characterized to be included in the risk equations. These include issues related to the degree and uniformity with which soil adheres to skin, exposed body surfaces, the frequency and duration of exposure, and the rate and amount of contaminant absorption.
- The method for estimating resuspended dust from soil concentrations using a PEF introduces large uncertainties in the resulting air concentrations and subsequent risk estimates. The assumption that the dust concentration remains constant may over-estimate the amount of dust in the air over time and, consequently, the concentration of contaminants present in dust. This could result in an overestimate of the inhalation as a particulate.
- Potential vapor intrusion into future buildings that may be located in the parking lot, small vacant lot, and large vacant lot exposure areas have been evaluated and all potential risks and hazards are exceedingly high. This represents an uncertainty for future development. If future buildings are constructed in these areas, vapor mitigation systems are recommended.

- The potential effect of the LNAPL on the shallow groundwater on indoor air risk estimation and as a long-term source of VOCs has not been addressed. However, it is acknowledged that the risks and hazards from exposure to VOCs would be unacceptable if buildings were to be located over the LNAPL before remediation takes place.
- For a construction worker, the EPA model used to estimate the amount of VOCs that would volatilize from groundwater used an assumed wind velocity factor in the trench. If risks and hazards were calculated using the Trench Worker Model recommended by the Virginia Department of Environmental Quality which assumes no wind, the results show a risk greater than 10^{-4} (6×10^{-4}) and an HI that exceeds 1 (34).

6.3 Toxicity Criteria and Factors

The availability and quality of toxicological data is another source of uncertainty in the risk assessment. Carcinogenic criteria are classified according to the amount of evidence available that suggests human carcinogenicity. In the establishment of the non-carcinogenic criteria, conservative multipliers, known as uncertainty and modifying factors, are used.

6.3.1 Uncertainties in Animal and Human Studies

Extrapolation of toxicological data from animal tests is one of the largest sources of uncertainty in a risk assessment. There may be important, but unidentified, differences in uptake, metabolism, and distribution of chemicals in the body between the test species and humans. For the most part, these uncertainties are addressed through use of conservative assumptions in establishing values for RfDs and CSFs, which results in the likelihood that the risk is overstated.

Typically, animals are administered high doses (e.g., maximum tolerated dose) of a chemical in a standard diet or in air. Humans may be exposed to much lower doses in a highly variable diet, which may affect the toxicity of the chemical. In these studies, animals, usually laboratory rodents, are exposed daily to the chemical agent for various periods of time up to their 2-year lifetimes. Humans are assumed to have an average 70-year lifetime and may be exposed either intermittently or regularly for an exposure period ranging from months to a full lifetime. Because of these differences, extrapolation error is a large source of uncertainty in a risk assessment.

6.3.2 Non-Carcinogenic Toxicity Criteria

In the establishment of the non-carcinogenic criteria, conservative multipliers, known as uncertainty factors, are used. Most of the chronic non-carcinogenic toxicity criteria that were located in the IRIS database have uncertainty factors of 1,000. This means that the dose corresponding to a toxicological endpoint (e.g., LOAEL was divided by 1,000). The purpose of the uncertainty factor is to account for the extrapolation of toxicity data from animals to humans and to insure the protection of sensitive individuals. However, in accomplishing these purposes, the uncertainty in the actual toxicity of the chemical in humans is greatly increased.

6.3.3 Carcinogenic Toxicity Criteria

For chemicals that are probable human carcinogens and lack human evidence of carcinogenicity, the EPA method for developing cancer slope factors extrapolates data from high-dose animal experiments to low-dose human exposures and thus is associated with a high potential for overestimating risk. Actual slope factors could be lower but are unlikely to be higher. The LMS assumes that there is no threshold for carcinogenic substances; that is, exposure to even one molecule of a carcinogen is sufficient to cause cancer. This is a highly conservative assumption because the body has several mechanisms to protect against cancer.

Toxicity values derived using the LMS are intended for chemicals with cancer risks below 1×10^{-2}. For scenarios producing risks greater than 1×10^{-2}, an alternative equation for calculating risk is suggested. The residential risk calculations from groundwater exceed 1×10^{-2} for arsenic and vinyl chloride, suggesting the use of an alternative risk characterization model. Use of such a model could slightly change the calculated ELCR. However, since the conclusions derived by using an alternate equation for these two chemicals would not change, the LMS method was retained (EPA 1989).

6.3.4 Additive vs. Synergistic vs. Antagonistic Properties of COPCs

When humans are exposed to more than one chemical in a medium, it is normally assumed that the adverse effects of the different chemicals are additive. However, in some cases, synergistic or antagonist interaction may occur. Although there are no data to suggest that synergistic or antagonist interactions occur between chemicals at this Site, this is a source of uncertainty in the HHRA. The term synergism describes the situation wherein the aggregated risks from simultaneous exposure to multiple chemicals is more than the sum of the risks from each alone. Antagonism is when the aggregated risks are less than the sum.

Synergism and antagonism represent complex interactions between two or more chemicals. Two chemicals may exert synergistic effects on one aspect of each other's toxicity, but not on other toxic effects. The synergy may be apparent within one range of exposure levels, but not within another range of exposure to the two chemicals. Addition of a third chemical may inhibit the synergy between the first two chemicals. Thus quantifying synergism or antagonism in a risk assessment can be problematic and requires a thorough understanding of the potential interactions between multiple chemicals and the development of relevant risk/toxicity values.

Superfund risk assessment guidelines (RAGS, Part A, Section 8.4.2) notes that "[i]n the absence of adequate information, carcinogenic risks should be treated as additive and that non-cancer hazard indices should also be treated as additive." It is a goal of the EPA to incorporate synergistic and antagonistic effects into risk assessments when there is sufficient credible scientific evidence that either exists and appropriate risk assessment tools are available. However, there are very few data available on synergism or antagonism of specific mixtures that are useful in a risk assessment context.

6.3.5 TCE

Toxicity values are not currently available for TCE in EPA's Integrated Risk Information System (EPA 2006a). EPA withdrew its previously published toxicity values for TCE in 1988 because of uncertainties relating to the science of TCE toxicity. The guidance lists Tier 1 as

IRIS, Tier 2 as PPRTV, and Tier 3 as other sources including NCEA and OEHHA. A more current inhalation factor of 0.007 $(mg/kg\text{-}day)^{-1}$ is available from another Tier 3 source (OEHHA 2006). EPA has proposed more stringent TCE toxicity values which are pending review (EPA 2009d).

6.3.6 Surrogates

A number of chemicals detected in Site media do not have established toxicity criteria. Where available, appropriate surrogate toxicity factors were used for detected chemicals without toxicity factors. Use of surrogate toxicity factors assumes the toxicity of structurally similar compounds is equivalent, which may result in under- or over-estimate of risks. If a surrogate chemical was not available, these chemicals were not evaluated quantitatively. A list of chemicals used as surrogates is presented in Table 18.

7.0 Summary and Discussion of Human Health Risk Assessment Results

The HHRA described in this appendix evaluated potential health risks to current and future workers, as well as future adult and child residents from exposure to hazardous chemicals in soil and groundwater at the former AMCO facility and adjacent parcels. In addition, a vapor intrusion evaluation was performed on hesidential homes near the former AMCO facility as well as the office building on the Site. Screening level risk evaluations were also conducted on the soil and homegrown produce from residential lots that are occupying the same city block as the former AMCO facility. Results from this HHRA will be one of the factors that EPA uses to determine if cleanup actions are warranted at the Site. Possible remedial actions in areas that have unacceptable risks will be addressed in the FS for the former AMCO facility. The baseline HHRA provides estimates of the human health risks and hazards that the former AMCO facility could pose if no action were taken. Standard EPA risk assessment procedures were used to conduct this risk assessment.

Consistent with the conceptual site model, the predominant exposure pathways for current and future workers to soil would be incidental ingestion of soil, inhalation of particulates and vapors, and dermal contact with soil. Current and future residents in the vicinity may potentially be exposed to contaminants through the same pathways as listed above for workers. In addition, residents could potentially be exposed by ingestion of contaminated groundwater and dermal contact with groundwater while showering. Vapor intrusion was evaluated using crawlspace air and ambient air data from nearby homes and the office on the former AMCO facility. Residents were also evaluated for exposure to soil in their yards and ingestion of homegrown produce.

For carcinogens, risks are generally expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen. These risks are probabilities that usually are expressed in scientific notation (e.g., 1×10^{-6}). An excess lifetime cancer risk of 1×10^{-6} indicates that an individual has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer an individual faces from other causes, such as smoking or exposure to too much sun. The chance of an individual developing cancer from all other causes has been estimated to be as high as one in three. EPA's target risk range for site-related exposures is 10^{-6} to 10^{-4}. An excess lifetime cancer risk of 10^{-4} is the point at which action is generally required at a site (EPA 1991b). Because the surrounding neighborhoods are a vulnerable community, EPA has decided to use an excess lifetime cancer risk of 10^{-6} as the point at which action will be required at this site.

The cancer risk estimates and non-cancer HIs calculated for each exposure scenario are summarized in Attachment 1, Table 1-109. The risk estimates are based on reasonable maximum exposure concentrations and were developed by taking into account various

conservative assumptions about the frequency and duration of exposure to contaminated materials as well as the toxicity of the chemicals of potential concern.

7.1 On-Facility Quantitative Soil Risk Estimates

Soil samples were divided into the following four exposure areas: former AMCO facility, parking lot, large vacant lot, and small vacant lot. An exposure area is a portion of the property that is contacted on a regular basis by a worker or resident. Risk estimates are discussed for each exposure area below.

Industrial Worker: Estimated cancer risks were at the upper end of the risk range for exposure to either shallow or deep soil at each of the four exposure areas. HIs were either at the non-cancer threshold of 1 or below 1 at all four exposure areas.

Construction Worker: Estimated cancer risks were within the risk range of 10^{-6} to 10^{-4} for exposure to shallow or deep soil at each of the 4 exposure areas. HIs exceeded the non-cancer threshold of 1 at all four exposure areas.

Residents: Estimated cancer risks exceeded the risk range for exposure to shallow or deep soil at all four of the exposure areas. HIs exceeded the non-cancer threshold of 1 at all four exposure areas.

In addition, lead levels at all four exposure areas exceed both the residential and industrial CHHSLs.

7.2 Groundwater Risk Estimates

The cancer risks and non-cancer hazards are significantly above the risk range when residential use of groundwater is considered. However, it is extremely unlikely that groundwater will be used as a source of drinking water.

An evaluation of vapor intrusion using groundwater data was not conducted, however, it is acknowledged that in a worst case scenario, the risks and hazards may be as high as when residential use of the groundwater is considered. As noted above, the cancer risks estimated for future residents using the groundwater as tap water in the home is 7×10^{-2} which is significantly above the risk management range and clearly unacceptable. Hazard indices for an adult (262) and child (628) resident are also significantly above the non-cancer threshold of 1.

7.3 Irrigation Well Results

During the RI, a previously unidentified well was discovered at a residence near the former AMCO facility. According to the property owner, the well is primarily used for backyard irrigation. The well is not a source of drinking water. The residential irrigation well was sampled on three occasions: September 2, 2004, June 24, 2005, and October 12, 2005. A summary of the results is presented in Table 13. As indicated in this table, the only analyte that exceeds the screening level is lead. However, boron, manganese, mercury, and sodium are at concentrations that exceed their agricultural water quality limit.

7.4 Vapor Intrusion Risk Estimates

To assess the potential human health risks and hazards associated with VOCs migrating from the groundwater into the office at the former AMCO facility and into nearby residences; crawlspace and ambient air sampling was performed over nine sampling events from September 2004 through June 2009. Ambient air and crawlspace air sample results were compared to acute reference exposure levels (RELs) developed by OEHHA and the Agency for Toxic Substances and Disease Registry's (ATSDR) acute minimal risk level (MRLs) for hazardous substances to confirm that contaminant levels would not pose an immediate health threat to residents.

In addition to the crawlspace and ambient air sampling, the June 2009 sampling event included indoor air sampling at some of the nearby residences and the office at the former AMCO facility. Because indoor air data was collected only once, it represents a snapshot in time, therefore it is compared to the crawlspace and ambient air data, as well as screening levels. ELCRs and hazards were not calculated using the indoor air data.

Industrial Exposure Evaluation

Potential cancer risks and non-cancer hazards were calculated using industrial worker exposure assumptions for the 1414 3rd Street office. Crawlspace air is used to represent the air that could potentially be inhaled by the workers in their offices. Potential cancer risk from exposure to VOCs in crawlspace air at the office building is 6×10^{-5}, which is within the risk management range of 10^{-6} to 10^{-4}. The main contributors to the cancer risk are carbon tetrachloride (35%) and vinyl chloride (18%). The non-cancer HI is below 1 for exposure by an indoor worker.

Residential Exposure Evaluation

All non-facility locations (residential parcels, South Prescott Park, background) were evaluated using residential exposure assumptions. Crawlspace and ambient air is used to represent the air that could potentially be inhaled by the residents inside and outside the living spaces of their homes. Potential cancer risks are within the risk management range at all residences for crawlspace and ambient air with the exception of two of the residential properties for crawlspace (1428 3rd Street and 1432 3rd Street) and one for ambient air (1428 3rd Street). These are also the only locations having non-cancer HIs greater than 1.

Potential cancer risks from inhalation of crawlspace air ranged from 5×10^{-5} to 3×10^{-4}. The primary chemical contributors to risk from inhalation of crawlspace air are vinyl chloride, benzene, 1,2-dichloroethane, carbon tetrachloride, and 1,4-dichlorobenzene at the four residences where crawlspace air and ambient air were collected. Crawlspace air HIs range from 0.5 to 8. The primary contributors to the HI in crawlspace air at the two locations that have HIs that exceed 1 are 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene.

Potential cancer risks from inhalation of ambient air ranged from 2×10^{-5} to 2×10^{-4}. The primary contributors to risk from inhalation of ambient air are naphthalene, benzene, carbon tetrachloride, and vinyl chloride. Vinyl chloride is only a primary contributor at one property - 1436 3rd Street. The HI from exposure to ambient air exceeds 1 at 1428 3rd Street (HI=4). Naphthalene (47%), 1,2,4-trimethylbenzene (18%), and 1,3,5-trimethyl-benzene (18%) are the primary contributors to the ambient air HI.

No VOC detections exceeded acute reference concentrations, indicating that there is no immediate health threat to residents. As a precautionary measure mitigation systems have been installed in selected homes nearest the site.

The background cancer risk estimated using the Lewis Street (located 3 blocks upwind of the site) ambient air data is 3×10^{-5}. The primary contributors to the background cancer risk estimate include benzene (31%), carbon tetrachloride (29%) and naphthalene (17%). The background non-cancer HI (0.5) is less than the non-cancer threshold of 1. The similarity in the risks and hazards between background and the residences near the site indicates that air quality is poor in the whole area due to sources of contamination other than the site.

Future Buildings

For future buildings, the potential vapor intrusion risk is exceedingly high. In a worst case scenario, the risks and hazards from vapor intrusion may be as high as when residential use of the groundwater is considered. The cancer risks estimated for future residents using the groundwater as tap water in the home is significantly above the risk management range and clearly unacceptable. Hazard indices for an adult and child resident are also significantly above the non-cancer threshold of 1.

Evaluation of future vapor intrusion risk from the soil gas data into future buildings at the parking lot, small vacant lot, and large vacant lot was not conducted because of the following uncertainties:

a) Subslab soil gas samples were not collected – only exterior soil gas was collected in residential yards.
b) Exterior soil gas samples may underestimate the concentrations found beneath a building because there is no floor covering the ground surface.
c) Soil gas samples could not be collected at the DTSC recommended depth because the groundwater is less than 5 feet from the ground surface.
d) Use of a generic attenuation factor may over/underestimate the VOC concentrations in indoor air.

If future buildings are constructed in these areas, vapor mitigation systems are recommended.

7.5 Screening Level Evaluation on Residential Media

Subsequent to the collection of the residential soil samples during the RI investigation, a soil removal action was performed at residential properties adjacent to and near the former AMCO facility in August/September 2007 based on the RI results. These properties include 1428, 1432, and 1436 3rd Street, and 320, 326, 356, 360, and 366/368 Center Street. The soil was generally excavated to a depth of approximately three feet; however, excavations were shallower in some areas if confirmation sampling indicated remaining lead concentrations were below screening levels. As a result, the soil and produce samples collected during the RI are no longer representative of the soil conditions at these properties.

Soil: PAHs, pesticides (DDT, DDE, dieldrin, and heptachlor epoxide), antimony, and iron also exceed screening levels in at least one property. Generally, within samples from each boring, the highest contaminant concentrations were observed in the shallow soil. VOCs

were sparsely detected at concentrations below screening levels. Benzo(a)pyrene and lead were detected at all residential parcels at concentrations above the screening level.

Homegrown Produce: The detection of TCE, PCE, and vinyl chloride in shallow groundwater and the potential for shallow groundwater to migrate into residential areas containing gardens prompted concerns that contaminants from the Site could be taken up and transferred into edible fruit or vegetables. To evaluate the ingestion of the homegrown produce pathway, 15 fruits and vegetables from four gardens located adjacent to the Facility were collected and analyzed for selected metals (arsenic, chromium, and lead) and VOCs. Arsenic concentrations in produce range from 0.06 to 0.08 mg/kg Chromium concentrations in produce range from 0.39 to 1.07 mg/kg. The lead concentrations in the homegrown produce ranged from 0.15 to 8.47 mg/kg.

Of the 47 VOCs analyzed for, only methyl acetate and styrene were detected. Methyl acetate was detected in figs, mint and red chili peppers. Styrene was detected only in cactus. The highest lead concentrations in produce were detected in mint at 8.47 mg/kg. However, even if this mint were ingested from the garden unwashed, lead levels would be below the FDA's PTTIL.

8.0 References

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Tables

Figures

Attachment 1
Detailed Risk and Hazard Results for Exposure to Soil

Attachment 2
Detailed Risk and Hazard Results for Exposure to Groundwater

Attachment 3
Detailed Risk and Hazard Results for Vapor Intrusion Evaluation

Attachment 4
Residential Neighborhood Screening Tables

Attachment 5
ATSDR ToxFaqs (on CD)

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Attachment 7
Responses to DTSC Comments on HHRA

Attachment 8
Responses to TAG Advisor Comments on HHRA

Attachment 9
Comments on the HHRA from the California Department of Public Health

Attachment 10
Handouts Provided at October 16, 2010 Public Meeting

Attachment 11
Updated Section 7 of the RI Report