Weiss Associates Environmental and Geologic Services

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May 31, 2000

Tom Bauhs
Chevron Products Company
P.O. Box 5004
San Ramon, California 94583-0804

RE: **Project Summary**
Former Chevron Service Station #9-5607
5269 Crow Canyon Road
Castro Valley, California
WA Job #4-1129-3

Dear Mr. Bauhs:

On behalf of Chevron Products Company (Chevron), Weiss Associates (WA) has prepared this project summary of **risk based corrective action (RBCA)** work conducted at the Forrest Creek Townhomes condominium complex in Castro Valley, California. The RBCA work was completed in response to a previous hydrocarbon release that has migrated from the above referenced site to ground water below the Townhomes complex. This summary of RBCA work satisfies two action items agreed upon between Tim Utterback of WA, Brett Hunter of Chevron, Scott Seery of Alameda County Health Care Services Agency (ACHCSA), and Chuck Headlee of the Regional Water Quality Control Board (RWQCB) in a January 12, 2000 meeting concerning the site. Included in this summary are a history of the site investigation and RBCA activities at the site and a summary of conclusions drawn from completing this work. The project history and project conclusions are presented in turn below.

PROJECT HISTORY

WA submitted a Proposed Corrective Action Work Plan dated, April 1, 1996, in response to the RBCA strategy discussion between Chevron and ACHCSA on October 20, 1995. The work plan specified collecting three vapor samples from one bore hole and one vapor sample from each of 7 bore holes. The work plan also included collecting 3 soil samples and one ground water grab sample from each bore hole. Vapor, soil, and water sample analyses were specified by EPA Methods for benzene, toluene, ethylbenzene, xylenes, (BTEX) and total petroleum hydrocarbons as gasoline (TPH-G). WA recommended submitting one soil sample for analysis of geotechnical parameters and fraction of organic carbon (foc). WA also proposed analyzing the vapor samples for oxygen, carbon dioxide, and methane to assess whether hydrocarbon degradation was occurring in the subsurface. The sample data were to be collected during two discrete sampling events in 1996. The purpose of the sample collection work was to obtain site-specific data for a RBCA analysis.

As agreed upon between Mike Cooke of WA and Amy Leech of ACHCSA, during a May 10, 1996 telephone conversation, WA submitted a Corrective Action Work Plan Addendum dated, May 14, 1996, specifying additional data to be collected. The addendum specified collecting 4 additional soil vapor samples and analyzing 2 additional soil samples for foc.

On August 19 and 20, 1996, WA collected samples as specified in the April 1, 1996 Work Plan and May 14, 1996 Work Plan Addendum. WA summarized the sample data in a report titled Soil Vapor Survey Sampling Report dated, January 20, 1997. The sampling activities included drilling 8 direct push soil borings and collecting vapor, soil, and ground water samples. The maximum concentration of benzene in pore vapor was 38 parts per million by volume (ppmv) from boring location SV-4 at 25 feet bgs. The highest concentration of benzene in shallow (3 feet bgs) vapor samples was 0.040 ppmv in boring SV-8. Benzene concentrations in soil were below laboratory detection limits in all samples collected at depths ranging from 3 feet to 10 feet bgs. Benzene was detected in soil at depths ranging from 21 feet to 25 feet bgs. Ground water was only encountered in boring location SV-1. The concentration of benzene in ground water at boring location SV-1 was 0.028 mg/L. The vapor sample results are summarized in Table 1.

Using the data collected on August 19 and 20, 1996, WA prepared a RBCA Report dated, January 20, 1997. The results of the RBCA evaluation indicated that subsurface hydrocarbons do not pose significant human health risk to the residents of Forrest Creek Townhomes in Castro Valley, California. The indoor air health risk was found to be nearly four orders of magnitude less than the trigger level (10^{-5} risk). In addition, WA conservatively determined indoor air health risk assuming that vapors enter the building without obstruction by the floor. WA also found that risk is insignificant to drinking water receptors if dissolved hydrocarbon concentrations remain below the Tier 1 RBSLs in wells C-10B, C-15 and C-16. Based on human health risk considerations, WA concluded that further operation of the ground water extraction system was unnecessary at the subject site. WA recommended preparing a contingency plan in case hydrocarbon concentrations exceed the SSTLs in the future.

WA submitted a cover letter dated, January 20, 1997, presenting the Soil Vapor Survey Sampling Report and RBCA report as attachments. The letter also included a comparison of the site to low-risk ground water case criteria as defined in the Supplemental Instructions to State Water Board December 8, 1995, Interim Guidance on Required Cleanup at Low-Risk Fuel Sites. WA found that the site met all of the definitions for classification as a low-risk ground water case. Based on the results of the Soil Vapor Survey, RBCA, and low risk ground water case comparison, WA recommended a future action plan that included shutting down the existing ground water extraction system and reducing the ground water monitoring requirements at the site. The future action plan also included a contingency plan in case hydrocarbon concentrations trend above the California maximum contaminant levels (MCLs) in downgradient wells C-10B, C-15 or C-16. Based on low risk, WA concluded that the second round of samples specified in the April 1, 1996, Work Plan was not necessary. The first round of data indicated there was no likelihood of human health risk above the trigger level. Thus, a second round of data collection was unjustified.

At the request of ACHCSA, Chevron and WA agreed to conduct the additional data collection specified in the April 1, 1996 Work Plan. WA submitted a Soil Vapor Sample Collection Work Plan dated, August 8, 1997, to collect the second round of soil vapor samples from three locations at a depth of approximately 3 feet below ground surface.

In addition to all previously planned work, ACHCSA requested that Chevron investigate potential preferential pathways and/or conduits that may result in vapor transport from subsurface hydrocarbons to indoor air at the Townhomes condominium units. In response to the ACHCSA request, WA conducted a preferential pathway survey and reported the results in the Vapor Pathway Survey report dated, August 8, 1997. The report investigated all potential preferential vapor pathways that may be present due to natural subsurface geologic conditions and man made conduits such as utility trenches. Based on review of geologic cross sections and city building department data, WA concluded that preferential vapor pathways are unlikely at the Forest Creek Townhomes. Impacted ground water or soil was several feet deeper than the conduits identified in the survey. There was no potential for vapor transport into Townhomes Unit #8 (Figure 1) and little potential for vapor transport into Unit #4. Some potential for preferential vapor transport was found to exist at the deepest end of the sewer service that leads into Townhomes Unit #1.

Based on the information presented in the August 8, 1997, Vapor Pathway Survey, WA prepared a Soil Vapor Sample Collection Work Plan Addendum dated, October 22, 1997. WA recommended collecting 5 additional vapor samples along the 250' stretch of sanitary sewer trench running beneath Waterford Place to investigate whether a preferential vapor pathway may intersect Townhomes Unit #1.

On July 30, 1998, WA collected the second round of samples. WA initially submitted the second round of sample results in a letter titled Soil Vapor Sample Collection Update dated, February 5, 1999. The data were initially rejected in the Update because the field geologist did not record the purge volume. The data were later accepted, as described below, because WA was able to estimate the purge volume.

WA re-evaluated the validity of the second round of sample data in a letter titled Re-Evaluation of Vapor Purge Technique dated, November 21, 1999. WA was able to estimate the purge volume upon requesting design specifications from the purge equipment manufacturer, Geoprobe™ Systems. WA determined that the purge equipment used on July 30, 1998 was capable of removing a maximum of approximately 7.72 liters. The 7.72 liter volume was found to be acceptable for the purpose of collecting soil vapor samples. The Re-Evaluation concluded that "data integrity was not compromised by the purge technique employed at the subject site on July 30, 1998" and that "the July 30, 1998 data are considered valid and useable for their intended purpose".

WA submitted a Soil Vapor Sample Report dated, November 21, 1999, presenting the results of the second sampling event conducted on July 30, 1998. The sample collection event consisted of collecting three vapor samples from 3 feet below ground surface (bgs) and five vapor samples from within the sand backfill for the existing sanitary sewer piping at approximately 6 feet bgs. The laboratory results indicated that the concentration of benzene and toluene in soil vapor was near or below detection limits for all samples collected. The only detected concentration of benzene in soil vapor was 0.0069 parts per million by volume (ppmv) in sample SV-10 collected at 3 feet bgs. The only detected concentration of toluene was 0.0047 ppmv in sample SV-9 at 3 feet bgs. No ethylbenzene or xylenes were detected in any of the soil vapor samples. In addition, BTEX vapor concentrations were below lowest laboratory detection limits in all of the sewer backfill samples. Thus, WA found no preferential vapor pathway into Townhomes Unit #1 or other units from the sewer service. The laboratory results are summarized in Table 2.

At the request of ACHCSA, WA prepared a RBCA Addendum to reflect the second round of soil vapor data collected on July 30, 1998. The RBCA Addendum included an evaluation of data quality, a reevaluation of the representative benzene concentration, and determinations of vapor pathway risk for children. In addition, Tier 2 site-specific target levels (SSTLs) were determined for soil vapor for adult and child receptors. The RBCA Addendum was a Tier 2 evaluation of benzene in the vapor pathways. WA concluded that benzene concentrations in soil vapor do not pose significant risk to human health for Forrest Creek Townhomes residents and that, based on risk, remedial action is not necessary at the subject site. The RBCA Addendum is attached to this letter.

PROJECT CONCLUSIONS

The purpose of this project was to determine whether the hydrocarbons released from former USTs at the subject site pose significant human health risk to residents at the Forrest Creek Townhomes condominiums. WA concludes that:

- The results of the 1997 RBCA report and 2000 RBCA Addendum indicate that hydrocarbons released at the subject site do not pose significant human health risk to Forrest Creek Townhomes residents.
- All data collected for the RBCA evaluations are valid and useable for their intended purpose.
- All data used in the RBCA evaluations are sufficient to fully characterize the extent of hydrocarbons in soil, ground water and soil vapor media in the vicinity of the Townhomes units.
- Concentrations of oxygen, carbon dioxide, and methane in vapor samples indicate that biological activity was present in the subsurface. WA finds that biological activity may be degrading the hydrocarbon plume.
- No vapor conduits or preferential vapor pathways were found in the vicinity of the Forrest Creek Townhomes units.
- Human health risk has been fully evaluated for residents of the Forrest Creek Townhomes with respect to hydrocarbons released from the former USTs at the subject site.

We trust this submittal and the attached RBCA Addendum satisfy the action items agreed upon in the January 12, 2000, meeting. Please call WA at (510) 450-6000 if you have any questions about this letter or the RBCA Addendum.

Sincerely,
Weiss Associates

Tim Utterback P.E.
Project Engineer

Enclosures: Figure 1. Site Plan View
Table 1. Analytic Results for Vapor Samples Collected on August 19 and 20, 1996
Table 2. Analytical Laboratory Results for Vapor Samples Collected on July 30, 1998
Attachment A. RBCA Addendum

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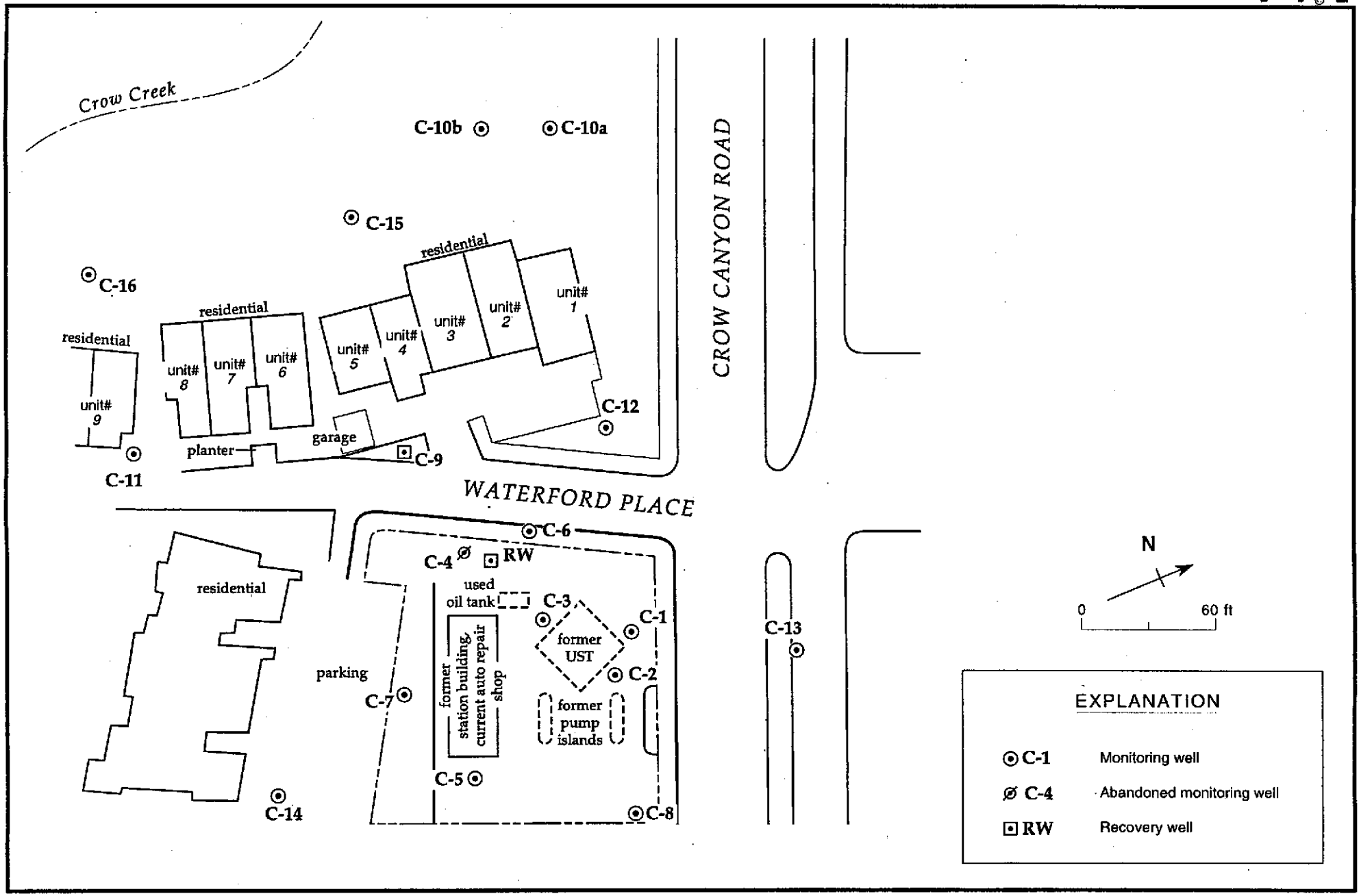


Figure 1. Site Plan - Chevron Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Table 1. Analytic Results for Vapor Samples - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Sample ID	Sample Depth (ft)	B	E	T	X	O_2	CO_2	CH_4
		←parts per billion by volume (ppbv)→				←percent by volume→		
SV-1	3	<4.3	<4.3	<4.3	<8.6	22	0.076	<0.002
SV-2	8	<6.1	<6.1	<6.1	<12.2	1.4	28	0.010
SV-3	8	<4.4	7.6	<4.4	6.7	21	0.25	<0.002
SV-3	25	2,100	3,800	680	2,300	21	0.58	0.004
SV-4	3	<4.3	<4.3	<4.3	<4.6	14	9.3	<0.002
SV-4	8	<4.2	<4.2	<4.2	5.7	21	0.35	<0.002
SV-4	11	<4.2	6.0	<4.2	<8.4	21	0.80	0.007
SV-4	25	38,000	140,000	20,000	83,000	21	0.37	0.002
SV-4	25^{dup}	39,000	140,000	22,000	87,000	21	0.35	0.002
SV-5	12	6.2	32	11	39	22	0.091	<0.002
SV-6	3	29	42	6.4	25.4	0.51	0.054	0.005
SV-7	3	<4.2	5.1	<4.2	6.8	21	0.47	<0.002
SV-8	3	40	83	9.5	59	19	3.6	<0.002

Abbreviations:

B = Benzene by EPA Method TO-14
E = Ethylbenzene by EPA Method TO-14
T = Toluene by EPA Method TO-14
X = Xylenes by EPA Method TO-14
O_2 = Oxygen by ASTM Method D3416
CO_2 = Carbon dioxide by ASTM Method D3416
CH_4 = Methane by ASTM Method D3416
<n = Not detected at detection limits of n ppbv

Notes:

Samples collected on 8/19/96 and 8/20/96 by Weiss Associates and analyzed by Air Toxics, Folsom, California.

Table 2. Analytical Laboratory Results for Vapor Samples – Former Chevron Service Station, 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Sample ID	Sample Depth (ft)	B	T	E	X
		←parts per million by volume (ppmv)→			
SV-9	3	<0.004	0.0047	<0.004	<0.004
SV-10	3	0.0069	<0.0039	<0.0039	<0.0039
SV-11	3	<0.004	<0.004	<0.004	<0.004
SV-12	6	<0.0039	<0.0039	<0.0039	<0.0039
SV-13	6.5	<0.004	<0.004	<0.004	<0.004
SV-14	6	<0.004	<0.004	<0.004	<0.004
SV-15	6	<0.004	<0.004	<0.004	<0.004
SV-16	6	<0.004	<0.004	<0.004	<0.004

Abbreviations:

B = Benzene by EPA Method TO-14.
E = Ethylbenzene by EPA Method TO-14.
T = Toluene by EPA Method TO-14.
X = Xylenes by EPA Method TO-14.
<n = Not detected at detection limit of n ppmv

Notes:

Samples collected on 7/30/98 by Weiss Associates and analyzed by Air Toxics, Folsom, California

ATTACHMENT A

RBCA ADDENDUM

Weiss Associates *Environmental and Geologic Services*

5801 Christie Avenue, Suite 600, Emeryville, CA 94608-1827 *Fax: 510-547-5043* ***Phone: 510-450-6000***

TIER 2 RISK-BASED CORRECTIVE ACTION (RBCA) ADDENDUM

for

Former Chevron Service Station 9-5607
5269 Crow Canyon Road
Castro Valley, California

Prepared for

Chevron Products Company
6001 Bollinger Canyon Road
P.O. Box 5004
San Ramon, CA 94583-0804

Weiss Associates *Environmental and Geologic Services*

5801 Christie Avenue, Suite 600, Emeryville, CA 94608-1827 *Fax: 510-547-5043* ***Phone: 510-450-6000***

TIER 2 RISK-BASED CORRECTIVE ACTION (RBCA) ADDENDUM

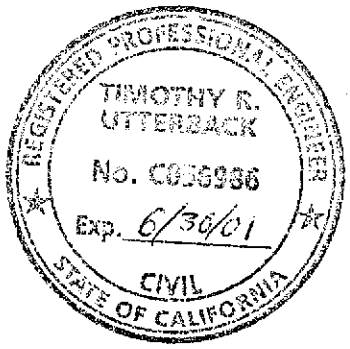
for

Former Chevron Service Station 9-5607
5269 Crow Canyon Road
Castro Valley, California

Prepared by

Weiss Associates
5801 Christie Avenue, Suite 600
Emeryville, CA 94608

WA Job #4-1129-4



Tim Utterback, P.E. Date
Project Engineer
No. C056986

Weiss Associates work for this Risk-Based Corrective Action Addendum, was conducted under my supervision. To the best of my knowledge, the data contained herein are true and accurate and satisfy the scope of work prescribed by the client for this project. The data, findings, recommendations, specifications or professional opinions were prepared solely for the use of Chevron Products Company in accordance with generally accepted professional engineering and geologic practice. We make no other warranty, either expressed or implied, and are not responsible for the interpretation by others of the contents herein.

6/6/00

Michael J. Zimmerman, P.E., R.E.A. Date
Sr. Project Engineer

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FIGURES

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APPENDICES

1. INTRODUCTION

This report is an Addendum to the January 20, 1997 Risk-Based Corrective Action (RBCA) report Weiss Associates (Weiss) completed for the former Chevron Service Station located at 5269 Crow Canyon Road in Castro Valley, California (Site). The RBCA report was prepared using site characterization data from soil and ground water investigations as well as data from the first soil vapor survey event conducted on August 19 and 20, 1996. Mr. Scott Seery of Alameda County Health Care Services Agency (ACHCSA) requested this Addendum in his January 13, 2000 letter to Brett Hunter of Chevron.

This Addendum and the initial RBCA Report were completed according to the guidance in the American Society for Testing and Materials Standard Guide for Risk-Based Corrective Action applied at Petroleum Release Sites (ASTM Standard E1739-95). This Addendum completes all RBCA tasks requested by Mr. Seery of ACHCSA. The tasks associated with this Addendum are to:

- Evaluate data quality for two soil vapor survey events. Evaluate data from the first event to determine whether oxygen, carbon dioxide, and methane concentrations are indicative of data quality. Evaluate data from the second event to determine whether difficulties estimating the sample purge volume have an impact on data quality.
- Determine the representative concentration of benzene in soil vapor based on data from both soil vapor survey events.
- Determine vapor pathway risk for the most sensitive potential receptor population (i.e. children). Determine Tier 2 soil vapor site-specific target levels (SSTLs) for adult and child receptors.

This Addendum is a RBCA Tier 2 evaluation as requested by ACHCSA. Exposure to benzene in vapor was the only chemical and exposure pathway evaluated in this Tier 2 Addendum. All other chemicals and exposure pathways did not require re-evaluation in this Addendum because the site was fully characterized for those pathways prior to preparing the initial RBCA Report. In addition, Weiss verified that the recent data from the second soil vapor survey event did not indicate any need to reevaluate the Tier 1 portion of initial RBCA Report.

This Addendum includes:

- Data selection, evaluation of data usability, and evaluation of data quality;
- A determination of the representative soil vapor concentration;
- A description of the vapor exposure pathway;
- Risk and site-specific target level (SSTL) calculations and results; and,
- Conclusions based on the Tier-2 vapor pathway evaluation.

Each of these items is presented in Sections 2, 3, 4, 5 and 6.

2. DATA EVALUATION

2.1 Data Selection

Only soil vapor data were used in this Addendum. Soil vapor data were collected at the Site on August 19 and 20, 1996 and July 30, 1998. These data were reported in the Soil Vapor Survey Sampling Report, dated January 20, 1997 (Weiss, 1997a), and the Soil Vapor Sample Report dated November 21, 1999 (Weiss, 1997b). A summary of the data is presented in Tables 1 and 2 of this report.

2.2 Data Usability

The data selected for this risk evaluation were considered valid and useable for their intended purpose. All soil vapor samples were analyzed by Air Toxics Laboratory of Folsom California. Air Toxics is certified by the State of California, Department of Health Services. Air Toxics analyzed the soil vapor samples for benzene, toluene, ethylbenzene, and xylenes (BTEX) by EPA Method TO-14. In addition, the laboratory analyzed all soil vapor samples from locations SV-1 through SV-8 for oxygen, carbon dioxide, and methane by ASTM Method D3416.

BTEX detection limits ranged from 3.9 parts per billion by volume (ppbv) to 12.2 ppbv for all soil vapor samples. All BTEX detection limits were acceptable for risk assessment purposes.

2.3 Data Quality

2.3.1 Review of Laboratory Data Quality

Weiss reviewed laboratory analytical reports for the soil vapor samples to ensure sample holding times were met, laboratory blanks were clean, and surrogate spike and method spike recoveries were acceptable.

Review of the data indicates that all holding times were met. BTEX compounds were non-detect in laboratory blank samples. All surrogate spike and method spike recoveries were between 70% and 130%. Therefore, each of the laboratory data quality objectives were met.

Low levels of oxygen were detected in the oxygen laboratory blanks analyzed by ASTM Method D3416. Qualifications were not placed on the oxygen data because the concentration of oxygen in soil vapor samples was more than ten times the concentration detected in the blanks.

2.3.2 *Evaluation of Data Quality Based on Biologic Indicator Gases*

At the request of Mr. Scott Seery of ACHCSA, Weiss has evaluated whether oxygen, carbon dioxide, and methane concentrations detected in soil vapor samples SV-1-3' through SV-8-3' confirmed or casted doubt upon the integrity of these samples.

In theory, oxygen concentrations should decrease with depth and carbon dioxide and methane concentrations should increase with depth if three assumptions about the existing subsurface conditions are true. The assumptions are:

Assumption 1—The upper boundary of the subsurface hydrocarbon plume is a broad two-dimensional plane that lies parallel to the local ground surface.

Assumption 2—Subsurface soil is completely homogeneous or contains consistent layering such that soil types are homogeneous in lateral directions.

Assumption 3—The hydrocarbon plume is the only organic material available for subsurface microorganisms to biodegrade.

If all three assumptions are true about the site, then oxygen, carbon dioxide, and methane concentrations should correlate with depth and the concentrations can be used to evaluate sample integrity as requested by ACHCSA.

Assumption 1 is true about the Site. The hydrocarbon plume lies at the approximate depth of the water table, which is roughly parallel to ground surface in the vicinity of the sample locations. Assumption 2 is not true about the Site because the samples were collected in an area that was excavated on one side, near SV-1 through SV-4 (Figure 1), and filled on the other side, near SV-6 through SV-8. Excavation and fill activities have disturbed the natural soil layers that existed above the plume. Assumption 3 is not likely true about the Site because natural organic materials exist in the root zone. When a clump of natural organic matter is present in the root zone, aerobic biological activity will cause oxygen consumption and carbon dioxide production at a shallow depth in that location. Ambient oxygen and carbon dioxide concentrations may be present at deeper locations with low natural organic matter while, only a few feet away, a clump of decaying natural organic matter may depress oxygen and increase carbon dioxide at a shallow depth.

We cannot make predictions about the spatial distribution of biological gases at this specific site because we cannot assume physical homogeneity (Assumption 2) and organic material homogeneity (Assumption 3) based on existing data. Sample integrity cannot be evaluated based on a correlation between depth and biological gas concentration because the correlation cannot be predicted. Deeper samples could have ambient oxygen, carbon dioxide, and methane concentrations while some shallow samples may have gas concentrations indicating significant biological activity.

Although we cannot quantitatively evaluate sample integrity, we can use the presence of biological indicators to confirm that samples were collected from the subsurface. Oxygen and carbon dioxide concentrations in samples SV-2-8, SV-4-3, SV-6-3, and SV-8-3 indicate that these samples were from a subsurface environment. These samples had depressed biologic indicator gas concentrations of oxygen and elevated carbon dioxide, which indicate biological activity. However, we don't know whether the biological activity was due to consumption of natural organic matter, consumption of hydrocarbon vapors, or a combination of the two. Yet, as explained above, we cannot reject deeper samples that contain ambient concentrations of biological gases because homogeneous conditions do not exist at this site.

2.3.3 *Evaluation of Purge Volume and Data Quality*

Weiss stated in the February 5, 1999, Soil Vapor Sample Collection Update, that BTEX results were rejected for soil vapor samples SV-9 through SV-16 because the field geologist did not record the sample purge volumes. Weiss later determined that the purge volume could be estimated based on manufacturer specifications and operation procedures for the purge equipment. The purge volume was a maximum of 7.72 liters, which is acceptable for soil vapor sampling purposes. Weiss then submitted a re-evaluation of the data to Mr. Scott Seery of ACHCSA in the letter entitled Re-Evaluation of Vapor Purge Technique, dated November 21, 1999. In the letter, Weiss stated that "data integrity was not compromised by the purge technique employed at the Site on July 30, 1998", and "the July 30, 1998 data are considered valid and useable for their intended purpose." Thus, qualifications were removed from the BTEX results for samples SV-9 through SV-16 and the July 30, 1998 data were not rejected.

3. DETERMINATION OF REPRESENTATIVE BENZENE CONCENTRATION IN SOIL VAPOR

All of the soil vapor samples collected at the Site are representative of hydrocarbon vapors in the subsurface. We selected 40 ppbv at three feet below ground surface (ft bgs) in sample SV-8-3' to be the representative concentration of benzene in soil vapor. This concentration is the most conservative possible representative concentration because it is the highest concentration at the nearest distance to the receptor. Although the concentration of benzene is higher in samples SV-3-25' and SV-4-25', these samples are not representative of reasonable points of compliance because they are located 22 ft further away from the receptor and within the hydrocarbon vapor source. Samples collected at 3 ft bgs represent more reasonable points of compliance because they are located between the source and receptor and far enough below ground to avoid positive interference from ambient air benzene concentrations.

4. EXPOSURE PATHWAYS AND RECEPTORS

This Addendum addresses exposure to benzene vapors in indoor and outdoor air only. The exposure pathway is based on benzene vapors migrating through the subsurface and into indoor and outdoor air from the source, which is located in the vicinity of the water table. All other open exposure pathways were fully addressed in the initial RBCA Report for the Site, and; therefore, were not evaluated in this Addendum.

4.1 Conceptual Model

Weiss calculated the concentration of benzene in indoor and outdoor air using the conceptual models that were described in detail in sections 4.1.2 and 4.1.3 of the initial RBCA Report.

Weiss used an indoor air conceptual model that was extremely conservative because it did not include a building foundation or physical barrier (floor) between the ground surface and building interior. A physical barrier is currently present between the ground surface and building interior at the closest residential receptor location, Forest Creek Townhomes. These housing units were constructed with a crawl space that separates the building floor from the ground surface. Most chemical vapors that flux up out of the ground will likely exit through crawlspace vents to outdoor air instead of entering the units through the floor. Thus, the indoor air exposure pathway may not be complete for the Townhome units and the indoor air risk may be zero. However, the indoor air pathway was evaluated without a barrier (i.e., dirt floor) to conservatively evaluate risk to human health from the vapor pathway.

5. CALCULATION OF RISK AND SITE-SPECIFIC TARGET LEVELS

Exposure media concentrations and risk were calculated for both adult and child receptors using the formulas described in sections 4.1.2 and 4.1.3 of the initial RBCA Report. All adult exposure parameters were standard values taken from Table X2.4 of ASTM Standard 1739-95. All child exposure parameters were the same as adult parameters except for body weight and exposure duration. Child body weight and exposure duration were selected based on US EPA guidance for parameter estimations (US EPA, 1985 and US EPA, 1989). We selected a conservative child body weight of 16 kg, which is the 50th percentile body weight for children ages 1 through 6 years old (US EPA, 1985).

We selected 20 years as a reasonable estimate of child exposure duration because childhood lasts, at most, 20 years. Risk was calculated for both adult and child receptors using the California standard slope factor for benzene of 0.1 kg-day/mg. SSTLs were determined by varying the soil vapor concentration value until the risk result was exactly equivalent to 10^{-5} risk. The calculations are presented in spreadsheet form in Appendix A.

5.1 Tier 2 Results

Based on the 40 ppbv concentration of benzene in soil vapor at 3 ft bgs the excess cancer risk for indoor air is 3.75×10^{-9} for adult receptors and 1.09×10^{-8} for child receptors. The excess cancer risk for outdoor air is 4.67×10^{-12} and 1.36×10^{-11} for adult and child receptors respectively. Typically, regulations and agencies require excess cancer risks to be within the range of 10^{-4} to 10^{-6}. All of the risk values were below 10^{-5} risk, indicating that benzene vapors do not pose significant risk to human health for the residential receptors at the Forrest Creek Townhomes.

The indoor and outdoor air SSTLs, for child receptors, are $3.66 \times 10^{+4}$ ppbv and $2.94 \times 10^{+7}$ ppbv, respectively for soil vapor at 3 ft bgs. Based on the soil vapor sample results, the representative concentration of benzene in soil vapor is approximately three orders of magnitude below the indoor air SSTL and more than 5 orders of magnitude below the outdoor air SSTL for child receptors. The SSTLs for adult receptors are $1.07 \times 10^{+5}$ ppbv and $8.57 \times 10^{+7}$ ppbv for indoor and outdoor air exposure respectively. The Risk and SSTL results of the Tier 2 RBCA evaluation are summarized in Table 3.

6. CONCLUSIONS

The data used in this Addendum were found to be valid and useable for their intended purpose. As expected, biological indicator gasses were present in several of the soil vapor samples. However, a quantitative evaluation of sample integrity, based on correlating biological gas concentrations and subsurface depth, was not possible due to inhomogeneous subsurface conditions at the Site. Weiss found no reason to question the integrity of any of the soil vapor samples.

Weiss found that although the exact purge volume was unknown for the soil vapor samples collected on July 30, 1998, the maximum purge volume could be accurately estimated. Weiss found that the maximum purge volume was acceptable for purging purposes and that the data are valid and useable for their intended purpose.

Weiss determined the representative concentration of benzene in soil vapor, presented the vapor exposure pathways and conceptual models, and calculated SSTLs and excess cancer risk due to benzene in the vapor pathways. Weiss found that benzene concentrations in soil vapor do not pose significant risk to human health for Forrest Creek Townhomes residents. The vapor pathway risk was below 10^{-5} for child and adult receptors. Based on the calculated vapor pathway risk, remedial action does not appear to be necessary at the Site.

7. REFERENCES

Alameda County Health Care Services Agency (ACHCSA), 2000. Letter from Mr. Scott Seery of ACHCSA to Brett Hunter of Chevron Regarding (former) Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley. January 13, 2000.

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Weiss, 1997b. Risk-Based Corrective Action, Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California. January 20, 1997.

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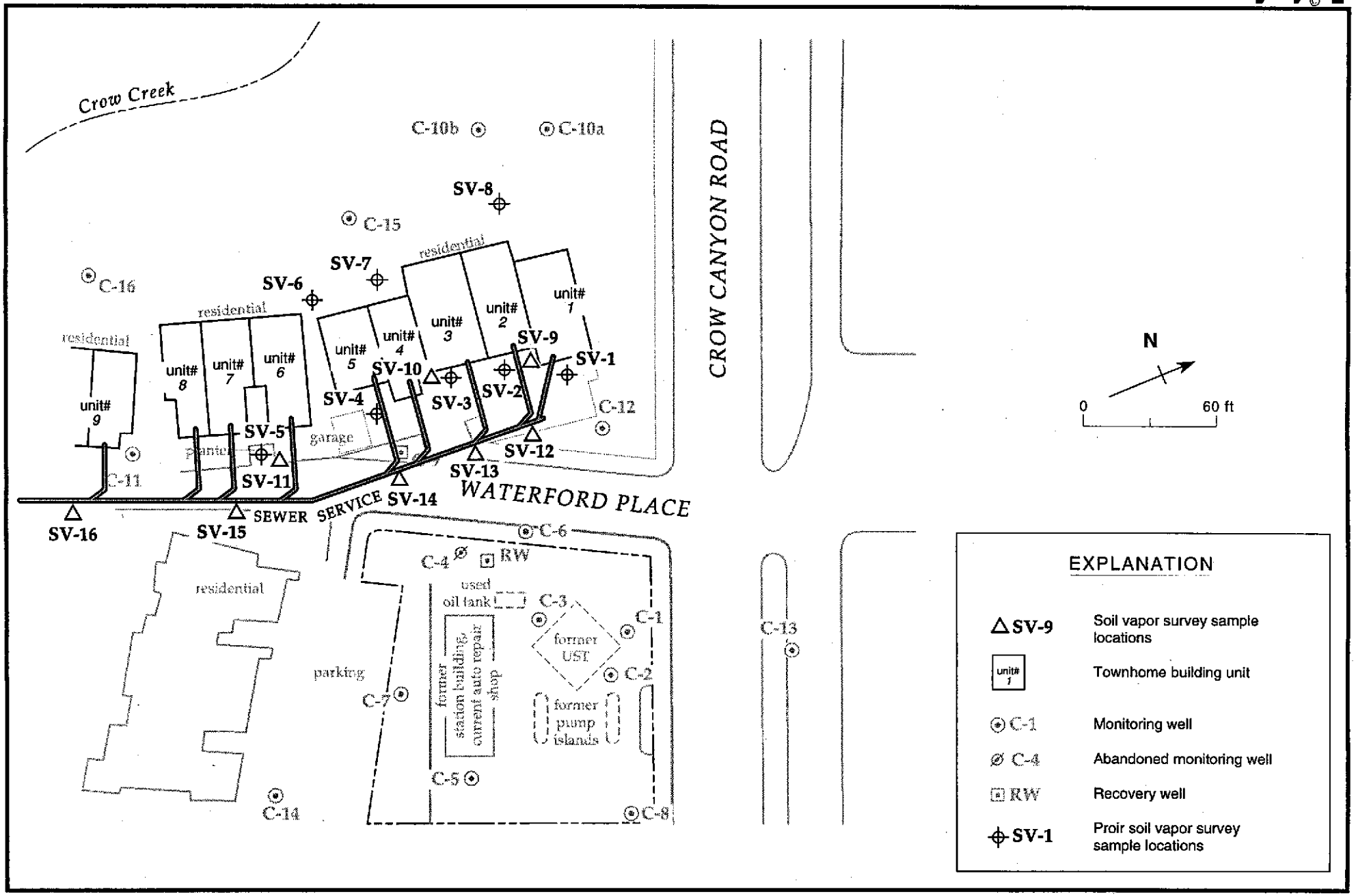

Figure 1. Plan View of Sewer Service Conduits and Soil Vapor Survey Sample Locations- Chevron Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Table 1. Summary of Analytical Laboratory Results for 1996 Soil Vapor Samples—Former Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California

Sample ID	Sample Depth (ft)	B	E	T	X	O_2	CO_2	CH_4
		← parts per billion by volume (ppbv) →				← percent by volume →		
SV-1	3	<4.3	<4.3	<4.3	<8.6	22	0.076	<0.002
SV-2	8	<6.1	<6.1	<6.1	<12.2	1.4	28	0.010
SV-3	8	<4.4	7.6	<4.4	6.7	21	0.25	<0.002
SV-3	25	2,100	3,800	680	2,300	21	0.58	0.004
SV-4	3	<4.3	<4.3	<4.3	<4.6	14	9.3	<0.002
SV-4	8	<4.2	<4.2	<4.2	5.7	21	0.35	<0.002
SV-4	11	<4.2	6.0	<4.2	<8.4	21	0.80	0.007
SV-4	25	38,000	140,000	20,000	83,000	21	0.37	0.002
SV-4	25[dup]	39,000	140,000	22,000	87,000	21	0.35	0.002
SV-5	12	6.2	32	11	39	22	0.091	<0.002
SV-6	3	29	42	6.4	25.4	0.51	0.054	0.005
SV-7	3	<4.2	5.1	<4.2	6.8	21	0.47	<0.002
SV-8	3	40	83	9.5	59	19	3.6	<0.002

Abbreviations:

B = Benzene by EPA Method TO-14
E = Ethylbenzene by EPA Method TO-14
T = Toluene by EPA Method TO-14
X = Xylenes by EPA Method TO-14
O_2 = Oxygen by ASTM Method D3416
CO_2 = Carbon dioxide by ASTM Method D3416
CH_4 = Methane by ASTM Method D3416
<n = Not detected at detection limits of n ppbv

Notes:

Samples collected on 8/19/96 and 8/20/96 by Weiss Associates and analyzed by Air Toxics, Folsom, California, a state-certified laboratory.

Table 2. Summary of Analytical Laboratory Results for 1998 Soil Vapor Samples—Former Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California

Sample ID	Sample Depth (ft)	B	E	T	X
		←parts per million by volume (ppmv)→			
SV-9	3	<0.004	<0.004	0.0047	<0.004
SV-10	3	0.0069	<0.0039	<0.0039	<0.0039
SV-11	3	<0.004	<0.004	<0.004	<0.004
SV-12	6	<0.0039	<0.0039	<0.0039	<0.0039
SV-13	6.5	<0.004	<0.004	<0.004	<0.004
SV-14	6	<0.004	<0.004	<0.004	<0.004
SV-15	6	<0.004	<0.004	<0.004	<0.004
SV-16	6	<0.004	<0.004	<0.004	<0.004

Abbreviations:

B = Benzene by EPA Method TO-14.
E = Ethylbenzene by EPA Method TO-14.
T = Toluene by EPA Method TO-14.
X = Xylenes by EPA Method TO-14.
<n = Not detected at detection limit of n ppmv

Notes:

Samples collected on 7/30/98 by Weiss Associates and analyzed by Air Toxics, Folsom, California, a state-certified laboratory.

Table 3. **Residential Receptors:** Summary of Tier 2 Risk-Based Corrective Action Results, Representative Risk and Site-Specfic Target Level Values—Former Chevron Service Station, 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Source Medium	Exposure Pathway	Benzene				
		Representative Concentration (ppbv)	Representative Risk[d] Adult	Representative Risk[d] Child	SSTL[b,c] Adult (ppbv)	SSTL[b,c] Child (ppbv)
Soil Vapor	Vapor Intrusion to Buildings	40[a]	3.75E-9	1.09E-8	1.07E+5	3.66E+4
	Volatilization to Outdoor Air	40[a]	4.67E-12	1.36E-11	8.57E+7	2.94E+7

Notes:

RBCA = Risk-Based Corrective Action
SSTL = ASTM RBCA Tier 2 Site-Specific Target Level.s
a = Representative concentration in soil vapor from sample location SV-8, collected on 8/20/1996 at 3 feet below ground surface.
b = The SSTL for inhalation of benzene vapors is based on an excess carcinogenic risk of 1 in 100,000 (10^{-5}) and California's standard cancer slope factor of 0.1 mg/kg-day.
c = Soil Vapor SSTLs are only applicable to vapor concentrations in soil at a depth of 3 feet below ground surface.
d = Risk values calculated from representative concentrations and site-specific parameters.

APPENDIX A

TIER 2 VAPOR PATHWAY CALCULATIONS

RISK CALCULATION

Tier 2 - Indoor Air Risk Predicted by Soil Vapor Data - Adult Residential Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Prediction of Flux From Benzene Concentration in Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Vapor Concentration (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Vapor Concentration (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Indoor Air Concentration		
ASTM 95	Lb	200	Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 95	ER_{air}-indoor	0.00014	Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	4.26E-10	Enclosed Space Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-indoor	15	Daily Indoor Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
ASTM 95	ED	30	Exposure Duration (years)
Calculated	Dose	0.067091	Dose (mg)
	Risk		
CAL EPA	SF_I	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 95	BW	70	Adult Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	Risk	3.75E-09	Risk (positives/population)

Formulas

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Bulk density and porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

RISK CALCULATION

Tier 2 - Indoor Air Risk Predicted by Soil Vapor Data - Child Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Prediction of Flux From Benzene Concentration in Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Vapor Concentration (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Vapor Concentration (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Indoor Air Concentration		
ASTM 95	Lb	200	Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 95	ER_{air}-indoor	0.00014	Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	4.26E-10	Enclosed Space Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-indoor	15	Daily Indoor Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
EPA 1985	ED	20	Exposure Duration (years)
Calculated	Dose	0.044727	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
EPA 1985	BW	16	Child Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	Risk	1.09E-08	Risk (positives/population)

Formulas

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

EPA 1985 = Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments. Office of Health and Environmental Assessment.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Bulk density and porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

SSTL CALCULATION

Tier 2 - Soil Vapor SSTL, Indoor Air Exposure - Adult Residential Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Rep Depth	d	91	Depth of Representative Vapor Sample (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Back Calculation of Soil Vapor SSTL		
SSTL	**C_v**	**106,632**	**SSTL Concentration, Benzene Vapor (ppbv)**
Unit Conv	C_v	346	Conversion from (ppbv) units to (ug/L) units
Calculated	F_{max}	3.18E-08	Maximum Diffusive Vapor Flux (ug/cm2-sec)
	Indoor Air Concentration		
ASTM 95	Lb	200	Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 95	ER_{air}-indoor	0.00014	Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	1.14E-06	Enclosed Space Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-indoor	15	Daily Indoor Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
ASTM 95	ED	30	Exposure Duration (years)
Calculated	Dose	178.85	Dose (mg)
	Risk		
CAL EPA	SF_I	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 95	BW	70	Adult Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	Risk	1.00E-05	Risk (positives/population)

Formulas

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Rep Depth: Depth of representative concentration used in RBCA evaluation. 91 cm = 3 feet.

SSTL: Site Specific Target Level. SSTL concentration is comparable to vapor samples collected at the Rep Depth (3 feet below ground surface).

Lab Data: Bulk density and porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs).

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

SSTL CALCULATION

Tier 2 - Soil Vapor SSTL, Indoor Air Exposure - Child Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Rep Depth	d	91	Depth of Representative Vapor Sample (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Back Calculation of Soil Vapor SSTL		
SSTL	**C_v**	**36,559**	**SSTL Concentration, Benzene Vapor (ppbv)**
Unit Conv	C_v	119	Conversion from (ppbv) units to (ug/L) units
Calculated	F_{max}	1.09E-08	Maximum Diffusive Vapor Flux (ug/cm2-sec)
	Indoor Air Concentration		
ASTM 95	Lb	200	Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 95	ER_{air}-indoor	0.00014	Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	3.89E-07	Enclosed Space Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-indoor	15	Daily Indoor Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
EPA 1985	ED	20	Exposure Duration (years)
Calculated	Dose	40.88	Dose (mg)
	Risk		
CAL EPA	SF_I	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
EPA 1985	BW	16	Child Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	Risk	1.00E-05	Risk (positives/population)

Formulas

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

EPA 1985 = Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments. Office of Health and Environmental Assessment.

Rep Depth: Depth of representative concentration used in RBCA evaluation. 91 cm = 3 feet.

SSTL: Site Specific Target Level. SSTL concentration is comparable to vapor samples collected at the Rep Depth (3 feet below ground surface).

Lab Data: Bulk density and porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs).

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

RISK CALCULATION

Tier 2 - Outdoor Air Risk Predicted by Soil Vapor Data - Adult Residential Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Prediction of Flux From Benzene Concentration in Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Vapor Concentration (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Vapor Concentration (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Outdoor Air Concentration		
ASTM 95	Uair	225	Air velocity (cm/sec)
ASTM 95	W	1500	Width of plume parallel to velocity (cm)
ASTM 95	δair	200	Ambient air mixing height (cm)
Calculated	$C_{v,outdoor}$	3.98E-13	Outdoor Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-outdoor	20	Daily Outdoor Air Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
ASTM 95	ED	30	Exposure Duration (years)
Calculated	Dose	8.35E-05	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 95	BW	70	Adult Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	$Risk_{sv}$	4.67E-12	Outdoor Air Risk Predicted by Soil Vapor Data

Formulas

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_s^{eff}\frac{C_{v,measured}}{d}$$

$$C_{v,outdoor} = \frac{F_{max} \times W}{U_{air} \times \delta_{air}}$$

$$Dose = C_{v,outdoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk_{sv} = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, outdoor air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

RISK CALCULATION

Tier 2 - Outdoor Air Risk Predicted by Soil Vapor Data - Child Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Prediction of Flux From Benzene Concentration in Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Vapor Concentration (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Vapor Concentration (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Outdoor Air Concentration		
ASTM 95	Uair	225	Air velocity (cm/sec)
ASTM 95	W	1500	Width of plume parallel to velocity (cm)
ASTM 95	δair	200	Ambient air mixing height (cm)
Calculated	$C_{v,outdoor}$	3.98E-13	Outdoor Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-outdoor	20	Daily Outdoor Air Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
EPA 1985	ED	20	Exposure Duration (years)
Calculated	Dose	5.57E-05	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
EPA 1985	BW	16	Child Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	$Risk_{sv}$	1.36E-11	Outdoor Air Risk Predicted by Soil Vapor Data

Formulas

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_s^{eff}\frac{C_{v,measured}}{d}$$

$$C_{v,outdoor} = \frac{F_{max} \times W}{U_{air} \times \delta_{air}}$$

$$Dose = C_{v,outdoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk_{sv} = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

EPA 1985 = Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments. Office of Health and Environmental Assessment.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, outdoor air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

SSTL CALCULATION

Tier 2 - Soil Vapor SSTL, Outdoor Air Exposure - Adult Residential Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Rep Depth	d	91	Depth of Representative Sample (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Back Calculation of Soil Vapor SSTL		
SSTL	**C_v**	**8.57E+07**	**SSTL Concentration, Benzene Vapor (ppbv)**
Unit Conv	C_v	277854	Conversion from (ppbv) units to (ug/L) units
Calculated	F_{max}	2.56E-05	Maximum Diffusive Vapor Flux (ug/cm^2-sec)
	Outdoor Air Concentration		
ASTM 95	Uair	225	Air velocity (cm/sec)
ASTM 95	W	1500	Width of plume parallel to velocity (cm)
ASTM 95	δair	200	Ambient air mixing height (cm)
Calculated	$C_{v,outdoor}$	8.52E-07	Outdoor Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-outdoor	20	Daily Outdoor Air Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
ASTM 95	ED	30	Exposure Duration (years)
Calculated	Dose	178.85	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 95	BW	70	Adult Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	$Risk_{sv}$	1.00E-05	Outdoor Air Risk

Formulas

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_s^{eff}\frac{C_v}{d}$$

$$C_{v,outdoor} = \frac{F_{max} \times W}{U_{air} \times \delta_{air}}$$

$$Dose = C_{v,outdoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk_{sv} = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Rep Depth: Depth of representative concentration used in RBCA evaluation. 91 cm = 3 feet.

SSTL: Site Specific Target Level. SSTL concentration is comparable to vapor samples collected at the Rep Depth (3 feet below ground surface).

Lab Data: Porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs).

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, outdoor air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.

SSTL CALCULATION

Tier 2 - Soil Vapor SSTL, Outdoor Air Exposure - Child Receptor

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
Lab Data	ρ_s	2.21	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Rep Depth	d	91	Depth of Representative Sample (cm)
	Diffusivity Parameters		
ASTM 95	H	0.22	Henry's Constant for Benzene
ASTM 95	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 95	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient in Soil (cm^2/s)
	Back Calculation of Soil Vapor SSTL		
SSTL	**C_v**	**2.94E+07**	**SSTL Concentration, Benzene Vapor (ppbv)**
Unit Conv	C_v	95264	Conversion from (ppbv) units to (ug/L) units
Calculated	F_{max}	8.76E-06	Maximum Diffusive Vapor Flux (ug/cm^2-sec)
	Outdoor Air Concentration		
ASTM 95	Uair	225	Air velocity (cm/sec)
ASTM 95	W	1500	Width of plume parallel to velocity (cm)
ASTM 95	δair	200	Ambient air mixing height (cm)
Calculated	$C_{v,outdoor}$	2.92E-07	Outdoor Air Concentration (ug/cm^3)
	Dose		
ASTM 95	IR_{air}-outdoor	20	Daily Outdoor Air Inhalation Rate (m^3/day)
ASTM 95	EF	350	Exposure Frequency (days/year)
EPA 1985	ED	20	Exposure Duration (years)
Calculated	Dose	40.88	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
EPA 1985	BW	16	Child Body Weight (kg)
ASTM 95	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	$Risk_{sv}$	1.00E-05	Outdoor Air Risk

Formulas

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_s^{eff}\frac{C_v}{d}$$

$$C_{v,outdoor} = \frac{F_{max} \times W}{U_{air} \times \delta_{air}}$$

$$Dose = C_{v,outdoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk_{sv} = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 95 = American Society for Testing and Materials, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

EPA 1985 = Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments. Office of Health and Environmental Assessment.

Rep Depth: Depth of representative concentration used in RBCA evaluation. 91 cm = 3 feet.

SSTL: Site Specific Target Level. SSTL concentration is comparable to vapor samples collected at the Rep Depth (3 feet below ground surface).

Lab Data: Porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs).

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, outdoor air concentration, dose and risk calculations from ASTM 95 guidance. Formulas presented above.