NEWFIELDS

RISK-BASED CORRECTIVE ACTION (RBCA) EVALUATION BP OIL SITE NO. 11133

OAKLAND, CALIFORNIA

Prepared for

BP OIL COMPANY

outlying wells reached steady state when using models. Has contam had time to reach outlying wells.

December 2000

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BP OIL CO.
ENVIRONMENTAL DEPT.
WEST COAST REGION OFFICE

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December 15, 2000

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The material and data in this report were prepared under the supervision and direction of the undersigned.

NEWFIELDS, INC.

No Signatures

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ACRONYMS

ADD	Average Daily Dose
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CSF	Cancer Slope Factor
DTSC	California Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
HI	Hazard Index
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
LADD	Lifetime Average Daily Dose
MADEP	Massachusetts Department of Environmental Protection
NA	Not Applicable
OEHHA	California Office of Environmental Health Hazard Assessment
OSHA	Occupational Safety and Health Administration
PAHs	Polynuclear Aromatic Hydrocarbons
RBCA	Risk-Based Corrective Action
RfD	Reference Dose
SSTL	Site-Specific Target Level
TPH	Total Petroleum Hydrocarbons
TPHCWG	Total Petroleum Hydrocarbon Working Group
UCL	Upper Confidence Limit
UST	Underground Storage Tank

EXECUTIVE SUMMARY

This report presents the results of a risk-based corrective action (RBCA) evaluation for the former BP Oil Facility No. 11133, which is a retail site, at 2220 98th Avenue, Oakland, California (Figure 1). The site is currently a commercial property. Plans to build a commercial car wash on the property are underway. Because a commercial car wash is proposed to be constructed on the property and the site is not zoned for residential, it is considered unlikely that the site will become residential any time in the near future. Surrounding the site are residential areas.

The purpose of this report is to evaluate whether constituents of gasoline and diesel, namely benzene, toluene, ethylbenzene, and xylenes (BTEX), methyl-tert-butyl ether (MTBE), and total petroleum hydrocarbons (TPH) detected in soil and groundwater at the site present a potential health risk to current and future on-site workers, and off-site residents. RBCA uses risk assessment to tailor site-specific solutions. The evaluation follows the basic procedures outlined in the *Oakland Risk-Based Corrective Action: Technical Background Document*, the *Oakland Urban Land Redevelopment Program: Guidance Document*, and the ASTM *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (*E1739-95e1*). The completed Oakland RBCA Eligibility Checklist for the site is presented in Table E-1.

The Oakland and ASTM RBCA processes consist of three steps or tiers. Using the Oakland RBCA process, the first two tiers are comparisons of site data to concentrations presented in Tier 1 and Tier 2 look-up tables. The Oakland RBCA Tier 1 and Tier 2 look-up values are based on conservative, generic exposure and modeling parameters, resulting in conservative risk-based screening levels. Where site conditions exceeded Oakland RBCA Tier 1 and Tier 2 levels, these conditions were further assessed under the Oakland RBCA Tier 3 analysis. The Tier 3 analysis replaces some of the conservative, generic assumptions of Tiers 1 and 2 with data that represent actual site conditions, thus more accurately reflecting existing and future risks.

Results of the Oakland RBCA Tier 3 evaluation indicate that remnant levels of petroleum hydrocarbons are below City of Oakland and U.S. EPA acceptable cancer risks and non-cancer levels. Therefore, soil and groundwater conditions at the site should not pose a risk to current and future on-site workers or off-site residents.

Table E-1

Oakland RBCA Eligibility Checklist

The Oakland Tier 1 RBSLs and Tier 2 SSTLs are intended to address human health concerns at the majority of sites in Oakland where commonly-found contaminants are present. Complicated sites—especially those with continuing releases, ecological concerns or unusual subsurface conditions—will likely require a Tier 3 analysis. The following checklist is designed to assist you in determining your site's eligibility for the Oakland RBCA levels.

CRITERIA	YES	NO
1. Is there a continuing, *primary* source of a chemical of concern, such as a leaking container, tank or pipe? (This does *not* include residual sources.)	☐	☒
2. Is there any mobile or potentially-mobile free product?[1]	☐	☒ ?
3. Are there more than five chemicals of concern at the site at a concentration greater than the lowest applicable Oakland RBCA level?	☐	☒
4. Are there any preferential vapor migration pathways—such as gravel channels or utility corridors—that are potential conduits for the migration, on-site or off-site, of a volatilized chemical of concern?	☐	☒
5. Do both of the following conditions exist? (a) Groundwater is at depths less than 300 cm (10 feet)[2] (b) Inhalation of volatilized chemicals of concern from groundwater in indoor or outdoor air is a pathway of concern but groundwater ingestion is *not**	☐	☒
6. Are there any existing on-site or off-site structures intended for future use where exposure to indoor air vapors from either soil or groundwater is of concern *and* one of the following three conditions is present?[3] (a) A slab-on-grade foundation that is less than 15 cm (6 inches) thick (b) An enclosed, below-grade space (e.g., a basement) that has floors or walls less than 15 cm (6 inches) thick (c) A crawl space that is not ventilated	☐	☒
7. Are there any immediate, acute health risks to humans associated with contamination at the site, including explosive levels of a chemical?	☐	☒
8. Are there any complete exposure pathways to nearby ecological receptors, such as endangered species, wildlife refuge areas, wetlands, surface water bodies or other protected areas?	☐	☒

*If groundwater ingestion *is* a pathway of concern, the associated Oakland RBCA levels will be more stringent than those for any groundwater-related inhalation scenario, rendering depth to groundwater irrelevant in the risk analysis.

[1] Liquid hydrocarbon product accumulations have been documented in wells MW-1 and RW-1. Remedial activities have abated product in well MW-1. Liquid product recently observed in RW-1 was removed by bailing. Product in RW-1 appears to be an isolated occurrence associated with the former location of the UST system and not subject to rapid or easy subsurface movement. FP continues to be detected in RW-1 since 1991 to 2001

[2] Although depth to groundwater in some areas of the site is sometimes below 10 feet, the average depth to groundwater is greater than 10 feet.

[3] Because building conditions for off-site structures is unknown, a conservative foundation thickness of one inch was used in the Tier 3 analysis.

If you answer "no" to all questions, your site is eligible for the Oakland RBCA levels. If you answer "yes" to any of the questions, your site is *not* eligible for the Oakland Tier 1 or Tier 2 RBCA levels at this time.

RISK-BASED CORRECTIVE ACTION (RBCA) EVALUATION

1. INTRODUCTION

This report presents the results of a risk-based corrective action (RBCA) evaluation for the former BP Oil Facility No. 11133, which is a retail site at 2220 98th Avenue, Oakland, California (Figure 1). RBCA uses risk assessment to identify technically defensible and site-specific solutions, in place of generic, universally-applied cleanup standards. The RBCA process is guided by standards issued by the American Society for Testing and Materials (ASTM) in the *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E1739-95e1)*, and in Oakland, the *Oakland Risk-Based Corrective Action: Technical Background Document* (1999).

1.1 Purpose of Report

The purpose of this report is to evaluate whether constituents of gasoline and diesel, namely benzene, toluene, ethylbenzene and xylenes (BTEX), methyl-tert-butyl ether (MTBE), and total petroleum hydrocarbons (TPH) detected in soil and groundwater at the site present a potential health risk to current and future on-site workers, and off-site residents. Depth to groundwater is believed to range from 10 to 22 feet below ground surface (bgs) based on measurements from multiple wells on-site. Potential downward migration to groundwater from soil is also assessed in this evaluation.

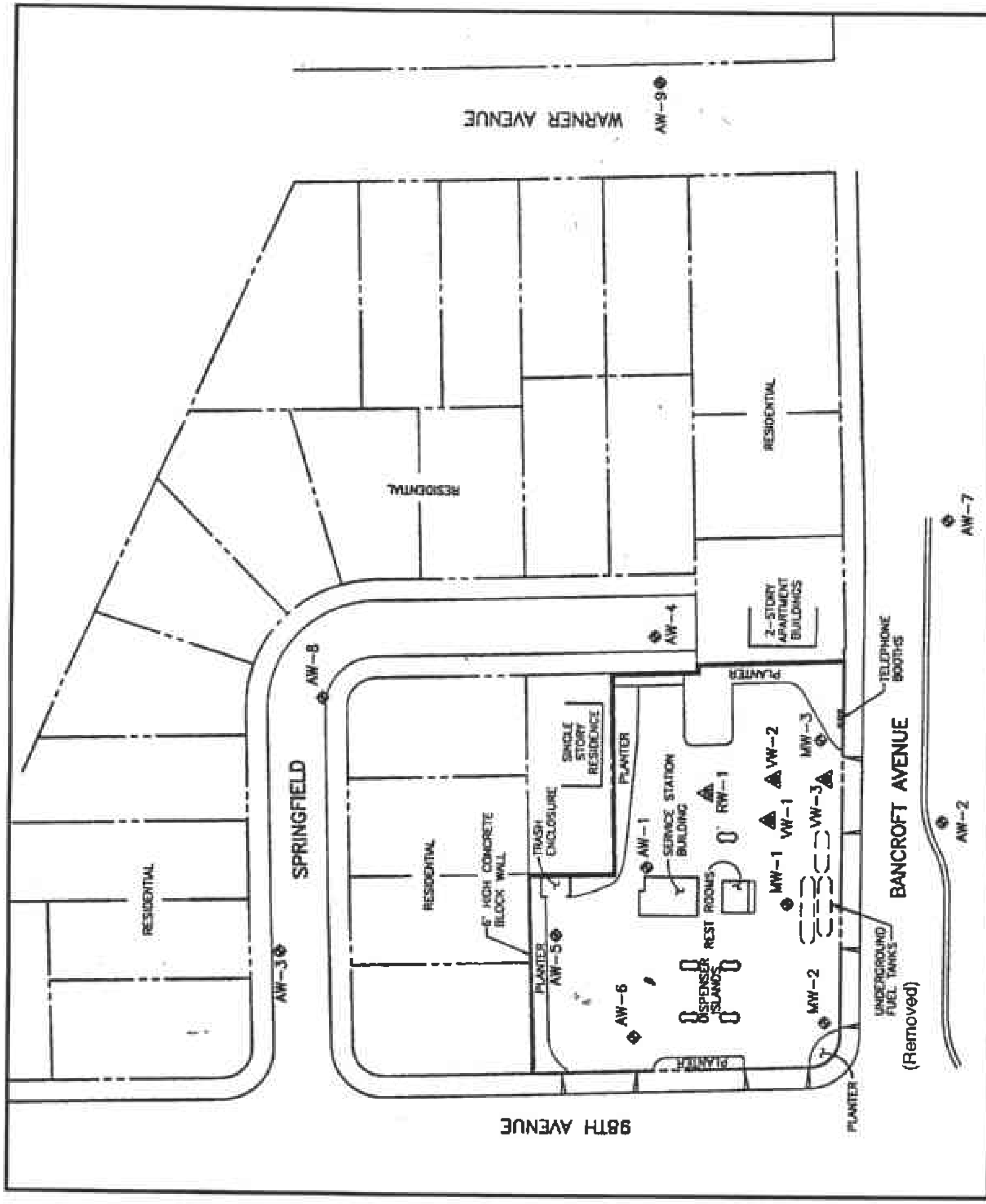
1.2 Methodology

The evaluation follows the basic procedures outlined in the *Oakland Risk-Based Corrective Action: Technical Background Document* (1999), the *Oakland Urban Land Redevelopment Program: Guidance Document* (2000), the ASTM *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (*E1739-95e1*; ASTM, 1999), and the U.S. Environmental Protection Agency's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (EPA, 1989). Other guidance documents consulted include the California Department of Toxic Substances Control's *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (DTSC, 1992).

1.3 Organization

The report is composed of several sections that are outlined below. This section presents the methods used in this evaluation and background on the site. Section 2 presents the results of the Oakland RBCA Tier 1 and Tier 2 evaluations. Section 3 contains a summary of the statistical evaluation conducted for the site. Section 4 presents the focused Oakland RBCA Tier 3 evaluation conducted for the site. Specifically, this section includes a discussion of the ways that people could be exposed to chemicals

Figure 1. Site Plan



1. Free Product migration offsite
2. max. dissolved phase concentration
3. Assume attenuation based on modeling and gw data.

loss of conservatism

Risk assessment

detected in soil and groundwater, the assumptions that are made about the extent to which people could be exposed, and the rates at which people could potentially intake the chemicals via the various exposure pathways. This section also presents a summary of the toxicity assessment component of the risk assessment, the risk characterization, and reviews the sources of uncertainty factored into the risk estimates. Section 5 summarizes the results, and Section 6 presents the references used to complete this evaluation.

1.4 Site Background

Mobil operated the site prior to 1989, BP Oil operated the site from 1990 to 1994, and Tosco operated the site after 1994. The following site background summarizes information provided in the Gettler-Ryan *Underground Storage Tank and Product Piping Removal Report* (1999), EMCON *Baseline Assessment Report* (1994), Alton Geoscience Phase III-*Supplemental Site Investigation Study* (1991), and Alton Geoscience *Supplemental Site Investigation Report* (1990).

In 1987, three underground storage tanks (USTs) were removed from the site. Soil samples were collected from the soils beneath the tanks (samples A1, A2, B1, B2, and C1), and TPH was detected in these samples. Subsequent to the tank removal, new tanks were installed at the former tank locations. In 1988, three monitoring wells were installed at the site (MW-1, MW-2, MW-3). Initial sampling from these wells indicated soil and groundwater at the site had been impacted with TPH. In 1990, additional soil borings were advanced at the site and additional monitoring wells and an extraction well were installed. Soil types encountered at the site were silty clays, clayey silts, and clayey sands. Results of chemical analyses indicated that on-site soils and groundwater were impacted with BTEX and TPH as gasoline (TPH-G). Additional soil borings and conversion of these borings to wells was conducted in 1991 by Alton. TPH and BTEX compounds were detected in these soil and groundwater samples. Supplemental soil borings were collected by EMCON in 1994. One location had a detected diesel concentration of 3,900 milligrams per kilogram (mg/kg) from below a dispenser. Further soil removal activities were conducted in late 1998 associated with the 1987 tank removal. The samples collected during this second removal and closure are considered representative of the current soil conditions at these former tank locations (formerly represented by samples A1, A2, B1, B2, and C1 described above). Quarterly groundwater monitoring activities have occurred for many of the groundwater monitoring wells at the site since 1991.

The results of the investigations identified petroleum releases that account for the current petroleum products found in the soil. The site investigations have shown petroleum products on site to be limited to soils in the vicinity of the product lines, dispensers, and USTs.

1.4.1 Geology

The site is approximately 40 feet above mean sea level in Oakland California, in the Alameda Bay Plain Groundwater Basin. The underlying unit in the area is Undivided

Quaternary deposits. Site investigations have revealed silty clays, clayey silts, and clayey sands beneath the site.

1.4.2 Groundwater

Has GW flow direction changed after extraction system was turned off

Depth to groundwater beneath the site ranges from approximately 10 to greater than 20 feet bgs and varies among the wells installed at the site, with notable seasonal fluctuations. Hydraulic gradient is approximately 0.08 feet/feet across the site, with an overall southerly groundwater flow direction.

1.5 Site Characterization Results

The data used in this evaluation were obtained from Alton Geoscience (1990a&b, 1991) Blaine Tech Services (1999), Alisto Engineering Group (1996, 1997), KEI Consulting Engineers (1990), Gettler-Ryan Inc (1999) and EMCON (1994). The soil sampling results and the results of the last four quarters of groundwater monitoring are presented in Appendix A.

1.5.1 Soils

Soil sample locations for the site (Appendix A, Table A-1) are shown on Figures 2 and 3. The following discusses the areal distribution of constituents found in site soils.

TPH. TPH-G has been detected at low concentrations near the former dispenser islands and product lines in the western portion of the site. The maximum detected TPH-G concentration was 33 mg/kg at RW-1 (at 25 feet bgs), which is southeast of the dispenser island, south of the former service station building. The maximum detected concentration of diesel-range organics (TPH-D) was at location TD-5 at 0.5 feet bgs. TD-5 is at the southern most dispenser island. TPH-G was also detected in one deep off-site soil location (AW-4, south of the site, 21 feet below Springfield Street) at low concentrations (1 mg/kg). No TPH-G or TPH-D were detected at the northern-most site sample (AW-6), eastern most site sample (AW-5), or along the western extent of the former dispenser islands on the northwest portion of the site.

Benzene, Toluene, Ethylbenzene, Xylenes and MTBE. Benzene was detected in approximately 50 percent of the samples collected at the site, whereas toluene, ethylbenzene and xylenes were detected in approximately 30 to 38 percent of the samples. Most of the higher benzene concentrations were detected in the "center axis" of the site, samples running the length of the site northwest to southeast (P1 through RW-1), with lower concentrations detected throughout the remainder of the site. Most of the benzene detections at the site have occurred below 7 to 10 feet bgs, with the highest detection at 25 feet bgs. Toluene, ethylbenzene, and xylene concentrations seem to show a similar trend. MTBE was only detected in a handful of locations along the former UST areas and product line samples (P2, P5, P7, SW-2, SW-3, SW-4) on the northwestern portion of the site.

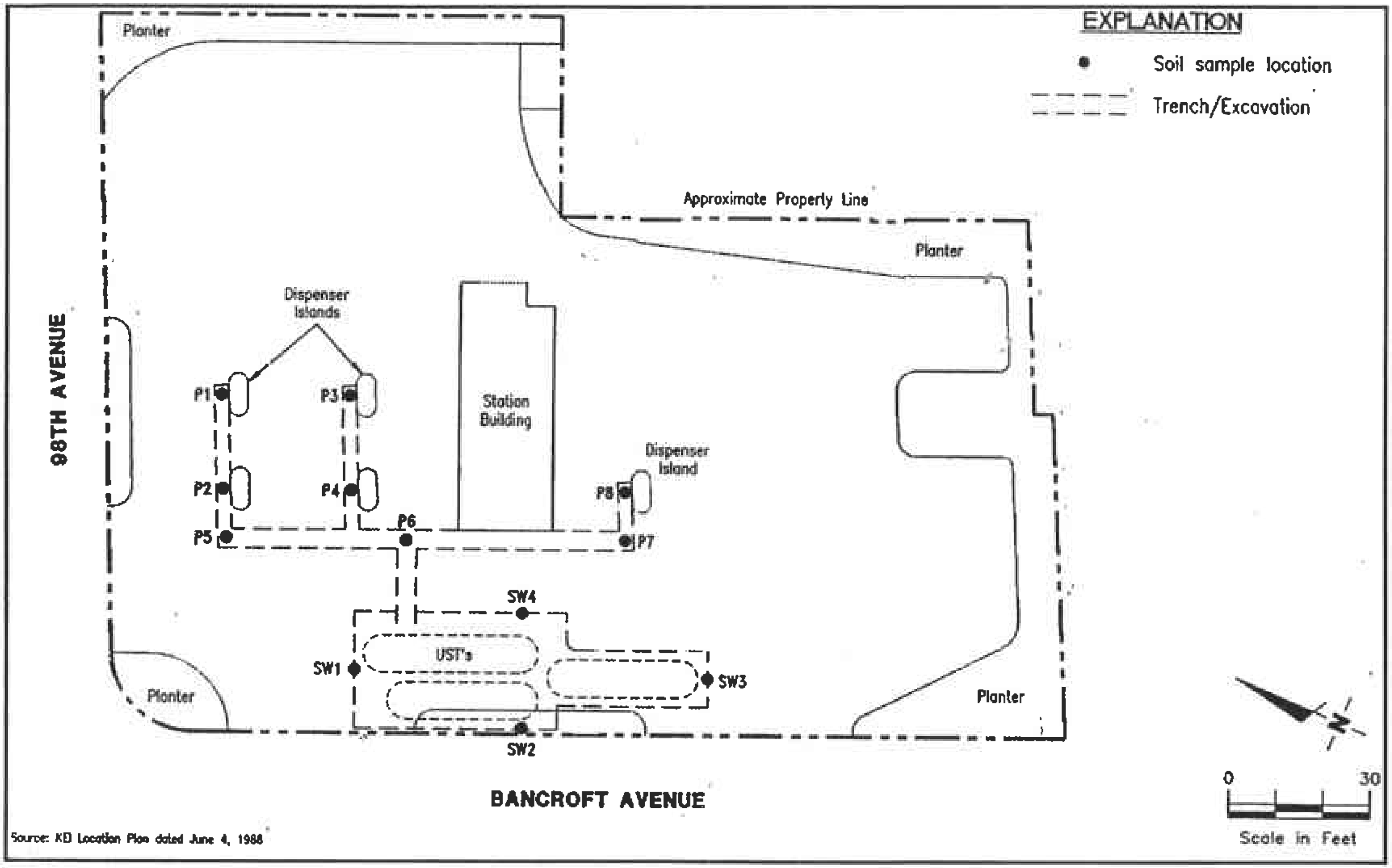
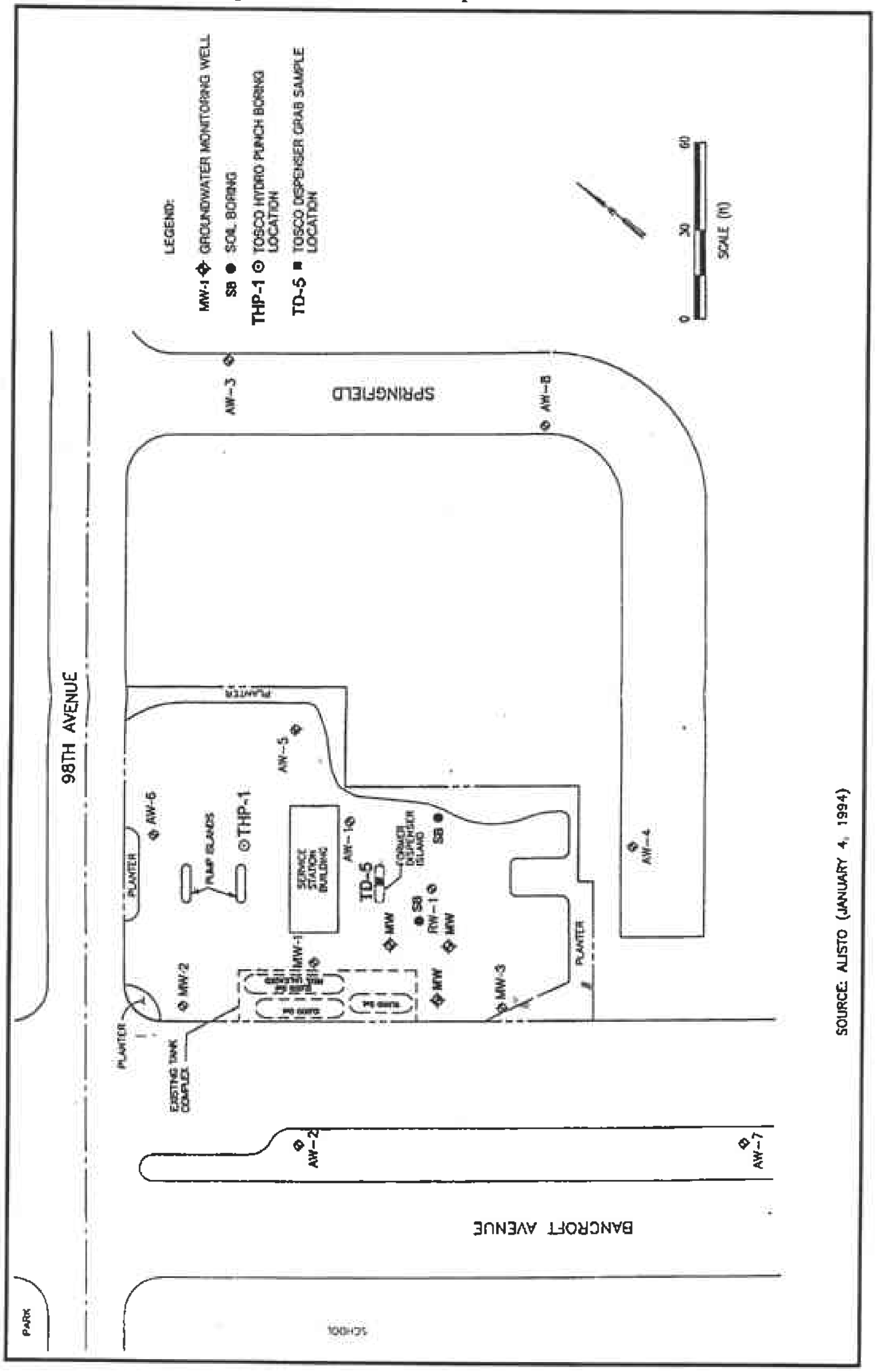


Figure 2. Soil Sample Locations – Product Lines and Dispensers

Figure 3. Monitoring Wells and Soil Sample Locations



1.5.2 Groundwater

Groundwater monitoring locations are shown on Figure 3. The following discusses the areal distribution of constituents found in groundwater in and around the site. Concentration trend charts for each well are presented in Appendix B.

Perimeter Wells. Well AW-3 (northeast of the site near the corner of Springfield Street and 98th Avenue) has had low microgram per liter (μg/L) levels of most BTEX constituents from 1991 to 1995, with generally low mg/L to high μg/L levels of TPH in the same period. Since 1995, most constituents have not been detected, and since mid-1998 all constituents have not been detected. Well AW-8, east of the site (on Springfield Street), has historically been "non-detect" for all constituents, with the occasional low μg/L detection (six out of 27 sampling events) of BTEX compounds. Since 1995, only one detection of a petroleum related compounds (MTBE; less than 1 mg/L; in 1997) has been found. Well AW-4 (southeast of the site at the end of Springfield Street) has experienced a steady decline of all constituents since 1991 to low mg/L levels of TPH and low μg/L levels of BTEX and MTBE in 1995 to non-detect levels in 1996 and 1997. Low mg/Llevels of all constituents were detected in 1999, with most dropping below detection limits again in 2000.

Well AW-9, southeast of the site beyond the residential area (Warner Avenue), has never detected petroleum constituents in the off-site groundwater. Well AW-7, south of the site along Bancroft Avenue, has historically had only a few detections of low μg/L and sub-μg/L levels of BTEX before 1993. Since 1993, no BTEX or TPH have been detected, and only one sample in 1997 had a MTBE detection of 1 mg/L. Well AW-2, west of the site (also along Bancroft Avenue), has also been an historically clean well, with only a few events detecting low μg/L and sub-μg/L levels of BTEX compounds and TPH in 1992, 1993, and 1998. In the last two years, no petroleum compounds have been detected.

Site Wells. Well AW-6, in the northern portion of the site (near 98th Avenue), has historically had only a few detections of low μg/L and sub-μg/L levels of all constituents. All constituents have been below detection levels from 1996 to 1998, with a recent detection of low mg/L levels of TPH and MTBE in 1999. Well AW-5, in the northeast portion of the site, has historically had low μg/L levels of petroleum compounds, with a decreasing trend from 1991 to 1998, dropping below detection levels in 1996. In 1998 and 2000, concentrations of all compounds have increased above detection levels to low μg/L levels (BTEX) to low mg/L levels (TPH and MTBE). Well AW-1, on the sites' western boundary (near the former service station building), has had consistent detections of petroleum compounds throughout its monitoring history, with BTEX hovering consistently in the one to 10 mg/L range, and TPH in the 10 to 40 mg/L range. During recent sampling events (2000), an increase occurred in the concentrations of both TPH-G and MTBE occurred (three-fold and 15-fold, respectively). In the most recent sampling event, TPH-G has returned to its former levels.

Well RW-1, in the southern portion of the site near the centrally located dispenser island, has also consistently detected petroleum compounds throughout its monitoring history, with BTEX consistently in the 10 to 40 mg/L range, and TPH in the 200 mg/L range. Benzene appears to have a generally decreasing trend over time, with the most significant drops in concentration occurring over the most recent monitoring events (2000). During the April 1997 sampling event, the concentrations of TPH-G, ethylbenzene and toluene more than tripled, only to return back to former levels the following sampling event. Well MW-3, in the southeastern corner of the site (near the telephone booths along Bancroft Avenue) has detected low μg/L levels of BTEX from 1992 to 1994, with concentrations dropping below detection limits from 1995 to 1997. In late 1997, BTEX concentrations increased to low mg/L levels (0.87 to 13 mg/L) for a single event, and then dropped below detection limits again, including during the most recent event. TPH-G concentrations have fluctuated between 0.5 and 1.5 mg/L increasing to 40 mg/L in late 1997, subsequently dropping back to former levels. MTBE concentrations consistently range between 0.5 and 4.3 mg/L.

Well MW-1, near the former UST area on the western portion of the site, has demonstrated a consistent downward trend of concentrations of all constituents from 1993 to the present, with brief periods of flux (increase) in the concentrations of TPH. The maximum concentrations occurred in March 1994. All constituents have dropped one to two orders of magnitude over the past six years. Well MW-2, in the northwest corner of the site, has detected petroleum compounds inconsistently between 1991 and 1994, and when found, the levels were generally below 1 μg/L . From late 1994 to 1998, all compound were below detection limits. In 1998, benzene was detected at 1 μg/L, and TPH-G was detected at 160 μg/L. TPH-G and benzene have not been detected since 1998.

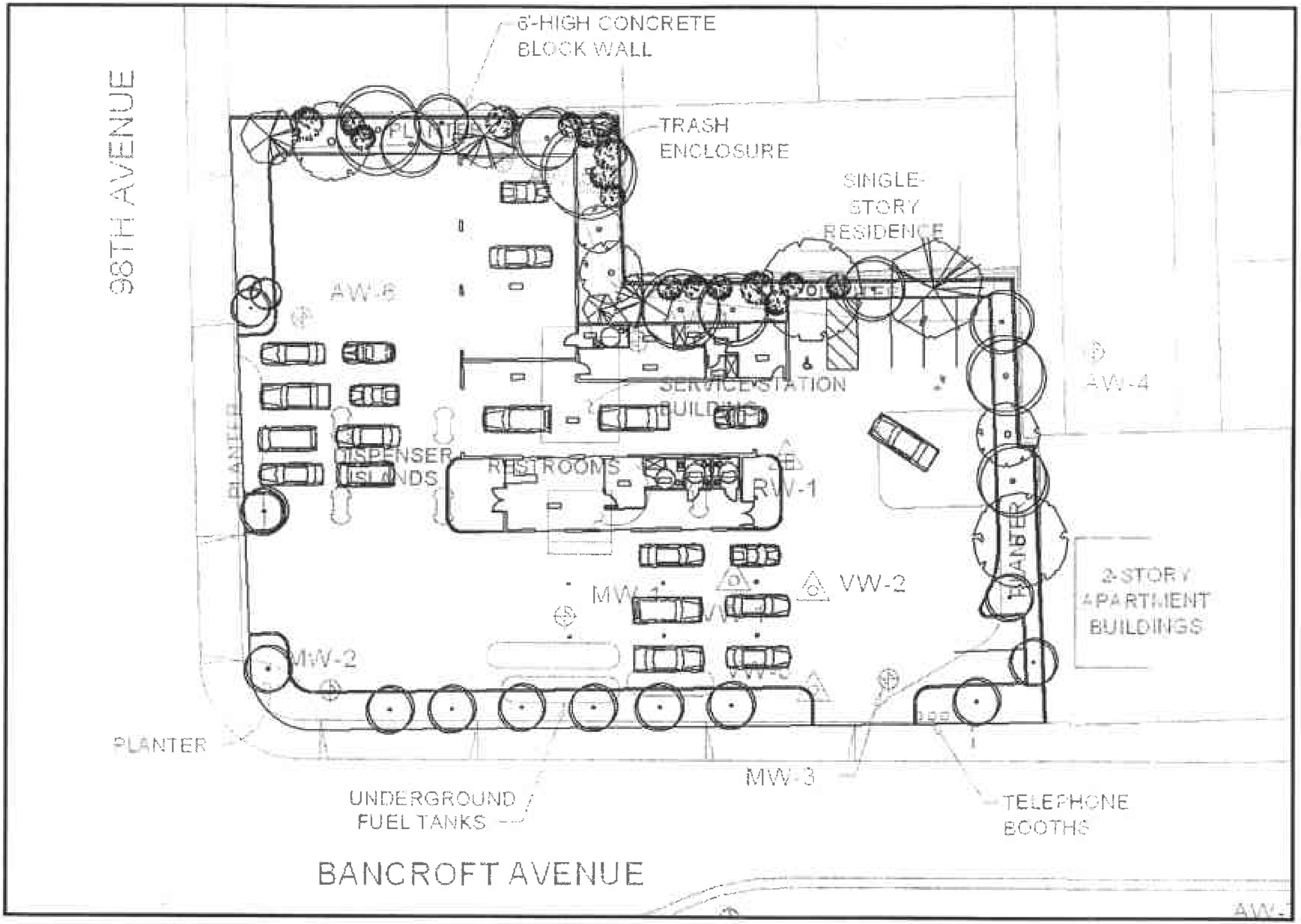
This RBCA evaluation was performed for chemicals detected at the site. Statistical summaries of the soil analytical results were done for BTEX, MTBE, and TPH-G and TPH-D. The statistical analyses performed on the data are described in Section 3.

2. RBCA TIER 1 AND TIER 2 EVALUATIONS

The Oakland and ASTM RBCA processes consist of three tiers. Using the Oakland RBCA process, the first two tiers are comparisons of site data to acceptable concentrations presented in Tier 1 and Tier 2 look-up tables. For the purposes of this analysis, Oakland RBCA Tier 1 and Tier 2 look-up values are based on conservative, generic exposure and modeling parameters, resulting in conservative risk-based screening levels considered appropriate for the site. For example, the vapor migration from soil into indoor air screening values used in the Oakland RBCA Tier 1 look-up table are based on a model by Johnson and Ettinger (1991). This model assumes that all chemical vapors below a building will enter a basement and become well-mixed once in the building. This model is widely used for screening purposes only due to its conservative assumptions.

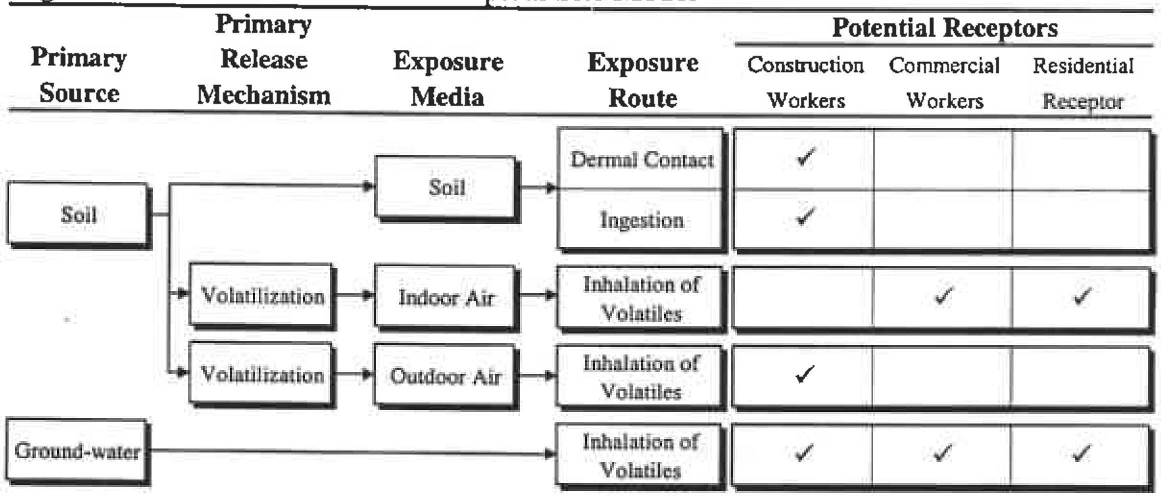
The site is currently a commercial property. Plans to build a commercial car wash on the property are underway. Because a commercial car wash is being constructed on the property, it is considered unlikely that the site will become residential any time in the near future. The car wash site plan is presented on Figure 4. Surrounding the site are residential areas. The RBCA Tier 1 evaluation considered exposures to on-site

Figure 4. Car Wash Site Plan



commercial workers, construction workers, and off-site residents. To be conservative, indirect exposures to off-site residents were evaluated without adjusting on-site concentrations of chemicals to account for migration off-site. In other words, for off-site residents, it is assumed that the concentrations to which they may be exposed are the same as the concentrations to which they would be exposed if residential units were constructed directly on the site. This is a conservative assumption because the concentrations to which off-site residents might be exposed would be lower than these estimates. For construction workers, exposures from direct contact with soils and inhalation of vapors were assessed. For commercial workers and residents, inhalation of vapors was assessed. Because the site is planned for development into a car wash and will be paved, direct soil exposures were not assessed for commercial workers or off-site residents. The conceptual site model is presented on Figure 5.

Figure 5. Tier 1 and 2 RBCA Conceptual Site Model



✓ Potentially complete exposure pathway.

Unlike the ASTM approach, the Oakland RBCA Tier 2 evaluation is much like a Tier 1 evaluation, except that the lookup values are specific to one of three soil types specific to the Oakland area: Merritt sands, sandy silts, and clayey silts. For each of these soil types, RBCA Tier 2 lookup values were calculated (by the City of Oakland Environmental Services Division) by modifying the Tier 1 soil property input parameters to reflect the properties of each of the soil types used in Tier 2 (*i.e.*, the soil properties for each of the three soil types are used to calculate new lookup values unique to each soil type).

Soil RBCA Tier 1 Evaluation

Based on the results of the Tier 1 soil evaluation, none of the constituent concentrations in soil at the site exceed the Oakland default Tier 1 look-up values except benzene for residents exposed to indoor air and TPH-G and TPH-D concentrations for all receptors because no Tier 1 values are available for TPH measurements. Because the maximum detected benzene and TPH concentrations exceeded the Tier 1 concentrations, a RBCA

Tier 2 evaluation of each in soil was performed. The results of the RBCA Tier 1 evaluation for soil are presented in Table 1.

Groundwater RBCA Tier 1 Evaluation

Based on the results of the Tier 1 groundwater evaluation, none of the constituent concentrations in groundwater at the site exceed the Oakland default Tier 1 look-up values except benzene for commercial workers and residents exposed to indoor air, and TPH-G concentrations for all receptors because no Tier 1 values are available for TPH measurements. Because the maximum detected benzene and TPH concentrations exceeded the Tier 1 concentrations, a RBCA Tier 2 evaluation of each in groundwater was performed. The results of the RBCA Tier 1 evaluation for groundwater are presented in Table 2.

Soil RBCA Tier 2 Evaluation

The soils beneath the site are predominantly silty clays, clayey silts and clayey sands. Based on these soil types, the Tier 2 values for sandy silts were used. Based on the results of the Tier 2 soil evaluation, residential exposure to benzene in indoor air was not evaluated further. Tier 2 look-up values for TPH-G and TPH-D were not available. Therefore, a RBCA Tier 3 evaluation of each in soil was performed for TPH-G and TPH-D. The results of the RBCA Tier 2 evaluation for soil are presented in Table 3.

Groundwater RBCA Tier 2 Evaluation

Based on the soil types beneath the site, the Tier 2 values for sandy silts were used. Based on the results of the Tier 2 groundwater evaluation, benzene in groundwater for commercial indoor air exposures was not evaluated further. However, maximum benzene concentrations for residential indoor air exposures exceeded Tier 2 lookup values. Because the maximum detected benzene and TPH concentrations exceeded the Tier 2 concentrations, a Tier 3 RBCA evaluation of each in groundwater was performed. The results of the Tier 2 evaluation for groundwater are presented in Table 4.

The remainder of this report presents the RBCA Tier 3 evaluation for the site. The results of the Tier 1 and 2 comparisons are presented in Tables 1 through 4. RBCA Tier 1 and 2 evaluations could not be performed for TPH because Tier 1 and 2 look-up values were not available for TPH. Therefore, the RBCA Tier 3 evaluation also includes TPH.

3. STATISTICAL EVALUATION OF CHEMICAL DATA

For the purposes of conducting statistical analyses for each chemical, non-detects were included at one-half the detection limit (EPA, 1989). For example, if benzene was not found at a detection limit of 0.005 mg/kg, a concentration of 0.0025 was used as an assumed concentration of benzene at this location. For groundwater, the four most recent quarters of monitoring data for each chemical were compiled. For each constituent, only

Use GW only source zone only

wells in which at least one sample had a positive detection in the last four quarters of analytical data were combined.

For each chemical and sampling location, the distribution of the data was determined using either the Shapiro-Wilk W Test for sample sizes less than 50, or the D'Agostino's Test for sample sizes greater than 50 (D-Test; Gilbert, 1987). Three different types of distribution profiles are possible: normal distribution, lognormal distribution, and non-parametric (*i.e.*, neither normal nor lognormal). Based on the distribution profile for each chemical, the 95 percent upper confidence limit (UCL) of the arithmetic mean was calculated. For data sets that did not fit normal or lognormal distributions, the 95 percent UCL was calculated as a normal distribution, resulting in a higher and more conservative UCL than using the non-parametric approach for these data sets. The non-parametric calculation of the 95 percent UCL tended to be lower than the estimation based on a normal distribution because of the large number of non-detect values. Therefore, using the normal distribution estimate is more conservative. That is, use of the normal distribution results in a higher estimate of exposure concentrations and consequently higher estimates of potential risks.

The purpose for using the 95 percent UCL instead of the average concentration is to account for "...the uncertainty associated with estimating the true average concentration at a site... The 95 percent UCL provides reasonable confidence that the true site average will not be underestimated" (EPA, 1992). The 95 percent UCL on the arithmetic mean was calculated following methods in EPA (1992) and Gilbert (1987). All of the chemical concentration distributions were non-parametric. For these non-parametrically distributed data, the following equation for a normal distribution was used:

$$UCL = \mu + \left(t \times \frac{s}{\sqrt{n}} \right)$$

where:

UCL	=	95 percent upper confidence limit on the arithmetic mean
μ	=	mean of the data
s	=	standard deviation of the data
t	=	t-statistic (from Gilbert, 1987)
n	=	number of samples

For the lognormally distributed data, the following equation was used:

$$UCL = e^{(\mu + 0.5s^2 + sH/\sqrt{n-1})}$$

where:

e	=	constant (base of the natural log, equal to 2.718)
μ	=	mean of the transformed data
s	=	standard deviation of the transformed data
H	=	H-statistic (from Gilbert, 1987)

For the RBCA Tier 3 evaluation, estimates of exposure point concentrations for direct soil contacts (construction workers only) are based on soil data from zero to ten feet bgs (DTSC, 1992). For certain datasets the estimated 95 percent UCL may result in a concentration higher then the maximum detected concentration. Therefore, the 95 percent UCL or the maximum detected value (whichever is lower) was the concentration used as the exposure point concentration used to assess risk from direct exposures to soil (*i.e.*, direct contact with surface soil, incidental soil ingestion). If modeling were used to evaluate the transfer of chemicals from groundwater to another media (*e.g.*, air), average values were used as model inputs. The results of the statistical analyses for soil and groundwater are presented in Tables 5 and 6.

4. RBCA TIER 3 EVALUATION

This evaluation follows a series of steps common to risk assessments. First, the ways in which people could be exposed to the chemicals are identified, and assumptions are made about the extent to which people could be exposed. Lastly, the estimated exposure rates are combined with chemical toxicity criteria to estimate the risks associated with the exposures. The differences between the RBCA Tier 3 evaluation and the RBCA Tier 2 evaluation are the use of the 95 percent UCLs as exposure point concentrations, quantification of TPH exposures and risks, use of site-specific soil parameters (see Section 4.1.5), and adjustment of the foundation thickness in the indoor air model to one inch to account for uncertainties associated with off-site residential structures.

4.1 Exposure Assessment

The exposure assessment step in a risk assessment combines information about the chemical concentrations in site media with assumptions about how a potential receptor could contact the impacted media. The result is an estimation of the level of intake, or dose, of a chemical.

In this section, the ways in which human receptors could be exposed to chemicals in soil and groundwater, and the populations of receptors that could be exposed, are identified and discussed. The concentrations of chemicals detected in soil and groundwater at locations where receptors might be exposed are identified and this information, presented in tables, is summarized. Fate and transport modeling were used to estimate potential exposure of receptors at potential receptor locations away from the currently impacted areas. Potential receptors are identified and assumptions regarding the activities of potential receptors, such as the frequency with which a person could come into contact with chemicals in soil and air, are also discussed. Finally, the methods used to estimate daily doses at the points of potential human contact, using the exposure assumptions and the chemical concentrations, are reviewed.

4.1.1 Tier 3 Conceptual Site Model

The conceptual site model is a tool used in risk assessment to describe relationships between chemicals and potentially exposed populations, thereby delineating the relationships between the suspected sources of chemicals identified at the property, the mechanisms by which the chemicals could be released and transported in the environment, and the means by which the receptors could come in contact with the chemicals. The potentially complete exposure pathways identified in the conceptual site model were carried through the risk evaluation. The conceptual site model for the Oakland site is presented on Figure 6.

Figure 6. Tier 3 RBCA Conceptual Site Model

Primary Source	Primary Release Mechanism	Exposure Media	Exposure Route	Potential Receptors: Construction Workers	Commercial Workers	Residential Receptor
Soil		Soil	Dermal Contact	✓		
			Ingestion	✓		
	Volatilization	Indoor Air	Inhalation of Volatiles		✓	✓
	Volatilization	Outdoor Air	Inhalation of Volatiles	✓		
	Leaching*	Ground-water	Inhalation of Volatiles	✓	✓	✓

✓ Potentially complete exposure pathway.
* Evaluated using the RBCA equations.

4.1.2 Land Use

To determine which receptor populations might be at risk for chemical exposure at the property, it is necessary to determine the present and potential future land use at and around the property. The site is in downtown Oakland, and is currently planned for redevelopment to a commercial carwash. Under these conditions, the exposure patterns associated with the site would include not only those associated with a commercial site, but might also include construction worker exposures. The site has thus been evaluated using construction and commercial land use assumptions for human exposure. Because some of the adjacent areas have residential development, the site has been evaluated using potential residential land use assumptions for human exposure associated with vapor transport pathways. The residential scenario is evaluated to ensure protection of current and potential future land uses for adjacent properties.

4.1.3 Potential Receptors

The identification of people who could potentially be exposed to chemicals at a site involves consideration of current and future land uses of a particular site. Because the site is in a commercial area, and is currently planned for commercial use and future use of the site will also be commercial, the most likely receptor to be exposed to chemicals in soils are on-site commercial workers (*e.g.*, convenience store workers, car wash workers) and construction workers. Because the chemicals in soil are not at the surface as well as lower exposure frequencies, this scenario would also be protective of the less intensely exposed individuals using the site (*e.g.*, visitors to the site [patrons], landscape workers). In addition, the adjacent residential receptor was also evaluated for the site.

4.1.4 Potential Exposure Pathways

An exposure pathway is a description of the ways in which a person could be exposed to chemicals and is defined by four elements: (1) a source and mechanism of chemical release to the environment; (2) an environmental transport medium (*e.g.*, air) for the released chemical; (3) a point of potential contact with the contaminated medium (the exposure point); and (4) an exposure route (*e.g.*, inhalation) at the contact point. In order for an exposure pathway to be considered complete, all four elements must be present. As presented in Figure 6, one potential exposure pathway exists for on-site commercial workers and off-site residents; inhalation of vapors volatilized from soil and groundwater. Direct contact with soil will not occur for residents or commercial workers because the site is currently paved and there are no plans for removal of the pavement. For on-site construction workers, inhalation of vapors volatilized from soil into ambient air, and direct contact with soils via incidental ingestion and dermal contact during construction activities are evaluated.

4.1.5 Fate and Transport Modeling

Indirect exposure to chemicals in soil can occur when chemicals migrate from the original media (soil) to a new media (*e.g.*, air) with which receptors could come into contact. Chemicals at a site can volatilize from impacted soil into indoor and outdoor ambient air. Predicting migration of chemicals at the site to indoor and ambient air from subsurface soil involved three models. Flux of chemicals from soil into air (as well as downward migration) is determined based on results of the use of the standard RBCA fate and transport equations presented in the Oakland and ASTM RBCA guidance documents.

In assessing the fate and transport of TPH-G and TPH-D, a "fractionation approach" was used, whereby the measurement of TPH is broken down into several indication fractions for the purposes of modeling exposure and toxicity assessment. Section 4.2.1 details this approach further.

As the soil parameters used in each of the equations are dependent upon the type of soils being assessed, it is important to identify the soil types present beneath the site. As described in Section 1.4, the primary soil types found beneath the site are silty clays, clayey silts, and sandy clays. Therefore, the soil parameters for the sandy silts and clayey silts, as identified in the Oakland RBCA guidance (1999) were used. The point value used for each parameter is the average of the parameter values for sandy silts and clayey silts. The predicted indoor and outdoor air concentrations are given in Tables 7 through 9.

In addition to modeling the infiltration of vapors from soil and groundwater through the vadose zone and into ambient and indoor air, RBCA equations were also used to evaluate whether the concentrations of BTEX, MTBE, and TPH might be expected to increase in groundwater beneath the site in the future as a result of vadose zone leaching. Results of the RBCA modeling predict that residual petroleum hydrocarbon concentrations in soils may reach groundwater beneath the site, but not in sufficient concentrations to increase the concentrations currently measured groundwater (see Table 10). The only exception to this is TPH-D, which has not yet been detected in groundwater. However, due to its limited extent in soils, and the current presence of asphalt and anticipated presence of asphalt over the site in the future, it is unlikely that sufficient infiltration by groundwater will occur to provide a means for TPH-D to reach groundwater. The following discussion provides further support for this conclusion.

The mobility of a liquid in the unsaturated zone depends upon a variety of factors, including (1) the kinematic viscosity, a physical parameter that represents the resistance of a fluid (*e.g.*, diesel) to move through soil, affecting the rate of percolation; (2) the quantity of free product released, which will affect the depth of penetration into the soil; (3) the permeability of the soil, which affects both the rate of percolation and the plume geometry; and (4) the residual saturation level of free product in the soil, which is dependent on both the soil type and the product viscosity (Dragun, 1988). Heavier petroleum hydrocarbons with higher viscosity do not penetrate as readily into soil as do lighter hydrocarbons with lower viscosity.

Because of retention by soil, the extent of migration of a particular quantity of petroleum hydrocarbons in soil is limited. As a mass of hydrocarbons migrates in the unsaturated zone, a small amount of the total hydrocarbon mass will remain adsorbed to the soil. The hydrocarbons that are retained by soil particles are considered immobile. In addition, petroleum hydrocarbons are considered to be biodegradable. In the unsaturated zone, vapor-phase molecular diffusion can maintain an oxygen supply even at depths of tens of feet bgs. This oxygen supply facilitates biodegradation. Thus, it is likely that hydrocarbon levels in the subsurface will decrease over time, further reducing vertical migration.

4.1.6 Quantification Of Exposure

The risks associated with exposure to chemicals depend not only on the concentrations of chemicals, but also on the extent to which receptors are exposed. For example, the risks associated with exposure to chemicals for one hour per day are less than those associated with exposure at the same concentrations for two hours per day. Because risks depend upon both the concentration and the extent of the exposure, the assumptions regarding the extent of exposure are discussed in this section for each of the complete exposure pathways identified above. Table 11 presents each of the exposure parameters used in this Tier 3 evaluation. All values are EPA and ASTM referenced values as selected by the Oakland RBCA process. These values are scientifically defensible and are regularly used in risk assessment. Using more site-specific data would be part of a more sophisticated Tier 3 evaluation, and would require additional site characterization.

Chemicals are grouped into carcinogens and non-carcinogens and risk are assessed differently depending on which classification a chemical has. Benzene has both carcinogenic and non-carcinogenic effects. TPH-D and TPH-G are assessed as non-carcinogens only. The lifetime average daily dose (LADD) for carcinogens and average daily dose (ADD) for non-carcinogens are estimated based on the parameters identified in Table 11, the air and soil concentrations presented in Tables 5, 7, 8 and 9, and the following equations:

$$ADD\ or\ LADD_{inhalation}(mg/kg-d) = \frac{C_{air} \times IR \times EF \times ED \times AF_i}{BW \times AT}$$

$$ADD\ or\ LADD_{dermal}(mg/kg-d) = \frac{C_{soil} \times CF \times SA \times SAF \times EF \times ED \times AF_d}{BW \times AT}$$

$$ADD\ or\ LADD_{ingestion}(mg/kg-d) = \frac{C_{soil} \times CF \times IR_s \times EF \times ED}{BW \times AT}$$

where:

C_{air}	=	chemical concentration in air (mg/m^3)
C_{soil}	=	95% UCL chemical concentration in soil (mg/kg)
CF	=	conversion factor (1×10^{-6} kg/mg)
IR	=	inhalation rate; the amount of the transport medium contacted per unit time (m^3/day)
IR_s	=	soil ingestion rate (mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AF_i	=	inhalation absorption fraction (fraction)
AT	=	averaging time; the time over which the exposure is averaged (days)
BW	=	body weight (kilograms)
AF_d	=	dermal absorption fraction (fraction)
SA	=	skin surface area exposed (cm^2/day)
SAF	=	soil-skin adherence factor (mg/cm^2)

For residential exposures, the exposure equation is calculated twice, once for adults, and once for children (using their respective exposure parameters) and the results are added together. The exposure parameter that differs between the calculation of an ADD and a LADD is averaging time (AT). A lifetime, 70 year, AT is used for the LADD while an

AT equal to exposure duration is used for the ADD. The resulting LADDs and ADDs are presented in Section 4.3 (Risk Characterization) and Tables 12 through 17.

4.2 Toxicity Assessment

Toxicity values, when available, are published by EPA in the on-line Integrated Risk Information System ([IRIS]; EPA, 1999) and by the California Office of Environmental Health Hazard Assessment (OEHHA, 1994). Cancer slope factors (CSFs) are chemical-specific, experimentally derived potency values that are used to calculate the risk of cancer resulting from exposure to potentially carcinogenic chemicals. A higher value implies a more potent carcinogen. The CSF for benzene obtained from OEHHA is more than three times greater (more conservative) than that developed by the EPA. The benzene CSF derived by OEHHA was used in this assessment. Reference Doses (RfDs) are used to evaluate exposures against non-cancer endpoints. The non-TPH RfDs were obtained from IRIS (EPA, 1999). For adverse non-cancer health effects, EPA assumes that a dose threshold exists, below which adverse effects are not expected to occur. A chronic RfD of a chemical is an estimate of an average daily dose to humans that is likely to be without appreciable deleterious non-carcinogenic effects.

4.2.1 Total Petroleum Hydrocarbons

Gasoline, diesel, motor oil and other petroleum products are complex mixtures of hydrocarbons. Once these products have been released into the environment, the composition of the mixture changes because the components have different physical and chemical properties (*e.g.*, solubility in water, volatility, and soil adsorption coefficients). These properties dictate the behavior of each component in the environment. Consequently, a receptor will not be exposed to fresh product but to a mixture of the various chemical components of petroleum hydrocarbons as they have 'weathered,' or changed in composition, during migration in the environment.

The chemical composition has not been quantitatively identified in most petroleum-based complex mixtures, such as gasoline and diesel. Routine qualitative and quantitative analyses of either commercial products or samples of impacted soil or groundwater for the purpose of establishing the chemical breakdown of hydrocarbon mixtures are currently impractical, primarily because the low potential usefulness of such data does not justify the high cost of routine chemical analysis. In addition, specific toxicity criteria that are essential to risk assessment have been developed for only a handful of the constituent hydrocarbons. The reason is that most of these hydrocarbons have not been subjected to the battery of toxicity tests required for developing the criteria.

Because a consensus method for setting cleanup levels for complex hydrocarbon mixtures has not been established, a number of different approaches that are not health-based or site-specific have been recommended by regulatory agencies. Two such approaches are:

Remediate TPH to a concentration equivalent to the practical limit of quantification (PLQ). This approach is generally considered by most environmental professionals to lack scientific basis and be an inefficient use of resources.

Remediate TPH to pre-established cleanup levels. These levels vary among regulatory agencies, and typically range between 10 and 10,000 mg/kg for soil. This approach is frequently criticized for being arbitrary and lacking scientific basis.

In an effort to move away from methods that are inefficient and lacking in scientific foundation, several approaches have been developed for the determination of more appropriate site-specific and health-based cleanup levels. Some of these approaches include:

Assess certain discrete compounds with established toxicity criteria. Typical examples of compounds included are benzene and the alkyl benzenes such as ethylbenzene, toluene, and total xylenes in gasoline, or polynuclear aromatic hydrocarbons (PAHs). The main rationale cited for this approach are: (a) these selected compounds are the predominate contributors to total risk; thus, the relative significance of other TPH constituents is low, (b) analytical procedures are well-established and affordable for individual the more toxic compounds, and (c) essential toxicity criteria have been established.

Assume the composition of residual TPH in soil is equivalent to fresh product. This approach has become feasible with the development by EPA of provisional toxicity criteria for several petroleum products, including gasoline, diesel, and jet fuels. This approach also assumes the presence of BTEX in the toxicity criteria, thus double counting the effects of BTEX, which are usually evaluated separately from TPH. In addition, petroleum products can change appreciably after release into soil due to the influence of differential rates of degradation and dispersion on individual compounds in the mixture (*i.e.*, weathering). For example, the aromatic versus the aliphatic constituents in hydrocarbon mixtures are prone to faster rates of degradation and dispersion. Therefore, the assumption that a TPH fraction in soil is equivalent to fresh product is likely to greatly overestimate risk.

The fractionation approach. This approach accounts for the differential weathering of petroleum hydrocarbons and estimation of risks of mixtures for which toxicity data are not available. The approach consists of a) fractionation of fuel products into chemical families or fractions, b) selection of surrogate chemicals that are considered representative of each fraction, c) normalization of surrogate chemicals to represent all chemicals within a fraction, d) fate and transport modeling of the surrogate chemicals, and e) risk characterization of the surrogate chemicals.

In order to develop risk-based screening benchmark values for petroleum hydrocarbons in soil for the Oakland site, the fractionation approach developed by the Massachusetts Department of Environmental Protection (MaDEP) in which the total mass of petroleum hydrocarbons is separated into aromatic and aliphatic fractions, is used. For each quantifiable analytical fraction, a "reference" toxicity value is assigned to conservatively represent the toxicity of that fraction. The utility of the MaDEP fractionation approach is its applicability to all forms of petroleum products, whether fresh or weathered. The environmental fractions identified using this approach are aliphatics (alkanes) and aromatics.

MaDEP recommended product-specific fractions and toxicity criteria for each fraction were used to develop the human health screening benchmark values. In the absence of site-specific TPH fractionation analytical data, composition recommendations for TPH as gasoline (TPH-g) and TPH as diesel (TPH-d) from the MaDEP are used to determine the percent of each fraction present in the environment. The product-specific fractions, fraction composition for each petroleum product, and toxicity criteria for each fraction used in the Tier 3 evaluation are presented in Table 18.

4.3 Risk Characterization

In the last step of a risk assessment, the estimated rate at which a person intakes a chemical is compared with information about the toxicity of that chemical to estimate the potential risks to human health posed by exposure to the chemical. This step is known as the risk characterization.

For carcinogens, risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of a chemical exposure. Theoretical upper-bound incremental lifetime cancer risks are evaluated by multiplying the estimated average exposure rate (*i.e.*, LADD) by the chemical's CSF. The CSF converts estimated daily intakes averaged over a lifetime to the incremental risk of an individual developing cancer. Theoretical upper-bound incremental lifetime cancer risk estimates are compared to EPA's acceptable risk range of one in one million (10^{-6}) to one in ten thousand (10^{-4}). A risk level of 10^{-5} is consistent with Oakland RBCA process for risk management decisions. A risk level of 1×10^{-5} represents a probability of one in one hundred thousand that an individual could develop cancer from exposure to the potential carcinogen under a defined set of exposure assumptions.

For non-carcinogenic health effects, a Hazard Index (HI) is used to evaluate exposure relative to a toxicity reference value. The HI is calculated by dividing the average exposure rate (ADD) by the chemical-specific RfD. An HI of 1.0 is typically used as an acceptable hazard level.

The pathway, location, and chemical or TPH fraction-specific HIs and theoretical upper-bound incremental lifetime cancer risks are presented in Tables 12 through 17. A summary of the HIs and risk estimates is presented in Table 19.

4.4 Uncertainty Analysis

Risk estimates are values that have uncertainties associated with them. These uncertainties, which arise at every step of a risk assessment, are evaluated to provide an indication of the relative degree of uncertainty associated with a risk estimate. In this section, a qualitative discussion of the uncertainties associated with the estimation of risks for the site is presented.

Risk assessments are not intended to estimate actual risks to a receptor associated with exposure to chemicals in the environment. Risk assessment is a means of estimating the probability that an adverse health effect (e.g., cancer, and impaired reproduction) will occur in a receptor. The multitude of conservative assumptions used in risk assessments guard against underestimation of risks.

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

It is possible to quantify the uncertainty in a risk assessment through the use of Monte Carlo simulations in the risk calculations. Risk assessments with quantitative uncertainty analyses are called "probabilistic evaluations." Instead of calculating risks using point estimates, which are often upper-bound values, for each parameter, as was done at the facility, a probability distribution function representing a range of data is used. A computer model performs the risk calculations up to 10,000 times, and each iteration incorporates a different combination of data from the various probability distribution functions. The result is a distribution of risks instead of a single value.

In general, theoretical upper-bound risks calculated in probabilistic risk assessments are lower and more realistic than those calculated in deterministic evaluations, and because the result is a distribution and not a point estimate, there is a greater level of certainty associated with the calculated risks. Regulatory agencies recognize the usefulness of a quantitative uncertainty analysis. However, the use of probabilistic methods is beyond the scope of this Oakland RBCA Tier 3 evaluation.

4.4.1 Uncertainty in Site Characterization

Uncertainty can exist in characterizing the nature and extent of the petroleum impacts on soils at the site. In an effort to reduce this uncertainty, multiple samples were collected from the site. The number of sampling locations and events is large and spans several years; therefore, the sampling and analysis data should be sufficient to characterize the distribution of petroleum hydrocarbons and the associated potential risks.

4.4.2 Soil Sampling Bias

The RBCA evaluation was based on data obtained during site characterization activities. Most data collected was focused on finding and delineating petroleum hydrocarbons in soil at the gasoline and diesel fueling systems. Sampling plans are designed to be efficient in defining the vertical and horizontal extent of petroleum hydrocarbons in soil. Thus, more samples are collected from impacted areas than non-impacted areas. This adds additional conservative bias to the evaluation, given that the assumed exposure concentration actually only make up a portion of the site, while actual exposure patterns would cover the whole site.

4.4.3 Uncertainty in the Exposure Assessment

Exposure assessment inputs used in this evaluation, and typically in risk assessments in general, attempt to incorporate reasonable maximum exposure assumptions to protect individuals likely to have the highest exposure. Therefore, while there is a great deal of variability and uncertainties in these exposure inputs because they are high-end assumptions, they would likely tend to overestimate rather than underestimate exposure to most individuals. In addition, no attempt was made to predict biodegradation or environmental decay of petroleum constituents. However, over the exposure durations used in the evaluation, some decrease in concentrations would be expected. A decrease in concentrations over time would lead to decreased risk. Therefore, the steady state assumption used in this evaluation would tend to overestimate risk.

In addition, there are Occupational Safety and Health Administration (OSHA) training requirements for workers engaged in construction activities at retail gasoline outlets. Proper adherence to OSHA requirements will enable a worker to take appropriate actions to mitigate potential chemical exposures.

Use of fate and transport models, in general, introduces some degree of uncertainty in any analysis In particular, environmental transport models were used in this evaluation to estimate partitioning of chemicals from soil. Uncertainties result both from any model's limited ability to predict complicated, constantly changing environmental conditions, as well as in the input parameters used to solve the models.

4.4.4 Toxicological Data and Dose Response Extrapolations

The availability and quality of toxicological data is another source of uncertainty in the risk assessment. Uncertainties associated with animal and human studies may have influenced the toxicity criteria. Carcinogenic criteria are classified according to the amount of evidence available that suggests human carcinogenicity. EPA assigns each carcinogen a designation of A through E, dependent upon the strength of the scientific evidence for carcinogenicity.

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 CSFs, which results in the likelihood that the risk is overstated. Even if studies of chemical effect in humans are available (*e.g.*, for benzene), they generally are for workplace exposures far in excess of those expected in the environment. Uncertainties can be large because the activity patterns, exposure duration and frequency, individual susceptibility, and dose may not be the same in the study populations as in the individuals exposed to environmental concentrations. Because conservative methods are used in developing the toxicity criteria, the possibility of underestimating risks is low.

5. SUMMARY

5.1 Risk Assessment Results

2220 - 98th

NewFields, Inc., has evaluated the potential risks to human health posed by BTEX, MTBE, and TPH in soil and groundwater at 3101 98th Avenue, Oakland, California. To ensure that human health is adequately protected, conservative concentrations, exposure parameters, and toxicity assumptions were used in estimating exposure potential and risks. Results of the RBCA Tier 1 and Tier 2 evaluations indicate that concentrations of toluene, ethylbenzene, xylenes, and MTBE in soil and groundwater should not pose a risk to construction workers, and that concentrations of benzene, toluene, ethylbenzene, xylenes, and MTBE should not pose a risk to commercial workers or off-site residents. Results of the RBCA Tier 2 evaluation indicate that levels of benzene in soil should not pose a risk to current and future on-site workers or residents.

Results of the RBCA Tier 3 evaluation indicate that levels of benzene in groundwater and TPH in soil and groundwater should not pose a risk to current and future on-site workers or off-site residents. The concentrations of chemicals to which individuals could potentially be exposed were based on available measured data and estimation of indoor air and outdoor air concentrations. This evaluation indicates that the theoretical upper-bound incremental lifetime cancer risk levels for benzene are below 10^{-5}, and well within or below the EPA acceptable cancer risk range of 10^{-4} to 10^{-6}. The evaluation indicates that the HI levels are below the acceptable level of 1.0. Because these values are less than 1.0, adverse non-carcinogenic health effects are not likely to be associated with the site.

Results of the risk assessment also served as a basis for the development of site-specific target level (SSTLs). The SSTLs calculated for each receptor were compared to the concentrations measured at the site and presented in Tables 12 through 17. Construction, commercial, and residential scenarios were evaluated and soil 95 percent UCL concentrations and groundwater average plume concentrations at the site are below their respective SSTLs.

It is important to note, that although some specific sample locations may have detected concentrations greater than the SSTLs, it is inappropriate to compare individual sample results to the SSTLs. Rather, the 95 percent UCL concentrations should be used for determining whether conditions at the site pose a risk to workers. There are two reasons why it is more appropriate to use the 95 percent UCL versus a single sample result: (1) any risk-based cleanup levels developed for the site are derived using toxicity criteria that are based on lifetime average exposures; and (2) the 95 percent UCL concentration is more representative of the concentration that would be contacted at the site over time (EPA, 1992). That is, a person would not expect to be exposed to soil at a single point on the site, rather they would be exposed to soil over an area of the site.

Chapter 2 of DTSC's supplemental guidance states, "Estimates of chemical concentrations in soil are to be derived using these principles for all state-lead sites..." (DTSC, 1992). Chapter 2 recommends calculating a 95 percent UCL for "an appropriate-sized area..." (DTSC, 1992). For a commercial site, this area of exposure may be very large and may in fact consist of the entire site. Risk assessors within both EPA and DTSC support and endorse this position. EPA and DTSC have consistently used this approach at other sites in California. There are numerous examples of sites where the 95 percent UCL was used to determine whether further action was warranted that were approved by DTSC. Scientists at DTSC's Office of Scientific Affairs should be contacted for supporting information regarding this issue.

5.2 *Nuisance Analysis*

In addition to standard health risk and hazard analyses, an analysis of the "nuisance hazard" was conducted. In conducting the nuisance analysis, the odor threshold for each COPC for which a Tier 3 RBCA evaluation was conducted was identified. These odor thresholds were considered "nuisance thresholds," that is, any air concentration of a COPC which exceeded its odor threshold would be considered a "nuisance." The odor thresholds identified for TPH-G (gasoline), TPH-D (diesel fuel oil), and benzene are listed in Tables 12 through 17. The ratio of the air concentration estimates for each COPC to the odor threshold was called the "nuisance index." Although it would not be indicative of a health hazard, any nuisance index that exceeded 1.0 (air concentration estimate equal to or greater than the odor threshold) would be considered a nuisance. As shown in Tables 12 through 17, none of the estimated air concentrations for benzene, TPH-G, or TPH-D were within four orders of magnitude of their respective odor thresholds. Or, in other terms, the estimated air concentrations for each COPC were 10,000 times less than their odor thresholds. Therefore, in addition to not posing a risk, residual hydrocarbons present in both soil and groundwater at the site are not considered to pose a nuisance to current and future on-site workers or off-site residents.

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Table 1. Soil RBCA Tier 1 Analysis

	Soil Concentration (mg/kg)[a]						
	Benzene	**Toluene**	**Ethyl-benzene**	**Xylenes**	**MTBE**	**TPH-G**	**TPH-D**
Minimum	0.01	0.01	0.003	0.01	0.10	1.00	3,900
Mean	0.08	0.04	0.025	0.14	0.5	3.0	--
Maximum	1.0	0.71	0.520	3.0	4.0	33.0	3,900
Location of Maximum	RW-1@25[c]	RW-1@25[c]	P3@2.5[d]	P3@2.5[d]	P3@3.5[d]	RW-1@25[c]	TD-5-0.5[e]
Soil Direct Contact-Construction							
Tier 1 level (Oakland-RBCA)[b]	195.0	5,833	3,438	31,250	177	NA	NA
Proceed to Tier 2?	No	No	No	No	No	**Yes**	**Yes**
Soil to Outdoor Air-Construction							
Tier 1 level (Oakland-RBCA)[b]	18.3	SAT	SAT	SAT	SAT	NA	NA
Proceed to Tier 2?	No	No	No	No	No	**Yes**	**Yes**
Soil to Enclosed Space Air-Workers							
Tier 1 level (Oakland-RBCA)	1.1	SAT	SAT	SAT	SAT	NA	NA
Proceed to Tier 2?	No	No	No	No	No	**Yes**	**Yes**
Soil to Enclosed Space Air-Residents							
Tier 1 level (Oakland-RBCA)	0.069	SAT	SAT	SAT	SAT	NA	NA
Proceed to Tier 2?	**Yes**	No	No	No	No	**Yes**	**Yes**

[a]From soil sampling for the site.
[b]Construction benzene Tier 1 level was calculated using construction worker exposure parameters (480 mg/day ingestion, exposure duration of 1 year).
[c]Alton Geoscience (1990b) .
[d]Gettler-Ryan Inc (1999) .
[e]EMCON (1994).
SAT = soil saturation concentration

Go to table 3, Tier 2 Analysis

Table 2. Groundwater RBCA Tier 1 Analysis

	Groundwater Concentration (µg/L)[a]						
	Benzene	**Toluene**	**Ethyl-benzene**	**Xylenes**	**MTBE**	**TPH-G**	**TPH-D**
Minimum	1	6.6	1.4	2	23.0	60	ND
Mean	2,811	6,272	1,332	5,906	2,779	36,492	ND
Maximum	19,000	46,000	5,800	28,000	37,000	330,000	ND
Location of Maximum	RW-1	RW-1	RW-1	RW-1	AW-1	AW-1	NA
GW to Outdoor Air-Construction							
Tier 1 level (Oakland)[b]	525,000	>Sol	>Sol	>Sol	>Sol	NA	NA
Proceed to Tier 2	No	No	No	No	No	Yes	No
GW to Indoor Air-Commercial							
Tier 1 level (Oakland)	1,800	>Sol	>Sol	>Sol	>Sol	NA	NA
Proceed to Tier 2	Yes	No	No	No	No	Yes	No
GW to Enclosed Space Air-Residential							
Tier 1 level (Oakland)	110	210,000	>Sol	>Sol	>1,000,000	NA	NA
Proceed to Tier 2	Yes	No	No	No	No	Yes	No

[a]From groundwater sampling for the site; the last 4 quarters where the constituent was analyzed (Blaine Tech Sevices, 1999)

[b]Construction benzene Tier 1 level was adjusted to reflect the difference between the construction worker exposure duration (1 year) versus the commercial worker exposure duration (assumed to be 25 years).

> Sol = the acceptable concentration is greater than the constituent's solubility in water. The constituent's solubility was not exceeded by the maximum detected concentration

Go to Table 4
Tier 2 analysis

Table 3. Soil RBCA Tier 2 Analysis

	Concentration (mg/kg)[a]		
	Benzene	TPH-G	TPH-D
Minimum	0.01	1.00	3,900
Mean	0.08	3.0	--
Maximum	1.00	33.0	3,900
Location of Maximum	RW-1@25[d]	RW-1@25[d]	TD-5-0.5[e]
Soil Direct Contact-Construction			
Tier 2 level (Oakland-RBCA-Sandy Silts)[b,c]	NA	NA	NA
Proceed to Tier 3	NA	**Yes**	**Yes**
Soil to Outdoor Air-Construction			
Tier 2 level (Oakland-RBCA-Sandy Silts)[b,c]	NA	NA	NA
Tier 2 level (Cal-EPA adjusted)[d]	NA	--	--
Proceed to Tier 3	NA	**Yes**	**Yes**
Soil to Enclosed Space Air-Workers			
Tier 2 level (Oakland-RBCA-Sandy Silts)	NA	NA	NA
Proceed to Tier 3	NA	**Yes**	**Yes**
Soil to Enclosed Space Air-Residents			
Tier 2 level (Oakland-RBCA-Sandy Silts)	1.1	NA	NA
Proceed to Tier 3	No	**Yes**	**Yes**

[a]From soil sampling for the site.

[b]Construction benzene Tier 1 level was adjusted to reflect the difference between the construction worker exposure duration (1 year) versus the commercial worker exposure duration (assumed to be 25 years).

[c]Sandy Silts Tier 2 values are used because they are considered the most appropriate based on the soil types beneath the site.

[d]Alton Geoscience (1990b).

[e]EMCON (1994).

SAT = soil saturation concentration

Table 4. Groundwater RBCA Tier 2 Analysis

	Concentration (µg/L)[a]	
	Benzene	**TPH-G**
Minimum	1	60
Mean	2,811	36,492
Maximum	19,000	330,000
Location of Maximum	RW-1	AW-1
<u>GW to Outdoor Air-Construction</u>		
Tier 2 level (Oakland-Sandy Silts)[b,c]	NA	NA
Tier 2 level (Cal-EPA adjusted)[d]	NA	--
Proceed to Tier 3	NA	**Yes**
<u>GW to Indoor Air-Commercial</u>		
Tier 2 level (Oakland-Sandy Silts)[c]	53,000	NA
Proceed to Tier 3	No	**Yes**
<u>GW to Enclosed Space Air-Residential</u>		
Tier 2 level (Oakland-Sandy Silts)[c]	3,400	NA
Proceed to Tier 3	Yes	**Yes**

[a]From groundwater sampling for the site; the last four quarters where the constituent was analyzed-see text.

[b]Construction benzene Tier 2 level was adjusted to reflect the difference between the construction worker exposure duration (1 year) versus the commercial worker exposure duration (assumed to be 25 years).

[c]Sandy Silts Tier 2 values are used because they are considered the most appropriate based on the soil types beneath the site.

Table 5. Soil Statistical Analysis

	Soil Concentration (mg/kg)[a]						
	Benzene	**Toluene**	**Ethyl-benzene**	**Xylenes**	**MTBE**	**TPH-G**	**TPH-D**
Soil (all depths)							
Samples	58	58	58	58	16	58	2
Detections	29	19	19	22	5	11	1
Detection Frequency	50%	33%	33%	38%	31%	19%	50%
Minimum Detection	0.01	0.01	0.030	0.01	0.10	1.00	3,900
Mean	0.14	0.10	0.061	0.29	0.5	9.20	NA
Maximum Detection	1.0	0.71	0.520	3.0	4.0	33	3,900
Standard Deviation	0.28	0.18	0.12	0.73	* 1.59	8.79	NA
Distribution	Lognormal	Lognormal	Lognormal	Lognormal	Normal	NP	NA
95% UCL	0.407	0.418	0.18	1.23	2.97	8.68	3,900
Soil (0-10 feet)							
Samples						23	2
Detections						8	1
Detection Frequency						35%	50%
Minimum Detection						1.20	3,900
Mean-Detects						8.3	NA
Mean						8.3	NA
Maximum Detection						23.0	3,900
Standard Deviation						7.46	NA
Distribution						Normal	NA
95% UCL						13.2	3,900

* Determined assuming the underlying distribution of the data is normal. See text

[a]Half the detection limit was used for non-detect values.

NP = Non-parametric

NA= not applicable

Table 6. Groundwater Statistical Analysis

	Groundwater Concentration (µg/L)[a]						
	Benzene	**Toluene**	**Ethyl-benzene**	**Xylenes**	**MTBE**	**TPH-G**	**TPH-D**
Groundwater							
Minimum Detection	1.0	6.60	1.40	2.0	23.0	60	ND
Mean	2,811	6,272	1,332	5,906	2778.8	36,492	ND
Maximum Detection	19,000	46,000	5,800	28,000	37,000.0	330,000	ND
Standard Deviation	5,519	14,194	1,580	9,315	6,867	72,598	ND
Distribution	NP	NP	NP	NP	NP	NP	ND
95% UCL	4,587*	11,759*	1,885*	9,165*	4,839*	57,026*	ND

* Determined assuming the underlying distribution of the data is normal

[a] Data used are the last four quarters of sampling where samples were collected. Only those wells which had at least one detection for the constituent were used. Half the detection limit was used for non-detect values.

NP = Non-parametric

ND = not detected

Table 7. Vapor Diffusion Model - Subsurface Soil to Ambient and Indoor Air[a]

Parameter	Abbrev.	Units	TPH-G: C5-C8 aliphatics Outdoor	Indoor Resident	Indoor Commercial
Henry's law constant[b]	H	unitless	42.64	42.64	42.64
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.35	0.35	0.35
Volumetric air content in crack[b]	θ_{acrack}	cm^3/cm^3	0.26	0.26	0.26
Volumetric water content in crack[b]	θ_{wcrack}	cm^3/cm^3	0.12	0.12	0.12
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45
Diffusion coefficient in water[b]	D^{wat}	cm^2/s	1.0 E-5	1.0 E-5	1.0 E-5
Vapor phase diffusion coefficient in air[b]	D^{air}	cm^2/s	0.100	0.100	0.100
Effective diffusion coefficient-soil[c]	D^{eff}_s	cm^2/s	4.6 E-4	4.9 E-4	4.9 E-4
Effective diffusion coefficient-crack[c]	D^{eff}_{crack}		5.2 E-3	5.2 E-3	5.2 E-3
Wind speed[d]	U_{air}	cm/s	322.0	--	--
Mixing zone height[b]	δ_{air}	cm	200	--	--
Partition coefficient for organic carbon[e]	k_{oc}	cm^3/g	1,778	1,778	1,778
Organic carbon content of soil[b]	f_{oc}	--	1.8%	1.8%	1.8%
Sorption coefficient[f]	k_s	cm^3/g	31.12	31.12	31.12
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5
Depth to subsurface soil sources[d]	L_S	cm	237.7	237.74	237.7
Width of source area parallel to wind[d]	W	cm	2,286	--	--
Enclosed space air exchange rate[b]	ER	sec^{-1}	--	5.6 E-4	1.4 E-3
Enclosed space volume/infiltration area ratio[g]	L_B	cm	--	2.3 E+2	3.1 E+2
Enclosed space or wall thickness[b]	L_{crack}	cm	--	15	15
Areal fraction of cracks in foundations/walls[b]	η	cm^2/cm^2	--	0.001	0.001
Soil to ambient air volatilization factor[h]	VF	$(mg/m^3)/(mg/kg)$	8.4 E-5	3.0 E-4	9.1 E-5
Concentration in soil[d]	C_s	mg/kg	3.0	3.0	3.0
Ambient air concentration[i]	C_{air}	mg/m^3	2.5 E-4	9.2 E-4	2.8 E-4

Table 7. Vapor Diffusion Model - Subsurface Soil to Ambient and Indoor Air[a]

Parameter	Abbrev.	Units	TPH-G: C9-C18 aliphatics			TPH-G: C9-C22 aromatics		
			Outdoor	Indoor Resident	Indoor Commercial	Outdoor	Indoor Resident	Indoor Commercial
Henry's law constant[b]	H	unitless	250.51	250.51	250.51	0.17	0.17	0.17
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13	0.13	0.13	0.13
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.35	0.35	0.35	0.35	0.35	0.35
Volumetric air content in crack[b]	θ_{acrack}	cm^3/cm^3	0.26	0.26	0.26	0.26	0.26	0.26
Volumetric water content in crack[b]	θ_{wcrack}	cm^3/cm^3	0.12	0.12	0.12	0.12	0.12	0.12
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45	0.45	0.45	0.45
Diffusion coefficient in water[b]	D^{wat}	cm^2/s	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5
Vapor phase diffusion coefficient in air[b]	D^{air}	cm^2/s	0.100	0.100	0.100	0.100	0.100	0.100
Effective diffusion coefficient-soil[c]	D^{eff}_s	cm^2/s	4.6 E-4	4.9 E-4	4.9 E-4	4.6 E-4	4.9 E-4	4.9 E-4
Effective diffusion coefficient-crack[c]	D^{eff}_{crack}		5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3
Wind speed[d]	U_{air}	cm/s	322.0	--	--	322.0	--	--
Mixing zone height[b]	δ_{air}	cm	200	--	--	200	--	--
Partition coefficient for organic carbon[e]	k_{oc}	cm^3/g	341,455	341,455	341,455	4,217	4,217	4,217
Organic carbon content of soil[b]	f_{oc}	--	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
Sorption coefficient[f]	k_s	cm^3/g	5975.46	5975.46	5975.46	73.80	73.80	73.80
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5	1.5	1.5	1.5
Depth to subsurface soil sources[d]	L_S	cm	237.7	237.74	237.7	237.7	237.74	237.7
Width of source area parallel to wind[d]	W	cm	2,286	--	--	2,286	--	--
Enclosed space air exchange rate[b]	ER	sec^{-1}	--	5.6 E-4	1.4 E-3	--	5.6 E-4	1.4 E-3
Enclosed space volume/infiltration area ratio[g]	L_B	cm	--	2.3 E+2	3.1 E+2	--	2.3 E+2	3.1 E+2
Enclosed space or wall thickness[b]	L_{crack}	cm	--	15	15	--	15	15
Areal fraction of cracks in foundations/walls[b]	η	cm^2/cm^2	--	0.001	0.001	--	0.001	0.001
Soil to ambient air volatilization factor[h]	VF	$(mg/m^3) / (mg/kg)$	2.9 E-6	1.0 E-5	3.1 E-6	1.6 E-7	5.9 E-7	1.8 E-7
Concentration in soil[d]	C_s	mg/kg	2.17	2.17	2.17	3.47	3.47	3.47
Ambient air concentration[i]	C_{air}	mg/m^3	6.2 E-6	2.3 E-5	6.8 E-6	5.6 E-7	2.1 E-6	6.2 E-7

Table 7. Vapor Diffusion Model - Subsurface Soil to Ambient and Indoor Air[a]

Parameter	Abbrev.	Units	TPH-D: C9-C18 aliphatics			TPH-D: C9-C22 aromatics		
			Outdoor	Indoor Resident	Indoor Commercial	Outdoor	Indoor Resident	Indoor Commercial
Henry's law constant[b]	H	unitless	250.51	250.51	250.51	0.17	0.17	0.17
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13	0.13	0.13	0.13
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.35	0.35	0.35	0.35	0.35	0.35
Volumetric air content in crack[b]	θ_{acrack}	cm^3/cm^3	0.26	0.26	0.26	0.26	0.26	0.26
Volumetric water content in crack[b]	θ_{wcrack}	cm^3/cm^3	0.12	0.12	0.12	0.12	0.12	0.12
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45	0.45	0.45	0.45
Diffusion coefficient in water[b]	D^{wat}	cm^2/s	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5	1.0 E-5
Vapor phase diffusion coefficient in air[b]	D^{air}	cm^2/s	0.100	0.100	0.100	0.100	0.100	0.100
Effective diffusion coefficient-soil[c]	D^{eff}_s	cm^2/s	4.6 E-4	4.9 E-4	4.9 E-4	4.6 E-4	4.9 E-4	4.9 E-4
Effective diffusion coefficient-crack[c]	D^{eff}_{crack}		5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3	5.2 E-3
Wind speed[d]	U_{air}	cm/s	322.0	--	--	322.0	--	--
Mixing zone height[b]	δ_{air}	cm	200	--	--	200	--	--
Partition coefficient for organic carbon[e]	k_{oc}	cm^3/g	341,455	341,455	341,455	4,217	4,217	4,217
Organic carbon content of soil[b]	f_{oc}	--	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
Sorption coefficient[f]	k_s	cm^3/g	5975.46	5975.46	5975.46	73.80	73.80	73.80
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5	1.5	1.5	1.5
Depth to subsurface soil sources[d]	L_S	cm	15.2	15.2	15.2	15.2	15.2	15.2
Width of source area parallel to wind[d]	W	cm	305	--	--	305	--	--
Enclosed space air exchange rate[b]	ER	sec^{-1}	--	5.6 E-4	1.4 E-3	--	5.6 E-4	1.4 E-3
Enclosed space volume/infiltration area ratio[g]	L_B	cm	--	2.3 E+3	9.4 E+3	--	2.3 E+3	9.4 E+3
Enclosed space or wall thickness[b]	L_{crack}	cm	--	15	15	--	15	15
Areal fraction of cracks in foundations/walls[b]	η	cm^2/cm^2	--	0.001	0.001	--	0.001	0.001
Soil to ambient air volatilization factor[h]	VF	$(mg/m^3) / (mg/kg)$	6.0 E-6	1.1 E-6	1.0 E-7	3.4 E-7	6.0 E-8	5.9 E-9
Concentration in soil[d]	C_s	mg/kg	2,535	2,535	2,535	1,365	1,365	1,365
Ambient air concentration[i]	C_{air}	mg/m^3	1.5 E-2	2.7 E-3	2.6 E-4	4.6 E-4	8.3 E-5	8.0 E-6

Table 7. Vapor Diffusion Model - Subsurface Soil to Ambient and Indoor Air[a]

-- = parameter not required for this model.

[a]ASTM, 1995, Oakland RBCA (1999)

[b]Oakland RBCA (1999) default value. The soils beneath the site are predominantly silty clay; therefore, soil parameters of the sandy silt and clayey silt parameters.

[c]$D^{air} \times (\theta_{as}^{3.33}/\theta_T^2) + D^{wat} \times (1/H) \times (\theta_{ws}^{3.33}/\theta_T^2)$.

[d]Based on site data.

[e]Based on available scientific literature.

[f]$f_{oc} \times k_{oc}$.

[g] For TPH-G estimates, the default is used. For TPH-D, only one sample had detected TPH-D. Because of the limited a to be impacted by TPH-D, it is assumed that an area 10' by 10' is impacted with TPH-D. For commercial buildings, Bu Building Volume/(Building Area Over Plume). Building dimensions (W × L × H) = 36' × 86' × 10', where 100 ft^2 is the of the building which is assumed to extend over impacted soils. For residential area, the DTSC residential lot size of 1 is assumed, of which, 100 ft^2 is assumed to be the amount of the building (10%) over the TPH-D soils.

[h]$(H \times \rho_s) / ((\theta_{ws} + k_s \times \rho_s + H \times \theta_{as}) \times (1 + ((U_{air} \times \delta_{air} \times L_S) / (D^{eff}_s \times W)))) \times 1{,}000\ cm^3\text{-}kg/m^3\text{-}g$ (indoor).

$1000\ L/m^3 \times H \times [D_{eff,ws}/(L_{GW} \times ER \times L_B)]/[1 + D_{eff,ws})/(L_{GW} \times ER \times L_B) + (D_{eff,ws} \times L_{crack})/(L_{GW} \times D_{eff,crack} \times \eta)]$ (outdoor).

[i]$C_s \times VF$.

Table 8. Vapor Diffusion Model - Groundwater to Indoor Air[a]

Parameter	Abbrev.	Units	Benzene	TPH-G: C5-C8 aliphatics	
			Resident	Resident	Commercial
Henry's law constant[b]	H	unitless	0.22	42.64	42.64
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13
Volumetric air content in capillary fringe soils[b]	$\theta_{a,cap}$	cm^3/cm^3	0.015	0.015	0.015
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.33	0.33	0.33
Volumetric water content in capillary fringe soils[b]	$\theta_{w,cap}$	cm^3/cm^3	0.44	0.44	0.44
Volumetric air content in foundation/wall cracks[b]	θ_{acrack}	cm^3/cm^3	0.26	0.26	0.26
Volumetric water content in foundation/wall cracks[b]	θ_{wcrack}	cm^3/cm^3	0.12	0.12	0.12
Effective diffusion coefficient through capillary fringe[c]	$D_{eff,cap}$	cm^2/s	1.6 E-5	4.9 E-7	5.0 E-7
Effective diffusion coefficient in soil[d]	$D_{eff,s}$	cm^2/s	4.6 E-4	4.9 E-4	4.9 E-4
Effective diffusion coefficient between groundwater and soil[e]	$D_{eff,ws}$	cm^2/s	7.0 E-5	2.5 E-6	2.5 E-6
Effective diffusion coefficient through cracks[f]	$D_{eff,crack}$	cm^2/s	5.2 E-3	5.6 E-3	5.6 E-3
Thickness of capillary fringe[b]	h_{cap}	cm	106	106	106
Thickness of vadose zone[g]	h_v	cm	427	427	427
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45
Diffusion coefficient in water[b]	D_w	cm^2/s	1.1 E-5	1.0 E-5	1.1 E-5
Vapor phase diffusion coefficient in air[b]	D_{air}	cm^2/s	0.093	0.100	0.100
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5
Depth to groundwater[g]	L_{GW}	cm	533.4	533.4	533.4
Enclosed-space volume/infiltration ratio[b]	L_B	cm	229	229	305
Enclosed-space foundation or wall thickness[b]	L_{crack}	cm	1	1	1
Areal fraction of cracks in foundations/walls[b]	η	cm^2/cm^2	0.001	0.001	0.001
Enclosed space air exchange rate[b]	ER	L/s	5.6 E-4	5.6 E-4	1.4 E-3
Groundwater to indoor air volatilization factor[h]	VF_{es}	$(mg/m^3)/(mg/L)$	2.2 E-4	1.5 E-3	4.7 E-4
Concentration in groundwater[g]	C_{gw}	mg/L	[redacted]	4.6	12.8
Enclosed-space air concentration[i]	C_{es}	mg/m^3	6.1 E-4	7.0 E-3	5.9 E-3

Table 8. Vapor Diffusion Model - Groundwater to Indoor Air[a]

Parameter	Abbrev.	Units	TPH-G: C9-C18 aliphatics		TPH-G: C9-C22 aromatics	
			Resident	Commercial	Resident	Commercial
Henry's law constant[b]	H	unitless	250.51	250.51	0.17	0.17
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13	0.13
Volumetric air content in capillary fringe soils[b]	$\theta_{a,cap}$	cm^3/cm^3	0.015	0.015	0.015	0.015
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.33	0.33	0.33	0.33
Volumetric water content in capillary fringe soils[b]	$\theta_{w,cap}$	cm^3/cm^3	0.44	0.44	0.44	0.44
Volumetric air content in foundation/wall cracks[b]	θ_{acrack}	cm^3/cm^3	0.26	0.26	0.26	0.26
Volumetric water content in foundation/wall cracks[b]	θ_{wcrack}	cm^3/cm^3	0.12	0.12	0.12	0.12
Effective diffusion coefficient through capillary fringe[c]	$D_{eff,cap}$	cm^2/s	4.3 E-7	4.3 E-7	1.8 E-5	2.0 E-5
Effective diffusion coefficient in soil[d]	$D_{eff,s}$	cm^2/s	4.9 E-4	4.9 E-4	4.9 E-4	4.9 E-4
Effective diffusion coefficient between groundwater and soil[e]	$D_{eff,ws}$	cm^2/s	2.2 E-6	2.2 E-6	7.9 E-5	8.6 E-5
Effective diffusion coefficient through cracks[f]	$D_{eff,crack}$	cm^2/s	5.6 E-3	5.6 E-3	5.6 E-3	5.6 E-3
Thickness of capillary fringe[b]	h_{cap}	cm	106	106	106	106
Thickness of vadose zone[g]	h_v	cm	427	427	427	427
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45	0.45
Diffusion coefficient in water[b]	D_w	cm^2/s	1.0 E-5	1.1 E-5	1.0 E-5	1.1 E-5
Vapor phase diffusion coefficient in air[b]	D_{air}	cm^2/s	0.100	0.100	0.100	0.100
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5	1.5
Depth to groundwater[g]	L_{GW}	cm	533.4	533.4	533.4	533.4
Enclosed-space volume/infiltration ratio[b]	L_B	cm	229	305	229	305
Enclosed-space foundation or wall thickness[b]	L_{crack}	cm	1	1	1	1
Areal fraction of cracks in foundations/walls[b]	η	cm^2/cm^2	0.001	0.001	0.001	0.001
Enclosed space air exchange rate[b]	ER	L/s	5.6 E-4	1.4 E-3	5.6 E-4	1.4 E-3
Groundwater to indoor air volatilization factor[h]	VF_{es}	$(mg/m^3)/(mg/L)$	7.9 E-3	2.4 E-3	2.0 E-4	6.4 E-5
Concentration in groundwater[g]	C_{gw}	mg/L	3.3	9.1	5.2	14.6
Enclosed-space air concentration[i]	C_{es}	mg/m^3	2.6 E-2	2.2 E-2	1.0 E-3	9.3 E-4

Table 8. Vapor Diffusion Model - Groundwater to Indoor Air[a]

[a]ASTM, 1995, Oakland RBCA (1999)

[b]Oakland RBCA (1999) default value. The soils beneath the site are predominantly silty clay; therefore, soil parameters are the average of the sandy silt and clayey silt parameters.

[c]$D_a \times (\theta_{a,cap}^{3.33}/\theta_T^2) + D_w \times (1/H) \times (\theta_{w,cap}^{3.33}/\theta_T^2)$

[d]$D_a \times (\theta_{as}^{3.33}/\theta_T^2) + D_w \times (1/H) \times (\theta_{ws}^{3.33}/\theta_T^2)$

[e]$(h_{cap} + h_v)/[(h_{cap}/D_{eff,cap}) + (h_v/D_{eff,s})]$

[f]$D_a \times (\theta_{a,crack}^{3.33}/\theta_T^2) + D_w \times (1/H) \times (\theta_{w,crack}^{3.33}/\theta_T^2)$

[g]Based on site data. For resident exposures, only the wells with detected concentrations in 1999 are used (AW-2, AW-3, and AW-4).

[h]$1000\ L/m^3 \times H \times [D_{eff,ws}/(L_{GW} \times ER \times L_B)]/[1 + D_{eff,ws})/(L_{GW} \times ER \times L_B) + (D_{eff,s} \times L_{crack})/(L_{GW} \times D_{eff,crack} \times \eta)]$

[i]$C_{gw} \times VF_{es}$

Table 9. Vapor Diffusion Model - Groundwater to Ambient Air[a]

Parameter	Abbrev.	Units	TPH-G C5-C8 aliphatics	TPH-G C9-C18 aliphatics	TPH-G C9-C22 aromatics
Henry's law constant[b]	H	unitless	42.64	250.51	0.17
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13
Volumetric air content in capillary fringe soils[b]	$\theta_{a,cap}$	cm^3/cm^3	0.015	0.015	0.015
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.33	0.33	0.33
Volumetric water content in capillary fringe soils[b]	$\theta_{w,cap}$	cm^3/cm^3	0.44	0.44	0.44
Effective diffusion coefficient through capillary fringe[c]	$D_{eff,cap}$	cm^2/s	4.9 E-7	4.3 E-7	1.8 E-5
Effective diffusion coefficient in soil[d]	$D_{eff,s}$	cm^2/s	4.9 E-4	4.9 E-4	4.9 E-4
Groundwater/soil effective diffusion coefficient[e]	$D_{eff,ws}$	cm^2/s	2.5 E-6	2.2 E-6	7.9 E-5
Thickness of capillary fringe[b]	h_{cap}	cm	106	106	106
Thickness of vadose zone[f]	h_v	cm	427	427	427
Total soil porosity[b]	θ_T	cm^3/cm^3	0.45	0.45	0.45
Diffusion coefficient in water[b]	D_w	cm^2/s	1.0 E-5	1.0 E-5	1.0 E-5
Vapor phase diffusion coefficient in air[b]	D_{air}	cm^2/s	0.100	0.100	0.100
Wind speed above source parallel to groundwater flow[b]	U_{air}	cm/s	322	322	322
Ambient air mixing zone height[b]	δ_{air}	cm	200	200	200
Width of source area parallel to groundwater flow[f]	W	cm	2,286	2,286	2,286
Soil bulk density[b]	ρ_s	g/cm^3	1.5	1.5	1.5
Depth to groundwater[f]	L_{GW}	cm	533.4	533.4	533.4
Groundwater to ambient air volatilization factor[g]	VF_{am}	$(mg/m^3)/(mg/kg)$	7.0 E-6	3.6 E-5	9.2 E-7
Concentration in groundwater[f]	C_{gw}	mg/L	12.8	9.1	14.6
Ambient air concentration[h]	C_{am}	mg/m^3	8.9 E-5	3.3 E-4	1.3 E-5

[a]ASTM, 1995, Oakland RBCA (1999)

[b]Oakland RBCA (1999) default value. The soils beneath the site are predominantly silty clay; therefore, soil parameters are the average of the sandy silt and clayey silt parameters.

[c]$D_a \times (\theta_{a,cap}^{3.33}/\theta_T^2) + D_w \times (1/H) \times (\theta_{w,cap}^{3.33}/\theta_T^2)$

[d]$D_a \times (\theta_{as}^{3.33}/\theta_T^2) + D_w \times (1/H) \times (\theta_{ws}^{3.33}/\theta_T^2)$

[e]$(h_{cap} + h_v)/[(h_{cap}/D_{eff,cap}) + (h_v/D_{s,eff})]$

[f]Based on site data.

[g]$1000\ L/m^3 \times H/[1 + (U_{air} \times \delta_{air} \times L_{GW})/(W \times D_{eff,ws})]$

[h]$C_{gw} \times VF_{am}$

Table 10. Leaching Model - Soil to Groundwater[a]

Parameter	Abbrev.	Units	Benzene	Toluene	Ethyl-benzene	Xylene	MTBE
Henry's law constant[c]	H	unitless	0.22	0.22	0.22	0.22	0.22
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13	0.13	0.13
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.33	0.33	0.33	0.33	0.33
Groundwater darcy velocity[b]	U_{air}	cm/s	33.0	33.0	33.0	33.0	33.0
Groundwater mixing zone thickness[b]	δ_{gw}	cm	1143	1143	1143	1143	1143
Partition coefficient for organic carbon[b]	k_{oc}	cm^3/g	83	83	83	83	83
Organic carbon content of soil[b]	f_{oc}	--	1.8%	1.8%	1.8%	1.8%	1.8%
Sorption coefficient[d]	k_s	cm^3/g	1.45	1.45	1.45	1.45	1.45
Soil bulk density[b]	ρ_s	g/cm^3	1.72	1.72	1.72	1.72	1.72
Infiltration rate[b]	I	cm/yr	4.5	4.5	4.5	4.5	4.5
Width of source area[e]	W	cm	2286.0	2286.0	2286.0	2286.0	2286.0
Soil to ambient air volatilization factor[f]	LF	(mg/L) / (mg/kg)	1.3 E-1	1.3 E-1	1.3 E-1	1.3 E-1	1.3 E-1
Concentration in soil[e]	C_s	mg/kg	0.41	0.42	0.18	1.23	2.97
Predicted groundwater concentration[g]	C_{gw}	mg/L	0.053	0.054	0.023	0.159	0.384
Current average groundwater concentration[e]	C_{gw}	mg/L	2.81	6.27	1.33	5.91	2.78
Predicted concentration>current concentration?			NO	NO	NO	NO	NO

* This model assumes that the asphalt is removed from the site. If the asphalt remains it will act as an effective barrier to infiltration. If infiltration is impeded, it is considered likely that there will no driving force for this COPC to move through the vadose zone, and if it does reach water it is unlikely to be in detectable amounts.

[a]ASTM, 1995, Oakland RBCA (1999)

[b]Oakland RBCA (1999) default value. The soils beneath the site are predominantly silty clay; therefore, soil parameters are the average of the sandy silt and clayey silt parameters.

[c]Based on available scientific literature.

[d]$f_{oc} \times k_{oc}$.

[e]Based on site data.

[f]$\rho_s/[\theta_{ws}+ks\times\rho s+\theta as\times H]\times(1+((U_{gwr}\times\delta_{gw}/(I\times W))$ cm^3-kg/l-g.

[g]$C_s \times LF$.

Table 10. Leaching Model - Soil to Groundwater[a]

			TPH-G			TPH-D	
Parameter	Abbrev.	Units	C5-C8 aliphatics	C9-C18 aliphatics	C9-C22 aromatics	C9-C18 aliphatics	C9-C22 aromatics
Henry's law constant[b]	H	unitless	42.64	250.51	0.17	250.51	0.17
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.13	0.13	0.13	0.13	0.13
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.33	0.33	0.33	0.33	0.33
Groundwater darcy velocity[b]	U_{air}	cm/s	33.0	33.0	33.0	33.0	33.0
Groundwater mixing zone thickness[b]	δ_{gw}	cm	1143	1143	1143	1143	1143
Partition coefficient for organic carbon[b]	k_{oc}	cm^3/g	1,778	341,455	4,217	341,455	4,217
Organic carbon content of soil[b]	f_{oc}	--	1.8%	1.8%	1.8%	1.8%	1.8%
Sorption coefficient[d]	k_s	cm^3/g	31.12	5975.46	73.80	5975.46	73.80
Soil bulk density[b]	ρ_s	g/cm^3	1.72	1.72	1.72	1.72	1.72
Infiltration rate[b]	I	cm/yr	4.5	4.5	4.5	4.5	4.5
Width of source area[e]	W	cm	2286.0	2286.0	2286.0	305	305
Soil to ambient air volatilization factor[f]	LF	(mg/L) / (mg/kg)	6.2 E-3	3.6 E-5	2.9 E-3	5.9 E-6	4.7 E-4
Concentration in soil[e]	C_s	mg/kg	3.04	2.17	3.47	2,535	1,365
Predicted groundwater concentration[g]	C_{gw}	mg/L	0.019	0.00008	0.010	0.015	0.647
Current average groundwater concentration[e]	C_{gw}	mg/L	12.77	9.12	14.60	ND	ND
Predicted concentration>current concentration?			NO	NO	NO	YES*	YES*

* This model assumes that the asphalt is removed from the site. If the asphalt remains it will act as an effective barrier to infiltration. If infiltration is impeded, it is considered likely that there will no driving force for this COPC to move through the vadose zone, and if it does reach water it is unlikely to be in detectable amounts.

[a]ASTM, 1995, Oakland RBCA (1999)

[b]Oakland RBCA (1999) default value. The soils beneath the site are predominantly silty clay; therefore, soil parameters are the average of the sandy silt and clayey silt parameters.

[c]Based on available scientific literature.

[d]$f_{oc} \times k_{oc}$.

[e]Based on site data.

[f]$\rho_s/[\theta_{ws}+ks \times ps+\theta as \times H] \times (1+((U_{gw} \times \delta_{gw}/(I \times W))$ cm^3-kg/l-g.

[g]$C_s \times LF$.

Table 11. Exposure Parameters

Parameter	Abbrev.	Units	Value[a]			
			Commercial Worker	Construction Worker	Resident Child	Resident Adult
Dermal absorption factor	ABS	--	0.1	0.1	NA	NA
Averaging time for carcinogens	AT_c	days	25,550	25,550	25,550	25,550
Averaging time for non-carcinogens	AT_{nc}	days	9,125	365	2,190	8,760
Body weight	BW	kg	70	70	15	70
Exposure frequency	EF	d/yr	250	183	350	350
Exposure duration	ED	years	25	1	6	24
Skin surface area exposed to soil	SA	cm^2	5,000	5,000	NA	NA
Soil adherence factor	AF	mg/cm^2	0.5	0.5	NA	NA
Soil ingestion rate	SI	mg/d	50	480	NA	NA
Exposure time to indoor air	ET_{ia}	hr/d	9	--	24	24
Exposure time to outdoor air	ET_{oa}	hr/d	--	9	--	--
Outdoor air inhalation rate	IR_{am}	m^3/d	--	20	--	--
Indoor air inhalation rate	IR_{es}	m^3/d	20	--	10	15

[a]Oakland RBCA (1999) unless otherwise noted.

Table 12. RBCA Tier 3 Evaluation for Soil - Residential

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] (mg/kg-d)$^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[f] (ppm)	Odor Threshold[f] (mg/m^3)	Nuisance Index[g]
Indoor Air											
TPH-G				9.4 E-4					0.025	281	3.4 E-6
C5-C8 aliphatics	Inhalation	0.06	---	9.2 E-4	1.2 E-4	---	7.8 E-4	**0.0129**			
C9-C18 aliphatics	Inhalation	0.6	---	2.3 E-5	2.8 E-6	---	1.9 E-5	**0.00003**			
C9-C22 aromatics	Inhalation	0.03	---	2.1 E-6	2.6 E-7	---	1.7 E-6	**0.00006**			
TPH-D				2.8 E-3					0.082	888	3.1 E-6
C9-C18 aliphatics	Inhalation	0.06	---	2.7 E-3	3.4 E-4	---	2.3 E-3	**0.038**			
C9-C22 aromatics	Inhalation	0.057	---	8.3 E-5	1.0 E-5	---	7.0 E-5	**0.0012**			
Total Risk/HI Across Pathways						--		**0.052**			6.5 E-6
Site-Specific Target Level (SSTL, in mg/kg)[e]-TPG-G						--		**665**			
Site-Specific Target Level (SSTL, in mg/kg)[e]-TPG-D						--		**>100,000**			
SSTL Exceeded?						--		**NO**			
Target Risk/HI						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3; for soil, concentration is in mg/kg.

[c]Air: LADD/ADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

Soil-Ingestion: LADD/ADD = $(C_{soil} \times CF \times IR_s \times ED \times EF) / (AT \times BW)$.

Soil-Dermal Contact: LADD/ADD = $(C_{soil} \times CF \times SA \times SAF \times ED \times EF \times AFd) / (AT \times BW)$.

[d]ILCR = LADD × CSF; HI = ADD × RfD.

[e]SSTL = $(C_{soil} \times (1 \times 10^{-5})) / ILCR$ or $(C_{soil} \times 1.0) / HI$.

[f]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[g]Nuisance index = air concentration/odor threshold.

Table 13. RBCA Tier 3 Evaluation for Soil - Commercial Worker

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[g] (ppm)	Odor Threshold[g] (mg/m^3)	Nuisance Index[h]
Indoor Air											
TPH-G				2.8 E-4					0.025	281	1.0 E-6
C5-C8 aliphatics	Inhalation	0.06	---	2.8 E-4	7.2 E-6	---	2.0 E-5	0.00034			
C9-C18 aliphatics	Inhalation	0.6	---	6.8 E-6	1.8 E-7	---	5.0 E-7	0.000008			
C9-C22 aromatics	Inhalation	0.03	---	6.2 E-7	1.6 E-8	---	4.6 E-8	0.0000008			
TPH-D				2.7 E-4					0.082	888	3.0 E-7
C9-C18 aliphatics	Inhalation	0.06	---	2.6 E-4	6.8 E-6	---	1.9 E-5	0.0003			
C9-C22 aromatics	Inhalation	0.057	---	8.0 E-6	2.1 E-7	---	5.9 E-7	0.00001			
Total Risk/HI Across Pathways[e]						---		0.0007			
Site-Specific Target Level (SSTL, in mg/kg)[f]-TPG-G						---		25,022			
Site-Specific Target Level (SSTL, in mg/kg)[f]-TPG-D						---		>100,000			
SSTL Exceeded?						---		NO			
Target Risk/HI						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3; for soil, concentration is in mg/kg.

[c]Air: LADD/ADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

Soil-Ingestion: LADD/ADD = $(C_{soil} \times CF \times IR_s \times ED \times EF) / (AT \times BW)$.

Soil-Dermal Contact: LADD/ADD = $(C_{soil} \times CF \times SA \times SAF \times ED \times EF \times AFd) / (AT \times BW)$.

[d]ILCR = LADD × CSF; HI = ADD × RfD.

[e]Assumes either an indoor or outdoor occupational worker.

[f]SSTL = $(C_{soil} \times (1 \times 10^{-5})) / ILCR$ or $(C_{soil} \times 1.0) / HI$.

[g]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[h]Nuisance index = air concentration/odor threshold.

Table 14. RBCA Tier 3 Evaluation for Soil - Construction Worker

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[f] (ppm)	Odor Threshold[f] (mg/m^3)	Nuisance Index[g]
Soil											
TPH-G				13.20							
C5-C8 aliphatics	Ingestion	0.06	---	4.62	2.3 E-7	---	1.6 E-5	**0.0003**			
C9-C18 aliphatics	Ingestion	0.6	---	3.30	1.6 E-7	---	1.1 E-5	**0.00002**			
C9-C22 aromatics	Ingestion	0.03	---	5.28	2.6 E-7	---	1.8 E-5	**0.0006**			
TPH-D				3,900							
C9-C18 aliphatics	Ingestion	0.06	---	2,535	1.2 E-4	---	8.7 E-3	**0.15**			
C9-C22 aromatics	Ingestion	0.03	---	1,365	6.7 E-5	---	4.7 E-3	**0.16**			
TPH-G				13.20							
C5-C8 aliphatics	Dermal	0.06	---	4.62	1.2 E-7	---	8.3 E-6	**0.0001**			
C9-C18 aliphatics	Dermal	0.6	---	3.30	8.4 E-8	---	5.9 E-6	**0.000010**			
C9-C22 aromatics	Dermal	0.03	---	5.28	1.4 E-7	---	9.5 E-6	**0.0003**			
TPH-D				3,900							
C9-C18 aliphatics	Dermal	0.06	---	2,535	6.5 E-5	---	4.5 E-3	**0.076**			
C9-C22 aromatics	Dermal	0.03	---	1,365	3.5 E-5	---	2.4 E-3	**0.081**			
Outdoor Air											
TPH-G				2.6 E-4					0.025	281	9.3 E-7
C5-C8 aliphatics	Inhalation	0.06	---	2.5 E-4	1.9 E-7	---	1.4 E-5	**0.0002**			
C9-C18 aliphatics	Inhalation	0.6	---	6.2 E-6	4.8 E-9	---	3.3 E-7	**0.0000006**			
C9-C22 aromatics	Inhalation	0.03	---	5.6 E-7	4.3 E-10	---	3.0 E-8	**0.0000010**			
TPH-D				1.6 E-2					0.082	888	1.8 E-5
C9-C18 aliphatics	Inhalation	0.06	---	1.5 E-2	1.2 E-5	---	8.1 E-4	**0.014**			
C9-C22 aromatics	Inhalation	0.057	---	4.6 E-4	3.5 E-7	---	2.5 E-5	**0.0004**			

Table 14. RBCA Tier 3 Evaluation for Soil - Construction Worker

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[f] (ppm)	Odor Threshold[f] (mg/m^3)	Nuisance Index[g]
Total Risk/HI Across Pathways						---		**0.47**			
Site-Specific Target Level (SSTL, in mg/kg)[e]-TPG-G						---		**8,351**			
Site-Specific Target Level (SSTL, in mg/kg)[e]-TPG-D						---		**8,249**			
SSTL Exceeded?						---		**NO**			
Target Risk/HI						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3; for soil, concentration is in mg/kg.

[c]Air: $LADD/ADD = (C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

Soil-Ingestion: $LADD/ADD = (C_{soil} \times CF \times IR_s \times ED \times EF) / (AT \times BW)$.

Soil-Dermal Contact: $LADD/ADD = (C_{soil} \times CF \times SA \times SAF \times ED \times EF \times AFd) / (AT \times BW)$.

[d]$ILCR = LADD \times CSF$; $HI = ADD \times RfD$.

[e]$SSTL = (C_{soil} \times (1 \times 10^{-5})) / ILCR$ or $(C_{soil} \times 1.0) / HI$.

[f]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[g]Nuisance index = air concentration/odor threshold.

Table 15. RBCA Tier 3 Evaluation for Groundwater - Residential

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[f] (ppm)	Odor Threshold[f] (mg/m^3)	Nuisance Index[g]
Indoor Air											
Benzene	Inhalation	0.0017	0.1	6.1 E-4	7.6 E-5	**8 E-6**	5.1 E-4	**0.302**	1.5	12,203	5.0 E-8
TPH-G				3.4 E-2					0.025	281	1.2 E-4
C5-C8 aliphatics	Inhalation	0.06	---	7.0 E-3	8.8 E-4	---	5.9 E-3	**0.099**			
C9-C18 aliphatics	Inhalation	0.6	---	2.6 E-2	3.2 E-3	---	2.2 E-2	**0.036**			
C9-C22 aromatics	Inhalation	0.03	---	1.0 E-3	1.3 E-4	---	8.7 E-4	**0.029**			
Total Risk/HI Across Pathways						**8 E-6**		**0.47**			
Site-Specific Target Level (SSTL, in mg/L)[e]-Benzene						**3.6**		**9.2**			
Site-Specific Target Level (SSTL, in mg/L)[e]-TPG-G						**---**		**80**			
SSTL Exceeded by Exposure Concentration?						**NO**		**NO**			
Target Risk/HI						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3. As residents are not on-site, calculations are based on average off-site concentrations in 1999 (wells AW-2, AW-3, and AW-4. See Table 8).

[c]Air: LADD/ADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

[d]ILCR = LADD × CSF; HI = ADD × RfD.

[e]SSTL = $(C \times (1 \times 10^{-5}))$ / ILCR or $(C \times 1.0)$ / HI. SSTLs are compared to the 1999 concentrations from wells AW-2, AW-3, and AW-4, presented Table 8 and appendix A. wells AW-2 and-3 should not be used.

[f]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[g]Nuisance index = air concentration/odor threshold.

Table 16. RBCA Tier 3 Evaluation for Groundwater - Commercial Worker

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[g] (ppm)	Odor Threshold[g] (mg/m^3)	Nuisance Index[h]
Indoor Air											
TPH-G				2.9 E-2					0.025	281	1.0 E-4
C5-C8 aliphatics	Inhalation	0.06	---	5.9 E-3	1.6 E-4	---	4.4 E-4	**0.0073**			
C9-C18 aliphatics	Inhalation	0.6	---	2.2 E-2	5.7 E-4	---	1.6 E-3	**0.0026**			
C9-C22 aromatics	Inhalation	0.03	---	9.3 E-4	2.5 E-5	---	6.9 E-5	**0.0023**			
Total Risk/HI Across Pathways[e]						---		**0.012**			
Site-Specific Target Level (SSTL, in mg/L)[f]-TPG-G						---		**2,991**			
SSTL Exceeded?						---		**NO**			
Target Risk						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3.

[c]Air: LADD/ADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

[d]ILCR = LADD × CSF; HI = ADD × RfD.

[e]Assumes either an indoor or outdoor occupational worker.

[f]SSTL = $(C \times (1 \times 10^{-5})) / ILCR$ or $(C \times 1.0) / HI$.

[g]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[h]Nuisance index = air concentration/odor threshold.

Table 17. RBCA Tier 3 Evaluation for Groundwater - Construction Worker

Chemical	Exposure Pathway	RfD[a] (mg/kg-d)	CSF[a] $(mg/kg\text{-}d)^{-1}$	Conc.[b]	LADD[c] (mg/kg-d)	ILCR[d]	ADD[c] (mg/kg-d)	Hazard Index[d]	Odor Threshold[f] (ppm)	Odor Threshold[f] (mg/m^3)	Nuisance Index[g]
Outdoor Air											
TPH-G				4.3 E-4					0.025	281	1.5 E-6
C5-C8 aliphatics	Inhalation	0.06	---	8.9 E-5	6.8 E-8	---	4.8 E-6	**0.00008**			
C9-C18 aliphatics	Inhalation	0.6	---	3.3 E-4	2.5 E-7	---	1.8 E-5	**0.00003**			
C9-C22 aromatics	Inhalation	0.03	---	1.3 E-5	1.0 E-8	---	7.2 E-7	**0.00002**			
Total Risk/HI Across Pathways						---		**0.00013**			
Site-Specific Target Level (SSTL, in mg/L)[e]-TPG-G						---		**274,594**			
SSTL Exceeded?						---		**NO**			
Target Risk/HI						**1 E-5**		**1.0**			

[a]From OEHHA (1994).

[b]For air, concentration is in mg/m^3.

[c]Air: LADD/ADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT \times BW)$.

[d]ILCR = LADD × CSF; HI = ADD × RfD.

[e]SSTL = $(C \times (1 \times 10^{-5})) / ILCR$ or $(C \times 1.0) / HI$.

[f]The most conservative odor thresholds from ATSDR, 1995a,b,c.

[g]Nuisance index = air concentration/odor threshold.

Table 18. Product-Specific Fractions, Fraction Composition, and Toxicity Criteria[a]

Product	Fractions	Composition	Toxicity Criteria
Benzene			CSF = 0.1 $(mg/kg\text{-}d)^{-1}$ [b]
TPH as gasoline (TPH-g)			
	C5-C8 aliphatics	35%	RfD = 0.06 mg/kg-d (n-hexane)
	C9-C18 aliphatics	25%	RfD = 0.6 mg/kg-d (n-nonane)
	C9-C22 aromatics	40%	RfD = 0.03 mg/kg-d (pyrene)
TPH as diesel (TPH-d)			
	C9-C18 aliphatics	65%	RfD = 0.6 mg/kg-d (n-nonane)
	C9-C22 aromatics	35%	RfD = 0.03 mg/kg-d oral (pyrene)
			RfD = 0.057 mg/kg-d inhalation (pyrene)[c]

[a]From MaDEP, 1997.

[b]From OEHHA, 1994.

[c]From TPHCWG, 1996.

Table 19. RBCA Tier 3 Hazard/Risk Summary

	Construction Worker	Commercial Worker	Resident
Hazard Index			
Soil	0.47	0.00067	0.052
Groundwater	0.00013	0.012	0.47
Incremental Lifetime Cancer Risk			
Soil	---	---	--
Groundwater	---	---	8 E-6

APPENDIX A

DATA SUMMARY

Table A-1. Soil Data Summary

Sample	Media	Sample Depth	Date	Units	TPH-G	TPH-D	TPH-O	Benzene	Toluene	Ethyl-benzene	Xylenes	MTBE
TD-5-0.5	Soil	0.5	Dec-94	ppm	ND	3900	ND	ND	ND	ND	ND	NA
P3	Soil	2.5	Jul-90	ppm	9.4	NA	NA	0.029	0.096	0.52	3	NA
P1	Soil	3	Jul-90	ppm	<1	NA	NA	0.9	0.079	0.0066	0.034	NA
P1	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	0.029	<0.05
P2	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	4
P3	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
P4	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
P5	Soil	3.5	Oct-98	ppm	<1	NA	NA	0.0085	0.047	0.0071	0.057	0.74
P6	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
P7	Soil	3.5	Oct-98	ppm	1.2	NA	NA	0.067	0.09	<0.005	0.042	2
P8	Soil	3.5	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
P2	Soil	4.5	Jul-90	ppm	<1	NA	NA	<0.005	0.047	0.011	0.037	NA
AW-1	Soil	5	Jun-90	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
RW-1	Soil	5	Jun-90	ppm	<1.0	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
D1	Soil	7	Jul-90	ppm	12	NA	NA	0.053	0.39	0.16	0.96	NA
D2	Soil	7	Jul-90	ppm	3.3	NA	NA	0.029	0.48	0.044	0.22	NA
THP1-S-9.5-10.5	Soil	9.5	Oct-94	ppm	ND	ND	ND	0.92	ND	0.008	ND	NA
AW-1	Soil	10	Jun-90	ppm	<1	NA	NA	0.011	<0.005	<0.005	<0.005	NA
RW-1	Soil	10	Jun-90	ppm	<1.0	NA	NA	0.006	<0.005	<0.005	<0.005	NA
SW1	Soil	10	Jul-90	ppm	1.3	NA	NA	0.011	0.056	0.025	0.035	NA
SW2	Soil	10	Jul-90	ppm	23	NA	NA	0.015	0.1	0.23	0.18	NA
SW3	Soil	10	Jul-90	ppm	12	NA	NA	0.016	0.018	0.12	0.25	NA
SW4	Soil	10	Jul-90	ppm	3.8	NA	NA	0.016	0.02	0.05	0.064	NA
AW-4	Soil	11	Jun-90	ppm	<1.0	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
SW1	Soil	12	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
SW2	Soil	12	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	0.43
SW3	Soil	12	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	0.099
SW4	Soil	12	Oct-98	ppm	<1	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05
THP-1-S-13-13.5	Soil	13	Oct-94	ppm	ND	ND	ND	0.024	ND	ND	ND	NA
AW-1	Soil	15	Jun-90	ppm	<1	NA	NA	0.007	<0.005	<0.005	<0.005	NA
RW-1	Soil	15	Jun-90	ppm	<1.0	NA	NA	0.031	<0.005	<0.005	<0.005	NA
AW-4	Soil	16	Jun-90	ppm	<1.0	NA	NA	0.17	0.01	0.024	0.045	NA
VEW-9	Soil	16.5	May-96	ppm	<0.1	NA	NA	<0.001	<0.002	<0.002	<0.002	<0.1

Table A-1. Soil Data Summary

Sample	Media	Sample Depth	Date	Units	TPH-G	TPH-D	TPH-O	Benzene	Toluene	Ethyl-benzene	Xylenes	MTBE
AW-1	Soil	20	Jun-90	ppm	1.2	NA	NA	0.47	<0.005	<0.005	<0.005	NA
RW-1	Soil	20	Jun-90	ppm	<1.0	NA	NA	0.23	0.088	0.01	0.04	NA
AW-2	Soil	21	Jun-90	ppm	<1.0	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
AW-3	Soil	21	Jun-90	ppm	<1.0	NA	NA	0.074	0.027	0.01	0.049	NA
AW-4	Soil	21	Jun-90	ppm	1	NA	NA	0.15	0.013	0.04	0.09	NA
AW-1	Soil	25	Jun-90	ppm	<1.0	NA	NA	0.013	<0.005	<0.005	<0.005	NA
RW-1	Soil	25	Jun-90	ppm	33	NA	NA	1	0.71	<0.005	2.3	NA
AW-2	Soil	26	Jun-90	ppm	<1.0	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
AW-3	Soil	26	Jun-90	ppm	<1.0	NA	NA	0.083	0.01	0.04	0.018	NA
AW-1	Soil	30	Jun-90	ppm	<1.0	NA	NA	<0.005	<0.005	<0.005	<0.005	NA
SBA-5 (AW-5)	Soil	10.5-11	Apr-91	ppm	<1	NA	NA	0.016	<0.003	<0.003	<0.003	NA
SBA-6 (AW-6)	Soil	10.5-11	Apr-91	ppm	<1	NA	NA	0.091	0.022	0.008	0.04	NA
SBA-7 (AW-7)	Soil	10.5-11	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
SBA-8 (AW-8)	Soil	10.5-11	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
AW-9	Soil	16.5-17	Dec-96	ppm	<0.1	NA	NA	<0.001	<0.002	<0.002	<0.002	<0.1
AW-9	Soil	19-19.5	Dec-96	ppm	<0.1	NA	NA	<0.001	<0.002	<0.002	<0.002	<0.1
SBA-5 (AW-5)	Soil	20.5-21	Apr-91	ppm	<1	NA	NA	0.02	<0.003	0.007	0.008	NA
SBA-6 (AW-6)	Soil	20.5-21	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
SBA-7 (AW-7)	Soil	20.5-21	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
SBA-8 (AW-8)	Soil	20.5-21	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
SBA-5 (AW-5)	Soil	25.5-26	Apr-91	ppm	<1	NA	NA	0.077	<0.003	0.003	0.011	NA
SBA-6 (AW-6)	Soil	25.5-26	Apr-91	ppm	<1	NA	NA	0.005	0.01	<0.003	0.0066	NA
SBA-7 (AW-7)	Soil	25.5-26	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
SBA-8 (AW-8)	Soil	25.5-26	Apr-91	ppm	<1	NA	NA	<0.003	<0.003	<0.003	<0.003	NA
VEW-9	Soil	comp	May-96	ppm	<0.1	NA	NA	<0.001	<0.002	<0.002	<0.002	<0.1

NA = not analyzed

ND = not detected, no detection limit located

Table A-2. Groundwater Data Summary

Sample	Media	Date	Units	TPH-G	Benzene	Toluene	Ethyl-benzene	Xylenes	MTBE
MW-1	GW	07/09/99	ppb	58,000	140	100	1,800	6,900	1,200
MW-1	GW	11/03/99	ppb	20,000	62	42	620	2,100	630
MW-1	GW	01/12/00	ppb	72,000	110	120	2,400	8,200	630
MW-1	GW	04/13/00	ppb	37,000	300	32	1,000	1,700	810
MW-2	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
MW-2	GW	07/09/99	ppb	NA	NA	NA	NA	NA	NA
MW-2	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
MW-2	GW	06/19/98	ppb	<50	<0.5	<1	<1	<1	<10
MW-2	GW	04/10/98	ppb	<50	1	<1	<1	<1	23
MW-2	GW	01/21/98	ppb	160	<0.5	<1	<1	<1	100
MW-2	GW	01/12/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	<0.5
MW-3	GW	01/21/99	ppb	1,100	<0.5	<1	<1	<1	1,200
MW-3	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
MW-3	GW	07/09/99	ppb	470	<0.5	<1	<1	<1	470
MW-3	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
MW-3	GW	01/12/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	34
MW-3	GW	07/26/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	<0.5
AW-1	GW	04/30/99	ppb	21,000	5,300	67	2,800	750	1,500
AW-1	GW	07/09/99	ppb	11,000	3,000	<10	760	180	1,300
AW-1	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-1	GW	01/12/00	ppb	330,000	5,300	10	2,900	560	2,200
AW-1	GW	07/26/00	ppb	15,000	290	98	77	220	37,000
AW-2	GW	04/09/98	ppb	NA	NA	NA	NA	NA	NA
AW-2	GW	04/10/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-2	GW	06/19/98	ppb	60	<0.5	<1	<1	<1	<10
AW-2	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-2	GW	01/21/99	ppb	<50	<0.5	<1	<1	<1	<1
AW-2	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
AW-2	GW	07/09/99	ppb	NA	NA	NA	NA	NA	NA
AW-2	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-2	GW	01/12/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	<0.5
AW-3	GW	04/09/98	ppb	NA	NA	NA	NA	NA	NA
AW-3	GW	04/10/98	ppb	<50	<0.5	<1	1	2	<10
AW-3	GW	06/19/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-3	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-3	GW	01/21/99	ppb	<50	<1	<1	<1	<1	<1
AW-3	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
AW-3	GW	07/09/99	ppb	NA	NA	NA	NA	NA	NA
AW-3	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-3	GW	01/12/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	<0.5
AW-4	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-4	GW	01/21/99	ppb	3,700	830	93	200	360	30
AW-4	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
AW-4	GW	07/09/99	ppb	76,000	12,000	7	2,000	8,700	320
AW-4	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-4	GW	01/12/00	ppb	67,000	12,000	3,500	2,900	15,000	280
AW-4	GW	07/26/00	ppb	910	<0.5	<0.5	<0.5	<0.5	3,500

Do not use GW data from AW-2, AW-3, AW-7, AW-8, AW-9

Table A-2. Groundwater Data Summary

Sample	Media	Date	Units	TPH-G	Benzene	Toluene	Ethyl-benzene	Xylenes	MTBE
AW-5	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-5	GW	01/21/99	ppb	2,800	<1	<1	<1	<1	1,800
AW-5	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
AW-5	GW	07/09/99	ppb	4,000	<1	<1	<1	<1	3,500
AW-5	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-5	GW	01/12/00	ppb	1,000	7	30	7	40	4,600
AW-5	GW	07/26/00	ppb	1,800	94	35	6	27	16,000
AW-6	GW	04/09/98	ppb	NA	NA	NA	NA	NA	NA
AW-6	GW	04/10/98	ppb	370	<0.5	<1	<1	<1	300
AW-6	GW	06/19/98	ppb	830	2	<1	<1	<1	690
AW-6	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-6	GW	01/21/99	ppb	2,300	<1	<1	<1	<1	1,900
AW-6	GW	04/30/99	ppb	NA	NA	NA	NA	NA	NA
AW-6	GW	07/09/99	ppb	NA	NA	NA	NA	NA	NA
AW-6	GW	11/03/99	ppb	NA	NA	NA	NA	NA	NA
AW-6	GW	01/12/00	ppb	<50	<0.5	<0.5	<0.5	<0.5	2,700
AW-7	GW	01/21/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-7	GW	06/19/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-7	GW	11/30/98	ppb	NA	NA	NA	NA	NA	NA
AW-8	GW	04/09/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-8	GW	06/19/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-8	GW	01/21/99	ppb	NA	NA	NA	NA	NA	NA
AW-9	GW	04/09/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-9	GW	06/19/98	ppb	<50	<0.5	<1	<1	<1	<10
AW-9	GW	1999	ppb	NA	NA	NA	NA	NA	NA
RW-1	GW	07/09/99	ppb	NA	NA	NA	NA	NA	NA
RW-1	GW	11/03/99	ppb	160,000	19,000	37,000	3,800	25,000	1,500
RW-1	GW	01/12/00	ppb	240,000	18,000	46,000	5,800	26,000	2,100
RW-1	GW	04/13/00	ppb	120,000	2,100	33,000	2,800	28,000	1,500
RW-1	GW	07/26/00	ppb	67,000	160	5,300	2,100	18,000	1,100

NA = not analyzed

TPH-G = Total petroleum hydrocarbons as gasoline

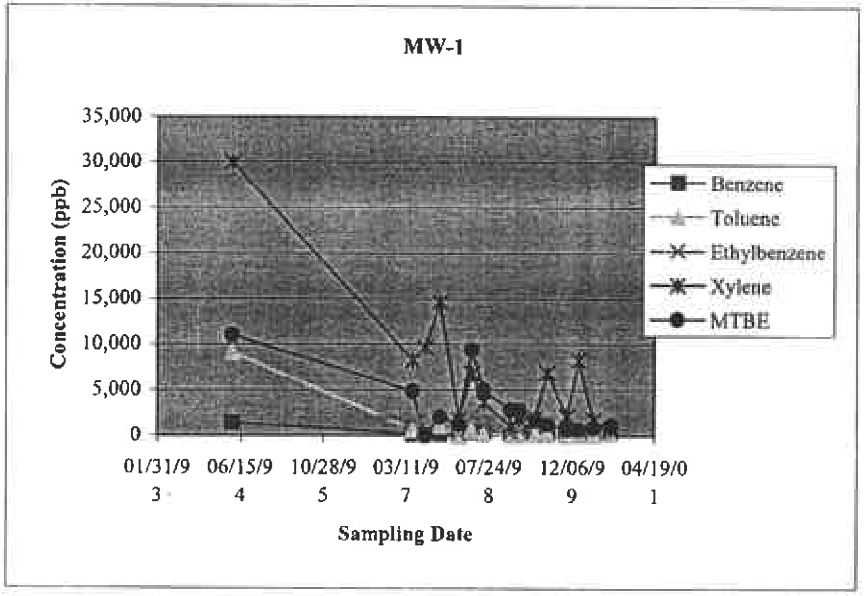
TPH-D = Total petroleum hydrocarbons as diesel

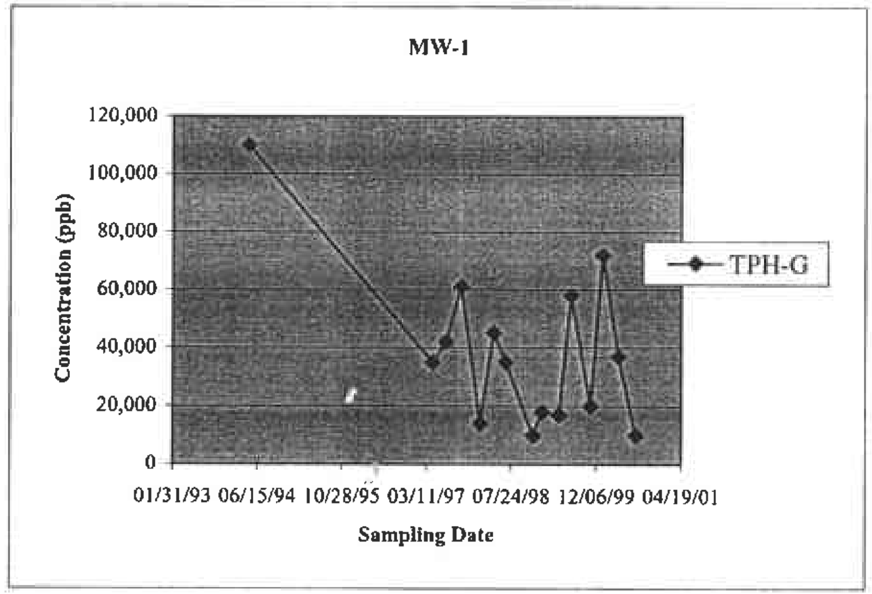
MTBE = Methyl tertiary butyl ether

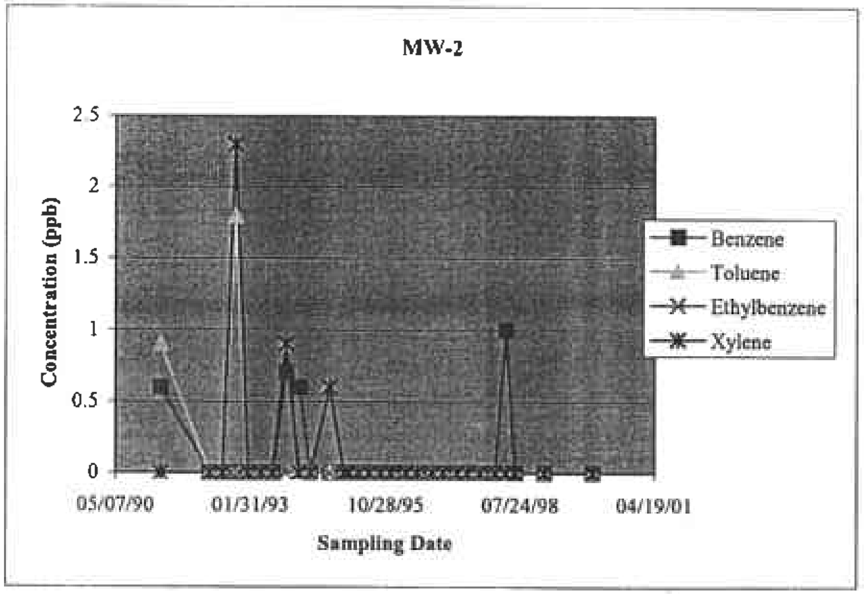
APPENDIX B

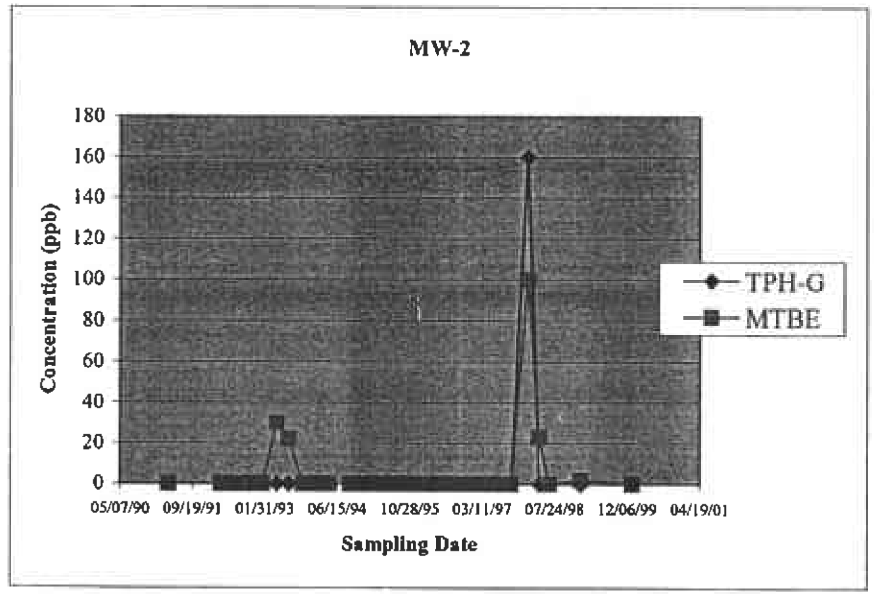
GROUNDWATER SAMPLING RESULTS – TREND CHARTS

Appendix B. Groundwater Sampling Results – Trend Charts

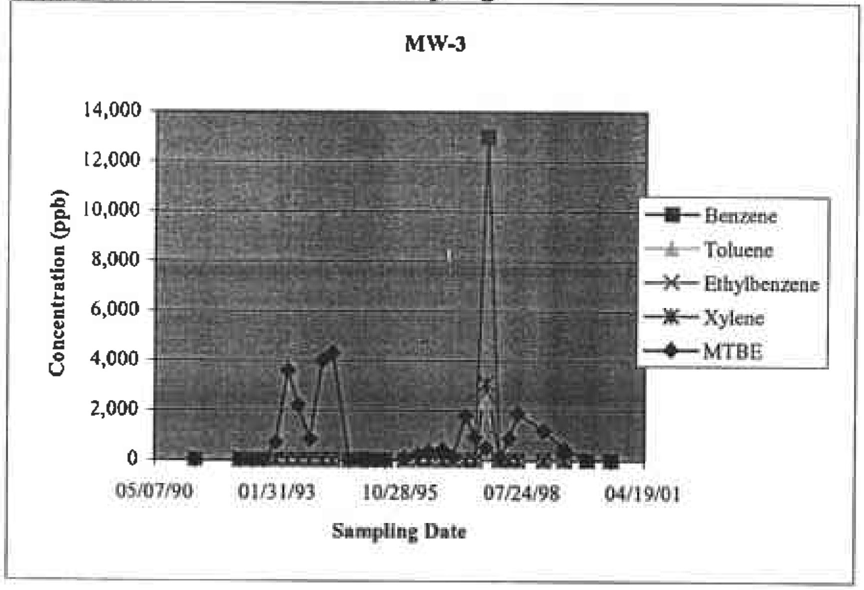


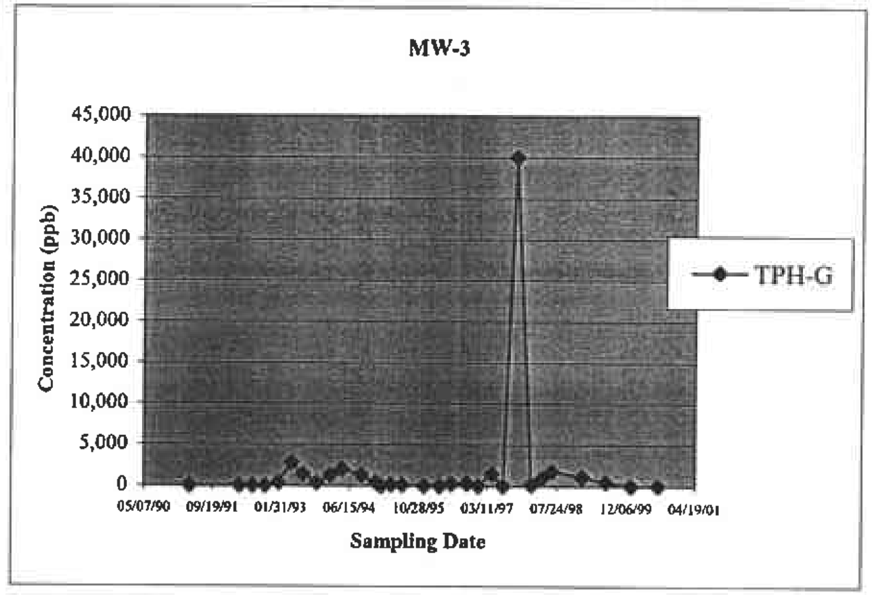


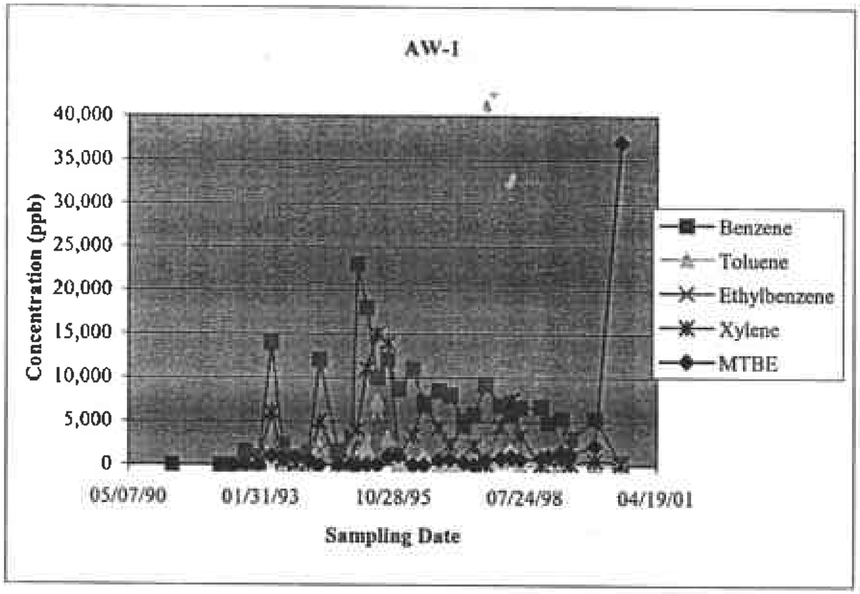


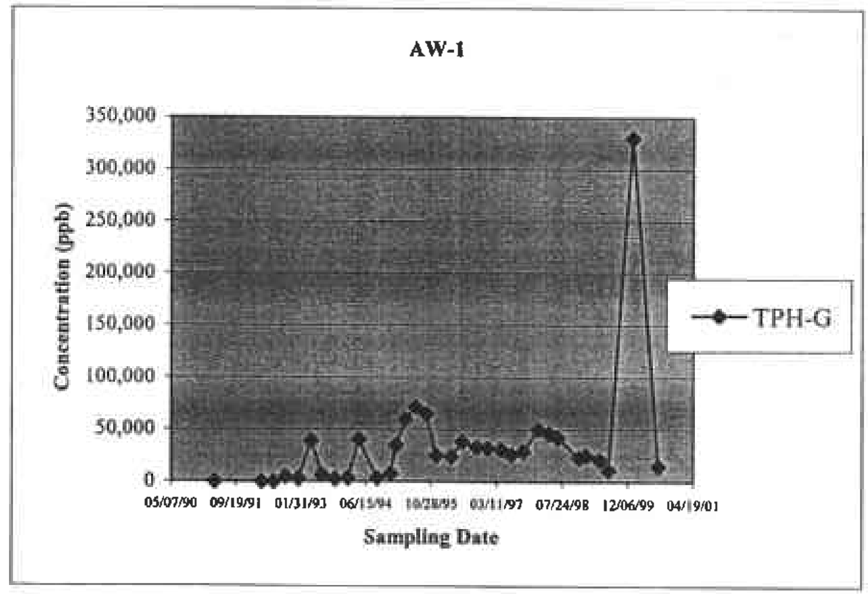


Appendix B. Groundwater Sampling Results – Trend Charts

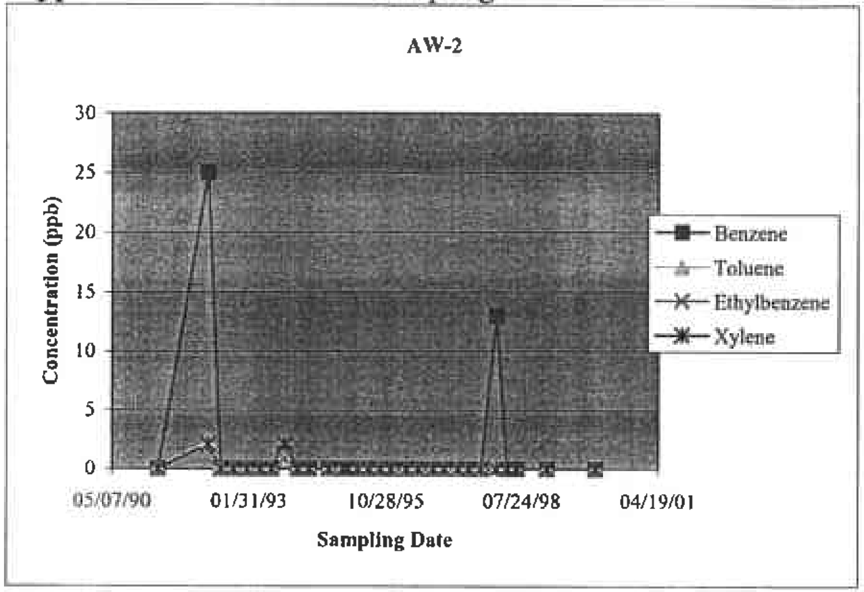


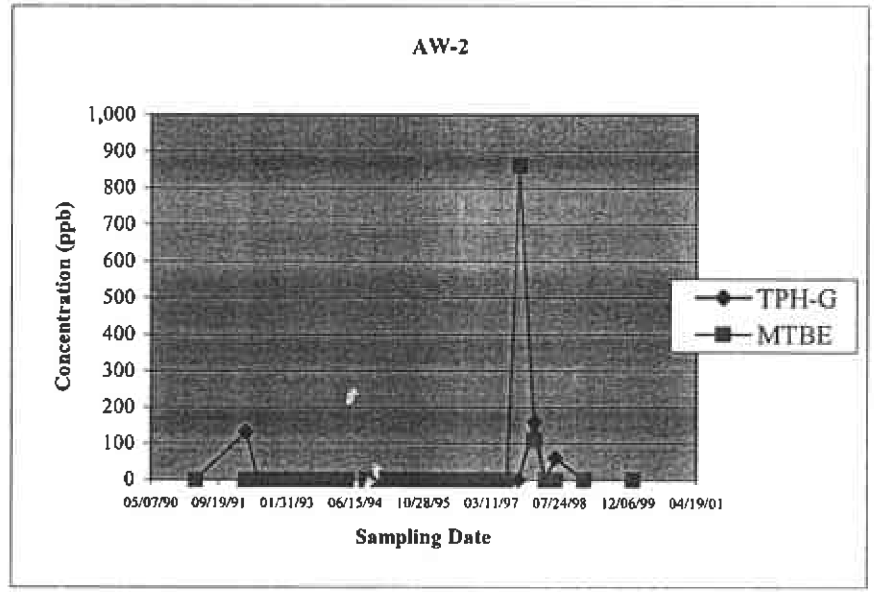


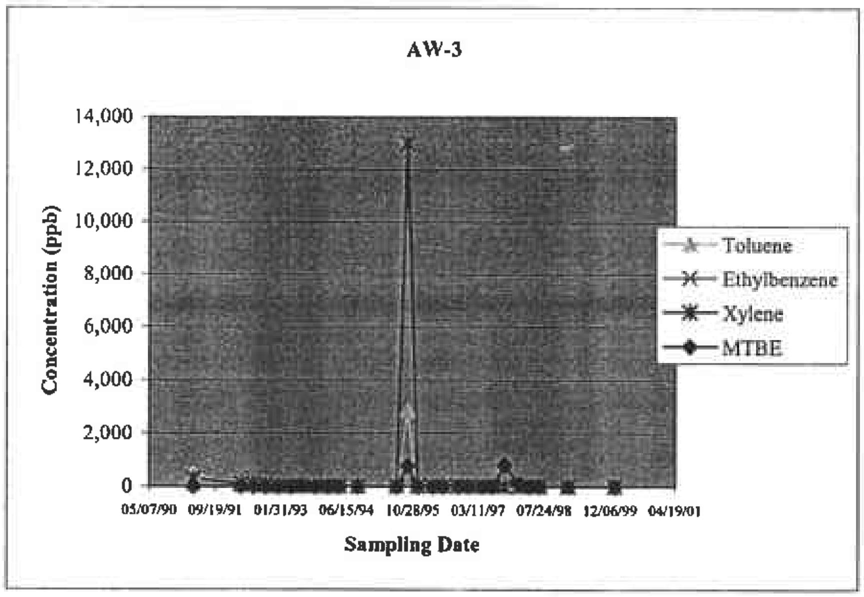


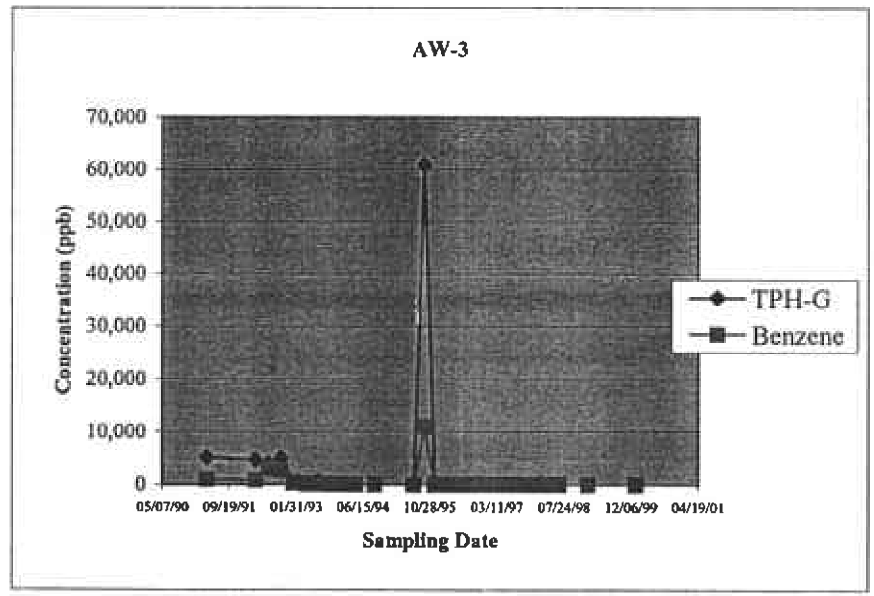


Appendix B. Groundwater Sampling Results – Trend Charts

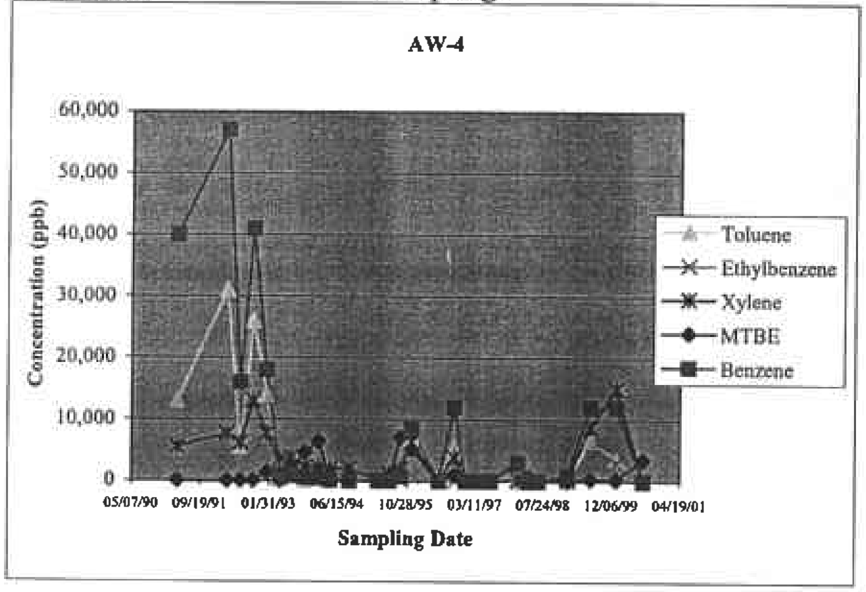


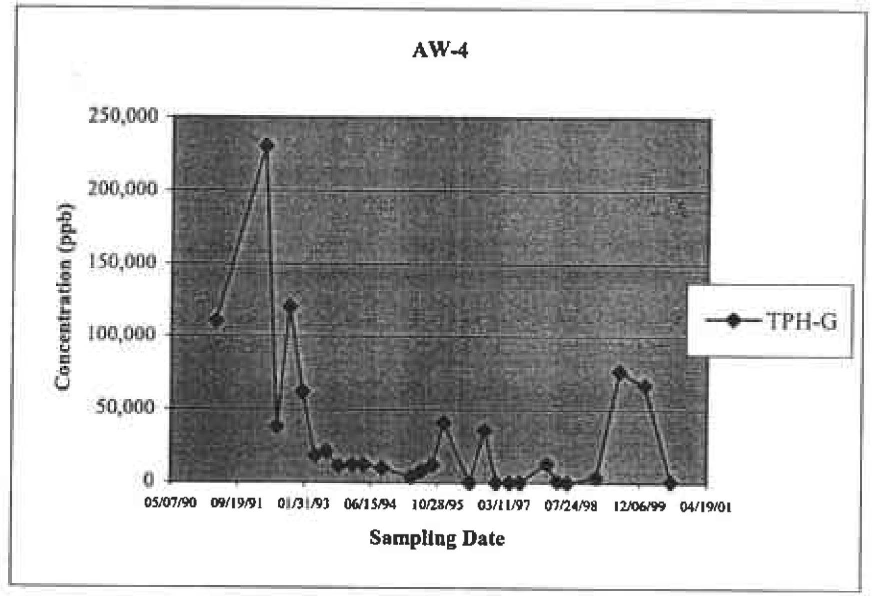


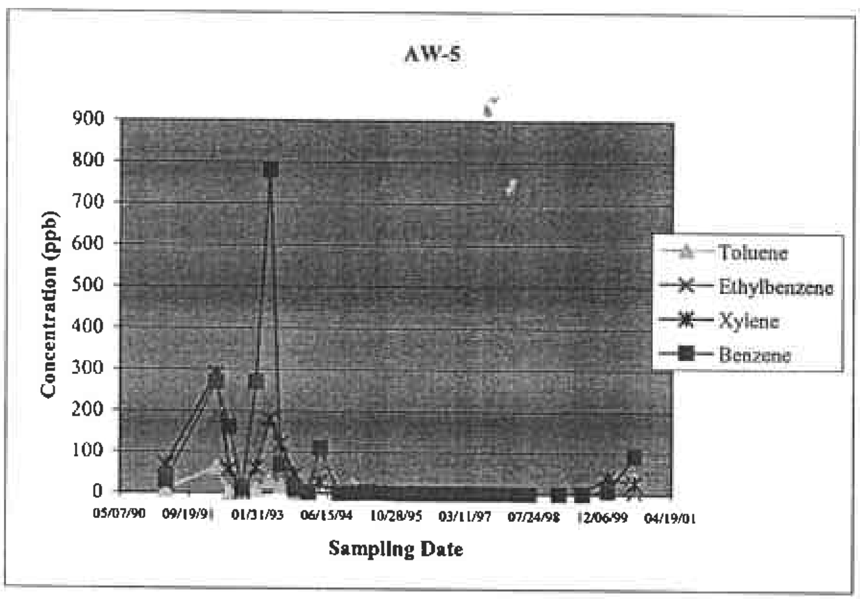


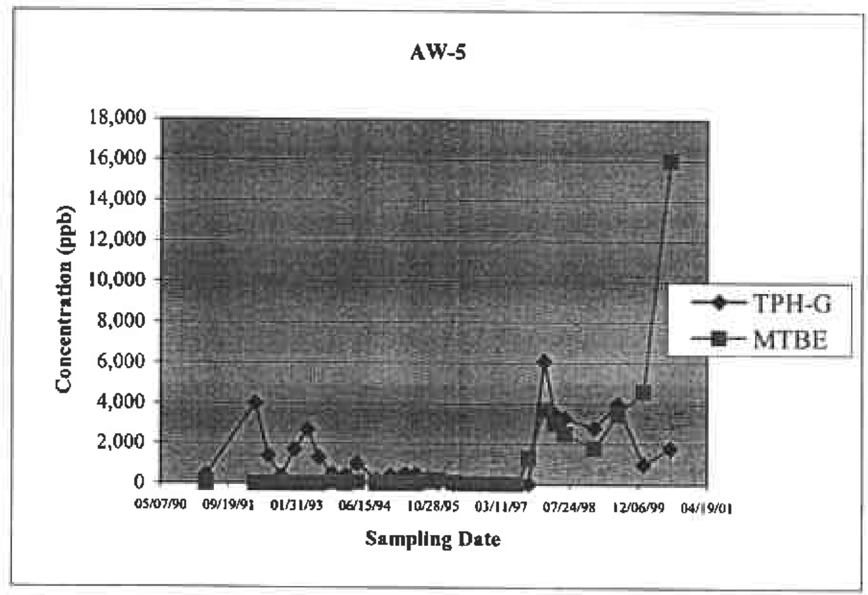


Appendix B. Groundwater Sampling Results – Trend Charts

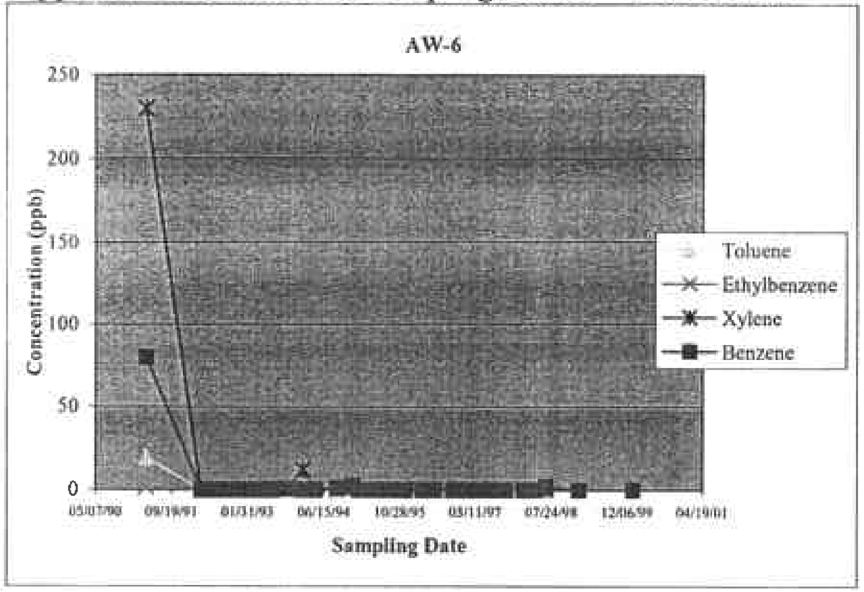


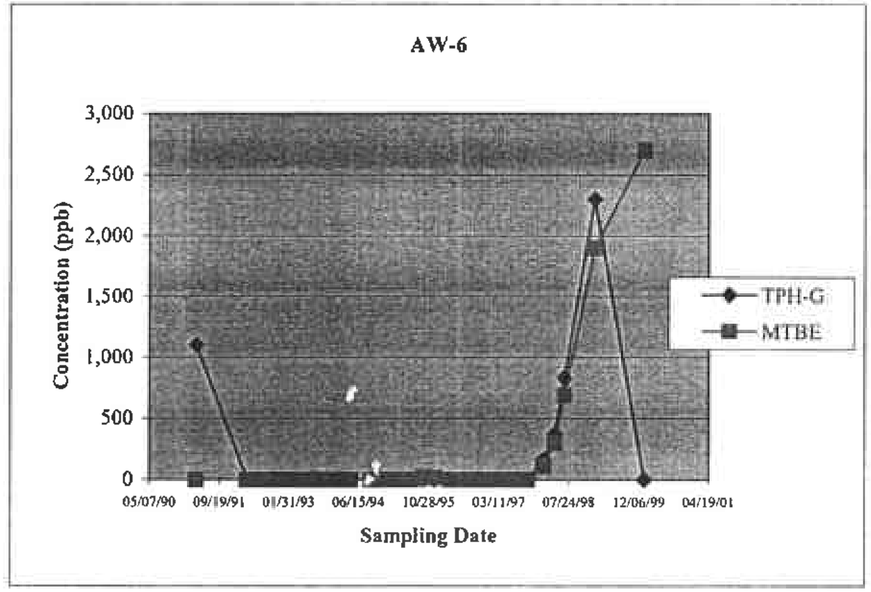


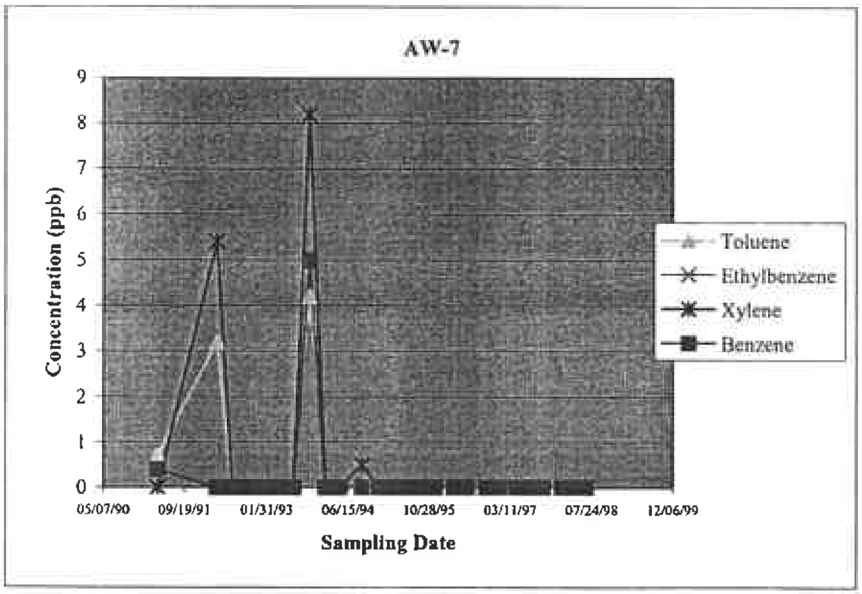


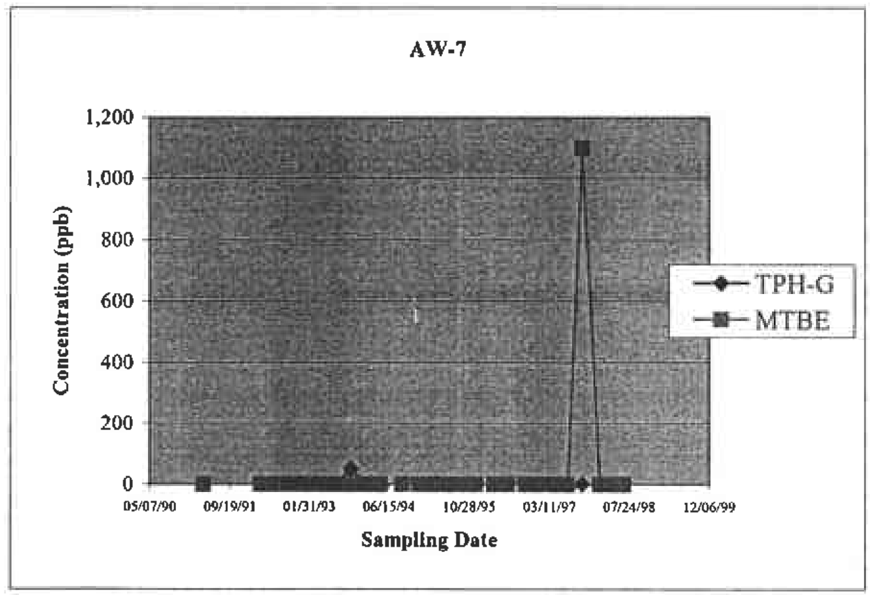


Appendix B. Groundwater Sampling Results – Trend Charts









Appendix B. Groundwater Sampling Results – Trend Charts