RRM
engineering contracting firm

October 1, 1997
AA12

Mr. Phil Briggs
Chevron Products Company
P. O. Box 5004
San Ramon, California 94583-0804

Re: Former Signal Bulk Plant
2001 Versailles Avenue
Alameda, California

Dear Mr. Briggs:

This letter serves as an addendum to the risk-based corrective action evaluation prepared for the referenced site. The original evaluation was completed by Touchstone Developments and presented in a document titled, "*Corrective Action Evaluation RBCA Tier 1*" dated June 13, 1997. The purpose of this addendum is to address concerns/requests described by the Alameda County Environmental Health Services (ACEHS) in their letter dated September 15, 1997.

The ACHES noted that for each area of the site characterized, a comparison of risk-based screening levels (RBSLs) with average benzene concentrations may show that spot soil excavation is not necessary. For this addendum, RRM, Inc. (RRM) calculated average benzene concentrations for each area and compared them with RBSLs. Also, to take the process a step further. RRM used site parameters (e.g., depth to soil impact) to develop site-specific target levels (SSTLs) and compared those to average benzene concentrations. Methods and results are described below, followed by conclusions and recommendations. For reference, site maps prepared by Touchstone Developments and presented in their corrective action evaluation are provided in Attachment A.

not true

METHODS

Data used in calculating average benzene concentrations were summarized by Touchstone Developments in their document titled *Corrective Action Evaluation RBCA Tier 1*. The summarized data were generated by Harding Lawson Associates, Kleinfelder, and Touchstone Developments. Only soil data examined, and only benzene concentrations were considered. Averages were calculated using established methods, and all benzene data were used. To make use of data reported as "not detected", one-half the detection limit (0.005 parts per million

[ppm]) was used. Average benzene concentrations, and data used to calculated them, are given in Table 1.

As mentioned previously, SSTLs were also calculated to compare with average benzene concentrations. SSTLs were developed using the relationships provided in American Society for Testing and Materials (ASTM) Standard E1739 for Risk-Based Corrective Action at Petroleum Release Sites. Additionally, Tier 1 input parameters provided in the ASTM Standard were used where site-specific data were not available. Because of the low average benzene concentrations, only inhalation risk scenarios were examined; no other risk scenarios were applicable. Leaching to groundwater followed by ingestion of groundwater was not considered because: (1) shallow groundwater is not a drinking water source; (2) there are no nearby exposure points; and (3) the dissolved hydrocarbon plume has been noted to be stable.

Site-specific parameters used to calculate SSTLs are described below.

- **Depth to Subsurface Soil Impact**: the Tier 1 input parameter is 3.28 feet (100 centimeters) below grade surface (bgs). The average depth to soil impact that exceeded RBSLs is 5.6 feet (170.7 centimeters). The value of 170.7 centimeters was used in calculating SSTLs.
- **Volumetric Air Content**: on average, the soil impact is either below the groundwater table or at the capillary fringe. The ASTM Standard Tier 1 parameter for volumetric air content at the capillary fringe is 0.038 cubic centimeters air per cubic centimeters soil; this value was used in calculating SSTLs.

SSTL calculation worksheets that show input parameters and calculation results are provided in Attachment B.

RESULTS

Area-specific average benzene concentrations are compared with RBSLs in Table 2. The comparison suggests there would be risks associated with atmospheric and enclosed space inhalation. Considering one in one million (1E-06) additional probability that an individual may develop cancer over a 70-year lifetime as a result of the exposure conditions evaluated, it can be seen:

- The residential and commercial atmospheric inhalation RBSLs are exceeded by the average benzene values for Areas 2 and 5;
- The residential and commercial enclosed space inhalation RBSLs are exceeded by the average benzene values for Areas 2, 4, 5, and 6.

Considering one in ten thousand (1E-04) additional probability, it was found:

- The residential enclosed space inhalation RBSL is exceeded by the average benzene values for Areas 2 and 5.

SSTLs are compared with area-specific average benzene concentrations in Table 3. The table shows that the enclosed-space inhalation SSTL for residential exposure, considering 1E-06 additional probability, is exceeded by average benzene values for Areas 2, 5, and 6. It can also be seen that the enclosed space inhalation SSTL for commercial exposure, considering 1E-06 additional probability, is exceeded by the average benzene value for Area 2. SSTLs associated with 1E-04 and 1E-05 additional probabilities are not exceeded by any average benzene values.

CONCLUSIONS AND RECOMMEDATIONS

Based on the comparison with SSTLs, there may be a 1E-06 additional probability that an individual may develop cancer over a 70-year lifetime as a result of enclosed space inhalation at the conditions evaluated. This risk does not exist at probability levels of 1E-04 and 1E-05; the recommended range of acceptable risk probabilities, according to the Environmental Protection Agency (EPA), is 1E-04 to 1E-06.

not true!

With proper precautions, such as implementation of a risk management plan and participation in a County operated property development notification program, the risk identified here can be controlled and/or mitigated. RRM understands some excavation is proposed, but given that risk probabilities for the site lie between 1E-05 and 1E-06 for enclosed space inhalation, it does not appear that excavation is necessary. Instead, RRM recommends development of a risk management plan (RMP) that is acceptable to the ACEHS, implementation of the approved RMP, and participation in a property development notification program.

Please call me at (408) 475-8141 with questions or comments regarding this letter.

Sincerely,

RRM, Inc.

R. L. Giattino

R. L. Giattino
Chemical Engineer

REGISTERED PROFESSIONAL ENGINEER
ROBERT L. GIATTINO
No. 5068
EXP. 6/99
CHEMICAL
STATE OF CALIFORNIA

Attachments:
Table 1 - Area Specific Average Benzene Concentrations in Soil
Table 2 - Area Specific Average Benzene Concentration in Soil Compared to RBSLs
Table 3 - Area Specific Average Benzene Concentration in Soil Compared to SSTLs and RBSLs
Attachment A - Site Maps
Attachment B - SSTL Calculation Worksheets

Table 1

Area Specific Average Benzene Concentration in Soil

Former Signal Bulk Plant
2001 Versailles Avenue
Alameda, California

Area	Depth (feet)	Benzene (ppm)
1	3	0.0025
	4	0.002
	5	0.0025
	5.25	0.0025
	mean	0.002375
	SD	0.00025
2	2.5	0.0025
	3.5	0.0025
	4	0.0025
	5.5	0.0025
	5.5	0.0025
	5.5	0.0025
	6	0.003
	7.5	2.9
	9	0.0025
	mean	0.3245
	SD	0.965813
3	4.75	0.0025
	7	0.0025
	mean	0.0025
	SD	0
4	0.1	0.0025
	1.5	0.0025
	2.5	0.0025
	3	0.0025
	4.5	0.0025
	5	0.63
	5	0.0025
	5	0.0025
	mean	0.080938
	SD	0.221855

Area	Depth (feet)	Benzene (ppm)
5	2.5	0.0025
	2.5	0.0025
	3.5	0.35
	5.5	1.1
	6	0.0025
	7	0.0025
	10	0.0025
	mean	0.208929
	SD	0.413718
6	0.75	0.0025
	2	0.0025
	3.75	0.0025
	4	0.0025
	5.25	0.0025
	5.25	0.0025
	5.5	0.0025
	5.5	0.0025
	7.5	0.49
	8	0.0025
	10	0.0025
	mean	0.046818
	SD	0.146987

Table 2

Area Specific Average Benzene Concentration in Soil Compared to RBSLs

Former Signal Bulk Plant
2001 Versailles Avenue
Alameda, California

Tier 0 adjusted to CA –

Area	Average Benzene Concentration (ppm)	Atmospheric Inhalation (ppm)				Enclosed Inhalation (ppm)				Ingestion/Dermal/Soil Inhalation (ppm)			
		Residential		Commercial		Residential		Commercial		Residential		Commercial	
		1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06
1	0.002	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9
2	0.32	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9
3	0.0025	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9
4	0.08	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9
5	0.21	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9
6	0.047	7.89	0.08	13.25	0.13	0.16	0.002	0.49	0.005	168.8	1.69	290	2.9

ppm = parts per million, milligrams per kilogram
RBSL = risk-based screening level

Table 3

Area Specific Average Benzene Concentration in Soil Compared to SSTLs and RBSLs

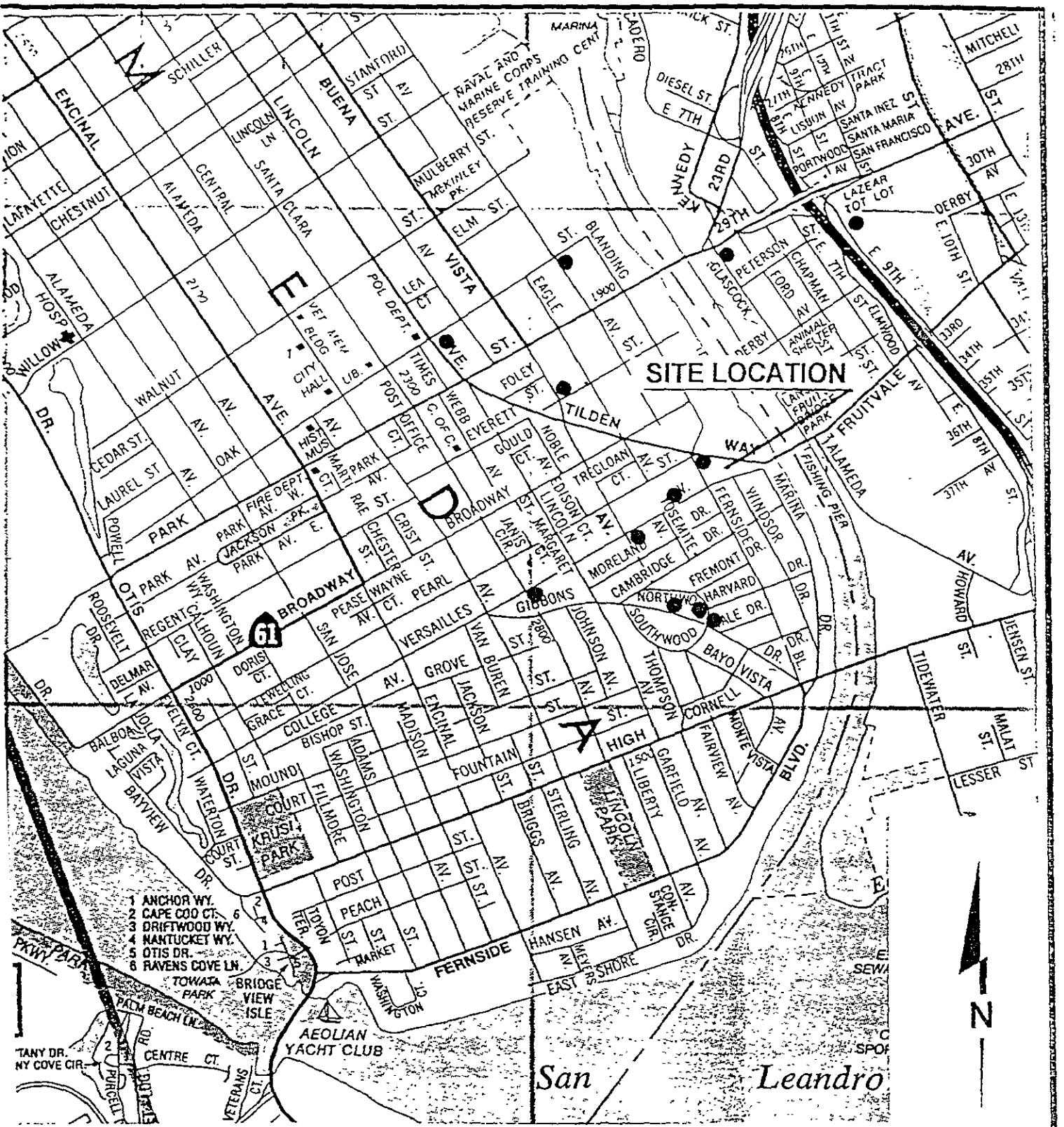
Former Signal Bulk Plant
2001 Versailles Avenue
Alameda, California

Area	Average Benzene Concentration (ppm)	SSTL Atmospheric Inhalation (ppm)				SSTL Enclosed Inhalation (ppm)				RBSL Ingestion/Dermal/Soil Inhalation (ppm)			
		Residential		Commercial		Residential		Commercial		Residential		Commercial	
		1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06	1.00E-04	1.00E-06
1	0.002	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9
2	0.32	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9
3	0.0025	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9
4	0.08	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9
5	0.21	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9
6	0.047	N	54	N	N	7	0.07	21	0.21	168.8	1.69	290	2.9

ppm = parts per million, milligrams per kilogram
SSTL = site specific target level
RBSL = risk-based screening level
N = not necessary, most stringent SSTL not exceeded

SSTL's based on site specific parameters

ATTACHMENT A
SITE MAPS



● WELL LOCATION

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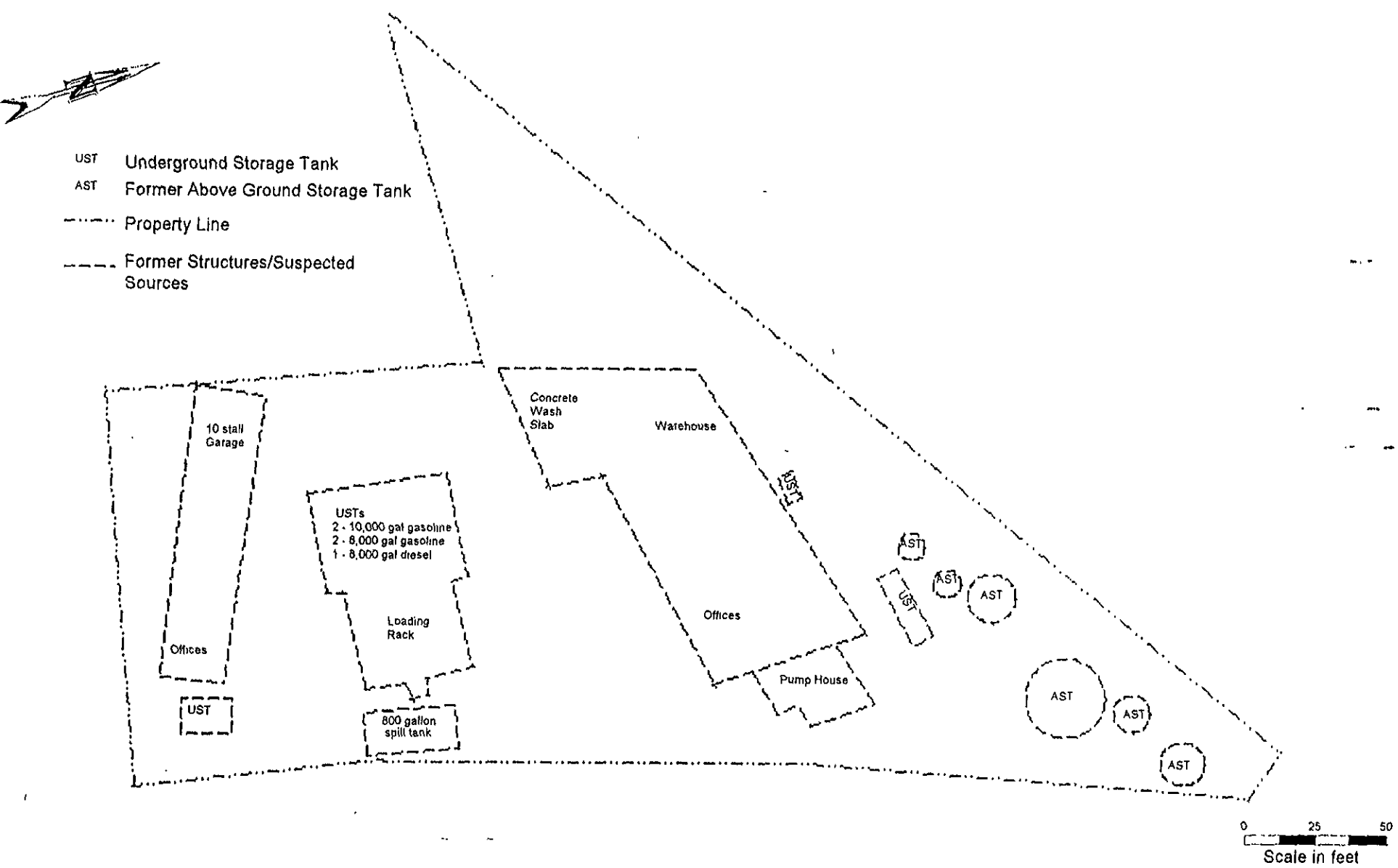
SITE VICINITY MAP and WELL SURVEY LOCATIONS

Former Chevron Bulk Plant
2001 Versailles Avenue
Alameda, California

FIGURE
1

PROJECT NO	DATE	DRAWN BY	BASE MAP
FABP-3	5/98	DJV	AAA ROAD MAP JANUARY 19(illegible)



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SITE PLAN
FORMER ALAMEDA BULK PLANT
2001 VERSAILLES AVENUE
ALAMEDA, CALIFORNIA

FIGURE
2

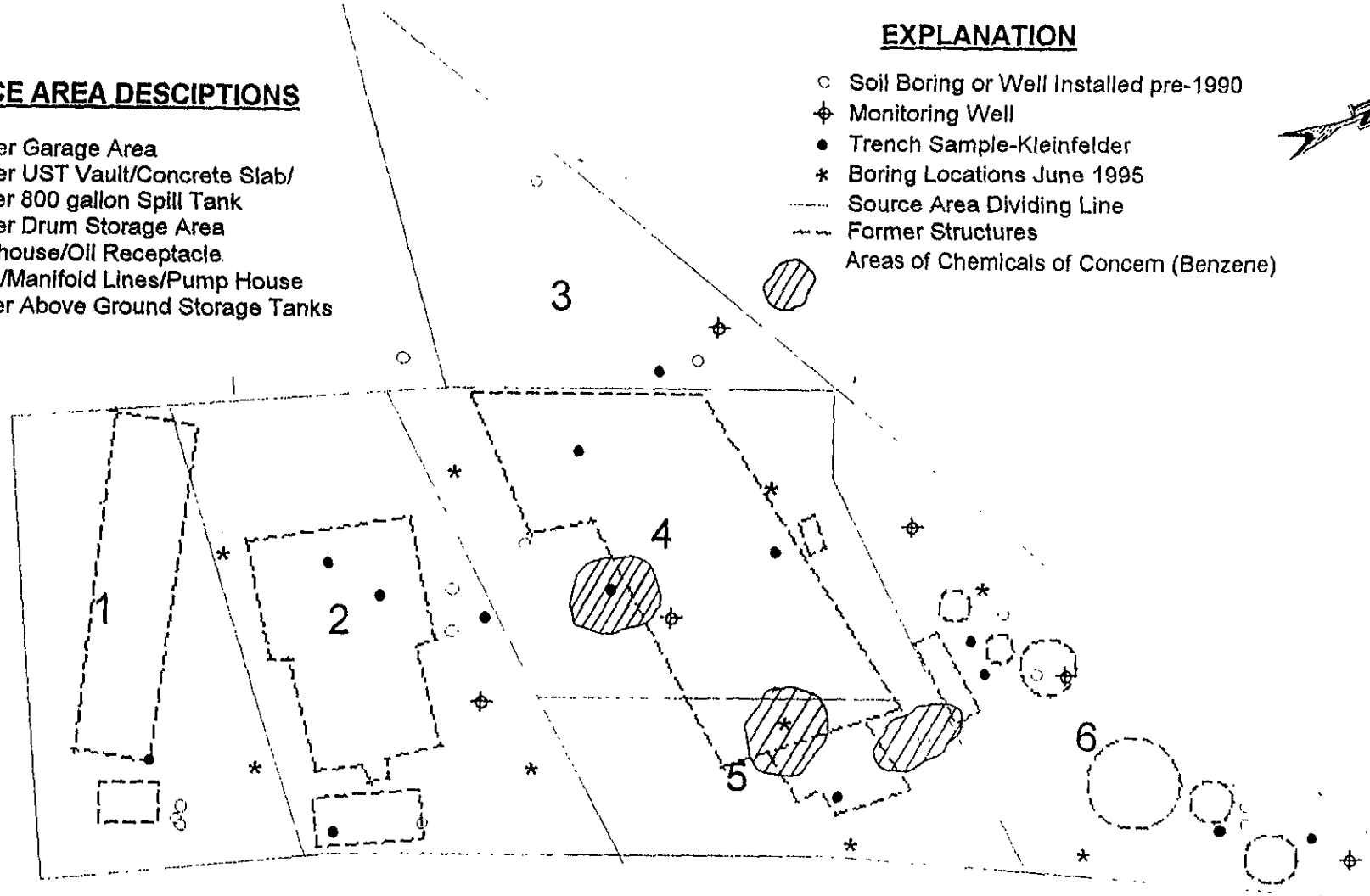
PROJECT NO.	DRAWN BY:	DATE	BASE MAP:
chev-1	AMD	1/95	KLEINFELDER

SOURCE AREA DESCIPTIONS

1) Former Garage Area
2) Former UST Vault/Concrete Slab/ Former 800 gallon Spill Tank
3) Former Drum Storage Area
4) Warehouse/Oil Receptacle
5) Sump/Manifold Lines/Pump House
6) Former Above Ground Storage Tanks

EXPLANATION

- ○ Soil Boring or Well Installed pre-1990
- ⊕ Monitoring Well
- • Trench Sample-Kleinfelder
- * Boring Locations June 1995
- ..... Source Area Dividing Line
- – – Former Structures
- Areas of Chemicals of Concern (Benzene)



Areas Are Approximate

0 25 50
Scale in feet

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POTENTIAL SOURCE AREAS and AREAS OF CONCERN
FORMER ALAMEDA BULK PLANT
2001 VERSAILLES AVENUE
ALAMEDA, CALIFORNIA

FIGURE
3

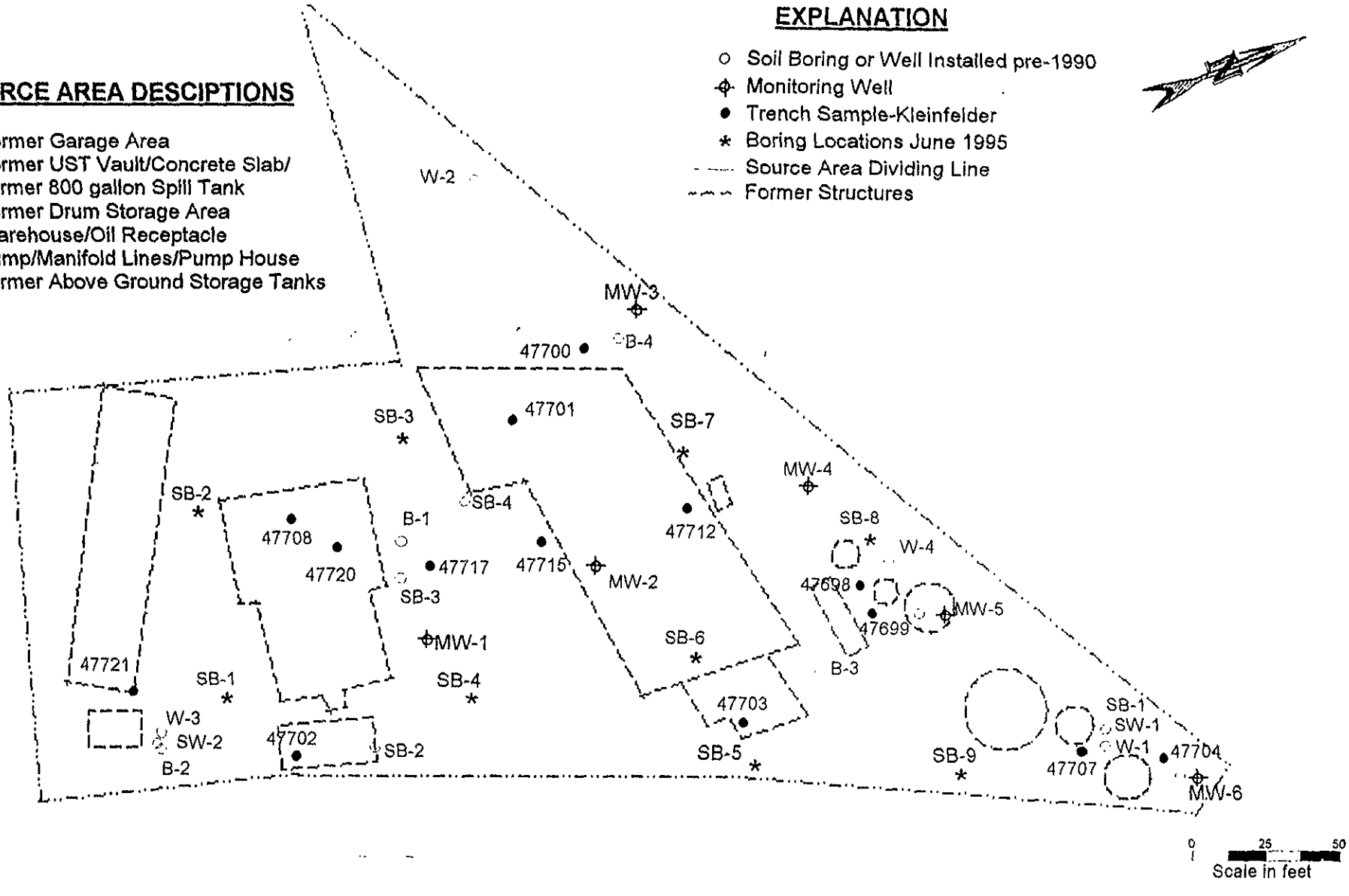
PROJECT NO.	DRAWN BY:	DATE	BASE MAP:
chev-1	AMD	7/95	KLEINFELDER

SOURCE AREA DESCIPTIONS

1) Former Garage Area
2) Former UST Vault/Concrete Slab/ Former 800 gallon Spill Tank
3) Former Drum Storage Area
4) Warehouse/Oil Receptacle
5) Sump/Manifold Lines/Pump House
6) Former Above Ground Storage Tanks

EXPLANATION

- ○ Soil Boring or Well Installed pre-1990
- ⊕ Monitoring Well
- ● Trench Sample-Kleinfelder
- * Boring Locations June 1995
- —— Source Area Dividing Line
- - - - Former Structures



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BORINGS AND SAMPLE LOCATIONS

FORMER ALAMEDA BULK PLANT
2001 VERSAILLES AVENUE
ALAMEDA, CALIFORNIA

FIGURE
4

PROJECT NO.	DRAWN BY:	DATE	BASE MAP:
chev-1	AMD	7/95	KLEINFELDER

ATTACHMENT B
SSTL CALCULATION WORKSHEETS

Risk Based Corrective Action Soil Cleanup Goal
Worksheet

Scenario: residual contaminant dissolved in soil moisture (residual soil impact) volatilizes and is transported through the vadose zone via diffusion. Contaminant vapors leave the soil surface and enter the atmosphere where they are inhaled by a 70 kilogram adult.

what about Children

Working Equations:

$VFamb = (H^*\rho s)^*(1/(\theta ws+Ks^*\rho s+H^*\theta as))^*(1/(1+(Uair^*\delta air^*Ls)/(D^{eff}*W)))^*10^3$

where,

		Benzene Imapct Conservative Generic Values	Benzene Impact Site Specific Values	Site Specific
H =	Henry's Law Constant (cm^3-water/cm^3-air)	0.22	0.22	
ρs =	soil bulk density (g-soil/cm^3-soil)	1.7	1.7	
θws =	volumetric water content in soil (cm^3-water/cm^3-soil)	0.12	0.342	
θas =	volumetric air content in soil (cm^3-air/cm^3-soil)	0.26	0.038	
θ_T =	total soil porosity (cm^3-void/cm^3-soil)	0.38	0.38	
Ks =	soil-water sorption coefficient (cm^3-water/g-soil) = foc*koc	0.380	0.380189	
foc =	fraction of organic carbon in soil (g-carbon/g-soil)	0.01	0.01	
koc =	carbon-water sorption cofficient (cm^3-water/g-carbon)	38.0189	38.0189	
Uair =	wind speed above ground surface in ambient mixing zone (cm/s)	225	225	
δair =	ambient air mixing zone height (cm)	200	200	
Ls =	depth to subsurface soil impact (cm)	100	170.7	
D^{eff} =	effective diffusion coefficient in soil, vapor (cm^2/s) =[D_{air}*(θ_{as}^3.33)/(θ_T^2)]+[D_{water}*(1/H)*(θ_{ws}^3.33)/(θ_T^2)]	0.0072576	2.1732E-05	
Dair =	diffusion coefficient in air (cm^2/s)	0.093	0.093	
Dwater =	diffusion coefficient in water (cm^2/s)	1.10E-05	1.10E-05	
W =	width of impact area parallel to wind direction (cm)	1500	1500	
VFamb =	relationship between outdoor air and soil concentrations (mg/m^3-air)/(mg/kg-soil)	0.001098675	1.5925E-06	
RBSLair =	risk-based screening level (ug-contaminant/m^3-air) - residential 10^-6 risk	2.94E-01	2.94E-01	
SSTL =	site specific target level (mg-contaminant/kg-soil) = (RBSLair/VFamb)*1E-3	2.68E-01	1.85E+02	
SSTL =	CalEPA risk for benzene multiply by 0.29	7.76E-02	5.35E+01	

Risk Based Corrective Action Soil Cleanup Goal Worksheet

Indoor

Scenario: residual contaminant dissolved in soil moisture (residual soil impact) volatilizes and is transported through the vadose zone via diffusion. Contaminant vapors leave the concrete surface through cracks and enter the atmosphere where they are inhaled by a 70 kilogram adult.

Working Equations: $VFsesp = (H^*\rho s)^*(1/(\theta ws+Ks^*\rho s+H^*\theta as))^*A^*B^*10^3$

		Benzene Imapct Conservative	Benzene Impact Site Specific	Site Specific
H =	Henry's Law Constant (cm^3-water/cm^3-air)	0.22	0.22	
ρs =	soil bulk density (g-soil/cm^3-soil)	1.7	1.7	
θws =	volumteric water content in soil (cm^3-water/cm^3-soil)	0.12	0.342	
θas =	volumetric air content in soil (cm^3-air/cm^3-soil)	0.26	0.038	
θ_T =	total soil porosity (cm^3-void/cm^3-soil)	0.38	0.38	
ks =	soil-water sorption coefficient (cm^3-water/g-soil) = foc*koc	0.380189396	0.380189396	
foc =	fraction of organic carbon in soil (g-carbon/g-soil)	0.01	0.01	
koc =	carbon-water sorption cofficient (cm^3-water/g-carbon)	38.01893963	38.01893963	
A =	$(D^{eff}/Ls)^*(1/(ER^*L_B))$	0.002592011	4.54691E-06	
B =	$1/(1+A+((D^{eff}/Ls)/((D_{crack}/L_{crack})^*\eta)))$	0.062489877	0.974357273	
Ls =	depth to subsurface soil impact (cm)	100	170.7	
D^{eff} =	effective diffusion coefficient in soil, vapor (cm^2/s)	0.007257629	2.17324E-05	
	$=[D_{air}^*(\theta_{as}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}^*(1/H)^*(\theta_{ws}\text{^}3.33)/(\theta_T\text{^}2)]$			
Dair =	diffusion coefficient in air (cm^2/s)	0.093	0.093	
Dwater =	diffusion coefficient in water (cm^2/s)	1.10E-05	1.10E-05	
D_{crack} =	effective vapor diffusion coefficient through concrete (cm^2/s)	0.007257629	0.007257629	
	$=[D_{air}^*(\theta_{acrack}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}^*(1/H)^*(\theta_{wcrack}\text{^}3.33)/(\theta_T\text{^}2)]$			
θ_{acrack} =	volumetric air content in crack (cm^3/cm^3)	0.26	0.26	
θ_{wcrack} =	volumetric water content in crack (cm^3/cm^3)	0.12	0.12	
L_{crack} =	foundation or wall thickness (cm)	15	15	
L_B =	enclosed space volume/infiltration area (cm)	200	200	
ER =	enclosed space air exchange rate (L/s)	0.00014	0.00014	
η =	areal fraction of cracks in foundation/walls (cm^2-cracks/cm^2-total area)	0.01	0.01	
VFsesp =	relationship between indoor air and soil concentrations (mg/m^3-air)/(mg/kg-soil)	0.073560189	0.001662454	
RBSLair =	risk-based screening level (ug-contaminant/m^3-air) - residential 10^-6 risk	3.92E-01	3.92E-01	
SSTL =	site specific target level (mg-contaminant/kg-soil)	5.33E-03	2.36E-01	
CalEPA	= (RBSLair/VFsesp)*1E-3 (CalEPA risk for benzene multiply by 0.29)	1.55E-03	6.84E-02	

Risk Based Corrective Action Soil Cleanup Goal
Worksheet

Scenario: residual contaminant dissolved in soil moisture (residual soil impact) volatilizes and is transported through the vadose zone via diffusion. Contaminant vapors leave the concrete surface through cracks and enter the atmosphere where they are inhaled by a 70 kilogram adult.

Working Equations: $VFsesp = (H^*\rho s)^*(1/(\theta ws+ks^*\rho s+H^*\theta as))^*A^*B^*10^3$

		Benzene Imapct Conservative	Benzene Impact Site Specific	Site Specific
H =	Henry's Law Constant (cm^3-water/cm^3-air)	0.22	0.22	
ρs =	soil bulk density (g-soil/cm^3-soil)	1.7	1.7	
θws =	volumteric water content in soil (cm^3-water/cm^3-soil)	0.12	0.342	
θas =	volumetric air content in soil (cm^3-air/cm^3-soil)	0.26	0.036	
θ_T =	total soil porosity (cm^3-void/cm^3-soil)	0.38	0.38	
ks =	soil-water sorption coefficient (cm^3-water/g-soil) = foc*koc	0.380189396	0.380189396	
foc =	fraction of organic carbon in soil (g-carbon/g-soil)	0.01	0.01	
koc =	carbon-water sorption cofficient (cm^3-water/g-carbon)	38.01893963	38.01893963	
A =	$(D^{eff}/Ls)^*(1/(ER^*L_B))$	0.002592011	4.54691E-06	
B =	$1/(1+A+((D^{eff}/Ls)/((D_{crack}/L_{crack})^*\eta)))$	0.062489877	0.974357273	
Ls =	depth to subsurface soil impact (cm)	100	170.7	
D^{eff} =	effective diffusion coefficient in soil, vapor (cm^2/s)	0.007257629	2.17324E-05	
	$=[D_{air}^*(\theta_{as}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}^*(1/H)^*(\theta_{ws}\text{^}3.33)/(\theta_T\text{^}2)]$			
Dair =	diffusion coefficient in air (cm^2/s)	0.093	0.093	
Dwater =	diffusion coefficient in water (cm^2/s)	1.10E-05	1.10E-05	
D_{crack} =	effective vapor diffusion coefficient through concrete (cm^2/s)	0.007257629	0.007257629	
	$=[D_{air}^*(\theta_{acrack}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}^*(1/H)^*(\theta_{wcrack}\text{^}3.33)/(\theta_T\text{^}2)]$			
θ_{acrack} =	volumetric air content in crack (cm^3/cm^3)	0.26	0.26	
θ_{wcrack} =	volumetric water content in crack (cm^3/cm^3)	0.12	0.12	
L_{crack} =	foundation or wall thickness (cm)	15	15	
L_B =	enclosed space volume/infiltration area (cm)	200	200	
ER =	enclosed space air exchange rate (L/s)	0.00014	0.00014	
η =	areal fraction of cracks in foundation/walls (cm^2-cracks/cm^2-total area)	0.01	0.01	
VFsesp =	relationship between indoor air and soil concentrations (mg/m^3-air)/(mg/kg-soil)	0.073560189	0.001662454	
RBSLair =	risk-based screening level (ug-contaminant/m^3-air) - residential 10^-4 risk	3.92E+01	3.92E+01	
SSTL =	site specific target level (mg-contaminant/kg-soil)	5.33E-01	2.36E+01	
CalEPA	= (RBSLair/VFsesp)*1E-3 (CalEPA risk for benzene multiply by 0.29)	1.55E-01	6.84E+00	

Risk Based Corrective Action Soil Cleanup Goal
Worksheet

Scenario: residual contaminant dissolved in soil moisture (residual soil impact) volatilizes and is transported through the vadose zone via diffusion. Contaminant vapors leave the concrete surface through cracks and enter the atmosphere where they are inhaled by a 70 kilogram adult.

Working Equations: $VFsesp = (H*\rho s)*(1/(\theta ws+ks*\rho s+H*\theta as))*A*B*10^3$

		Benzene Imapct Conservative	Benzene Impact Site Specific	Site Specific
H =	Henry's Law Constant (cm^3-water/cm^3-air)	0.22	0.22	
ρs =	soil bulk density (g-soil/cm^3-soil)	1.7	1.7	
θws =	volumteric water content in soil (cm^3-water/cm^3-soil)	0.12	0.342	
θas =	volumetric air content in soil (cm^3-air/cm^3-soil)	0.26	0.038	
θ_T =	total soil porosity (cm^3-void/cm^3-soil)	0.38	0.38	
ks =	soil-water sorption coefficient (cm^3-water/g-soil) = foc*koc	0.380189396	0.380189396	
foc =	fraction of organic carbon in soil (g-carbon/g-soil)	0.01	0.01	
koc =	carbon-water sorption cofficient (cm^3-water/g-carbon)	38.01893963	38.01893963	
A =	$(D^{eff}/Ls)*(1/(ER*L_B))$	0.00105183	1.84512E-06	
B =	$1/(1+A+((D^{eff}/Ls)/((D_{crack}/L_{crack})*\eta)))$	0.062495892	0.974359838	
Ls =	depth to subsurface soil impact (cm)	100	170.7	
D^{eff} =	effective diffusion coefficient in soil, vapor (cm^2/s) $=[D_{air}*(\theta_{as}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}*(1/H)*(\theta_{ws}\text{^}3.33)/(\theta_T\text{^}2)]$	0.007257629	2.17324E-05	
Dair =	diffusion coefficient in air (cm^2/s)	0.093	0.093	
Dwater =	diffusion coefficient in water (cm^2/s)	1.10E-05	1.10E-05	
D_{crack} =	effective vapor diffusion coefficient through concrete (cm^2/s) $=[D_{air}*(\theta_{acrack}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}*(1/H)*(\theta_{wcrack}\text{^}3.33)/(\theta_T\text{^}2)]$	0.007257629	0.007257629	
θ_{acrack} =	volumetric air content in crack (cm^3/cm^3)	0.26	0.26	
θ_{wcrack} =	volumetric water content in crack (cm^3/cm^3)	0.12	0.12	
L_{crack} =	foundation or wall thickness (cm)	15	15	
L_B =	enclosed space volume/infiltration area (cm)	300	300	
ER =	enclosed space air exchange rate (L/s)	0.00023	0.00023	
η =	areal fraction of cracks in foundation/walls (cm^2-cracks/cm^2-total area)	0.01	0.01	
VFsesp =	relationship between indoor air and soil concentrations (mg/m^3-air)/(mg/kg-soil)	0.029853385	0.000674621	
RBSLair =	risk-based screening level (ug-contaminant/m^3-air) - commercial 10^-6 risk	4.93E-01	4.93E-01	
SSTL =	site specific target level (mg-contaminant/kg-soil)	1.65E-02	7.31E-01	
CalEPA	= (RBSLair/VFsesp)*1E-3 (CalEPA risk for benzene multiply by 0.29)	4.79E-03	2.12E-01	

Risk Based Corrective Action Soil Cleanup Goal
Worksheet

Scenario: residual contaminant dissolved in soil moisture (residual soil impact) volatilizes and is transported through the vadose zone via diffusion. Contaminant vapors leave the concrete surface through cracks and enter the atmosphere where they are inhaled by a 70 kilogram adult.

Working Equations: $VFsesp = (H*\rho s)*(1/(\theta ws+ks*\rho s+H*\theta as))*A*B*10^3$

		Benzene Imapct Conservative	Benzene Impact Site Specific	Site Specific
H =	Henry's Law Constant (cm^3-water/cm^3-air)	0.22	0.22	
ρs =	soil bulk density (g-soil/cm^3-soil)	1.7	1.7	
θws =	volumteric water content in soil (cm^3-water/cm^3-soil)	0.12	0.342	
θas =	volumetric air content in soil (cm^3-air/cm^3-soil)	0.26	0.038	
θ_T =	total soil porosity (cm^3-void/cm^3-soil)	0.38	0.38	
ks =	soil-water sorption coefficient (cm^3-water/g-soil) = foc*koc	0.380189396	0.380189396	
foc =	fraction of organic carbon in soil (g-carbon/g-soil)	0.01	0.01	
koc =	carbon-water sorption cofficient (cm^3-water/g-carbon)	38.01893963	38.01893963	
A =	$(D^{eff}/Ls)*(1/(ER*L_B))$	0.00105183	1.84512E-06	
B =	$1/(1+A+((D^{eff}/Ls)/((D_{crack}/L_{crack})*\eta)))$	0.062495892	0.974359838	
Ls =	depth to subsurface soil impact (cm)	100	170.7	
D^{eff} =	effective diffusion coefficient in soil, vapor (cm^2/s) $=[D_{air}*(\theta_{as}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}*(1/H)*(\theta_{ws}\text{^}3.33)/(\theta_T\text{^}2)]$	0.007257629	2.17324E-05	
Dair =	diffusion coefficient in air (cm^2/s)	0.093	0.093	
Dwater =	diffusion coefficient in water (cm^2/s)	1.10E-05	1.10E-05	
D_{crack} =	effective vapor diffusion coefficient through concrete (cm^2/s) $=[D_{air}*(\theta_{acrack}\text{^}3.33)/(\theta_T\text{^}2)]+[D_{water}*(1/H)*(\theta_{wcrack}\text{^}3.33)/(\theta_T\text{^}2)]$	0.007257629	0.007257629	
θ_{acrack} =	volumetric air content in crack (cm^3/cm^3)	0.26	0.26	
θ_{wcrack} =	volumetric water content in crack (cm^3/cm^3)	0.12	0.12	
L_{crack} =	foundation or wall thickness (cm)	15	15	
L_B =	enclosed space volume/infiltration area (cm)	300	300	
ER =	enclosed space air exchange rate (L/s)	0.00023	0.00023	
η =	areal fraction of cracks in foundation/walls (cm^2-cracks/cm^2-total area)	0.01	0.01	
VFsesp =	relationship between indoor air and soil concentrations (mg/m^3-air)/(mg/kg-soil)	0.029853385	0.000674621	
RBSLair =	risk-based screening level (ug-contaminant/m^3-air) - commercial 10^-4 risk	4.93E+01	4.93E+01	
SSTL =	site specific target level (mg-contaminant/kg-soil)	1.65E+00	7.31E+01	
CalEPA	= (RBSLair/VFsesp)*1E-3 (CalEPA risk for benzene multiply by 0.29)	4.79E-01	2.12E+01	