FOSTER WHEELER ENVIRONMENTAL CORPORATION

November 1, 1996

Scott Hooton
BP Oil
295 SW 41st Street
Renton, Washington 98055

Subject: Tier 2 RBCA Evaluation for the Former BP Oil Site No. 11270, Island & Mecartney, Alameda, California

Dear Mr. Hooton:

This report presents the results of a focused risk-based corrective action (RBCA) evaluation for the former BP Oil Service Station Site No. 11270, 3255 Mecartney Road, Alameda, California. RBCA is a streamlined approach to site remediation that uses risk assessment to identify technically-defensible and cost-effective solutions, in place of universally-applied cleanup standards. The RBCA process is currently 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 (E 1739-95)*.

The purpose of this report was to evaluate whether benzene detected in subsurface soil at the site presents a potential health risk to on-site workers at the site. The evaluation follows the basic procedures outlined in the ASTM *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E 1739-95)* and the U.S. Environmental Protection Agency's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (USEPA, 1989).

The ASTM RBCA process consists of three tiers. The first tier is a comparison of site data to acceptable concentrations presented in a Tier 1 look-up table. Based on this comparison, benzene concentrations in subsurface soil at the site exceed the low-end of the ASTM default Tier 1 look-up values. Because the values presented in the ASTM default Tier 1 look-up table do not represent site-specific conditions, a Tier 2 RBCA evaluation was warranted. This report presents the Tier 2 RBCA evaluation for the site.

2525 NATOMAS PARK DRIVE, SUITE 250, SACRAMENTO, CA 95833-2900
TEL: 916-921-2525 FAX: 916-921-5124

Tier 2 RBCA Evaluation

A Tier 2 RBCA evaluation involves the development of target levels using information specific for the site. This Tier 2 RBCA evaluation focuses exclusively on potential health risks to potential receptors (*i.e.*, on-site workers and future hypothetical residents) associated with the inhalation of benzene vapors from subsurface soil, eight feet below the ground surface. The maximum benzene concentration at this depth is 5 milligrams per kilogram (mg/kg). The site is an operating service station within a commercial area.

ASTM Volatilization from Groundwater to Outdoor Air Model

A model developed by ASTM (1995) was used to assess the volatilization of benzene from subsurface soil to ambient (outdoor) air. This model combines information on (1) the behavior of benzene in the subsurface environment, and (2) site and atmospheric parameters to determine a volatilization factor (VF_{amb}) of benzene at the soil surface following upward migration from subsurface soil. The volatilization factor is used in RBCA equations for sites where the subsurface is impacted with volatile chemicals and where the inhalation of ambient, outdoor air is a complete exposure pathway (*i.e.*, a pathway with a source, transport mechanism, point of contact, and exposure route). The volatilization factor model is defined by the following equation.

$$VF_{amb} = \frac{H \times \rho_s}{(\theta_{ws} + k_s \rho_s + H \times \theta_{as})\left(1 + \frac{U_{air} \times \delta_{air} \times L_S}{W \times D_s^{eff}}\right)} \times CF$$

where:

VF_{amb}	=	volatilization factor for ambient (outdoor) vapors [(mg/m^3 -air)/(mg/kg-soil)]
H	=	Henry's Law constant (cm^3-H_2O)/(cm^3-air)
ρ_s	=	soil bulk density (g-soil/cm^3-soil)
θ_{as}	=	volumetric air content in soil (cm^3-air/cm^3-soil)
θ_{ws}	=	volumetric water content in soil (cm^3-H_2O/cm^3-soil)
k_s	=	soil-water sorption coefficient (cm^3-H_2O/g-soil); equal to $f_{oc} \times k_{oc}$
f_{oc}	=	fraction of organic carbon in soil (g-C/g-soil)
k_{oc}	=	carbon water sorption coefficient (cm^3-H_2O/g-C)
U_{air}	=	wind speed above ground surface in ambient mixing zone (cm/s)
δ_{air}	=	ambient air mixing zone height (cm)
L_S	=	Source depth (cm)
W	=	width of source area parallel to wind direction (cm)
D^{eff}_s	=	effective diffusion coefficient in soil (cm^2/sec)
CF	=	conversion factor (10^3 cm^3-kg/m^3-g)

eg $(10)^3 = x$

$\log x = 3 \log 10$

$\log x = 3$

$x = \text{antilog } 3 = 10^3$

$(.26)^3 = x$

$\log x = 3(\log .26)$

$\log .26 = -.586$

$\log x = -1.757$

$x = \text{anti log } -1.757$

$= \text{anti}.243 \times 10^{-2}$

$x \simeq 1.75 \times 10^{-2}$

$(.26)^{10/3} = x \qquad -.586$

$\log x = \frac{10}{3} \log(.26)$

$= -1.953$

$\approx \text{anti}.047 \times 10^{-2}$

$= 1.1 \times 10^{-2}$

Model input parameters that describe benzene's behavior in the environment include the Henry's Law constant, the soil-water sorption coefficient, and the effective diffusion coefficient in the soil. The Henry's Law constant is a measure of fugacity or escaping tendency and is a function of the vapor pressure and solubility of a chemical. A large Henry's Law constant indicates the chemical is more likely to exist in the vapor phase than in the liquid phase. The soil-water sorption coefficient is a measure of a chemical's tendency to adsorb to the soil and is dependent on the chemical's carbon water sorption coefficient and the fraction of organic carbon in the soil. The other chemical parameter in this model that describes environmental mobility is the effective diffusion coefficient in the soil. The effective diffusion coefficient in the soil describes how a chemical will move from the subsurface through the soil column to the soil surface. It is a function of the volumetric water and air content in subsurface soil, the chemical's diffusion coefficients in air and water, and the soil porosity. The derivation of the effective diffusion coefficient is provided below.

$$D_s^{eff} = \left(D^{air} \times \frac{\theta_{as}^{3.33}}{\theta_T^2} \right) + \left(D^{wat} \times \frac{\theta_{ws}^{3.33}}{H \times \theta_T^2} \right)$$

where:

D^{air}	=	diffusion coefficient in air (cm^2/s)
D^{wat}	=	diffusion coefficient in water (cm^2/s)
θ_T	=	total soil porosity (cm^3/cm^3-soil)

ASTM default values were used for the equation parameters discussed above. The remaining parameters in the model describe the site or the atmosphere. The source depth, wind speed, and the width of the source area parallel to wind direction were parameters obtained either directly from the site or from locally available information. Wind speed data for the Alameda Naval Air Station was obtained and used in the equation. The width of the source area was assumed to be 10 feet (305 cm). A smaller crosswind width would result in a lower ambient air concentration. The ASTM default value for the mixing height is 6.6 feet, or 200 cm, which is the approximate breathing height of an adult. The mixing of vapors in ambient, outdoor air is analogous to mixing vapors in a hypothetical box of width W and height δ. It is assumed that vapors are mixed uniformly and instantaneously with the volume of air in the hypothetical box. Table 1 presents the model calculations, input parameter values, and resultant volatilization factor for the site.

Tier 2 Risk Calculations and Derivation of Site-Specific Target Levels

ASTM Tier 2 RBCA calculations are based on three primary steps; exposure assessment, toxicity assessment, and risk characterization. Each of these three steps and how they are applied to the site are discussed below.

The exposure assessment step in a risk evaluation combines information about the chemical concentrations in site media with assumptions about how an individual could contact the impacted media. The result is an estimation of a person's rate of intake, or dose, of a chemical.

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 located in a commercial area, and is currently zoned for commercial use, the most likely receptor to be exposed to benzene in the subsurface is an on-site worker. Although it is unlikely that the site will become residential in the foreseeable future, risks to residential receptors were also evaluated in this report.

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.*, ingestion, inhalation) at the contact point. In order for an exposure pathway to be considered complete, all four elements must be present. As discussed above, only one potential exposure pathway, inhalation of benzene vapors from subsurface soil, is evaluated in this report.

The risks associated with exposure to benzene in subsurface soil depend not only on the concentrations of benzene, but also on the extent of exposure. Table 2 presents each of the exposure parameters used in this Tier 2 evaluation. All values are USEPA and ASTM default values.

The lifetime average daily dose (LADD) of benzene is estimated based on the parameters identified in Table 2, the ambient air concentration presented in Table 1, and the following equation.

$$LADD_{inhalation}\ (mg/kg-d) = \frac{C_{air} \times IR \times EF \times ED \times AF_i \times \left(\frac{1}{VF_{amb}}\right)}{BW \times AT}$$

The resulting LADD is presented in Table 3, along with definitions for the terms in the above equation.

The toxicity value for benzene was obtained from the California Office of Environmental Health Hazard Assessment (OEHHA, 1994). The OEHHA cancer slope factor (CSF) for benzene is more than three times greater (more conservative) than that developed by the USEPA.

In the last step of a risk evaluation, the estimated rate at which a person incidentally takes in 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 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. Carcinogenic 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. High-end carcinogenic risk estimates are compared to USEPA's acceptable risk range of one in one million (10^{-6}) to one in ten thousand (10^{-4}). A risk level of 10^{-6} represents a probability of one in one million that an individual could develop cancer from exposure to the potential carcinogen under a defined set of exposure assumptions. If the estimated risk falls below the risk value considered acceptable by USEPA, the chemical is considered unlikely to pose a significant carcinogenic health risk to individuals under the given exposure conditions. If estimated risk is above the acceptable risk, , a site-specific target level can be obtained by backcalculating based on an acceptable risk level (*e.g.*, 10^{-6}). The results of the Tier 2 RBCA evaluation for the site are presented in Table 3.

Uncertainty Analysis

Risk estimates are calculated by combining site data, assumptions about the potential exposures to impacted media, and toxicity data. As with any type of risk-based analysis, uncertainties exist because of the assumptions used throughout the process. Risk evaluations are not intended to estimate actual risks to a person associated with exposure to chemicals in the environment. In fact, estimating actual risks is impossible because of the variability in the exposed or potentially exposed populations. Therefore, risk evaluations are a means of estimating the probability that an adverse health effect (*e.g.*, cancer) will occur in a person at some point in the future. Risk estimates are not likely to be underestimated due to the multitude of conservative assumptions used in the process.

Conclusions

Foster Wheeler Environmental has evaluated the potential risks to human health posed by benzene in subsurface soil at the former BP Oil Service Station, No. 11270 in Alameda, California. The concentrations of benzene in the subsurface soil to which individuals could potentially be exposed were based on available measured data and estimation of ambient air concentrations. To ensure that human health is adequately protected, conservative concentrations, exposure parameters, and toxicity assumptions were used in estimating exposure potential, risks, and in subsequent development of site-specific target levels.

Results of the evaluation indicate that levels of benzene in soil eight feet below the ground surface should not pose a risk to on-site workers. Risks to potential hypothetical future residents exceed the low end of the USEPA acceptable risk range. However, risks at the lower, more protective end of the acceptable risk range. In addition, chemical, physical, and biological processes will act on benzene over time to reduce chemical concentrations

in the soil at the site. Therefore, it is likely that benzene concentrations will naturally be reduced to below the acceptable risk range prior to the unlikely scenario of the site being converted to residential use.

If you have any questions or comments concerning this report please don't hesitate to call me at (916) 921-2525

Sincerely,

Mark K. Jones
Principal Toxicologist
Risk Assessment and Risk Management Program

c: Chris Velicer, Foster Wheeler Environmental-Bellevue

REFERENCES

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

California Office of Environmental Health Hazard Assessment (OEHHA). 1994. *California Cancer Potency Factors*: Update. November.

EMCON. 1994. *Baseline Assessment Report, BP Oil Site 11270, 3255 Mecartney Road, Alameda, California.*

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

Table 1

Vapor Diffusion Model - Subsurface Soil to Ambient Air[a] for Benzene

Parameter	Abbrev.	Units	Benzene
Henry's law constant[b]	H	unitless	0.22 L-H2O/L-air ✓
Volumetric air content in vadose zone soils[b]	θ_{as}	cm^3/cm^3	0.26 ✓
Volumetric water content in vadose zone soils[b]	θ_{ws}	cm^3/cm^3	0.12 ✓
Total soil porosity[b]	θ_T	cm^3/cm^3	0.38 ✓
Diffusion coefficent in water[b]	D^{wat}	cm^2/s	1.1 E-5 cm^2/s ✓
Vapor phase diffusion coefficient in air[b]	D^{air}	cm^2/s	0.093 cm^2/s ✓
Effective diffusion coefficient[c]	D^{eff}_s	cm^2/s	7.3 E-3 ✓
Wind speed[d]	U_{air}	cm/s	388.9 ✓
Mixing zone height[b]	δ_{air}	cm	200 ✓
Partition coefficient for organic carbon[e]	k_{oc}	cm^3/g	(83)
Organic carbon content of soil[b]	f_{oc}	(--) ?	1.00%
Sorption coefficient[f]	k_s	cm^3/g	0.83 ✓
Soil bulk density[b]	ρ_s	g/cm^3	1.7 ✓
Depth to subsurface soil sources[d]	L_S	cm	244.0 cm ✓
Width of source area parallel to wind[d]	W	cm	305 ✓
Soil to ambient air volitilization factor[g]	VF_{amb}	$(mg/m^3) / (mg/kg)$	2.8 E-5 ✓
Concentration in soil[d]	C_s	mg/kg	5.0 ✓
Ambient air concentration[h]	C_{air}	mg/m^3	1.4 E-4 ✓

[a]ASTM (1995).

[b]ASTM (1995) default value.

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

[h]$C_s \times VF_{amb}$.

References:
1) USEPA 1986 Superfund Public Health Evaluation Manual
2) Lyman et al, 1990, Handbook of Chemical Property Estimation Methods — Environmental Behavior of Organic Compounds
3) Karickhoff et al, Sorption of Hydrophobic Pollutants on Natural Sediments, Water Resources Journal, Volume 13, Pages 231-248, 1979

Table 2

Exposure Parameters[a]

Parameter	Abbrev.	Units	Value
Exposure point concentration[b]	C_{air}	mg/m^3	1.4 E-4
Residential outdoor inhalation rate	IR_{res}	m^3/day	20
Occupational inhalation rate	IR_{occ}	m^3/day	20
Residential exposure duration	ED_{res}	years	30
Occupational exposure duration	ED_{occ}	years	25
Residential exposure frequency	EF_{res}	days/year	350
Occupational exposure frequency	EF_{occ}	days/year	250
Inhalation absorption factor	AF_i	unitless	1.0
Carcinogenic averaging time[c]	AT_c	days	25,550
Adult body weight	BW	kg	70

[a]All parameter values are ASTM and USEPA standard default exposure factors.

[b]Based on outdoor air modeling results (Table 1).

[c]Carcinogenic averaging times are equal to a 70-year lifetime times 365 days/year.

Table 3

RBCA Tier 2 Evaluation Results

Exposure Pathway	Cancer Slope Factor[a] $(mg/kg\text{-}d)^{-1}$	Air Concentration (mg/m^3)	Residential LADD[b] (mg/kg-d)	Residential Upper Bound Excess Cancer Risk[c]	Residential Site-Specific Target Level	Occupational LADD[b] (mg/kg-d)	Occupational Upper Bound Excess Cancer Risk[c]	Occupational Site-Specific Target Level
Outdoor Air								
Benzene	0.1	1.4 E-4	1.6 E-5 ✓	**2 E-6** ?	**3.0**	9.8 E-6	**1 E-6**	**5.1**

[a]From OEHHA (1994).

[b]LADD = $(C_{air} \times IR \times ED \times EF \times AF_i) / (AT_c \times BW)$ - see Table 2.

[c]Risk = LADD × CSF.

R = LADD x CSF
= 1.6 x 10⁻⁶

Is it alright that they didn't conduct Indoor Inhalation? Refer to attached figure showing location of Sample SW-3, which identified the 5 ppm Benzene concentration being used in this assessment