TECHNICAL MEMORANDUM CH2MHILL

Groundwater and Air Modeling, and Risk Assessment at the City of Tempe Right-of-Way

PREPARED FOR United States Environmental Protection Agency

PREPARED BY CH2M HILL/PHX

DATE December 14, 2001

1. Introduction

This memorandum presents the groundwater and air modeling results, and risk assessment for the contamination observed in soil vapor beneath the City of Tempe Right-of-Way (COT-ROW) The COT-ROW is located in the alley adjacent to and west of Perry Lane between 3rd Street and the east-west projection of the 5th Street alignment Figure 1-1 is a site map of the COT-ROW Currently, volatile organic compounds (VOC) are known to be present beneath the COT-ROW This evaluation is intended to

- Assess whether the contamination beneath the COT-ROW should be treated separately within the Indian Bend Wash Superfund Site-South (IBW-South or SIBW) or should be treated as part of Subsite No 6 (CH2M HILL, 1997) Subsite No 6 consists of properties in the vicinity of the COT-ROW including, IMC Magnetics Corporation, Service & Sales Inc , and parcel numbers 132-41-029A, 132-41-027A, and 132-41-025
- Assess what compounds observed in soil vapor can be attributed to the COT-ROW
- Present an estimate of the COT-ROW impact on groundwater using VLEACH
- Present an estimate of the impact of the COT-ROW on indoor air using Johnson & Ettinger (J&E) modeling and an infinite source scenario
- Perform a risk assessment for human health using the estimated groundwater and air impacts

This memorandum is divided into eight sections and is organized as follows

1 Introduction
2 Sources of Data
3 Potential VOC Sources
4 Occurrence and Distribution of VOCs
5 Evaluations Pursuant to the Plug-in Process for VOCs in the Vadose Zone
6 Risk Assessment
7 Conclusions
8 References

LEGEND

⊗ SVMW-5 SOIL VAPOR MONITOR WELL

△ SEPARATOR LOCATION

132-41-025 PARCEL NUMBER

PARCEL BOUNDARY

COT-ROW

SUBSITE BOUNDARY

N

80 0 80

(1 = 80)

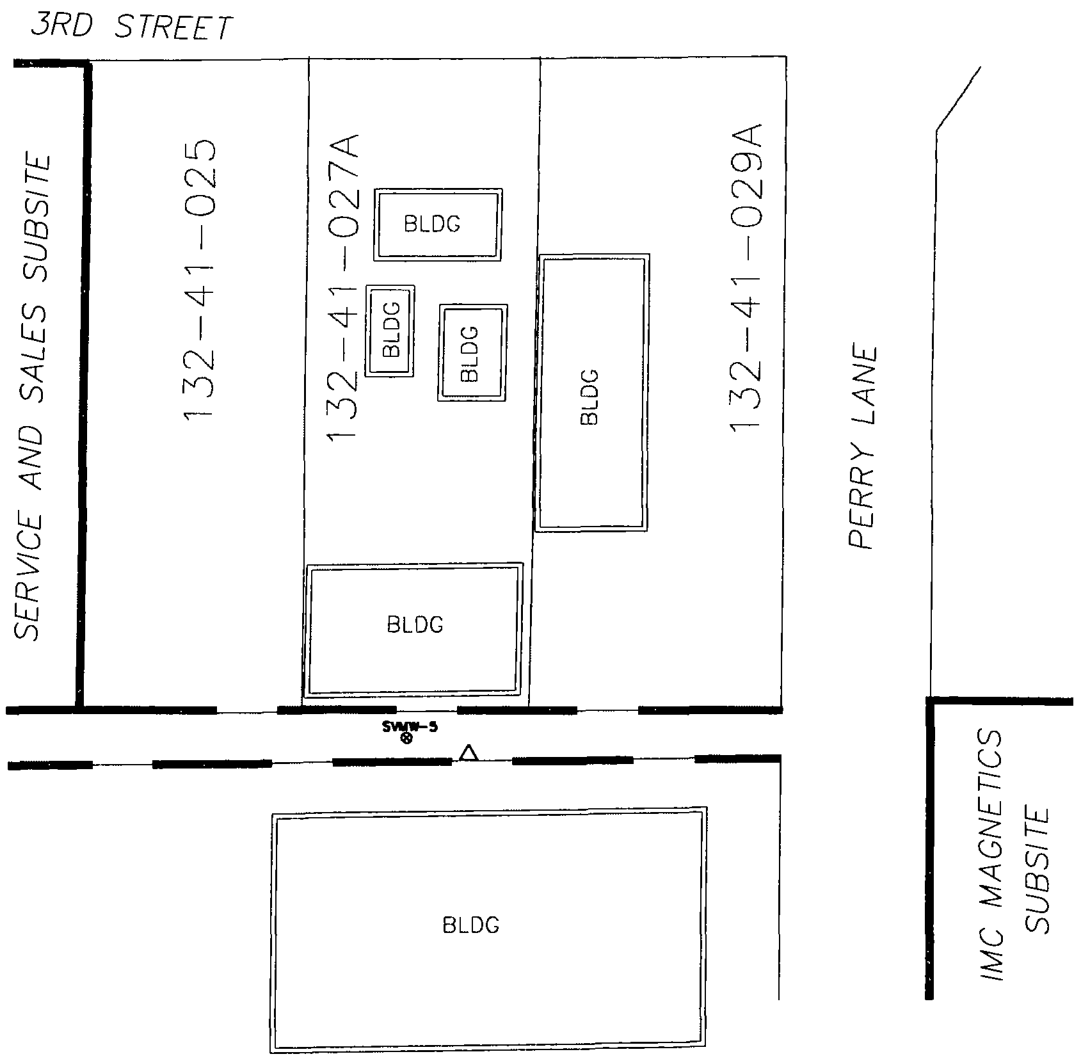

FIGURE 1-1
SITE MAP
COT ROW
IBW SOUTH TEMPE ARIZONA

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Attachments to this memorandum include a soil boring log, geotechnical analyses, a soil vapor monitoring well (SVMW) construction diagram, VLEACH preprocessor and input/output files, as well as groundwater mixing cell results and J&E output files

2 Sources of Data

Data that were reviewed to perform this evaluation included

- Maps showing the positions of possible contributing disposal facilities within or near the COT-ROW
- Shallow soil vapor surveys that were performed in 1988, 1990, and 1994
- SVMW data collected by the Arizona Department of Environmental Quality (ADEQ) in the spring of 1997 within the COT-ROW
- SVMW data collected adjacent to the COT-ROW in Subsite No 6

3 Potential VOC Sources

The potential VOC sources currently identified within the COT-ROW are limited to the City of Tempe sewer system, a drywell that was observed by the ADEQ, and vapor migration of VOCs from Subsite No 6 The following are descriptions of each potential source

- The City of Tempe sewer may serve as a source of VOC contamination if it is ruptured or otherwise compromised and is or was receiving wastes containing VOCs The drywell may serve as a source of VOCs if it was ever used for disposing of materials containing VOCs
- The drywell actually appears to be some sort of separator and is hereafter referred to as "separator CH2M HILL visited the site and photographed the manhole access and its contents (Figures 3-1 and 3-2) The ADEQ reportedly snaked the structure and was unable to determine the discharging facility
- Vapor-phase transport of VOCs, through preferential pathways, from Subsite No 6 may also contribute to the VOC contamination Preferential pathways (such as utility trenches) may have been established in the near surface as a result of developing infrastructure

4 Occurrence and Distribution of VOCs

The chemicals of potential concern (COPCs) that were identified in shallow soil vapor within the COT-ROW and SVMW data include tetrachloroethene (a k a perchloroethene [PCE]), 1,1,1-trichloroethane (1,1,1-TCA), and trichloroethene (TCE) These compounds were identified as COPCs because they were pervasive and persistent Dichloroethane (1,1-DCA) and dichloroethene (1,1-DCE) were also considered because they were observed offsite within Subsite No 6 and may have been considered COPCs at other subsites These two compounds were also of interest because they may occur as degradation products 1,1,1-TCA can degrade to 1,1-DCA, while both 1,1,1-TCA and TCE can degrade to 1,1-DCE

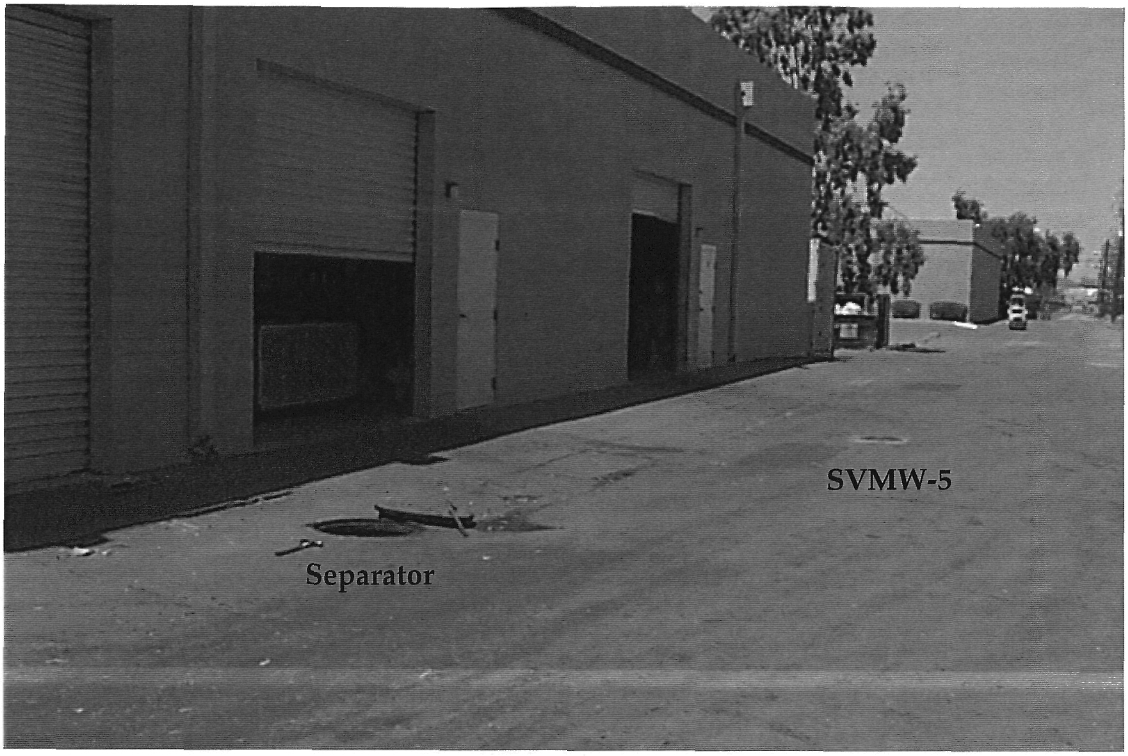


Figure 3-1: General area around the separator looking southwest

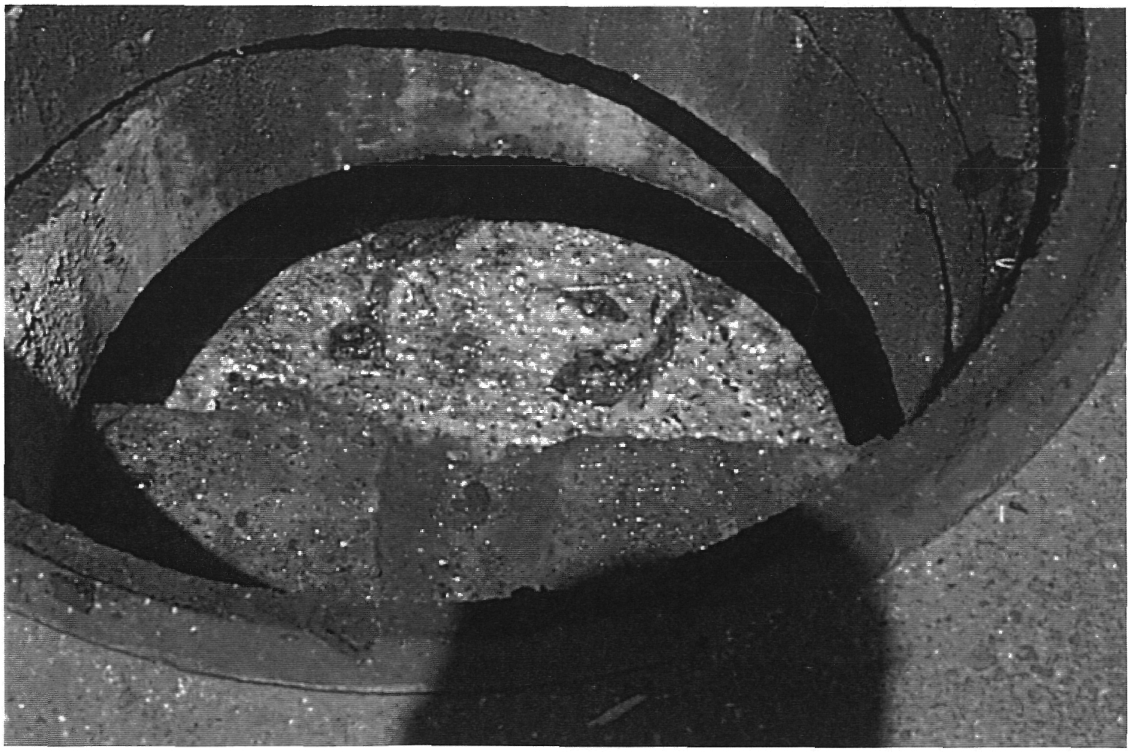


Figure 3-2: Separator on the COT-ROW. The ADEQ attempted to snake the structure and determine which facility was discharging to the structure, but was unsuccessful.

However, because 1,1-DCA and 1,1-DCE were not pervasive and persistent in the COT-ROW they are not discussed below A review of the data for this technical memorandum yielded the following information regarding occurrence and distribution of the COPCs

PCE—PCE occurs beneath and around the COT-ROW Figure 4-1 shows the distribution of PCE in the vicinity of the COT-ROW PCE in soil vapor exhibits the highest concentrations within the COT-ROW and concentrations decrease with distance from the COT-ROW The observed pattern of soil vapor contamination suggests that the COT-ROW is a distinct source of PCE contamination in soil vapor, however, because the plume extends across the Service & Sales subsite and a slightly elevated concentration of PCE was observed near the Service & Sales drywell, one cannot definitively say that the COT-ROW is the sole source of PCE contamination

1,1,1-TCA—Similar to PCE, 1,1,1-TCA occurs beneath and around the COT-ROW Figure 4-2 shows the distribution of 1 1,1-TCA in the vicinity of the COT-ROW Although present, the distribution of 1,1,1-TCA suggests that a release that occurred to the east, within Subsite No 6 near IMC Magnetics, is the source Additionally, a separate 1,1,1-TCA release appears to have occurred to the northwest of the COT-ROW near the Service & Sales area A line of points that did not exhibit detectable concentrations of 1,1,1-TCA separates the two soil vapor contamination plumes

TCE—Similar to PCE and 1,1,1-TCA, TCE occurs beneath and around the COT-ROW Figure 4-3 shows the TCE distribution in the vicinity of the COT-ROW TCE was used at the Service & Sales and IMC Magnetics facilities as a liquid-phase solvent The TCE soil vapor plume beneath the COT-ROW is separated from a TCE plume observed at the Service & Sales subsite by a line of points that do not exhibit detectable concentrations of TCE The distribution of TCE in the vicinity of the COT-ROW suggests that the vapor plume is most likely a mixture of TCE soil vapor from the IMC Magnetics facility and TCE as a degradation product of PCE beneath the COT-ROW However, there is no record of what chemicals may have been discharged within the COT-ROW, therefore, no definitive statement may be made regarding TCE as a primary source or degradation product beneath the COT-ROW

Although PCE, 1,1,1-TCA, and TCE were detected beneath the COT-ROW and some of the facilities within Subsite No 6, no apparent trend in the data definitively indicates that the COT-ROW soil vapor contamination resulted solely from contamination at Subsite No 6 facilities, additionally, there is no information to suggest that a facility separate from Subsite No 6 is associated with the COT-ROW However, because similar compounds are detected beneath both locations, the contamination in soil vapor beneath the COT-ROW and Subsite No 6 are not entirely separate either A likely scenario that explains the observed patterns of contamination is mixed-point sources A mixed point source scenario would include a contribution of PCE, 1,1,1-TCA, and TCE contamination from the individual facilities within Subsite No 6 and from the City of Tempe sewer or nearby separator

To further assess whether the observed concentrations of PCE, 1,1,1-TCA, and TCE resulted from releases beneath the COT-ROW or vapor migration from the adjacent subsite, the ratios of parent compounds to their degradation products were reviewed A comparison of these ratios indicates that three separate and distinct releases resulted in the mixed soil vapor contamination plumes The character of the release beneath the COT-ROW suggests

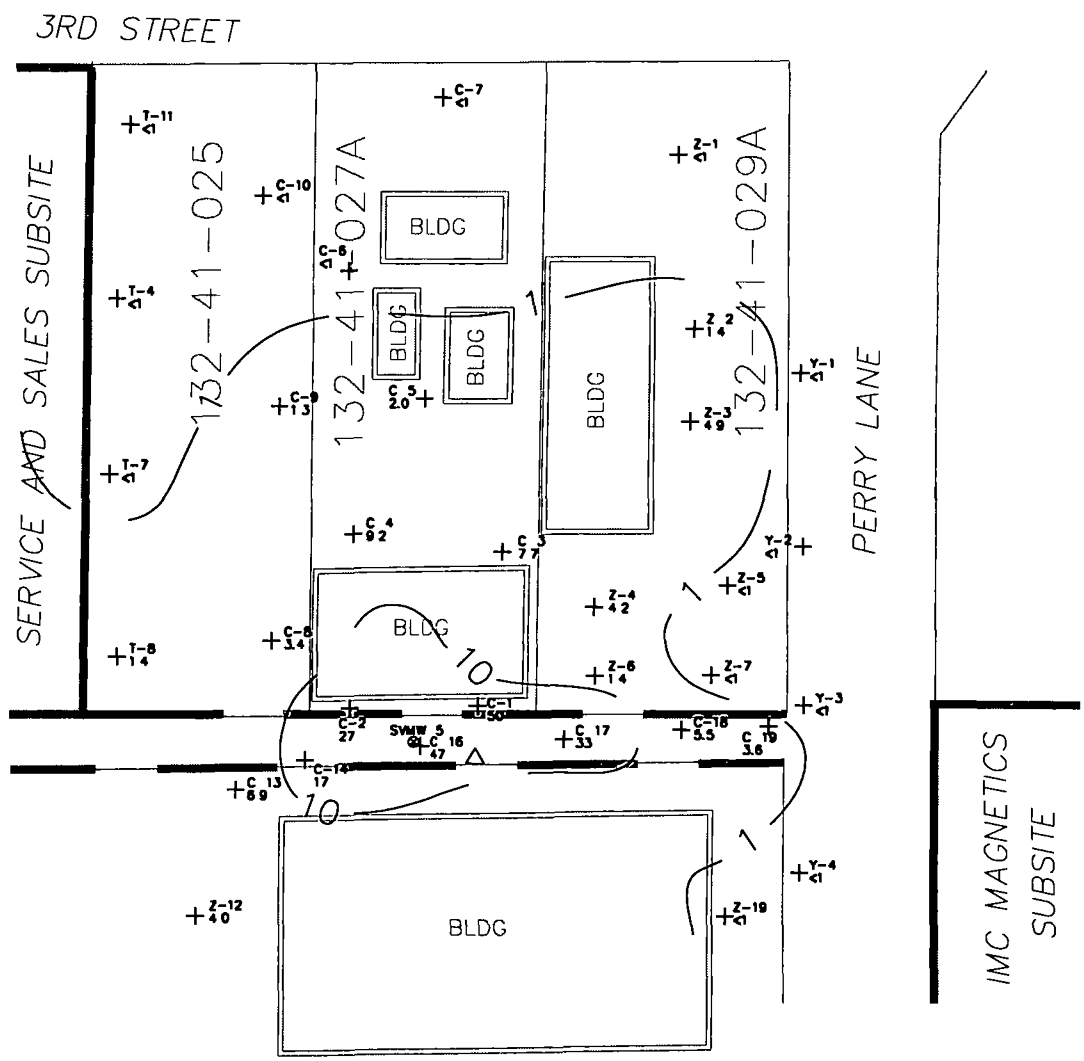
LEGEND

+ C-1 50	1994 SHALLOW SOIL VAPOR SAMPLE
⊗ SVMW-5	SOIL VAPOR MONITOR WELL
△	SEPARATOR LOCATION
132-41-025	PARCEL NUMBER
———	PARCEL BOUNDARY
▬ ▬	COT-ROW
▬▬▬	SUBSITE BOUNDARY
~10~	ISOCONCENTRATION CONTOUR

N

80 0 80

(1 = 80)



NOTES

1. Soil vapor contamination given in micrograms per liter (µg/L)
2. Concentration contours are logarithmic and approximate

FIGURE 4-1
PCE SHALLOW SOIL
VAPOR CONCENTRATION
COT ROW
IBW SOUTH TEMPE ARIZONA

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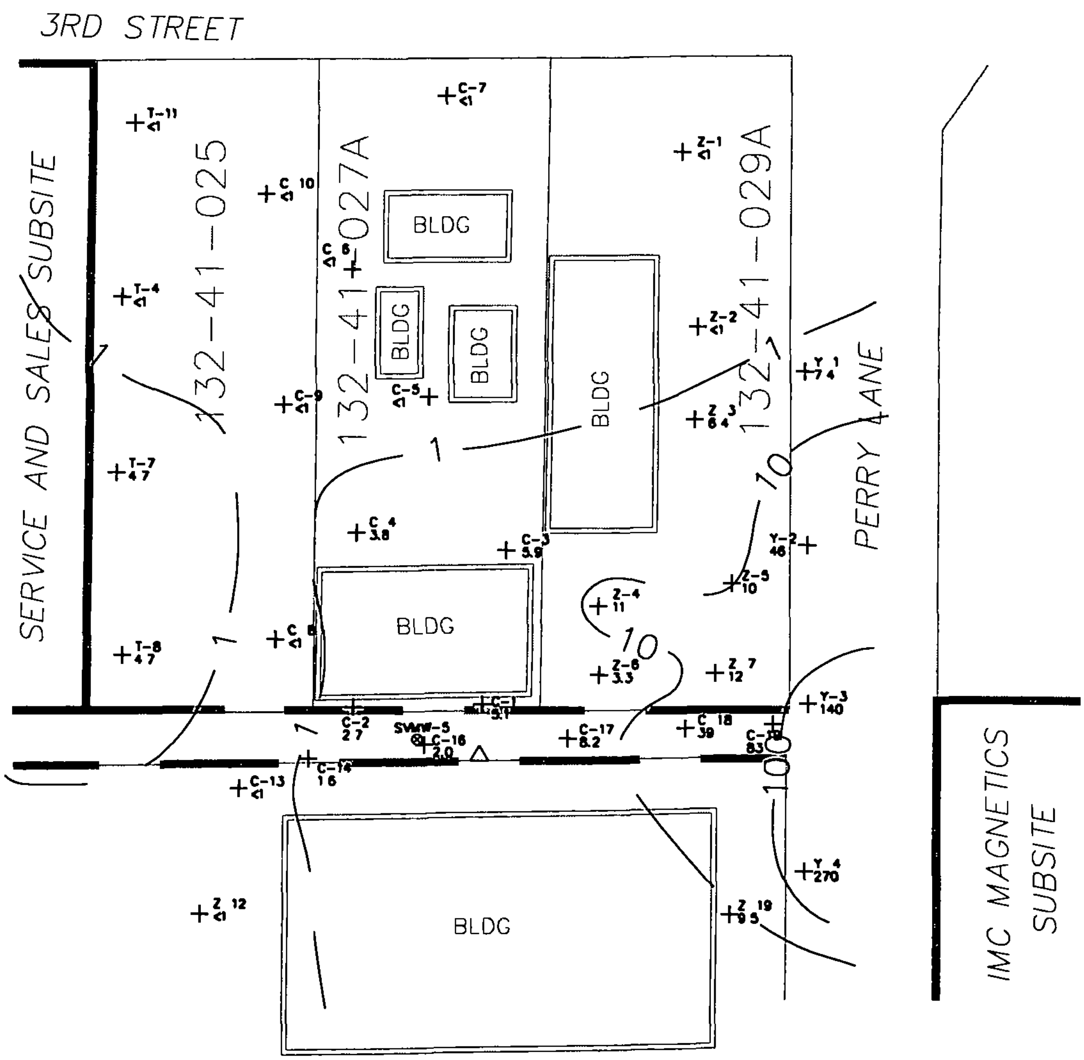
LEGEND

+ C-1 5.1	1994 SHALLOW SOIL VAPOR SAMPLE
⊗ SVMW-5	SOIL VAPOR MONITOR WELL
△	SEPARATOR LOCATION
132-41-025	PARCEL NUMBER
———	PARCEL BOUNDARY
— —	COT-ROW
━━━	SUBSITE BOUNDARY
~10~	ISOCONCENTRATION CONTOUR

N

80 0 80

(1 = 80)



NOTES

1 Soil vapor contamination given in micrograms per liter (µg/L)

2 Concentration contours are logarithmic and approximate

FIGURE 4-2
1,1,1-TCA SHALLOW SOIL VAPOR CONCENTRATION
COT ROW
IBW SOUTH TEMPE ARIZONA

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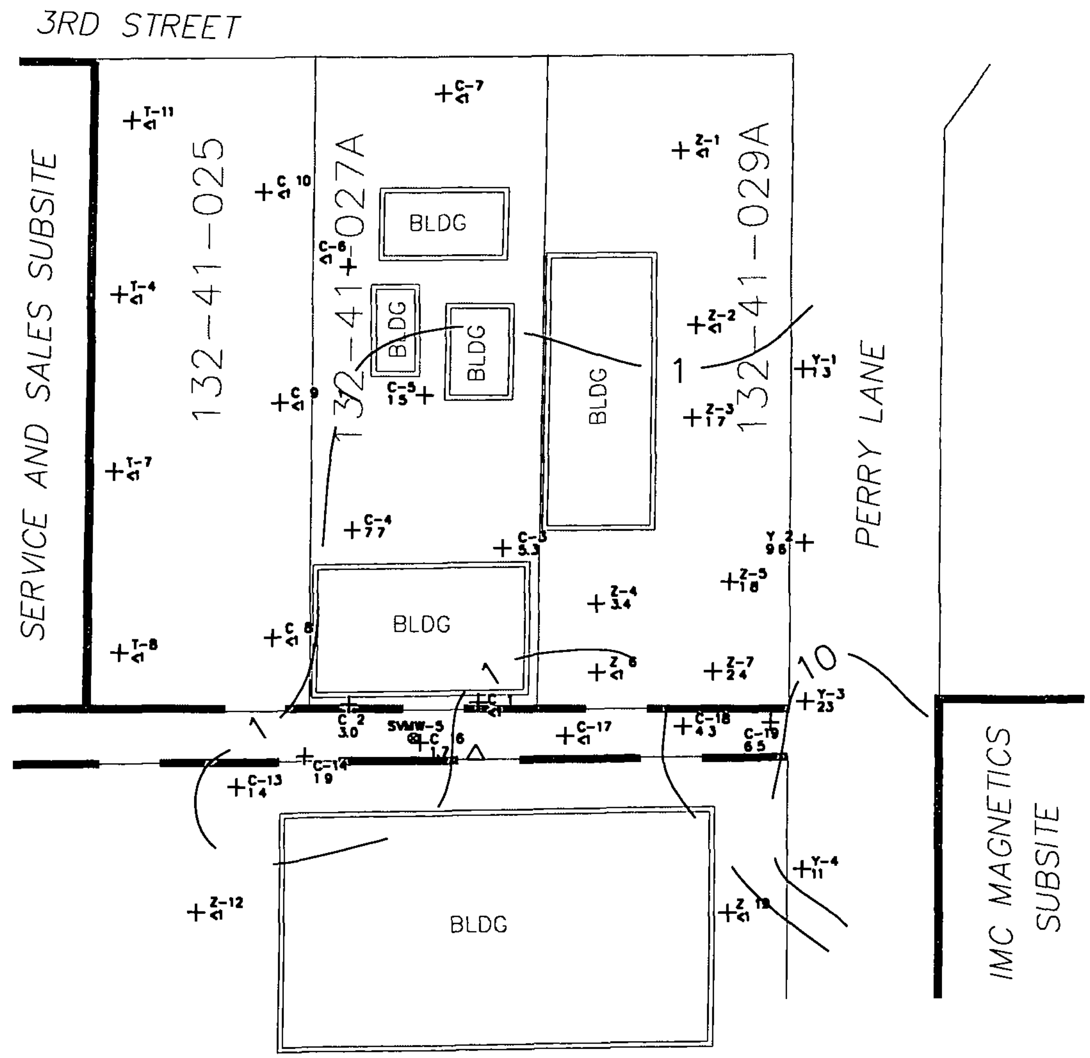
LEGEND

+ C-1 <1	1994 SHALLOW SOIL VAPOR SAMPLE
⊗ SVMW-5	SOIL VAPOR MONITOR WELL
△	SEPARATOR LOCATION
132-41-025	PARCEL NUMBER
——	PARCEL BOUNDARY
▬ ▬	COT-ROW
▬▬	SUBSITE BOUNDARY
~10~	ISOCONCENTRATION CONTOUR

N

80 0 80

(1 = 80)



NOTES

1 Soil vapor contamination given in micrograms per liter (µg/L)

2 Concentration contours are logarithmic and approximate

FIGURE 4-3
TCE SHALLOW SOIL
VAPOR CONCENTRATION
COT ROW
IBW SOUTH TEMPE ARIZONA

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that it is primarily a PCE release with a TCE component that is most likely the result of PCE degradation The observed 1,1,1-TCA is most likely a soil vapor front emanating from the IMC Magnetics area

5 Evaluations Pursuant to the Plug-in Process for VOCs in the Vadose Zone

Based on the information and assessment described above, CH2M HILL has prepared this memorandum as an alternative to a complete Focused Remedial Investigation (Focused RI) Report The sections presented below describe the groundwater and air modeling process, results, and risk assessment The groundwater and air modeling that were performed for this memorandum are described in detail in the Final Remedial Investigation (CH2M HILL, 1997), and 1993 Soils Record of Decision (ROD) (United States Environmental Protection Agency [EPA], 1993)

The EPA issued two RODs to address contamination within the soil and groundwater operable units (OUs) at the IBW-South The 1993 Soils ROD addresses the incremental future impact of the existing soil contamination found at various subsites on groundwater and air The *Record of Decision, VOCs in Groundwater Operable Unit, September 1998* (EPA, 1998), on the other hand, addresses the impact of existing groundwater contamination across the entire study area This memorandum has been prepared pursuant to the requirements set forth in the 1993 Soils ROD

The IBW-South is complex and contains many separate subsites, therefore, the 1993 Soils ROD invoked an innovative approach, called the 'Plug-in Approach, which allows for more efficient and effective administration of the remedy The Plug-in Approach allows multiple, similar, but separate subsites to make use of the same remedy, the "presumed remedy," at different times Under this approach, the EPA selects a standard remedy that applies to a defined set of conditions, rather than to a specific subsite The 1993 Soils ROD prescribed a process and criteria for determining whether those conditions exist Subsites have been investigated, at varying times, since the 1993 Soils ROD The EPA will issue a subsite-specific determination to plug-in subsites to the standard remedy according to the process promulgated in the 1993 Soils ROD This memorandum plays a role in applying the Plug-in Approach specifically to the COT-ROW

The 1993 Soils ROD prescribes a specific decision process that must be followed before the EPA determines that the presumed remedy, soil vapor extraction (SVE), must be used at any particular subsite The decision tree in the 1993 Soils ROD is reprinted as Figure 5-1 of this memorandum The 1993 Soils ROD provides a complete background of the presumed remedy

To comply with the 1993 Soils ROD, the COT-ROW must follow a process that includes

- <u>Verifying that conditions at the COT-ROW fall within the range of conditions that SVE can address</u> Verification is accomplished by comparing COT-ROW conditions with the Remedy Profile in the 1993 Soils ROD As long as the COT-ROW meets the Remedy Profile, SVE can be used as the remedy

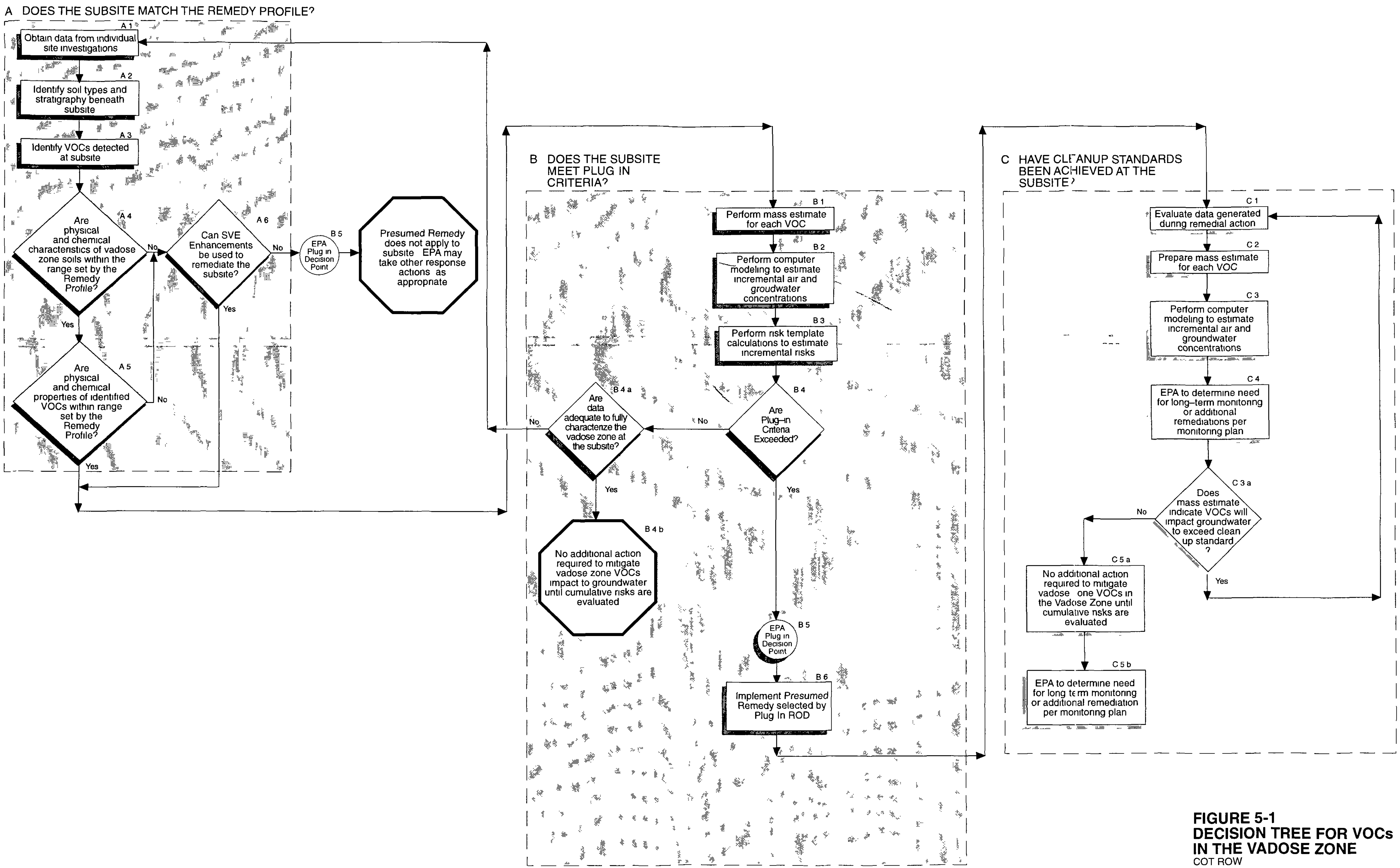


FIGURE 5-1
DECISION TREE FOR VOCs IN THE VADOSE ZONE
COT ROW
IBW SOUTH TEMPE ARIZONA

- <u>Determining whether the risk posed by VOCs in the soils at the COT-ROW warrants application of SVE</u> Risk posed by the VOCs in soil is compared with the risk-based Plug-in Criteria in the 1993 Soils ROD The Plug-in Criteria, defined in the 1993 Soils ROD, are restated in Section 5 of this memorandum This comparison requires running a model that uses site-specific environmental data collected during the site investigation to estimate the impact of VOCs to groundwater and indoor air

The 1993 Soils ROD selected VLEACH and an associated groundwater mixing zone model to predict the impact of vadose zone contamination to groundwater The 1993 Soils ROD also called for using the VLEACH or an equivalent model to evaluate the migration of contaminants from soils to indoor air Methods for assessing VOC migration from soil to indoor air have advanced since publication of the 1993 Soils ROD as new modeling methods have gained acceptance In this document, the EPA selects, for the indoor air pathway, the equivalent J&E model Both the VLEACH model and the J&E model, are one-dimensional models that simulate diffusive transport of contaminants in subsurface soils In addition, both models use soil concentrations to predict indoor air concentrations and incorporate conservative parameters in their estimation For these reasons, the EPA considers the VLEACH and J&E models to be equivalent under these circumstances From a conceptual standpoint, the J&E model is technically preferable for the indoor air because it not only considers diffusive (concentration-driven) transport, but also takes into account convective (pressure-driven) transport of VOCs, once the contaminants have reached the zone of influence of a building This is considered an improvement over the earlier model, VLEACH, therefore, the J&E model is preferred today for modeling the soil-to-indoor-air pathway However, the EPA continues to believe that the VLEACH model is appropriate for modeling impacts to groundwater

The 1998 Groundwater ROD addresses the impact of existing groundwater contamination across the entire study area The 1993 Soils ROD, on the other hand, addresses the incremental future impact of the existing soil contamination found at various subsites on groundwater and air The 1993 Soils ROD also establishes the Plug-in Approach and presumed remedy (SVE) for use at individual subsites within the IBW-South In general, the Plug-in Approach consists of the following steps

1 Collect soil, soil vapor, and groundwater data to characterize the physical and chemical conditions at the Subsite (in this case the COT-ROW) The physical and chemical conditions at a subsite comprise the "Site Profile

2 Compare the physical and chemical conditions at the particular Subsite (Site Profile) to the range of conditions that the presumed remedy can address The range of conditions that the presumed remedy can effectively address comprises the "Remedy Profile

3 Estimate the incremental future impact of existing soil contamination on groundwater and air using a VLEACH model for groundwater and VLEACH or an equivalent model for air

4 Use the results of the air and groundwater modeling to perform a risk assessment for the Subsite and compare the estimated risk to risk thresholds established in the 1993 Soils ROD In addition, use the resulting groundwater concentrations from VLEACH modeling to compare to Federal Maximum Contaminant Levels (MCLs) The risk thresholds and Federal MCLs are called the 'Plug-in Criteria

This section discusses the results of the comparison of the Site Profile to the Remedy Profile The profile comparison and VLEACH modeling of groundwater are presented in Sections 5 1 through 5 4 2 and the discussion of the J&E air modeling is described in Sections 5 5 through 5 5 1 3 A separate discussion of the risk assessment for human health is described in Section 6

To plug in, the conditions at the COT-ROW must (1) meet the Remedy Profile and (2) exceed the Plug-in Criteria Figure 5-2 illustrates the Subsite evaluation process established by the 1993 Soils ROD The results of this process are presented in this Plug-in Assessment Detailed descriptions of this approach are presented in the 1993 Soils ROD, and in *the Operable Unit Feasibility Study VOCs in the Vadose Zone, Indian Bend Wash Superfund Site, South Area, June 1993* (CH2M HILL, 1993)

5 1 Comparison of Site Profile with Remedy Profile

The first step in the Plug-in Approach is to compare the Site Profile with the Remedy Profile The Site and Remedy Profiles are defined by various physical and contaminant parameters that may have an impact on the effectiveness of SVE as a remedial action alternative

The data collected by the EPA and ADEQ, during the investigations of the COT-ROW, were used to characterize the Site Profile for the site The Remedy Profile used for comparison with the Site Profile is summarized in Table 5-1 A more detailed description of the Remedy Profile is described in Section 8 3 4 of the 1993 Soils ROD Although air permeability measurements in the vadose zone were not made during the site investigation, typical permeability values for the soil types were available from the literature (Freeze and Cherry, 1979) and were used to determine if the COT-ROW met the Remedy Profile for remediation

5 2 Comparison of COT-ROW Conditions with the Plug-in Criteria

According to the 1993 Soils ROD, the SVE remedy is required at a subsite if the VOCs in the vadose zone at that facility exceed the Plug-in Criteria as defined in Section 8 3 5 (pages II-63 through II-65) of the 1993 Soils ROD The Plug-in Criteria are restated in Table 5-2 The SVE remedy is required if VOCs present in soil at a subsite exceed any of these five criteria

Evaluating whether the COT-ROW would plug into the presumed remedy required an estimate of the incremental quantity of VOCs, primarily PCE, 1,1 1-TCA, and TCE, which could enter the groundwater or air over time As mentioned in Section 4, PCE, 1,1,1-TCA, and TCE are the COPCs Data collected during the shallow soil vapor survey were used to estimate the horizontal distribution of the COPCs in soil Data collected from SVMW-5 were used to estimate vertical distribution of the COPCs This estimate was input to a computer model to estimate the maximum future incremental concentrations contributed to groundwater or air from PCE, 1,1,1-TCA, and TCE in soil at the COT-ROW

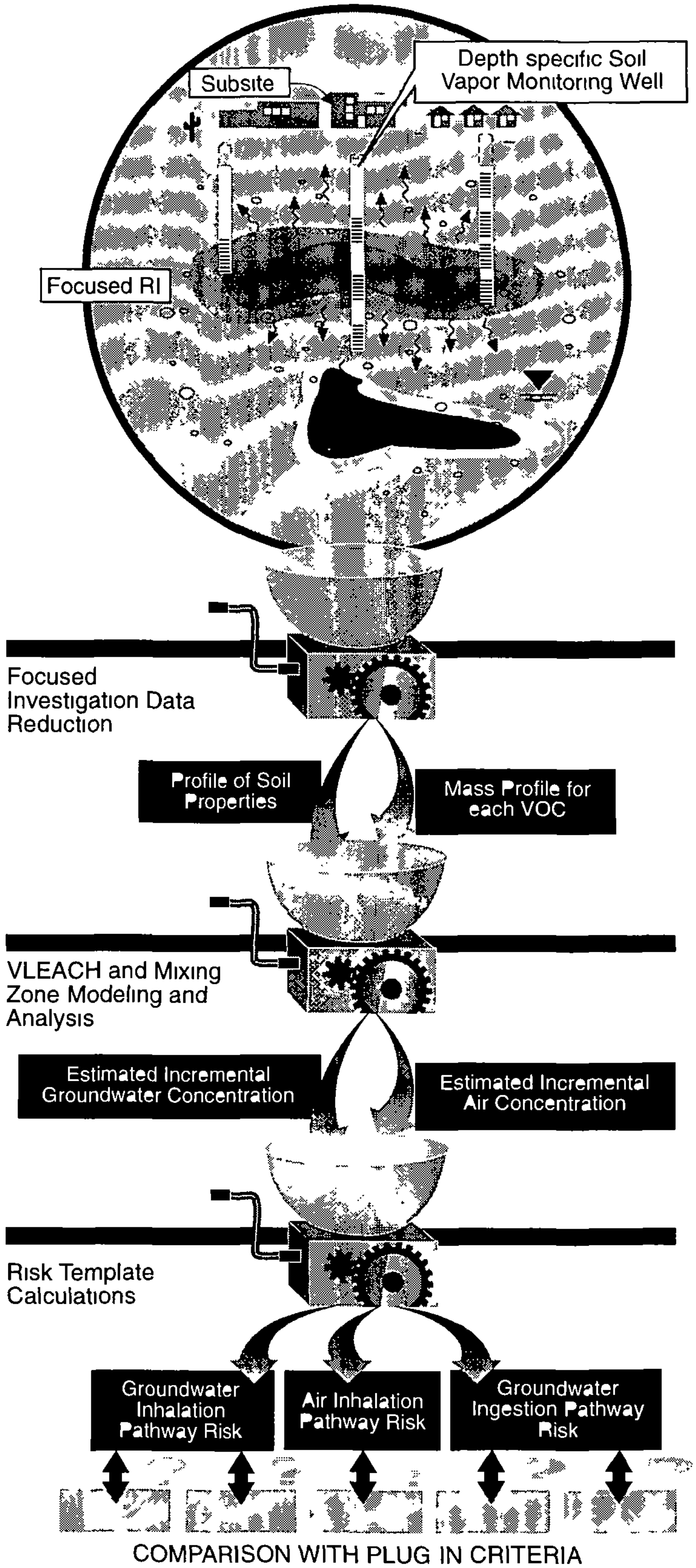


FIGURE 5-2
THE SUBSITE EVALUATION APPROACH WITHIN THE PLUG-IN PROCESS
COT ROW
IBW SOUTH TEMPE ARIZONA

TABLE 5 1
Comparison of Site Profile with Remedy Profile Parameters for SVE
COT ROW Technical Memorandum

Remedy Profile Parameter	Remedy Profile Boundaries and Range of Inclusion	Site Profile	Site Meets Remedy Profile?
Permeability of the Vadose Zone	Greater than 1 x 10 3 darcies	~10 darcies based on literature values for sands silty sands[a]	Yes
Percent Saturation	Less than 60 percent	9 to 91 percent	Yes
Depth to Groundwater	Greater than 5 feet	37 to 76 feet (SIBW 19U)	Yes
Henry s Law Constant of Contaminant	Greater than 100 atmospheres/mole	1 492 atmospheres/mole[b]	Yes
Vapor Pressure of Contaminant	Greater than 1 0 millimeter of mercury at 20 degrees Celsius	14 0 millimeters of mercury at 20 degrees Celsius[c]	Yes

Sources
[a]Freeze and Cherry 1979
[b]EPA 1990
[c]Yaws et al 1991

TABLE 5-2
Plug in Criteria
COT ROW Technical Memorandum

Criteria	Description
1	Present an incremental cancer risk of more than 1 in 1 million to a person from ingestion of VOCs in groundwater
2	Present a cancer risk to a person of more than 1 in 1 million from inhalation of air above the soils at the COT ROW itself over a lifetime
3	Present a hazard index for non cancer effects of more than 1 to a person from both ingestion of VOCs in groundwater and inhalation of VOCs during household uses of groundwater over a lifetime
4	Present a hazard index for non cancer effects of more than 1 to a person from inhalation of air above the soils at the COT ROW itself over a lifetime
5	Increase the incremental concentration of VOCs in groundwater by an amount greater than the federal MCL under the Safe Drinking Water Act

5 3 Data Collection

Data for the VLEACH model were obtained from the 1994 soil vapor survey and from SVMW-5 in 1997 The investigations were conducted by the ADEQ SVMW-5 consisted of four depth-specific completions to monitor VOC (primarily the COPCs) concentrations in soil vapor within discrete stratigraphic horizons within the vadose zone SVMW-5 was installed near the highest observed shallow soil vapor concentrations of VOCs and near the onsite separator

The stratigraphy of the vadose zone beneath the COT-ROW generally consists of two distinct layers—an upper silty sand from land surface to about 12 feet below ground surface (bgs), and a lower, much coarser sand, gravel, and cobble layer from about 12 feet to the water table The screened intervals of SVMW-5 are 4 to 7 feet bgs, 20 to 25 feet bgs, 41 to 44 feet bgs, and 58 to 61 feet bgs The deepest screened interval is typically submerged beneath the water table Therefore, only data from the upper three intervals were used for the VLEACH model

During the drilling of SVMW-5, the ADEQ prepared a geologic log that describes general lithologic characteristics of subsurface materials, contacts between distinct layers, and any unique geologic conditions Two-inch diameter split-spoon soil samples were collected at 7 to 8 feet, 17 to 18 feet, 40 5 to 41 5 feet, and 53 5 to 54 5 feet in the SVMW-5 borehole The samples were analyzed for moisture content, dry bulk density, and total organic carbon (TOC) Bulk soil samples collected at 6 to 7 feet, 16 to 17 feet, 22 to 24 feet, 37 to 38 feet, 45 to 46 feet, and 57 to 58 feet in SVMW-5 were analyzed for grain size distribution The soil boring log, geotechnical analyses, and SVMW construction summary are included as attachments

5 3 1 Derivation of VLEACH Model Inputs

Model simulations were performed using the latest version of VLEACH, a one-dimensional finite-difference unsaturated zone fate and transport model The VLEACH model chosen in the 1993 Soils ROD simulates leaching through a "polygon ' with distinct soil properties, recharge rate, depth to groundwater, and initial soil concentrations At the COT-ROW, one polygon was used to represent the areal extent of contaminated soil in the vicinity of SVMW-5 The VLEACH preprocessor and input files are included as an attachment

The soil profile beneath the polygon is represented by a vertical stack of cells, each 1 foot in thickness, reaching from the land surface to the water table At the time of the investigation, the average depth to groundwater beneath the COT-ROW was approximately 52 feet bgs The mass of contaminant in each cell is partitioned among liquid (dissolved in water), vapor, and sorbed phases Over a series of user-specified time steps, transport processes are simulated in VLEACH Contaminants in the liquid phase are subject to downward advection, contaminants in the vapor phase are subject to gaseous diffusion in both upward and downward directions, and contaminant mass is equilibrated according to distribution coefficients A detailed description of the VLEACH modeling methodology is presented in the EPA Center for Subsurface Modeling Support VLEACH Version 2 2a User s Manual The results from VLEACH were then input into a groundwater mixing zone model that converts the mass fluxes to incremental concentrations in groundwater attributable to PCE, 1,1,1-TCA, and TCE in the soil at the COT-ROW

The shallow soil vapor survey data were used to estimate the horizontal extent of contamination and assist in delineating the VLEACH polygon Data collected from the SVMW (1) helped verify PCE, 1,1,1-TCA, and TCE as the predominant contaminants in the soil vapor, (2) provided estimates of soil properties used in the model, and (3) provided soil vapor data used to estimate the total soil concentrations of PCE, 1,1,1-TCA, and TCE at different depths in soil The references or sources for the various model input parameters are presented in Tables 5-3 The values of the vadose zone properties that were input into VLEACH are discussed in Section 5 3 1 1 and are summarized in Table 5-4 Contaminant mass estimates and model input values representing contaminant concentrations in soil are discussed in Section 5 3 1 2 Assumptions used in the VLEACH modeling effort are discussed in Section 5 3 1 3

TABLE 5-3
VLEACH Model Input Parameters
COT ROW Technical Memorandum

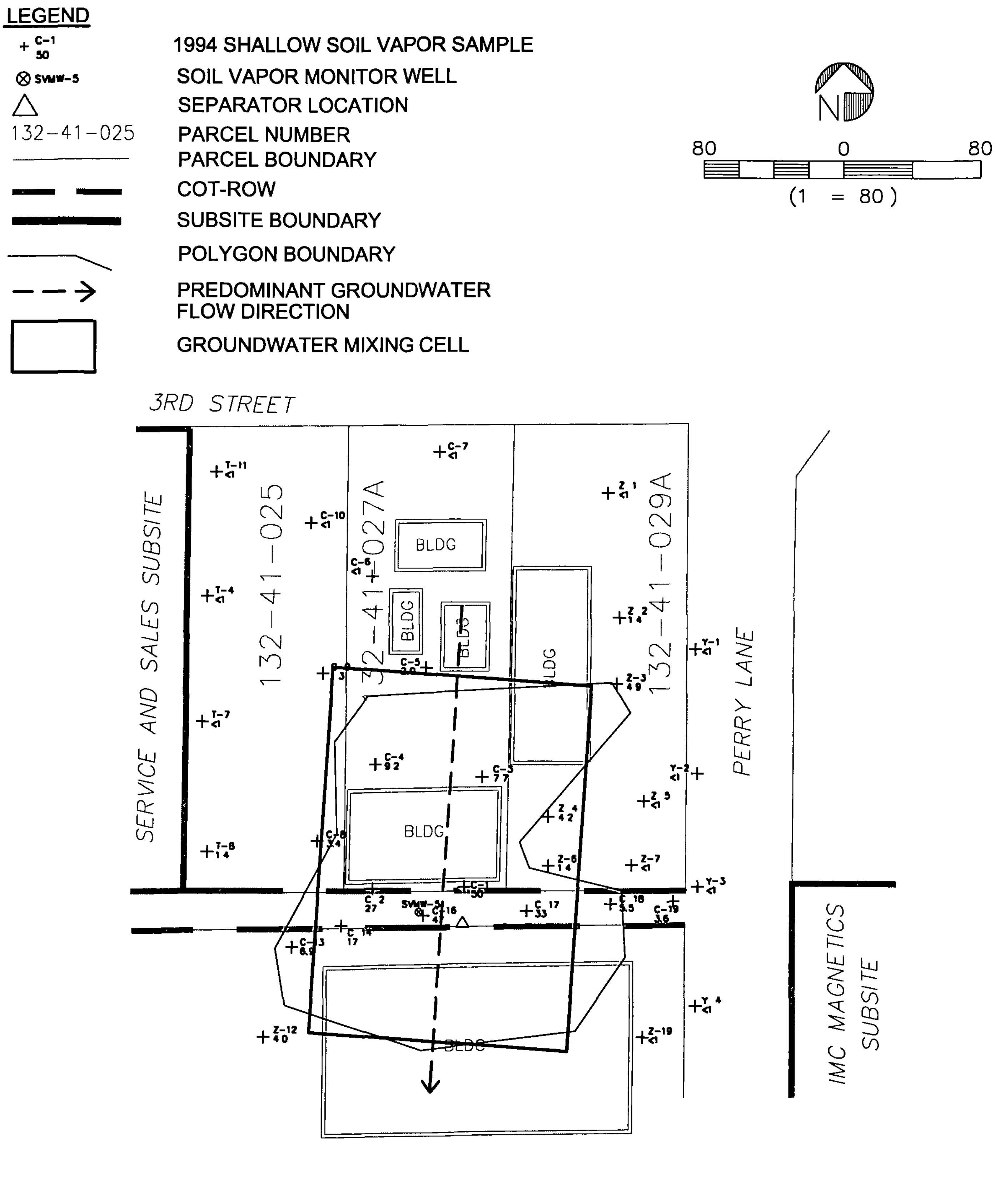
Parameter	Source/Reference
Water organic Carbon Distribution Coefficient (mL/g)	Graf 1993
Henry s Constant (dimensionless)	Graf 1993
Aqueous Solubility Limit (mg/L)	Graf 1993
Free Air Diffusion Coefficient (m^2/day)	EPA 1994
Polygon Area (ft^2)	Measured from Figure 5 3
Vertical Cell Thickness (feet)	Assigned
Groundwater Recharge Rate (ft/yr)	Same as North Indian Bend Wash (CH2M HILL 1991)
Dry Bulk Density (g/cm^3)	Depth Weighted Average of Assumed Adjusted and Unadjusted Laboratory Data (see Table 5 4)
Total Porosity (dimensionless)	Depth Weighted Average of Data Calculated from Assumed Adjusted and Unadjusted Bulk Density Values (see Table 5 4)
Volumetric Water Content (dimensionless)	Depth Weighted Average of Adjusted and Unadjusted Laboratory Data (see Table 5 4)
Fraction of Organic Carbon (dimensionless)	Depth Weighted Average of Adjusted and Unadjusted Laboratory Data (see Table 5 4)
Initial Total Soil Concentrations (μg/kg)	Maximum soil vapor concentrations converted to total soil concentrations using Equation 5 below

5 3 1 1 Vadose Zone Properties

The VLEACH model assumes that soil properties are homogeneous laterally and vertically within the polygon However, as described previously, soil beneath the COT-ROW generally consists of two distinct layers Depth-weighted averages of physical property values reported for samples collected from these distinct layers were calculated to derive model input values for the polygon The lower layer is thicker, therefore, soil properties in this layer were accorded greater weight in VLEACH Depth-weighted averages of estimates of dry bulk density, porosity, volumetric water content, and fraction of organic carbon (f_{oc}) discussed in the following paragraphs are summarized in Table 5-4 The results of the geotechnical analyses are included as an attachment

Recharge Rate

The groundwater recharge rate in conjunction with the volumetric water content determine the velocity of water moving downward through the vadose zone A rate of 0 0375 feet per year (0 45 inches per year) was input into VLEACH at the COT-ROW This recharge rate was established for the Indian Bend Wash Superfund Site–North (IBW-North) by evaluating numerous recharge studies conducted in similar environments (i e , climate and soils) The rate has also been used at other subsites within the IBW-South



NOTES

1 Polygon figure based on PCE concentrations greater than 5 micrograms per liter (µg/L)

2 Polygon area = 32 185 square feet

3 Groundwater Mixing Cell Length = 213 feet Width = 151 feet

FIGURE 5-3
POLYGON DELINEATION
COT ROW
IBW SOUTH TEMPE ARIZONA

CH2MHILL

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TABLE 5-4
Vadose Zone Parameters Used in VLEACH
COT ROW Technical Memorandum

Polygon Number	Polygon Area (ft^2)	$\overline{\rho_b}$ Dry Bulk Density[a] (g/cm^3)	$\overline{\theta_t}$ Total Porosity[a] (dimensionless)	$\overline{\theta_w}$ Volumetric Water Content[b] (dimensionless)	$\overline{f_{oc}}$ Fraction of Organic Carbon[b] (dimensionless)
I	32 185	1 96	0 261	0 044	0 000378

Notes

[a]Values are depth weighted averages of assumed values and adjusted and unadjusted laboratory data

[b]Values are depth weighted averages of adjusted and unadjusted laboratory data

ft^2 = square feet

g/cm^3 = grams per cubic centimeter

Correction for Stony Vadose Zone Soils

Physical and chemical properties measured in soil samples collected at the COT-ROW have been corrected to account for that portion of soil of grain size greater than 1 inch

Where appropriate, adjustments were made to the bulk density, f_{oc}, and volumetric water content data to better represent the bulk soil properties The general form of the Bouwer and Rice Correction is presented in the following equation (Bouwer and Rice, 1984)

$$\theta'_w = (1 - V_r)\theta_w \qquad (1)$$

Where

θ'_w = Adjusted volumetric water content (dimensionless)

V_r = Volume fraction of rock soil (percent of sample larger than 1 inch)

θ_w = Measured volumetric water content (dimensionless)

The volume fraction of rock soil was estimated as that percentage of the total soil matrix larger than 1 inch, according to the sieve analyses performed on bulk soil samples from the drill cuttings

Dry Bulk Density

The sample collected from the upper layer at the well borehole had a measured bulk density of 1 66 g/cm^3 Although the value is representative of bulk density for this type of soil, it was adjusted in accordance with the method used at other IBW-South subsites, as described below The two soil samples collected near the contact between the upper fine-grained and lower coarse-grained layer had measured bulk density values of 1 93 g/cm^3 and 2 09 g/cm^3 at SVMW-5 The measured values of bulk density below 2 0 g/cm^3 were considered low and representative of the soils that would fit inside a 2-inch brass sleeve The bulk density was adjusted using the Bouwer and Rice Correction to better represent bulk soil properties Equation (1) above has been slightly modified to account for the density of the rock material present in the soil matrix, as presented in the following equation

$$\rho'_b = 2\ 65 \times (V_r) + (1 - V_r) \times \rho_b \qquad (2)$$

Where

ρ_b' = Adjusted dry bulk density (g/cm^3)

V_r = Volume fraction of rock soil (percent of sample larger than 1 inch)

ρ_b = Measured dry bulk density (g/cm^3)

For cases where the correction resulted in adjusted dry bulk densities greater than 2 0 g/cm^3, a bulk density value of 2 0 g/cm^3 was used to represent the soils This value is consistent with the bulk density values in stony vadose zones (Bouwer and Rice, 1984) and with the values used at other IBW-South subsites and at the IBW-North For cases where no bulk density data were available, a bulk density value of 2 0 g/cm^3 was used to represent the soils The bulk density adjusted for stony soils at the COT-ROW ranged from 1 74 to 2 09 g/cm^3 The depth-weighted average was 1 96 g/cm^3 (Table 5-4)

Total Porosity

The estimates of total porosity are based on bulk density and computed using Equation 3, as follows

$$\theta_t = 1 - \frac{\rho_b}{\rho_p} \qquad (3)$$

Where

θ_t = Total porosity (dimensionless)

ρ_b = Assumed, adjusted or unadjusted dry bulk density [(g/cm^3) see criteria above]

ρ_p = Particle density (g/cm^3), typically ± 2 65 g/cm^3 for granitic materials

The depth-weighted average value for porosity listed in Table 5-4 was used to represent the total porosity for the simulated soil profile beneath the COT-ROW

Volumetric Water Content

The volumetric water content is the volume of liquid per volume of soil The soil samples collected at the COT-ROW were analyzed gravimetrically to obtain percent moisture Equation (1) above has been slightly modified to account for the fact that gravimetric water content was measured by the lab The adjusted volumetric water content, modified for stony soils is calculated using percent moisture in the following expression

$$\theta_w' = \frac{\theta_g\,(1 - V_r)\,\rho_b}{\rho_w} \qquad (4)$$

Where

θ_w' = Adjusted volumetric water content (dimensionless)

θ_g = Gravimetric water content (mg/kg expressed as a percentage)

V_r = Volume fraction of rock soil (percent of sample larger than 1 inch)

ρ_b = Measured dry bulk density (g/cm[3])

ρ_w = Density of water (1 g/cm[3])

The depth-weighted average value used to represent the volumetric water content for the simulated soil profile beneath the COT-ROW is listed in Table 5-4

Fraction Organic Carbon

The f_{oc} is the relative amount of organic carbon present in the soil Soil samples are analyzed for TOC using a two-step method, which includes an acid step to remove any carbonate that may be present in the soil and a thermal oxidation step to drive off the volatile fraction that may be present in the soil The TOC values are converted to f_{oc} through simple unit conversion Adjustments based on the Bouwer and Rice Correction were made to f_{oc} to better represent bulk soil properties at the COT-ROW The calculated f_{oc} adjusted for stony soils at the COT-ROW varied vertically and ranged from 2 15x10^{-5} to 1 38x10^{-3} (dimensionless) The depth-weighted average value used to represent the simulated soil profile at the COT-ROW is listed in Table 5-4

Polygon Definition

The horizontal extent of PCE contamination detected in shallow soil vapor was used to define the size and shape of the polygon for VLEACH since it was the most prevalent and areally extensive compound present at the COT-ROW (Figure 5-3) The boundaries of the polygon were located such that the areas included all points where the shallow soil vapor concentrations were 5 µg/L or greater

5 3 1 2 Estimated Contaminant Mass and Concentration in Soil

VOC Mass Estimates

As discussed in Section 4, soil vapor monitoring data collected from the SVMW indicate that PCE, 1,1 1-TCA, and TCE are the predominant contaminants present in the vadose zone at the COT-ROW The maximum VOC soil vapor concentrations detected at each depth of the SVMW were converted to total concentrations in soil and then to total mass within the polygon Total VOC soil concentrations derived from depth-specific soil vapor data collected at SVMW-5 were also used as input values for the VLEACH modeling to represent the contaminant profile in the vadose zone The vadose zone depth intervals monitored by the SVMW are discussed in Section 5 3

The VOC concentrations in soil vapor were converted to total concentrations in soil as follows

$$C_T = \left[C_G \left[\frac{K_D \overline{\rho_b}}{H_D} + \frac{\overline{\theta_w}}{H_D} + (\overline{\theta_t} - \overline{\theta_w}) \right] \right] - \overline{\rho_b} \qquad (5)$$

Where

C_T = Concentration in the bulk volume soil (µg/kg)

C_G = Highest concentration in the vapor phase at a specific depth (µg/L)

K_D = Water-solid distribution coefficient (L/kg)

$\overline{\rho_b}$ = Depth-weighted average of dry bulk density (kg/L)

H_D = Henry's constant for air-water partitioning (dimensionless)

$\overline{\theta_w}$ = Depth-weighted average of volumetric water content (dimensionless)

$\overline{\theta_t}$ = Depth-weighted average of total porosity (dimensionless)

The water-solid distribution coefficient is calculated as follows

$$K_D = K_{oc} \times \overline{f_{oc}} \qquad (6)$$

Where

K_D = Water-solid distribution coefficient (L/kg)

K_{oc} = Water-organic carbon distribution coefficient (L/kg)

$\overline{f_{oc}}$ = Depth-weighted average of fraction of organic carbon in soil (dimensionless)

The chemical properties used to convert vadose zone VOC soil vapor concentrations to total soil concentrations are presented in Table 5-5 The depth-weighted average value of f_{oc} at the polygon that was used in the conversion is presented in Table 5-4

TABLE 5-5
Chemical Properties used in VOC Mass Estimation
COT ROW Technical Memorandum

Compound	H_D Henry's Constant (dimensionless)	K_{oc} Water organic Carbon Distribution Coefficient (mL/g)
PCE	0 545	364
1 1 1 TCA	0 54	152
TCE	0 3	126

Source Graf 1993

Note

The unit L/kg specified in equation 6 is mathematically equivalent to mL/g (milliliters per gram) specified in this table

Total soil concentrations of VOCs with depth are presented in Table 5-6

TABLE 5-6
VLEACH Model Inputs – Estimated Total Soil Concentrations
COT ROW Technical Memorandum

Well Number	Sample Interval	Depth (feet bgs) Start	Depth (feet bgs) End	PCE (µg/kg)	1,1,1 TCA (µg/kg)	TCE (µg/kg)
SVMW 5	1	0	12	6 66	0 29	0 05
	2	12	31	5 07	0 57	0 12
	3	31	52	1 25	0 06	0 03

Usmg the estimated C_T, the total mass of contammant contamed withm the polygon was determmed usmg the followmg equation

$$M_{voc} = C_T(\overline{\rho_b} \times A \times t) \times 10^{-06} \times 28\ 32 \quad (7)$$

Where

M_{voc} = Mass of the contammant of concern (grams)

C_T = Maximum total soil concentration of the contammant of concern (µg/kg)

$\overline{\rho_b}$ = Depth-weighted average of dry bulk density (kg/L)

A = Polygon area (ft²)

t = Thickness of soil layer withm polygon (feet)

VOC mass estimates for the polygon are presented m Table 5-7

TABLE 5 7
Vadose Zone VOC Mass Estimates
COT ROW Technical Memorandum

Polygon	Analyte	Grams	Pounds
I	PCE	361 2	0 796
	1 1 1 TCA	27 4	6 04E 02
	TCE	5 9	1 30E 02

Other chemical properties used as input parameters to VLEACH are listed m Table 5-8

TABLE 5-8
Chemical Properties Used in VLEACH Modeling
COT ROW Technical Memorandum

Compound	Aqueous Solubility[a] (g/mL)	Free Air Diffusion Coefficient[b] (m²/day)
PCE	200	0 62208
1 1 1 TCA	720	0 67392
TCE	1 100	0 68256

Sources
[a]Graf 1993
[b]EPA 1994

Notes
g/mL = grams per milliliter
m²/day = square meters per day

5 3 1 3 VLEACH Modeling Assumptions for Groundwater

VLEACH model simulations were performed to support the risk assessment for the COT-ROW described m Section 6 of this technical memorandum The results of these simulations for the COPCs were input to the groundwater mixmg cell model to assess the potential impact to groundwater The assumptions used m the modelmg are as follows

- VOC fluxes to groundwater were estimated assuming that the upper model boundary was impermeable to gaseous diffusion In other words, diffusion of vadose zone contaminants from site soils into the atmosphere was assumed not to occur This approach maximizes the estimated impacts of vadose zone contamination on groundwater

- For all modeling runs, the water table was assumed to be impermeable to gaseous diffusion With this option, it is assumed that all mass exchange into the groundwater is due to the process of liquid advection This option also prevents any upward migration of volatile contaminants from the groundwater into the vadose zone

- Free product (dense non-aqueous phase liquids) are not present at the site

- The depth to water (vadose zone thickness) used in the calculations was 52 feet bgs The vadose zone thickness was derived by calculating the mean depth to water for a groundwater monitoring well in the vicinity of the COT-ROW

- The entire thickness of the vadose zone is considered homogeneous with no preferential pathways to flow

- There is no VOC sorption onto mineral surfaces All sorption of VOCs is onto organic carbon

- Liquid-phase dispersion is not considered

- There is no in situ degradation of VOCs

- Vapor-phase advection caused by barometric pressure changes or cyclic changes in the water table is neglected

- The model input contaminant concentrations used in the modeling are presented in Table 5-6 Chemical-specific parameters K_{oc} and H_D for PCE, 1,1,1-TCA, and TCE are presented in Table 5-5, the aqueous solubility and free-air diffusion coefficient parameters for PCE, 1,1,1-TCA, and TCE are presented in Table 5-8

5 4 Predicted Future Impact of Soil Contamination on Groundwater

5 4 1 VLEACH Results

The VOC mass loadings to groundwater were estimated using a time-step of 0 1 year over a period of 100 years These mass loading estimates were then converted to incremental concentrations in groundwater under the site using the mixing zone model described below VLEACH simulations were performed to estimate the contaminant mass flux to groundwater The maximum mass fluxes to groundwater estimated by VLEACH for PCE, 1,1,1-TCA, and TCE are presented in Table 5-9 The VLEACH output files and groundwater mixing cell results are included as an attachment

TABLE 5 9
Mass Fluxes to Groundwater from VOCs in Vadose Zone
COT ROW Technical Memorandum

	Maximum Flux		
Chemical	**g/yr**	**g/ft² yr**	**g/m² s**
PCE	0 376	1 86E 05	5 57E 12
1 1 1 TCA	5 69E 02	2 26E 06	6 77E 13
TCE	1 78E 02	6 85E 07	2 05E 13

Notes
g/yr = grams per year
g/ft² yr = grams per square foot year
g/m² s = grams per square meter second

5 4 2 Mixing Zone Calculations for Groundwater

Mass loadings from the polygon were used to estimate incremental VOC concentrations in groundwater beneath the COT-ROW Incremental concentrations at a specific time step were calculated with the following mixing zone model

$$C_n = \left[\frac{M_n \times L}{q \times Z} - \left(\frac{(M_n \times L)}{(q \times Z)} - C_{n-1} \right) \times e^{\frac{(-q \times t)}{(L \times R)}} \right] \times 35313\ 67 \quad \textbf{(8)}$$

Where

C_n = Groundwater Concentration at time step n (μg/L)

M_n = Mass flux of contaminant at time step n (g/ft²-day)

L = Length of the mixing cell along groundwater flow path (feet)

q = Darcy velocity [≈ Ki (ft/day), where K is the hydraulic conductivity and i is the hydraulic gradient]

Z = Vertical thickness of the mixing cell (feet)

C_{n-1} = Groundwater concentration at time step n-1 (g/ft³)

R = $\overline{\theta_t} + \left(\overline{\rho_b} K_D\right)$ (dimensionless)

t = Length of time step (days)

Aquifer parameters used in the mixing zone model are presented in Table 5-10 The vertical thickness of the mixing cell is assumed to be 50 feet, as specified in the 1993 Soils ROD (page II-69)

TABLE 5-10
Aquifer Parameters
COT ROW Technical Memorandum

Parameter (Units)	Value
Hydraulic Conductivity (ft/day)[a]	245
Transmissivity (ft^2/day)[b]	12 250
Hydraulic Gradient (ft/ft)	0 001
Flow Field Width (feet)	151
Flow Field Length (feet)	213

Notes
[a] Hydraulic Conductivity value was estimated from the geometric mean of aquifer test recovery data for all IBW South wells perforated in the Upper Alluvial Unit
[b] Transmissivity is estimated assuming an aquifer thickness of 50 feet
ft^2/day = square feet per day
ft/ft = feet per feet

The mass loading values output by VLEACH are related to the above equation by Equation 9

$$M_n = \frac{M_v}{W \times L \times t} \quad (9)$$

Where

M_n = Mass flux of contaminant at time step n (g/ft^2-day)
M_v = Mass of contaminant obtained from VLEACH (grams)
W = Width of the site perpendicular to groundwater flow (feet)
L = Length of the site parallel to groundwater flow (feet)
t = time (day)

The incremental concentrations of VOCs in groundwater beneath the area of the polygon were estimated using the mixing zone model and are presented on Figures 5-4 through 5-6 The maximum incremental concentration of the COPCs in groundwater in any one year are estimated at 3 12×10^{-2} µg/L for PCE, 3 78×10^{-3} µg/L for 1,1,1-TCA, and 1 15×10^{-3} µg/L for TCE These concentrations were inserted into the risk assessment templates to characterize health risks associated with VOCs in the vadose zone

5 5 Predicted Future Impact of Soil Contamination on Indoor Air

This section presents the risk assessment methods for calculating excess lifetime cancer risks (ELCRs) and hazard quotients (HQs) for VOCs in soils, based on an indoor air exposure scenario ELCRs and HQs based on this exposure scenario have been developed for the IBW-South Focused RIs

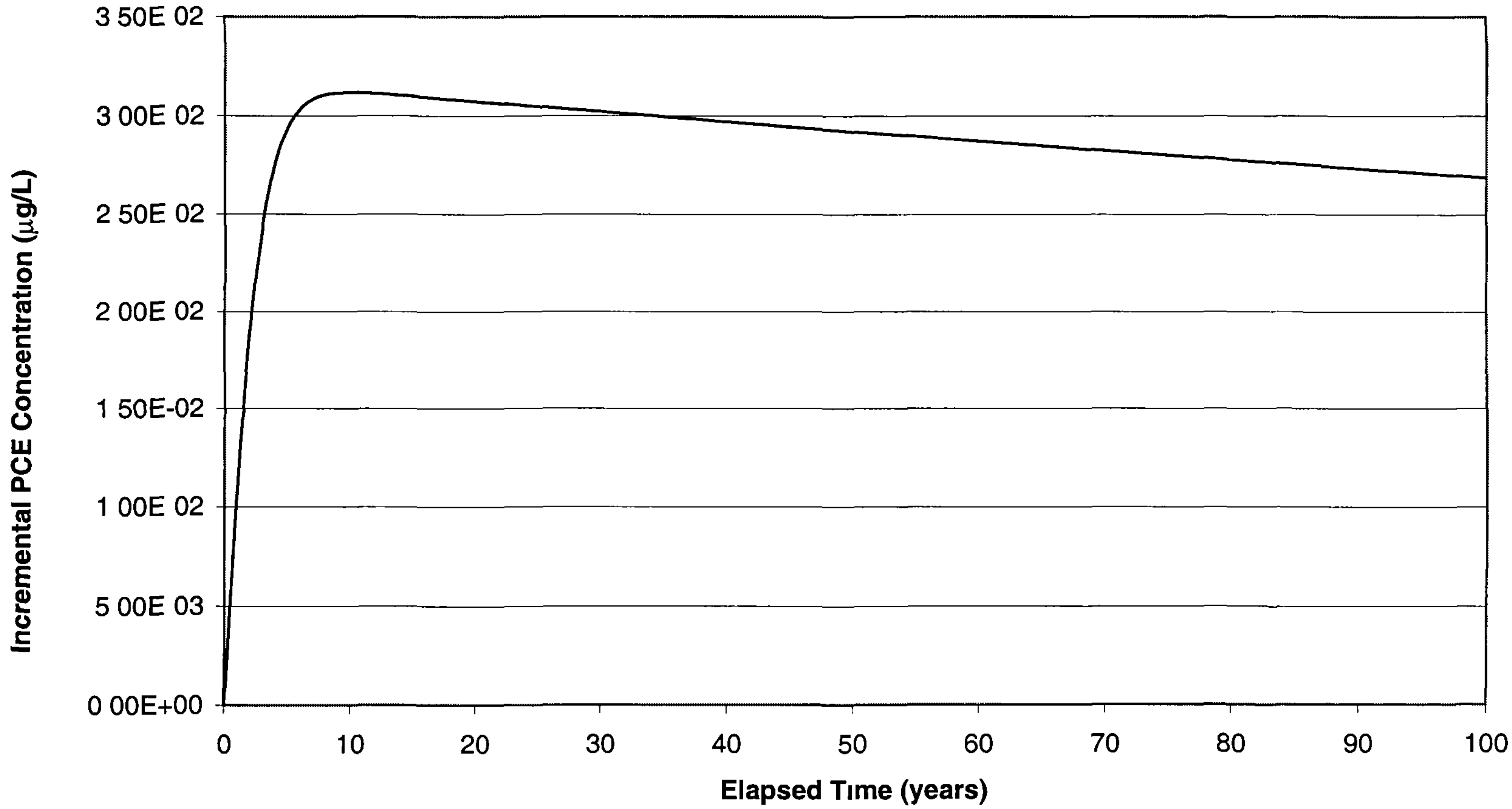

FIGURE 5-4
INCREMENTAL PCE CONCENTRATION IN GROUNDWATER
COT ROW
IBW SOUTH TEMPE ARIZONA

PCE_gwmix xls FIGURE 5 4 PCE

CH2MHILL

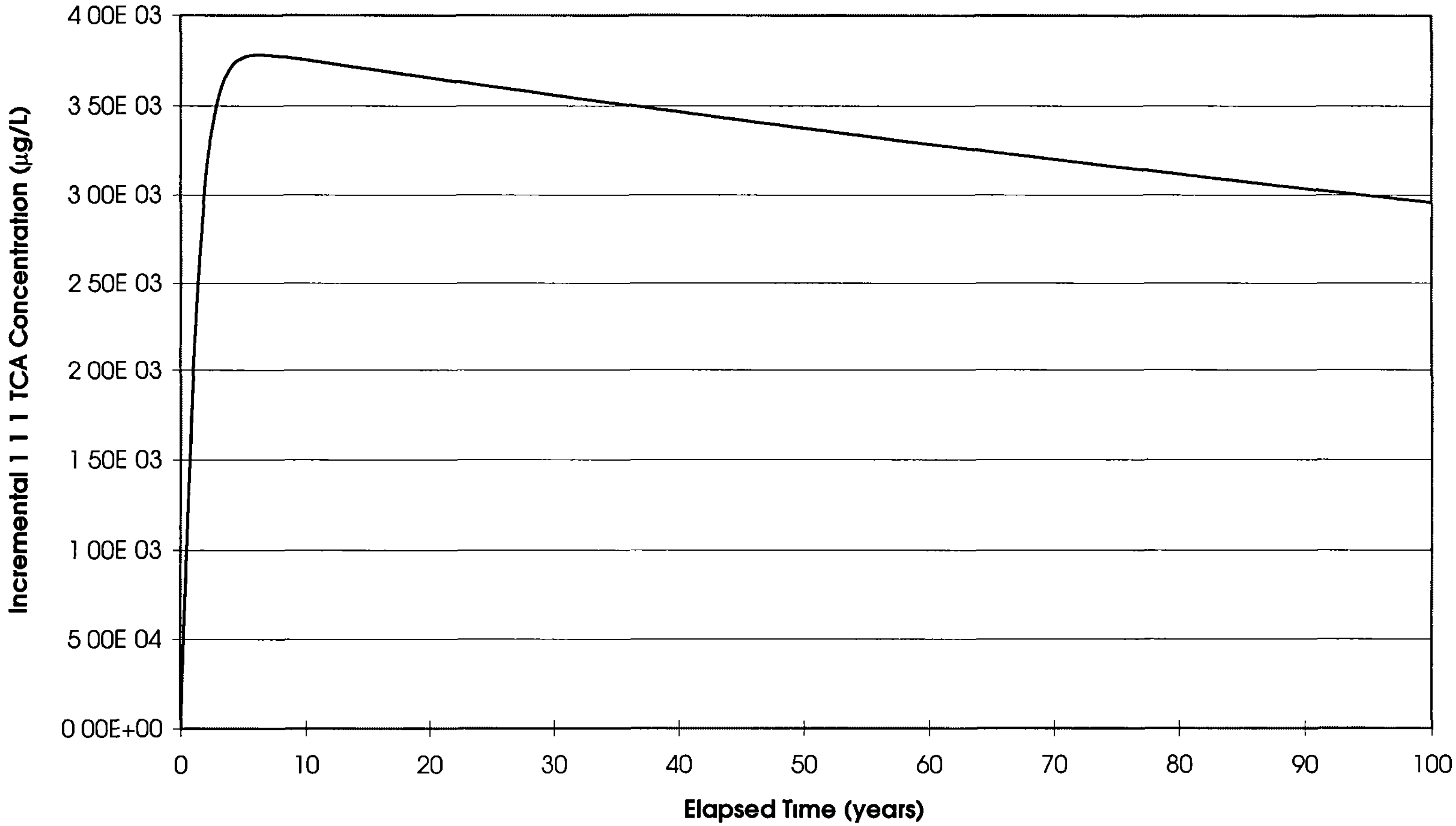

FIGURE 5-5
INCREMENTAL 1,1,1-TCA CONCENTRATION IN GROUNDWATER
COT ROW
IBW SOUTH TEMPE ARIZONA

TCA_gwmix xls FIGURE 5 5 TCA

CH2MHILL

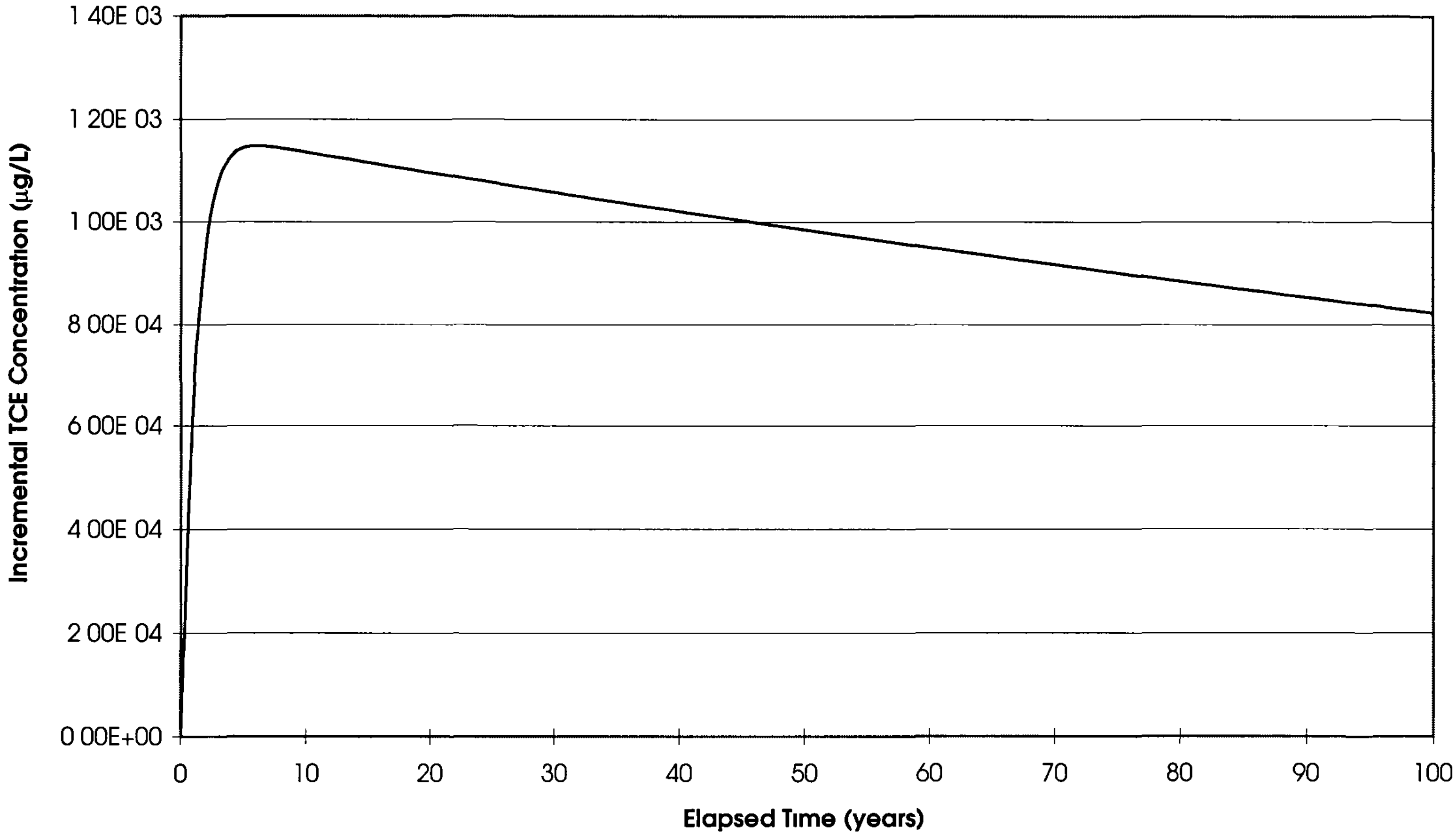

FIGURE 5-6
INCREMENTAL TCE CONCENTRATION IN GROUNDWATER
COT ROW
IBW SOUTH TEMPE ARIZONA

TCE_gwmix xls FIGURE 5 6 TCE

CH2MHILL

5 5 1 Overview of the Johnson & Ettinger (1991) Model

This section introduces the J&E model provides a brief history of its use, lists the key assumptions in the model, and describes its use in calculating risk estimates A detailed description of the model theory and equations is presented in the user guide for the J&E model (EPA, 1997)

5 5 1 1 Background

Volatilization of contaminants located in subsurface soils or in groundwater, and the subsequent transport of these vapors into indoor spaces constitutes a potential inhalation exposure pathway This potential exposure pathway was evaluated as part of this technical memorandum As described above, although VLEACH was the original model selected in the 1993 Soils ROD, an alternative model was used to estimate the impact of VOCs in soil on indoor air J&E introduced a screening-level model which incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above or in close proximity to the source of contamination

The EPA has evaluated the risk estimate results obtained from three different modeling methods including an adaptation of VLEACH, the Volatilization Factor Model, and the J&E infinite source model The rationale for using the J&E model is provided in Section 5 The J&E model may be run assuming either an infinite source or a finite (mass-limited) source of contamination The EPA's default position assumes that the source of contamination is infinite The EPA selected the use of the J&E infinite source model in accordance with their default position, for the COT-ROW to estimate health risks from exposure to indoor air emanating from subsurface soils A finite source of contamination may be used when the results of an infinite source exceed the Plug-in Criteria (Table 5-2) and there is an adequate density and spacing of sample locations to justify a finite source air emissions model Other subsites within the IBW-South met these conditions and were modeled using finite sources of contamination, however these conditions were not met at the COT-ROW

5 5 1 2 Exposure Scenario and Model Description

The J&E model is used to estimate the concentration in indoor air emanating from a contaminant vapor source located some distance (L_T) below the floor of an enclosed building constructed with a basement or constructed slab-on-grade The source of contamination is assumed to be either a soil-incorporated VOC or a VOC in solution with groundwater below the water table In this case, the contaminant source is a soil-incorporated VOC

A simplified conceptual diagram of the exposure scenario that was evaluated using the J&E model is presented on Figure 5-7 The source of contamination is incorporated in soil and buried some distance below the enclosed space floor At the top boundary of contamination, molecular diffusion moves the volatilized contaminant towards the soil surface until it reaches the zone of influence of the building Here convective air movement within the soil column transports the vapors through cracks between the foundation and the basement slab floor This convective sweep effect is induced by a negative pressure within the structure caused by a combination of wind effects and stack effects due to building heating and mechanical ventilation

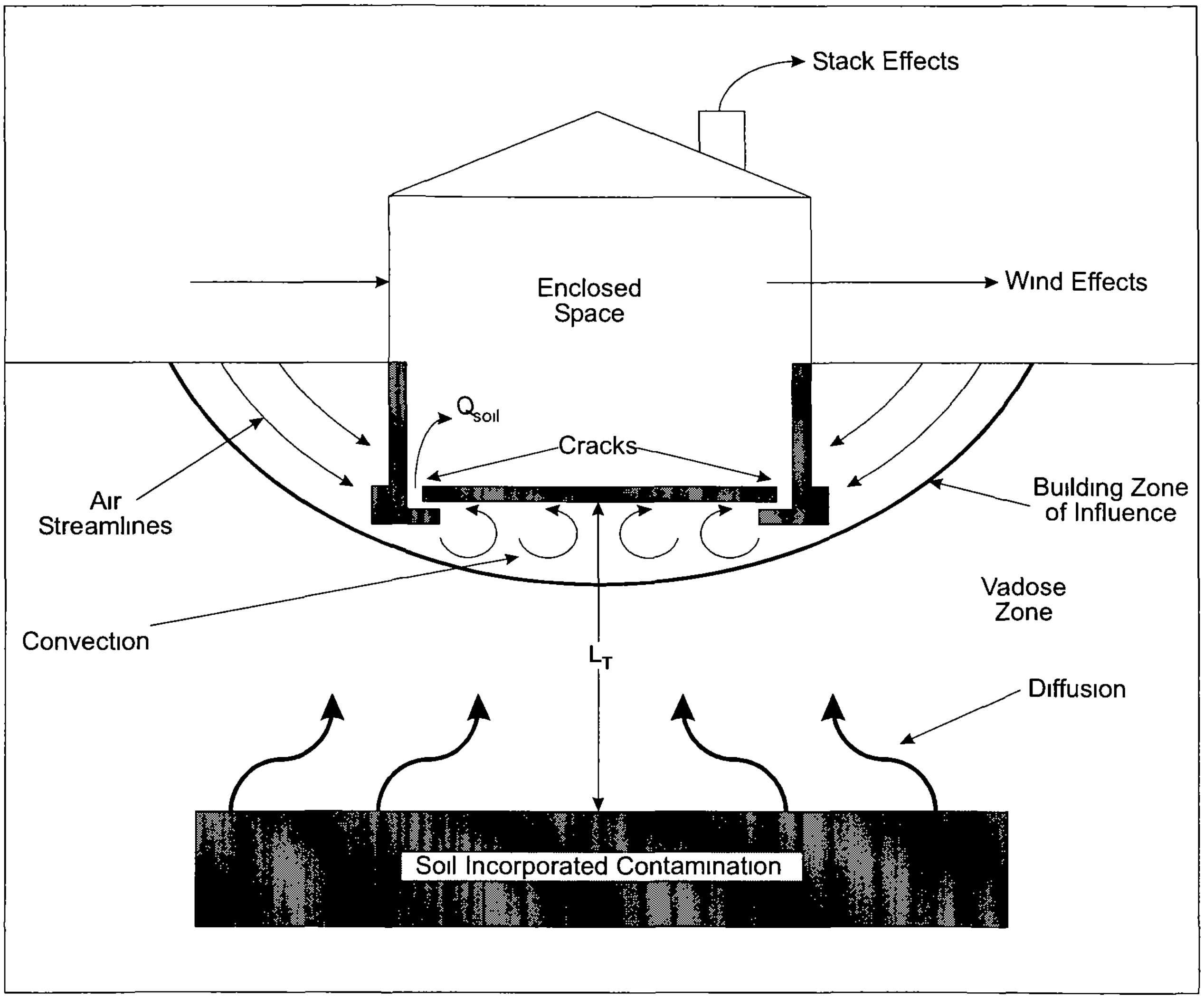

FIGURE 5-7
CONCEPTUAL MODEL OF VOC INTRUSION FROM SOIL TO INDOOR AIR
COT ROW
IBW SOUTH TEMPE ARIZONA

The rate of soil vapor entry is a function solely of convection, however, the VOC concentration entering the structure may be limited by either convection or diffusion depending upon the magnitude of the source-building separation (L_T) Analytical solutions have been developed for both an infinite source and a finite source model The infinite source model used during this investigation is based on the assumption of steady-state mass transfer The finite source model is based on the assumption that the thickness of VOC contamination in soil is known The development of these analytical solutions are described in detail in the user's guide for the model (EPA, 1997)

The concentration in indoor air resulting from VOC intrusion into a structure resulting from pressure-driven air-flow is calculated from the building volume (length, width, and height) and the building ventilation rate (numbers of air changes per hour) The following represent the major assumptions and limitations of the J&E model

- The initial concentration of VOC in soil does not contain a residual-phase (e g , non-aqueous-phase liquid or solid)
- Contaminant vapors enter the structure primarily through cracks and openings in the walls and foundation
- Convective transport occurs primarily within the building zone of influence and vapor velocities decrease rapidly with increasing distance from the structure
- Diffusion dominates vapor transport between the source of contamination and the building zone of influence
- All vapors originating from below the building will enter the building unless the floors and walls are perfect vapor barriers
- All soil properties in any horizontal plane are homogeneous
- The contaminant is homogeneously distributed within the zone of contamination
- The areal extent of contamination is greater than that of the building floor in contact with the soil
- Vapor transport occurs in the absence of convective water movement within the soil column (i e , evaporation or infiltration), and in the absence of mechanical dispersion
- The model does not account for transformation processes (e g , biodegradation, hydrolysis, etc)
- The soil layer in contact with the structure floor and walls is isotropic with respect to permeability
- Both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values

5 5 1 3 Use of Johnson & Ettinger (1991) Model for Calculating Risk Estimates

This section presents the methodology used to derive soil vapor concentrations for input into the J&E infinite model and presents the model input parameters used to calculate ELCRs and HQs Soil vapor data used to estimate health risks were collected during the site investigation for the purpose of estimating the total mass and horizontal and vertical distribution of VOCs in soil The following describes the procedures used to calculate health risks from exposure to indoor air

1 VOC concentrations are originally measured in soil vapor samples collected from the SVMW, and subsequently the units are converted from parts per billion to µg/L

2 For sites that have three or fewer sampling events from each sampling port (i e , each depth interval), the maximum concentration of each chemical detected is selected from each port

3 For sites with greater than three sampling events from each sampling port, an average concentration may be calculated from each port

4 For SVMWs with greater than one port, a depth-weighted chemical concentration is calculated for each chemical detected using the maximum concentration from each sampling port

5 The lowest depth range where VOC concentrations are observed is determined and used as an input parameter for the J&E model

6 VOC concentrations in soil vapor (µg/L) are converted to total concentrations in soil (µg/kg) in accordance with the procedure described in Section 5 3 1 2 (VOC Mass Estimates)

7 The J&E infinite source model is used to calculate ELCRs and/or HQs for each VOC measured in soil vapor The soil and building input parameters used for the infinite source model are presented in Table 5-11 The residential exposure scenario intake parameters used to calculated ELCRs and HQs are presented in Table 5-12

8 Risk per unit concentration for each chemical is calculated using an initial soil concentration of 1 µg/kg ELCRs and HQs are calculated by multiplying the Risk or HQ per unit concentration in soil by the total soil concentration

6 Risk Assessment

The risk assessment presented in the 1993 Soils FS sets the framework for assessing risks associated with VOCs in soils at a generic individual subsite The Plug-in Approach uses this framework (specifically the risk templates presented in the 1993 Soils FS and incorporated in the 1993 Soils ROD) to estimate risks at individual subsites The risks estimated in the templates are then compared to the risk-based Plug-in Criteria reprinted in Table 5-2 of this memorandum The three potential exposure pathways considered in this risk assessment were as follows

- Inhalation of VOCs volatilized from groundwater
- Inhalation of VOCs emitted from soil to indoor air
- Ingestion of drinking water from groundwater

TABLE 5-11
Soil and Building Input Parameters
COT ROW Technical Memorandum

Parameter	Description	Selected Value	Notes
Depth from Soil Surface to Bottom of Enclosed Space Floor	This is the depth from soil surface to the bottom of the floor in contact with soil	15 cm	Default value in User's Guide for slab on grade construction (EPA 1997) Represents 6 inch thick concrete slab
Depth from Soil Surface to Top of Contamination	This is the depth from soil surface to the top of VOC contaminated soil It represents the depth of a VOC contaminant source in soil or the dry zone between the surface and VOC contaminant source	Site & Chemical Specific (cm)	Selected depth is the top of the screening interval where maximum contaminant concentrations were observed (i e L_T=300 cm)
Vadose Zone SCS Soil Type	This parameter is associated with convective transport of vapors within the zone of influence of a building It is related to the size and shape of connected soil pores The J&E model provides 12 different soil types to estimate permeability	Sand 1 0 x 10 ^{8} cm^2	Represents a value of 1 darcy This parameter and water filled porosity are used to estimate the soil vapor permeability of Stratum A which is in contact with the floor and walls of the enclosed space below grade
Soil Dry Bulk Density	This parameter is used to calculate total porosity	1 96 g/cm^3	This is a site specific value developed for this site and is also used for VLEACH modeling
Total Porosity	Used with water filled porosity to calculate air filled porosity	0 261 (dimensionless)	This is a site specific value developed for this site and is also used for VLEACH modeling
Water filled porosity	Used with total porosity to calculate air filled porosity	0 044 cm^3/cm^3	This is a site specific value developed for this site and is also used for VLEACH modeling
Fraction of Organic Carbon	Used to calculated chemical specific distribution coefficient (K_d) from K_{oc}	0 000378 (dimensionless)	This is a site specific value developed for this site and is also used for VLEACH modeling

Notes
cm = centimeters
cm^2 = square centimeters
cm^3/cm^3 = cubic centimeters per cubic centimeters

TABLE 5-12
Parameters Used to Calculate Preliminary Cleanup Goals for Indoor Air Scenarios
COT ROW Technical Memorandum

Exposure Parameters	Abbreviations	Value
Target cancer risk	TR	Chemical Specific
Target Hazard Quotient	THQ	Chemical Specific
Body weight adult (kg)	BW	70
Inhalation rate (m^3/day)	IRA	20
Exposure frequency (days/yr)	EF	350
Exposure duration (yr)	ED	30
Averaging time – carcinogenic (yr)	AT_C	70
Averaging time – noncarcinogenic (yr)	AT_N	30
Unit Risk Factors ($\mu g/m^3$) [1]	URF	Chemical Specific
Reference Concentration (mg/m^3)	RfC	Chemical Specific

Notes
kg = kilograms
m^3/day = cubic meters per day
days/yr = days per year
yr = years
$\mu g/m^3$ = micrograms per cubic meter
mg/m^3 = milligrams per cubic meter
*The unit for Unit Risk Factors is written in the form necessary for use in the program and is equivalent to $m^3/\mu g$

The estimated incremental increased concentrations in groundwater calculated with VLEACH were used to estimate risks associated with the first two exposure pathways The risk assessment templates used to calculate risks associated with these concentrations in groundwater are presented in Tables 6-1 and 6-2 The risks potentially associated with inhalation of VOCs emitted from soil to indoor air were calculated using the J&E, 1991 infinite source model The results from the risk assessment for the indoor air exposure pathway are summarized in Table 6-3 All ELCR and noncancer hazard quotients were less than the Plug-in Criteria The ELCR from exposure to groundwater was $2x10^{-8}$ and the ELCRs ranged between $2x10^{7}$ and $6x10^{9}$ at SVMW-5 from exposure to indoor air, all noncancer hazard quotients were less than 1 0 The J&E output files are included as an attachment

None of the Plug-in Criteria adopted in the 1993 Soils ROD and described in Table 6-4 were exceeded for the COT-ROW

TABLE 6 1
Risk Assessment Template for
Cancer risk from VOCs in Groundwater
Indian Bend Wash – South

Subsite Information
COT ROW

Prepared By DD
Date 08/07/2000

See instructions in 1993 Vadose Zone ROD

Chemical	Line 1 Concentration in Groundwater (mg/L)	Line 2 Chemical Intake Ingestion (mg/kg day)	Line 3 Chemical Intake Inhalation (mg/kg day)	Line 4 Oral Slope Factor (mg/kg day) [1]	Line 5 Inhalation Slope Factor (mg/kg day) [1]	Line 6 Estimated Cancer Risk Ingestion	Line 8 Estimated Cancer Risk Inhalation
Benzene				0 029	0 029		
Benzyl chloride				0 17			
Bromomethane							
Carbon Tetrachloride				0 13	0 053		
Chlorobenzene							
Chloroform				0 061	0 081		
Chloromethane				0 013	0 0063		
1 2 Dibromoethane				85	0 76		
1 2 Dichlorobenzene							
1 3 Dichlorobenzene							
1 4 Dichlorobenzene				0 024			
1 1 Dichloroethane							
1 2 Dichloroethane				0 091	0 091		
1 1 Dichloroethylene							
cis 1 2 Dichloroethylene							
trans 1 2 Dichloroethylene							
Dichloromethane				0 0075	0 0016		
1 2 Dichloropropane				0 068			
cis 1 3 Dichloropropene				0 18	0 13		
trans 1 3 Dichloropropene				0 18	0 13		
Ethylbenzene							
4 Ethyltoluene							
Trichlorofluoromethane (Freon 11)							
Dichlorodifluoromethane (Freon 12)							
1 1 2 Trichloro 1 2 2 trifluoromethane (Freon 113)							
Dichlorotetrafluoroethane (Freon 114)							
Hexachlorobutadiene				0 078	0 078		
Methylethylketone (MEK)							

TABLE 6 1
Risk Assessment Template for
Cancer risk from VOCs in Groundwater
Indian Bend Wash – South

Subsite Information
COT ROW

Prepared By DD
Date 08/07/2000

See instructions in 1993 Vadose Zone ROD

Chemical	Line 1 Concentration in Groundwater (mg/L)	Line 2 Chemical Intake Ingestion (mg/kg day)	Line 3 Chemical Intake Inhalation (mg/kg day)	Line 4 Oral Slope Factor (mg/kg day) [1]	Line 5 Inhalation Slope Factor (mg/kg day) [1]	Line 6 Estimated Cancer Risk Ingestion	Line 8 Estimated Cancer Risk Inhalation
Styrene							
1 1 1 2 Tetrachloroethane				0 026	0 026		
Tetrachloroethylene (PCE)	3 12E 05	3 66E 07	1 37E 06	0 051	0 0018	1 87E 08	2 47E 09
Toluene							
1 2 4 Trichlorobenzene							
1 1 1 Trichloroethane	3 78E 06	4 44E 08	1 66E 07			0 00E+00	0 00E+00
1 1 2 Trichloroethane				0 057	0 057		
Trichloroethylene (TCE)	1 15E 06	1 35E 08	5 06E 08	0 011	0 006	1 49E 10	3 04E 10
Vinyl chloride				1 9	0 29		
Total xylenes							

Line 7 Total Ingestion Risk: 1 88E 08

Line 9 Total Inhalation Risk: 2 77E 09

Line 10 **Total Subsite Risk**: 2 E 08

Line 11 Estimated Lifetime Cancer Risk Exceeds Plug in Criteria: [ ]

Line 12 Estimated Lifetime Cancer Risk Does Not Exceed Plug in Criteria: X

Be sure to compare concentrations in groundwater with MCL values

Note
mg/kg day = milligrams per kilogram day

TABLE 6 2
Risk Assessment Template for
Noncancer Effects from VOCs in Groundwater
Indian Bend Wash South

Subsite Information
COT ROW

Prepared By DD
Date 08/07/2000

See instructions in 1993 Vadose Zone ROD

Chemical	Line 1 Concentration in Groundwater (mg/L)	Line 2 Chemical Intake Ingestion (mg/kg day)	Line 3 Chemical Intake Inhalation (mg/kg day)	Line 4 Oral Reference Dose (mg/kg day)	Line 5 Inhalation Reference Dose (mg/kg day)	Noncancer Target Organ/ Critical Toxic Effect Ingestion	Line 6 Noncancer Hazard Quotients Ingestion	Noncancer Target Organ/ Critical Toxic Effect Ingestion	Line 8 Noncancer Hazard Quotients Inhalation
Benzene									
Benzyl chloride									
Bromomethane				0 0014	0 001	GI		URT	
Carbon Tetrachloride				0 0007		LIVER			
Chlorobenzene				0 02	0 005	LIVER		LIVER	
Chloroform				0 01		LIVER			
Chloromethane									
1 2 Dibromoethane									
1 2 Dichlorobenzene				0 09	0 04	LIVER		LIVER	
1 3 Dichlorobenzene									
1 4 Dichlorobenzene				0 1	0 2	LIVER		LIVER	
1 1 Dichloroethane				0 1	0 1	LIVER		LIVER	
1 2 Dichloroethane									
1 1 Dichloroethylene				0 0009	0 0009	LIVER		LIVER	
cis 1 2 Dichloroethylene				0 009		LIVER			
trans 1 2 Dichloroethylene				0 009		LIVER			
Dichloromethane				0 06	0 86	LIVER		LIVER	
1 2 Dichloropropane					0 001			URT	
cis 1 3 Dichloropropene				0 0003	0 006	LIVER		URT	
trans 1 3 Dichloropropene				0 0003	0 006	LIVER		URT	
Ethylbenzene				0 1	0 29	LIVER		DEV	
4 Ethyltoluene									
Trichlorofluoromethane (Freon 11)				0 3	0 2	BW		URT	
Dichlorodifluoromethane (Freon 12)				0 2	0 05	BW		LIVER	
1 1 2 Trichloro 1 2 2 trifluoromethane (Freon 113)				30	8 6	BW		BW	
Dichlorotetrafluoroethane (Freon 114)									
Hexachlorobutadiene				0 002		LIVER			
Methylethylketone (MEK)				0 05	0 1	CNS		DEV	
Styrene				0 2	0 3	LIVER		LIVER	
1 1 1 2 Tetrachloroethane				0 03		LIVER			
Tetrachloroethylene (PCE)	3 12E 05	8 55E 07	3 12E 06	0 01		LIVER	8 549E 05		
Toluene				0 2	0 1	LIVER		CNS	

TABLE 6 2
Risk Assessment Template for
Noncancer Effects from VOCs in Groundwater
Indian Bend Wash South

Subsite Information
COT ROW

Prepared By DD
Date 08/07/2000

See instructions in 1993 Vadose Zone ROD

Chemical	**Line 1** Concentration in Groundwater (mg/L)	**Line 2** Chemical Intake Ingestion (mg/kg day)	**Line 3** Chemical Intake Inhalation (mg/kg day)	**Line 4** Oral Reference Dose (mg/kg day)	**Line 5** Inhalation Reference Dose (mg/kg day)	Noncancer Target Organ/ Critical Toxic Effect Ingestion	**Line 6** Noncancer Hazard Quotients Ingestion	Noncancer Target Organ/ Critical Toxic Effect Ingestion	**Line 8** Noncancer Hazard Quotients Inhalation
1 2 4 Trichlorobenzene				0 01	0 003	LIVER		LIVER	
1 1 1 Trichloroethane	3 78E 06			0 09	0 3	LIVER	0	LIVER	0
1 1 2 Trichloroethane				0 004		LIVER			
Trichloroethylene (TCE)	1 15E 06	3 15E 08	1 15E 07	0 09	0 3	LIVER	3 501E 07	LIVER	3 83333E 07
Vinyl chloride									
Total xylenes				2	0 09	LIVER		CNS	

Line 7 Total Ingestion HQ: 8 58E 05

Line 9 Total Inhalation HQ: 3 83E 07

Line 10 **Hazard Index**: 8 62E 05

Segregated Hazard Quotients

	Ingestion			**Critical Effect/ Target Organ**
Line 11a		**11b**		GI
Line 12a		**12b**		URT
Line 13a		**13b**		LIVER
Line 14a		**14b**		DEV
Line 15a		**15b**		BW
Line 16a		**16b**		CNS

Segregated Hazard Indices

Line 17		GI
Line 18		URT
Line 19		LIVER
Line 20		DEV
Line 21		BW
Line 22		CNS

TABLE 6 2
Risk Assessment Template for
Noncancer Effects from VOCs in Groundwater
Indian Bend Wash South

Subsite Information
COT ROW

Prepared By DD
Date 08/07/2000

See instructions in 1993 Vadose Zone ROD

Chemical	**Line 1** Concentration in Groundwater (mg/L)	**Line 2** Chemical Intake Ingestion (mg/kg day)	**Line 3** Chemical Intake Inhalation (mg/kg day)	**Line 4** Oral Reference Dose (mg/kg day)	**Line 5** Inhalation Reference Dose (mg/kg day)	Noncancer Target Organ/ Critical Toxic Effect Ingestion	**Line 6** Noncancer Hazard Quotients Ingestion	Noncancer Target Organ/ Critical Toxic Effect Ingestion	**Line 8** Noncancer Hazard Quotients Inhalation

Line 23 Estimated Hazard Index Exceed Plug in Criteria [ ]

Line 24 Estimated Hazard Index Does Not Exceed Plug in Criteria [x]

Be sure to also compare concentrations in groundwater with MCL values

TABLE 6 3
COT ROW Summary of Chemical Concentrations and Risk Estimates for SVMW 5 (Infinite Source)
COT ROW Technical Memorandum

Contaminant	Depth Range	Maximum Concentration 0 12 feet	Maximum Concentration 12 31 feet	Maximum Concentration 31 52 feet	Depth Weighted + Maximum Soil Vapor Concentration (µg/L)	K_{OC}	H_D
Methylchloroform (1 1 1 Trichloroethane)	52	1 157	2 264	0 222	0 940	152	0 540
Tetrachloroethylene (PCE)	52	17 417	13 242	3 269	7 607	364	0 545
Trichloroethylene (TCE)	52	0 149	0 349	0 078	0 169	152	0 540

$\overline{f_{oc}}$	$\overline{\rho_b}$	$\overline{\theta_w}$	$\overline{\theta_t}$
0 000378	1 96	0 044	0 261

$$C_T \backslash C_G = \left(\left(K_D \right) \left(\overline{\rho_b} \right) / H_D \right) + \left(\overline{\theta_w} / H_D \right) + \left(\overline{\theta} - \overline{\theta_w} \right)$$

Where

C_T = total soil concentration (µg/kg)

C_G = total soil vapor concentration (µg/L)

K_D = water solid distribution coefficent = (K_{oc})($\overline{f_{oc}}$) [L/kg]

$\overline{\rho_b}$ = depth weighted average of dry bulk density (kg/L)

H_D = air water distribution coefficient (dimensionless)

$\overline{\theta_w}$ = depth weighted average of volumetric water content (dimensionless)

$\overline{\theta_t}$ = depth weighted average of total porosity (dimensionless)

$\overline{f_{oc}}$ = depth weighted average of fraction of organic carbon in soil (dimensionless)

TABLE 6 3
COT ROW Summary of Chemical Concentrations and Risk Estimates for SVMW 5 (Infinite Source)
COT ROW Technical Memorandum

Contaminant	C_T/C_G	Total Soil Concentration (μg/kg)	Risk Per Unit Concentration (ug/kg) in Soil	HQ Per Unit Concentration (μg/kg)	Excess Lifetime Cancer Risk	Noncancer Hazard Quotient
Methylchloroform (1 1 1 Trichloroethane)	0 508	0 244		2 97E 04		7 24E 05
Tetrachloroethylene (PCE)	0 793	3 080	6 07E 08		1 87E 07	
Trichloroethylene (TCE)	0 508	0 044	1 33E 07		5 82E 09	

$\overline{f_{oc}}$	$\overline{\rho_b}$	$\overline{\theta_w}$	$\overline{\theta_t}$
0 000378	1 96	0 044	0 261

$$C_T \backslash C_G = \left((K_D)\left(\overline{\rho_b}\right)/H_D \right) + \left(\overline{\theta_w}/H_D \right) + \left(\overline{\theta} - \overline{\theta_w} \right)$$

Where

C_T = total soil concentration (µg/kg)

C_G = total soil vapor concentration (µg/L)

K_D = water solid distribution coefficent = (K_{oc})($\overline{f_{oc}}$) [L/kg]

$\overline{\rho_b}$ = depth weighted average of dry bulk density (kg/L)

H_D = air water distribution coefficient (dimensionless)

$\overline{\theta_w}$ = depth weighted average of volumetric water content (dimensionless)

$\overline{\theta_t}$ = depth weighted average of total porosity (dimensionless)

$\overline{f_{oc}}$ = depth weighted average of fraction of organic carbon in soil (dimensionless)

TABLE 6-4
Plug in Criteria Comparison
COT ROW Technical Memorandum

Criterion No	Plug in Criteria Description	Criteria Exceeded at the COT ROW?
1	Present a cancer risk (incremental risk) to a person of more than 1 in 1 million from both ingestion of VOCs in groundwater and inhalation of VOCs during household uses of groundwater over a lifetime	No
2	Present a cancer risk to a person of more than 1 in 1 million from inhalation of air above the soils at the Subsite itself over a lifetime	No
3	Present a hazard index to a person for non cancer effects of more than 1 from both ingestion of VOCs in groundwater and inhalation of VOCs during household uses of groundwater over a lifetime	No
4	Present a hazard index to a person for non cancer effects of more than one from inhalation of air above the soils at the Subsite itself over a lifetime	No
5	Increase the concentration of VOCs in groundwater (incremental concentration) by an amount greater than the federal Maximum Contaminant Level under the Safe Drinking Water Act	No

7 Conclusions

Based on the data, modeling and risk assessment indicated above, conclusions for the COT-ROW are as follows

- Soil vapor contamination observed in the vicinity of the COT-ROW is a result of three separate and distinct releases, therefore, the COT-ROW may be treated separately from the nearby Subsite No 6, which includes the IMC Magnetics and Service & Sales facilities
- The compounds that may be directly attributed to the COT-ROW include PCE and TCE (as a degradation product of PCE)
- The estimated maximum incremental concentrations of PCE and TCE to groundwater in any one year are 3 12x10^{-2} µg/L and 1 15x10^{3} µg/L respectively
- The ELCRs ranged between 2x10^{7} and 6x10^{-9} at SVMW-5 from exposure to indoor air
- The estimated cumulative risk and hazard quotients do not warrant implementation of an SVE system in this area

8 References

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CH2M HILL 1991 Public Comment Draft North Indian Bend Wash Remedial Investigation/Feasibility Study Report Tempe, Arizona April

Freeze and Cherry 1979 *Groundwater* Prentice Hall, Inc

Graf, Charles 1993 Behavior of Organic Contaminants in the Environment notes for a seminar June

U S Environmental Protection Agency (EPA) 1998 Record of Decision for VOCs in Groundwater OPERABLE UNIT at Indian Bend Wash Superfund Site, South Area, September 1998

U S Environmental Protection Agency (EPA) 1997 User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings Contract No 68-D30035, Work Assignment No III-106 Office of Emergency and Remedial Response, Toxics Integration Branch, Washington, D C September

U S Environmental Protection Agency (EPA) 1994 Technical Background Document for Soil Screening Guidance, Review Draft EPA Office of Solid Waste and Emergency Response, Washington D C July

U S Environmental Protection Agency (EPA) 1993 Record of Decision for Volatile Organic Compounds in the Vadose Zone at Indian Bend Wash-South, pages cited II-31 through II-36, II-40, II-57, II-58, II-62 through II-65, Table II-11, II-68 through II-70, and II-71 September 27

U S Environmental Protection Agency (EPA) 1990 Subsurface Contamination Reference Guide

Yaws, C , Haur-Chung Yang Xiang Pan 1991 'Henry s Law Constant for 362 Organic Compounds in Water, *Engineering Practice* November

ATTACHMENTS

Soil Boring Log (SVMW-5)

SVMW-5 COT/Arizona Electrical Products 7/10/96

0	Asphalt and Gravels (6")
0 5	Gravelly SAND (veryfine to fine), light brown, subangular (FILL)
4	Silty SAND (veryfine), trace fine Gravels, brown, slightly moist
6-7	Sieve Sample (SVMW-5, 6-7 ft), 7/11/96
6 5-8 0	Spoon Sample (SVMW-5, 7-8 ft), 7/10/96
9	Pieces of clay pipe at lithologic interface, 2"-3" long and 1" thick, 4" thick in boring
10	Gravelly SAND, subangular to subrounded, light brown grey, slightly moist
12	increased fine gravels
14	color change dark reddish brown, very moist
15 5	Gravelly SAND (veryfine to medium), trace Cobbles, light brown, dry
16-17	Sieve Sample (SVMW-5, 16-17 ft), 7/11/96
17 0-18 5	Spoon Sample (SVMW-5, 16 5-18 0 ft), 7/10/96
18	-veryfine to coarse sand, some Cobbles, brown, subrounded to rounded, moist
20	-moist
22-24	Sieve Sample (SVMW-5, 22-24 ft), 7/11/96
24	SAND and GRAVEL (veryfine to coarse), little Cobbles, brown, subrounded to rounded, damp
25	Gravelly SAND (veryfine to medium), trace silt, powdery texture, light grey brown, dry
26	veryfine to coarse, brown, damp
28	SAND and GRAVEL, little cobbles, brown, dry
32	increasing SAND, dry
34	-1" to 2", greenish-pinkish coloration zones
36	greenish zone, 1 ft, trace boulders, dry
37	pinkish zone 1 ft
37-38	Sieve sample (SVMW-5, 37-38 ft), 7/11/96

40-41 5	Spoon Sample (SVMW-5, 40 5-41 5 ft), 7/10/96
40	Clayey SAND and GRAVEL (veryfine to coarse), little cobbles, dark brown, moist, subangular to subrounded, fines stick to gravels and sands
42	maroon color, moist
44	-pink, friable rock zone 6" think, pink in the matrix, then mottled with dark olive brown, subangular to subrounded
45-46	Spoon Sample (SVMW-5, 45-46 ft), 7/11/96
45	-trace cobbles, brown, very moist, fines stick to gravels and sands
46	SAND and GRAVEL some Clay, brown, moist
48	-2" cohesive gravel and sand stuck together with clay and is the shape of the core barrel
50	-light yellow brown
50 5	-dark pinkish matrix color, damp
52	Clayey Gravelly SAND, reddish brown orange, damp, subrounded
53	Gravelly SAND some Silt (veryfine to coarse), very moist, 1 ft, it is the shape of the core barrel, light olive brown
53-54 5	Spoon Sample (SVMW-5, 53 5-54 5 ft), 7/11/96
54	Clayey Gravelly SAND, little silt, subangular to subrounded, slightly moist, medium brown,-mottled dark olive brown to black zones 1/2" thick, discontinuous
57	SAND and GRAVEL some Clay, brown, subrounded
57-58	Sieve Sample (SVMW-5, 57-58 ft), 7/11/96
59	Water Table - Drillers call
59 7	-pinkish color in matrix, very moist
60	Clayey SAND and GRAVEL (veryfine to coarse), subrounded gravel, subangular sand, light brown, very cohesive matrix sticking to sand and gravels
62	Sandy GRAVEL some Clay, orangish brown (angular orange rocks in the gravel), damp

64	trace Cobbles
66	very damp to wet
68	Total Depth

Geotechnical Analyses

TABLE 1 MOISTURE CONTENT AND DRY DENSITY TEST RESULTS

Sample ID [Well No (Sample Interval)]	Moisture Content[1] (% of dry wt.)	Dry Density (pcf)
SVMW - 1 (7 0 - 8 0)	16 3	109 3
SVMW - 1 (17 0 - 18 0)	5 2	82 9 [2]
SVMW - 1 (29 0)	6 5	130 6
SVMW - 1 (41 0)	5 2	122 9
SVMW - 2 (7 0 - 8 0)	17 9	84 5
SVMW - 2 (40 5 - 41 5)	5 9	132 4
SVMW - 2 (50 0 - 51 0)	6 3	113 2
SVMW - 2 (61 5 - 62 5)	9 0	129 6
SVMW - 3 (6 0 - 7 0)	1 6	103 3
SVMW - 3 (16 0 - 17 0)	2 1	126 1
SVMW - 3 (37 0 - 38 0)	6 4	122 8
SVMW - 3 (51 0 - 51 5)	10 2	113 1
SVMW - 4 (8 0 - 9 0)	16 3	86 5
SVMW - 4 (26 0 - 27 0)	2 7	137 5
SVMW - 4 (37 5 - 38 5)	3 0	129 4
SVMW - 4 (60 5 - 61 5)	9 2	129 5
SVMW - 5 (7 0 - 8 0)	7 0	103 9
SVMW - 5 (17 0 - 18 0)	2 5	130 7
SVMW - 5 (40 5 - 41 5)	2 6	120 7
SVMW - 5 (53 5 - 54 5)	7 1	126 8

Notes
1. Moisture contents determined by Aquatic Consulting and Testing Inc on duplicate soil samples from same sample interval
2. Sample disturbed during trimming due to presence of large gravel particles

IAS Laboratories

2515 East University Drive
Phoenix Arizona 85034
(602) 273-7248
Fax (602) 275-3836

22-Jul-96

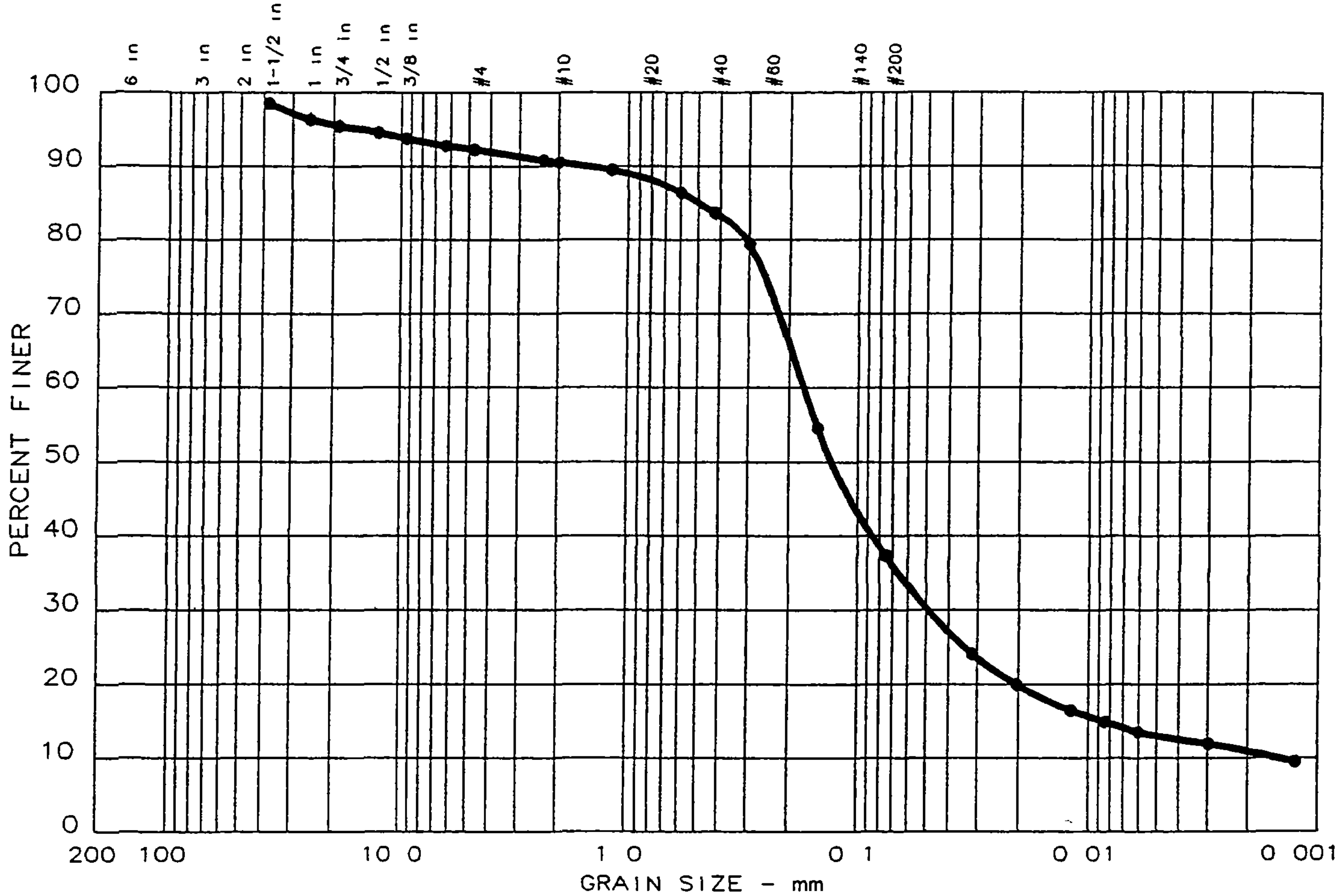
Submitted By Aquatic Consulting & Testing Inc

Report To Rick Amalfi

Report NO 6600551

Sender ID	Lab NO	Total Organic Carbon in ppm
BB-03881	405	1500
BB-03882	406	220
BB-03883	407	50
BB-03884	408	100

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	7 7	54 9	24 3	13 1	SM		

SIEVE inches size	PERCENT FINER ●		
1 5	98 5		
1	96 3		
0 75	95 5		
0 5	94 5		
0 375	93 7		
0 25	92 8		
	GRAIN SIZE		
D_{60}	0 17		
D_{30}	0 05		
D_{10}	0 00		
	COEFFICIENTS		
C_c	9 44		
C_u	118 9		

SIEVE number size	PERCENT FINER ●		
4	92 3		
8	90 8		
10	90 5		
16	89 5		
30	86 4		
40	83 7		
50	79 4		
100	54 6		
200	37 3		

Sample information
● SVMW-5 @ 6-7 feet

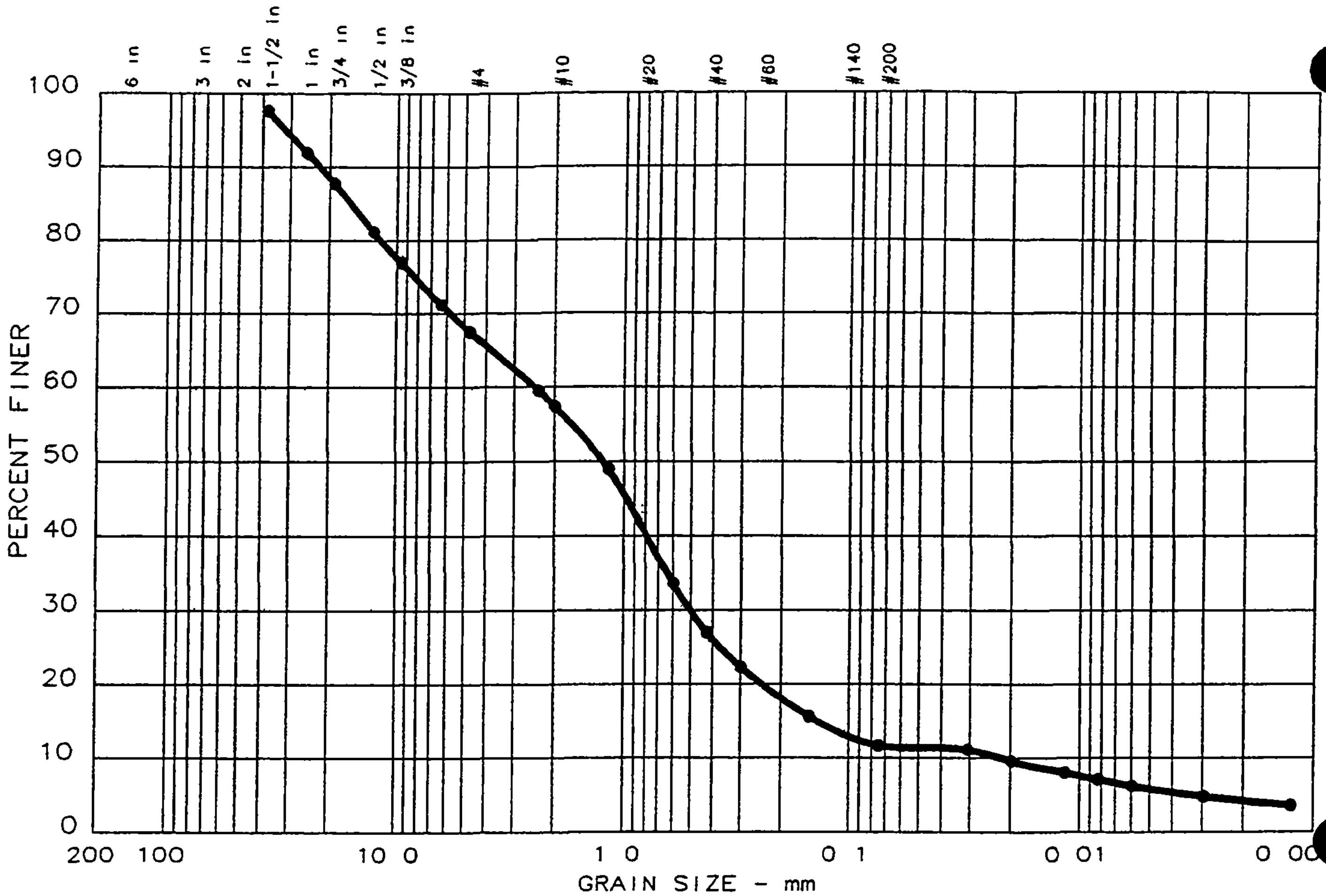
Remarks
Sampled By ADEQ
Tested By SQ
Checked By CLJ
of GEC Inc

Geotechnical & Environmental Consultants, Inc.

Project No 96-0093
Project SIBW Vapor Moitoring wells

Date 07-30-96 Figure Number 28

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	32 5	55 8	5 9	5 8	SP-SM		

SIEVE inches size	PERCENT FINER ●		
1 5	97 6		
1	91 9		
0 75	87 7		
0 5	81 1		
0 375	77 0		
0 25	71 2		
	GRAIN SIZE		
D_{60}	2 43		
D_{30}	0 50		
D_{10}	0 02		
	COEFFICIENTS		
C_c	4 78		
C_u	112 3		

SIEVE number size	PERCENT FINER ●		
4	67 5		
8	59 5		
10	57 4		
16	49 0		
30	33 6		
40	27 0		
50	22 2		
100	15 6		
200	11 7		

Sample information
● SVMW-5 @ 16-17 feet

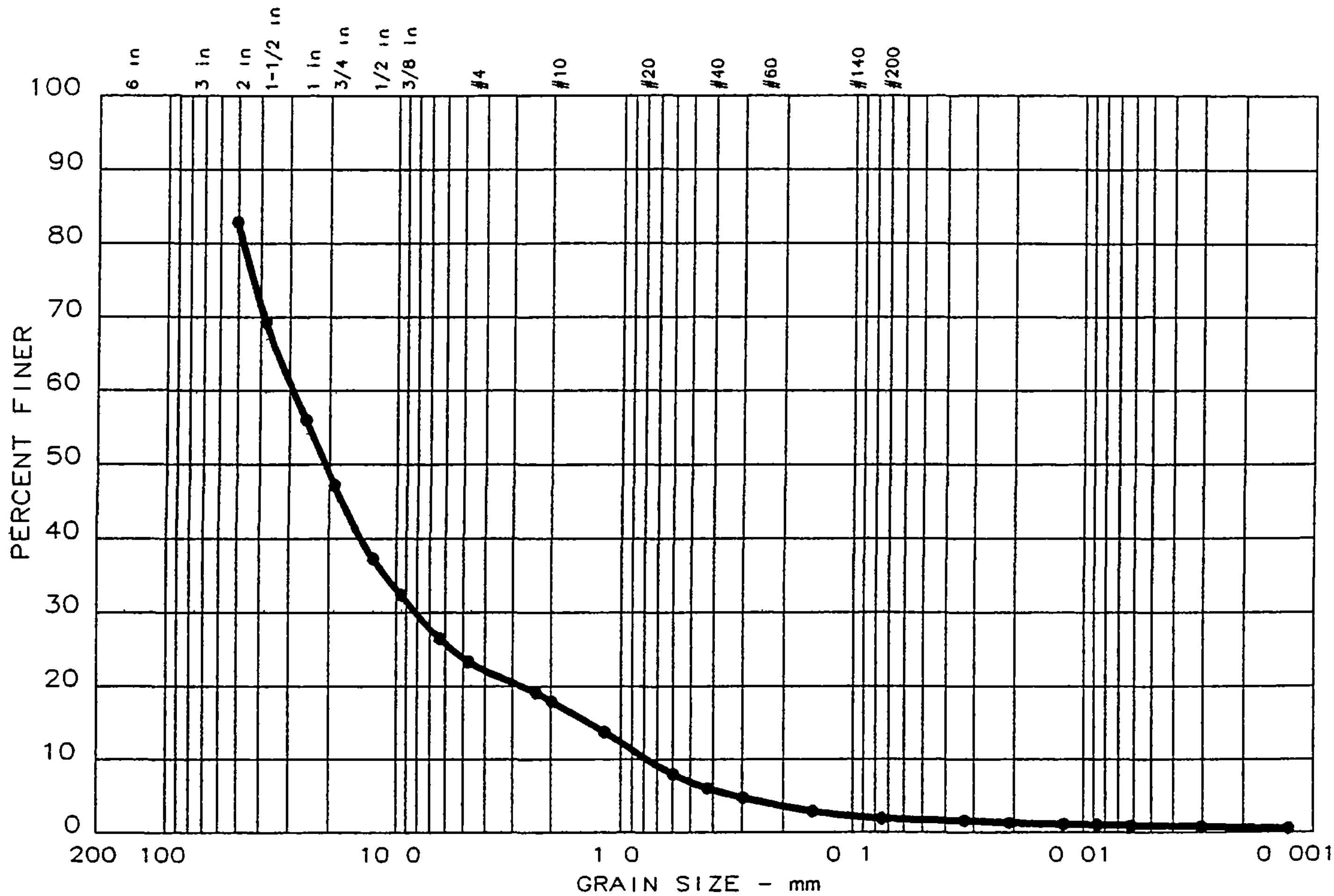
Remarks
Sampled By ADEQ
Tested By SQ
Checked By CLJ
of GEC Inc

Geotechnical & Environmental Consultants, Inc.

Project No 96-0093
Project SIBW Vapor Moitoring wells

Date 07-30-96 Figure Number 29

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	76 7	21 5	1 0	0 8	GW		

SIEVE inches size	PERCENT FINER ●		
2	82 9		
1 5	69 4		
1	56 0		
0 75	47 2		
0 5	37 3		
0 375	32 4		
0 25	26 5		
	GRAIN SIZE		
D_{60}	28 90		
D_{30}	8 14		
D_{10}	0 76		
	COEFFICIENTS		
C_c	2 98		
C_u	37 6		

SIEVE number size	PERCENT FINER ●		
4	23 3		
8	19 2		
10	17 9		
16	13 8		
30	8 0		
40	6 0		
50	4 7		
100	2 8		
200	1 9		

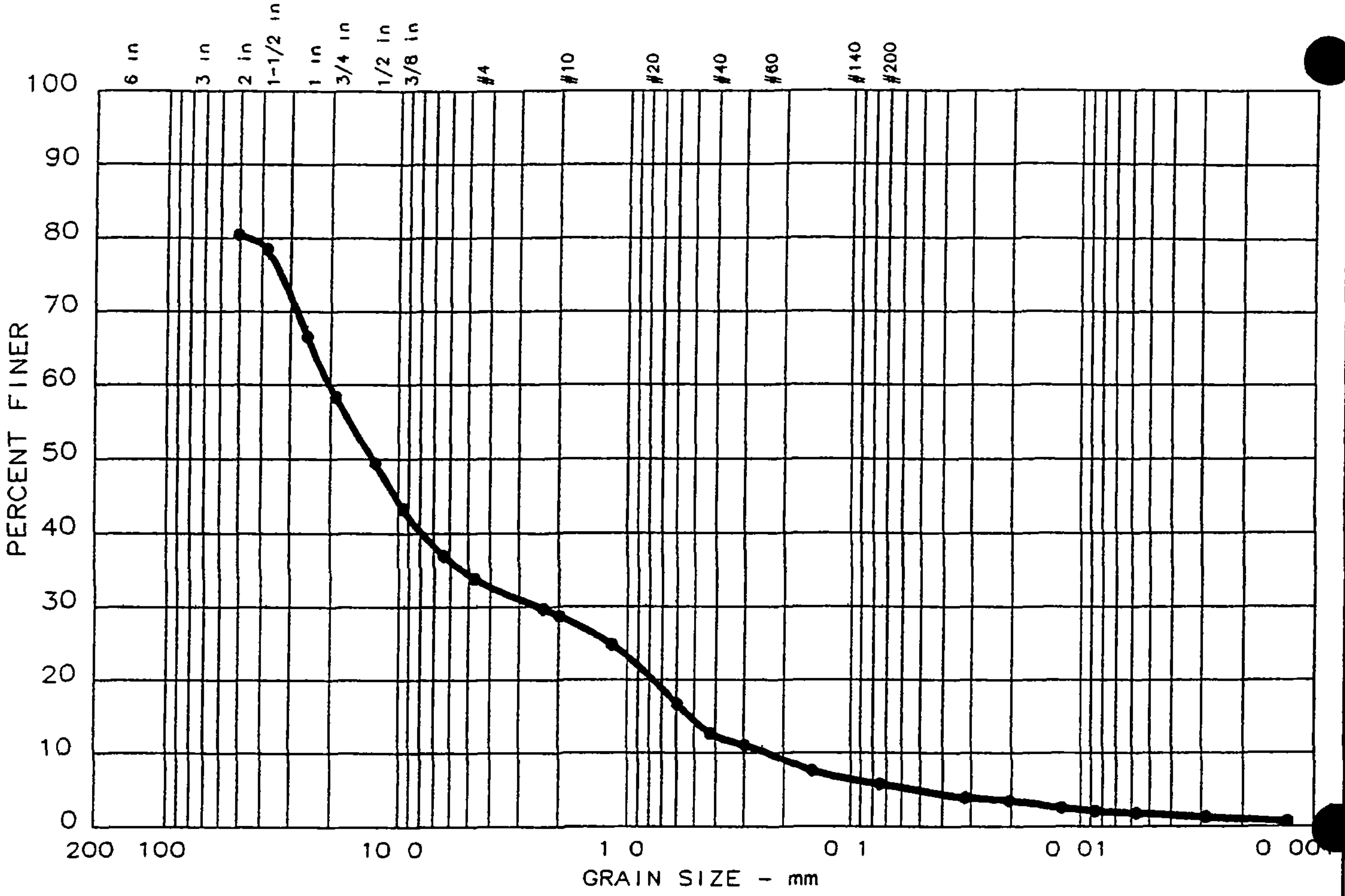
Sample information
● SVMW-5 @ 22-24 feet

Remarks
Sampled By ADEQ
Tested By SQ
Checked By CLJ
of GEC Inc

Geotechnical & Environmental Consultants, Inc.

Project No 96-0093
Project SIBW Vapor Moitoring wells
Date 07-30-96
Figure Number 30

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	66 1	28 1	4 1	1 7	GW-GM		

SIEVE inches size	PERCENT FINER ●		
2	80 4		
1 5	78 5		
1	66 6		
0 75	58 4		
0 5	49 4		
0 375	43 3		
0 25	37 0		
	GRAIN SIZE		
D_{60}	20 22		
D_{30}	2 46		
D_{10}	0 23		
	COEFFICIENTS		
C_c	1 26		
C_u	85 1		

SIEVE number size	PERCENT FINER ●		
4	33 9		
8	29 7		
10	28 7		
16	24 8		
30	16 7		
40	12 7		
50	11 1		
100	7 6		
200	5 7		

Sample information
● SVMW-5 @ 37-38 feet

Remarks
Sampled By ADEQ
Tested By SQ
Checked By CLJ
of GEC Inc

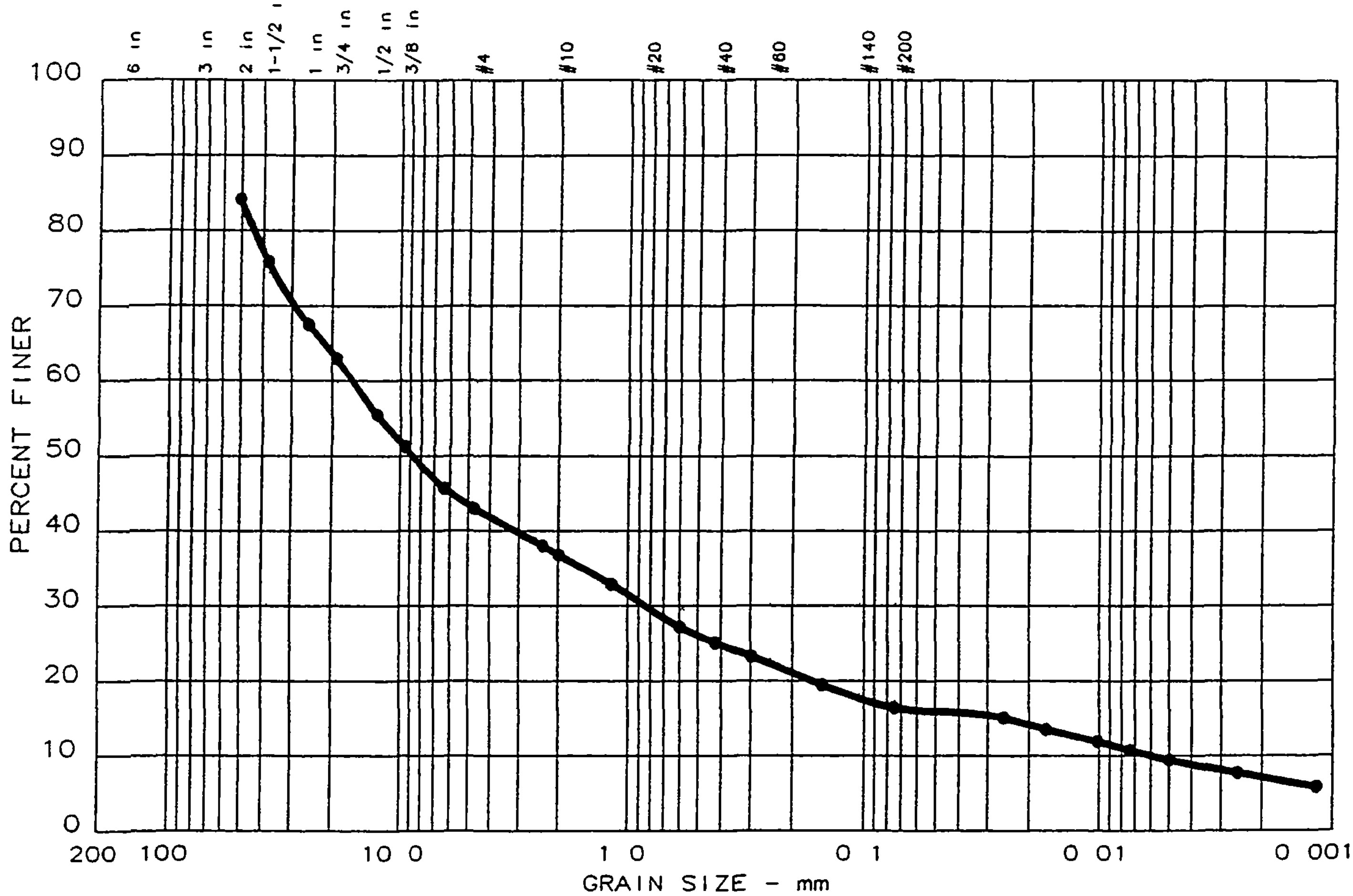
Geotechnical & Environmental Consultants, Inc.

Project No 96-0093
Project SIBW Vapor Moitoring wells

Date 07-31-96

Figure Number 31

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	57 0	26 5	7 0	9 5	GC		

SIEVE inches size	PERCENT FINER ●		
2	84 2		
1 5	75 9		
1	67 5		
0 75	63 0		
0 5	55 5		
0 375	51 2		
0 25	45 6		
	GRAIN SIZE		
D_{60}	16 06		
D_{30}	0 83		
D_{10}	0 00		
	COEFFICIENTS		
C_c	7 41		
C_u	2754		

SIEVE number size	PERCENT FINER ●		
4	43 0		
8	38 0		
10	36 8		
16	32 9		
30	27 1		
40	25 1		
50	23 3		
100	19 5		
200	16 5		

Sample information

● SVMW-5 @ 45-46 feet

Remarks

Sampled By ADEQ ,

Tested By SQ

Checked By CLJ

of GEC Inc

Geotechnical & Environmental Consultants, Inc.

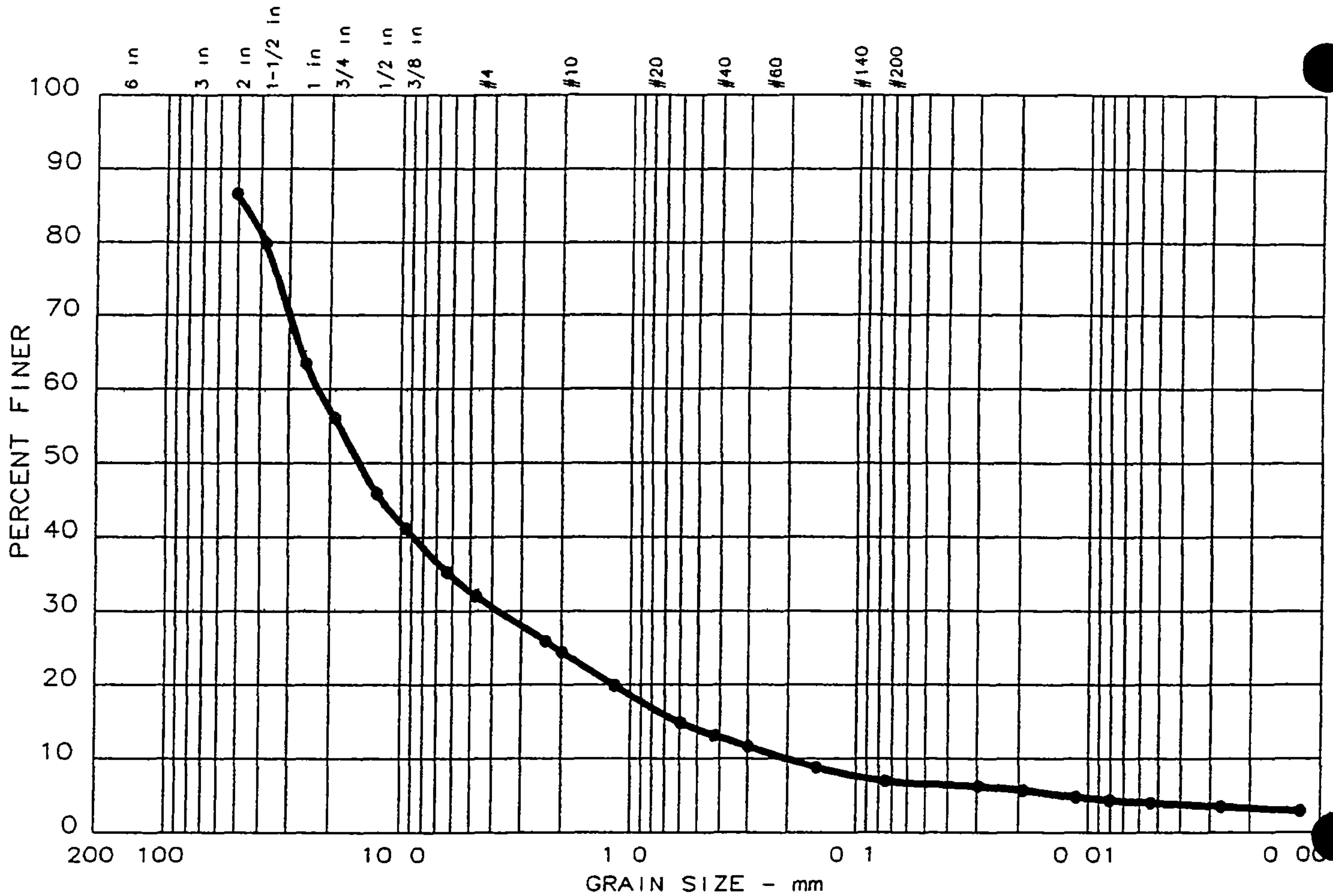
Project No 96-0093

Project SIBW Vapor Moitoring wells

Date 07-31-96

Figure Number 32

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0 0	67 9	25 1	3 1	3 9	GP-GC		

SIEVE inches size	PERCENT FINER ●		
2	86 6		
1 5	79 8		
1	63 5		
0 75	56 1		
0 5	45 8		
0 375	41 2		
0 25	35 2		

	GRAIN SIZE		
D_{60}	22 36		
D_{30}	3 75		
D_{10}	0 20		

	COEFFICIENTS		
C_c	3 12		
C_u	111 2		

SIEVE number size	PERCENT FINER ●		
4	32 1		
8	25 9		
10	24 4		
16	19 9		
30	14 9		
40	13 2		
50	11 7		
100	8 8		
200	7 0		

Sample information

● SVMW-5 @ 57-58 feet

Remarks

Sampled By ADEQ

Tested By SQ

Checked By CLJ

of GEC Inc

Geotechnical & Environmental Consultants, Inc.

Project No 96-0093

Project SIBW Vapor Moitoring wells

Date 07-31-96

Figure Number 33

GEL, INC

~~Analytical Technologies, Inc.~~
~~San Diego • Phoenix • Seattle • Pensacola • Ft. Collins • Portland~~

CHAIN OF CUSTODY

DATE 7/10/96 PAGE 1 OF 2

ATI LAB I.D.

08/12/1996 13:08 9568821 GEC PAGE 07

PLEASE FILL THIS FORM IN COMPLETELY. SHADED AREAS ARE FOR LAB USE ONLY

PROJECT MANAGER: NICKI FATHERLY

COMPANY: ADEQ
ADDRESS: 3033 N Central Ave
PHX AZ
PHONE:
FAX: 207-4411

BILL TO COMPANY: ADEQ
ADDRESS:

ANALYSIS REQUEST: Petroleum Hydrocarbons (418.1); (MOD 8015) Fuel Fingerprint; (MOD 8015) Gas; (BLS-191) Diesel; BTEX/MTBE (8020); % Moisture; Chlorinated Hydrocarbons (601/8010); Aromatic Hydrocarbons (602/8020); SDWA Volatiles (502.1/503.1), 502.2 Reg. & Unreg.; Bulk Density; Particle Size Dist.; Pesticides/PCB (608/8080); Herbicides (615/8150); Base/Neutral/Acid Compounds GC/MS (625/8270); Volatile Organics GC/MS (624/8240); Polynuclear Aromatics (610/8310); Total Organic Carbon; SDWA Primary Standards - Arizona; SDWA Secondary Standards - Arizona; SDWA Primary Standards - Federal; SDWA Secondary Standards - Federal; The 13 Priority Pollutant Metals; RCRA Metals by Total Digestion; RCRA Metals by TCLP (1311); NUMBER OF CONTAINERS

SAMPLE ID	DATE	TIME	MATRIX	LAB ID	% Moisture	Bulk Density	Total Organic Carbon	NUMBER OF CONTAINERS
SVMW-5 (7.0-7.5)	7/10/96	815a	Soil		X	X	X	1
(7.5-8.0)	↓	↓	↓		X	X	X	1
SVMW-5 (17.5-18.0)	↓	9³⁰a	↓		X	X	X	1
(17.-17.5)	↓	↓	↓		X	X	X	1
SVMW-5 (40.5-41)	↓	230p	↓		X	X	X	1
(41-41.5)	↓	↓	↓		X	X	X	1
SVMW-5 (53.5-54)	7/11/96	9am	↓		X	X	X	1
(54-54.5)	↓		↓		X	X	X	1

PROJECT INFORMATION	
PROJ. NO.	SIBW
PROJ. NAME	
P.O. NO.	
SHIPPED VIA	

SAMPLE RECEIPT: NO. CONTAINERS; CUSTODY SEALS Y/N/NA; RECEIVED INTACT; BLUE ICE/ICE

PRIOR AUTHORIZATION IS REQUIRED FOR RUSH PROJECTS

(RUSH) ☐ 24hr ☐ 48hr ☐ 72hr ☐ 1 WEEK (NORMAL) ☐ 2 WEEK

Comments:

SAMPLED & RELINQUISHED BY: 1	RELINQUISHED BY: 2	RELINQUISHED BY: 3
Signature: Nicki Fatherly Time: 1217	Signature: Time:	Signature: B Deneke Time: 1337
Printed Name: NICKI FATHERLY Date: 7/11/96	Printed Name: Date:	Printed Name: Bill Deneke Date: 7/11/96
Company: ADEQ Phone: 207-4411	Company:	Company: ADEQ

RECEIVED BY: 1	RECEIVED BY: 2	RECEIVED BY (LAB): 3
Signature: B Deneke Time: 1217	Signature: Time:	Signature: [illegible] Time: 1337
Printed Name: BILL DENEKE Date: 7/11/96	Printed Name: Date:	Printed Name: [illegible] Date: 7/11/96
Company: ADEQ	Company:	Analytical Technologies, Inc.

GEC UMC

~~Analytical Technologies, Inc.~~, Phoenix, Arizona
San Diego • Phoenix • Seattle • Pensacola • Ft Collins • Portland

CHAIN OF CUSTODY

DATE 7/10/96 PAGE 2 OF 2

ATI LAB I.D

08/12/1996 13 08 9668821 GEC PAGE 08

PLEASE FILL THIS FORM IN COMPLETELY SHADED AREAS ARE FOR LAB USE ONLY

PROJECT MANAGER NICK FATHERLY

COMPANY ADEQ
ADDRESS 3033 N Central Ave
PHX AZ 85012
PHONE
FAX 207-4411

BILL TO ADEQ
COMPANY
ADDRESS

ANALYSIS REQUEST

- ~~Petroleum Hydrocarbons (418.1)~~
- ~~(MOD 8015) Fuel Fingerprint~~
- ~~(8015) Gas~~
- ~~(BLS-191) Diesel~~
- ~~BTXE/MTBE (8020)~~
- Portable Sparging
- ~~Chlorinated Hydrocarbons (601/8010)~~
- ~~Aromatic Hydrocarbons (602/8020)~~
- ~~SDWA Volatiles (502.1/503.1) 502.2 Reg. & Unreg.~~
- ~~Pesticides/PCB (608/8080)~~
- ~~Herbicides (615/8150)~~
- ~~Base/Neutral/Acid Compounds GC/MS (625/8270)~~
- ~~Volatile Organics GC/MS (624/8240)~~
- ~~Polynuclear Aromatics (610/8310)~~
- ~~SDWA Primary Standards - Arizona~~
- ~~SDWA Secondary Standards - Arizona~~
- ~~SDWA Primary Standards - Federal~~
- ~~SDWA Secondary Standards - Federal~~
- ~~The 13 Priority Pollutant Metals~~
- ~~RCRA Metals by Total Digestion~~
- ~~RCRA Metals by TCLP (1311)~~

SAMPLE ID	DATE	TIME	MATRIX	LAB I.D.	NUMBER OF CONTAINERS
SVMW-5 (6'-7')	7/11/96	12n	Soil		1
↓ (16-17')	↓	↓	↓		1
(22-24)					1
(37-38)					1
(45-46)					1
(57-58)					1

PROJECT INFORMATION		SAMPLE RECEIPT	
PROJ. NO.	SLBW	NO. CONTAINERS	
PROJ. NAME		CUSTODY SEALS	Y/N/NA
P.O. NO.		RECEIVED INTACT	
SHIPPED VIA		BLUE ICE/ICE	

PRIOR AUTHORIZATION IS REQUIRED FOR RUSH PROJECTS

(RUSH) ☐ 24hr ☐ 48hr ☐ 72hr ☐ 1 WEEK (NORMAL) ☐ 2 WEEK

Comments

SAMPLED & RELINQUISHED BY: 1	RELINQUISHED BY: 2	RELINQUISHED BY: 3
Signature: Nick Fatherly Time: 12:17	Signature: Time:	Signature: B. Denke Time: 13:37
Printed Name: NICK FATHERLY Date: 7/11/96	Printed Name: Date:	Printed Name: Bill Denke Date: 7/11/96
Company: ADEQ Phone: 207-4411	Company:	Company: ADEQ

RECEIVED BY: 1	RECEIVED BY: 2	RECEIVED BY (LAB): 3
Signature: B. Denke Time: 12:17	Signature: Time:	Signature: [illegible] Time: 13:37
Printed Name: Bill DENKE Date: 7/11/96	Printed Name: Date:	Printed Name: [illegible] Date: 7/11/96
Company: ADEQ	Company:	Analytical Technologies, Inc. GEC

ATI Labs: San Diego (619) 458-9141 Phoenix (602) 496-4400 Seattle (206) 228-8335 Pensacola (904) 474-1001 Portland (503) 684-0447 DISTRIBUTION: White, Canary ANALYTICAL TECHNOLOGIES INC ORIGINATOR

AQUATIC CONSULTING & TESTING, INC
1525 W University Drive Suite 106 Tempe AZ 85281
Phone (602) 921 8044 Fax (602) 921 0049

CHAIN OF CUSTODY

Client: GEC
Address: 2447 W. 12th St #4 (Street)
Tempe Az 85281 (City State Zip)
Phone: 966-8651 Fax 966-8821
Contact: Chris Jaquemin
Client Signature: [signature]

SAMPLE ID	DATE	TIME	SAMPLE TYPE	Metals / TCLP	TDS / TSS / TS/SS	418 1 AZ / VOC	BOD / COD	TKN / Tot P / O PO_4	Nitrate / Nitrite / Ammonia	O & G / MBAS	TOC	Moisture			Tot Coliform P/A	Tot Coliform MPN / Colilert	Fecal Coliform			Acute	Chronic	AWET (SWRO)			No. of Containers ACID	NONE	OTHER	Laboratory Number
SVMW-5 (7.0-7.5)	7/10/96	8:15a	Soil								/	/															1	BB-03881
SVMW-5 (17.5-18)	7/10/96	9:30a	Soil								/	/															1	-03882
SVMW-5 (40.5-41.0)	7/10/96	2:30p	Soil								/	/															1	-03883
SVMW-5 (54.0-54.5)	7/11/96	9:00a	Soil								/	/															1	-03884

Remarks

Sample Receiving	1 Relinquished By	2 Relinquished By	3 Relinquished By
Intact ✓ Yes ___ No	[signature]		
	Date \ Time 7/11/96 1503	Date \ Time	Date \ Time
Temp cool	1 Received By [signature]	2 Received By	3 Received By
Preserved ___ Yes ✓ No	Date \ Time 7-11-96 1503	Date \ Time	Date \ Time
Total # containers 4			

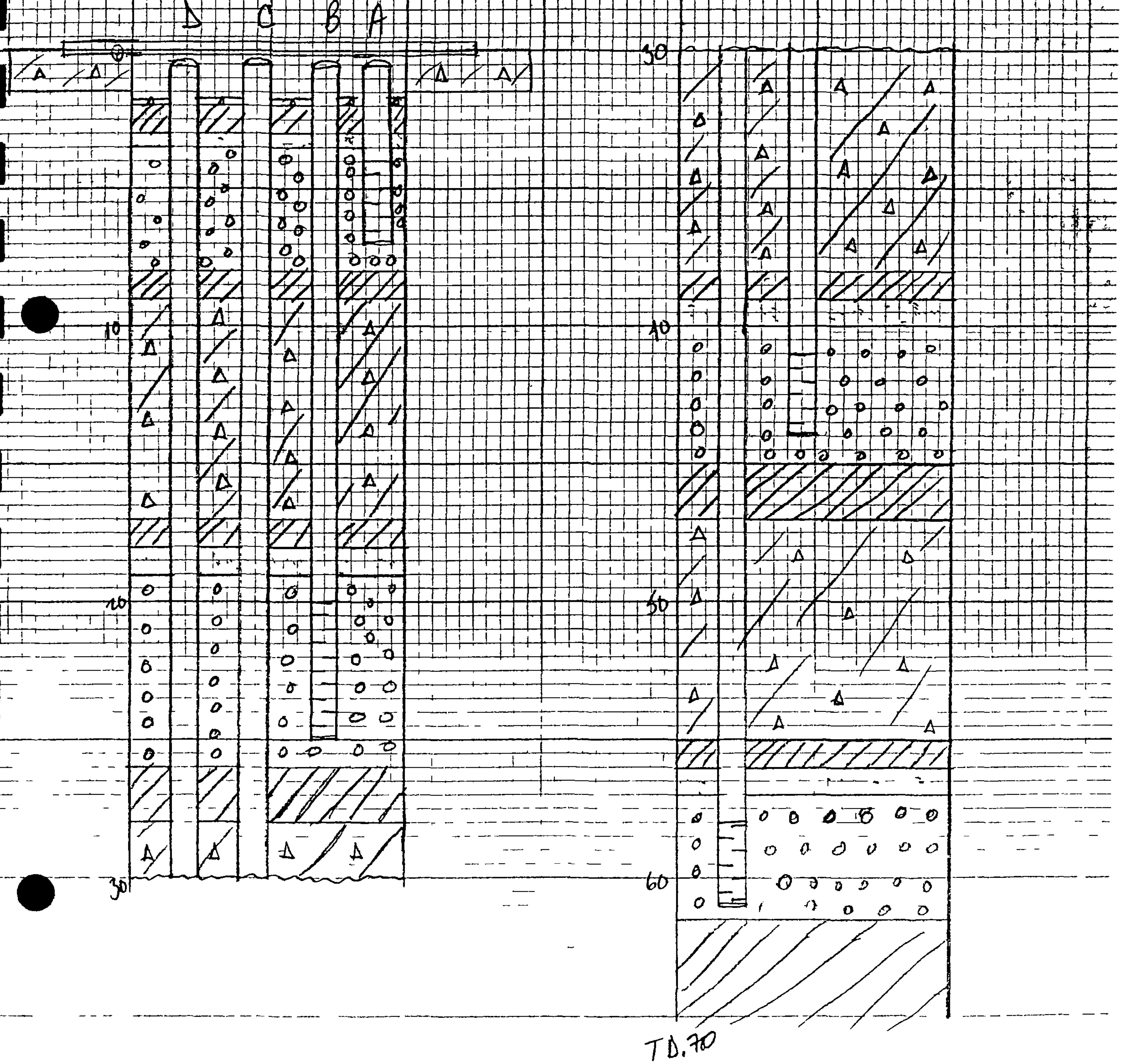
** Using the "Remarks" area, please specify which metals are to be analyzed*

Distribution White Laboratory Yellow Report Pink Client

Construction Diagram (SVMW-5)

SUMW-5 7-12-96

COT easement (former Arizona Electrical Products)



VLEACH Preprocessor, Input, and Output Files
Groundwater Mixing Cell Results

This spreadsheet calculates total soil concentrations based on soil gas concentrations and Ct/Cg

COT ROW

WELL	SVMW 5
CONTAMINANT	PCE

C_T/C_G	0 75	Area (ft2)	32185
		P_b (g/cm3)	1 96

DEPTHS		SOIL GAS (ug/l)			SOIL GAS (ug/l)			TOTAL SOIL (ug/Kg)			MASS (g)		
from (ft)	to (ft)	03/12/1997	05/02/1997	06/23/1997	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX
0	12	6 172	13 646	17 417	12	18	17 417	5	7	6 66[illegible]	101 6	148 5	142 6
12	31	12 853	13 151	13 242	13	13	13 242	5	5	5 07[illegible]	169 6	172 3	171 7
31	52	0 395	3 269	2 513	2	4	3 269	1	1	1 25[illegible]	29 5	50 9	46 8
										TOTALS	**300 8**	**371 6**	**361 2**

NOTE SHADED VALUES ARE THE INPUTS TO VLEACH INPUT FILE

```
COT-ROW VLEACH Model  SVMW-5  PCE contamination
  1
       0 1      100         1        10
     364         545       200      62208
Polygon I
    32185         1       0375      1 96       261        044     000378
       0         -1         -1
   52y       100
    1    12       6 66
   13    31       5 07
   32    52       1 25
```

|------------------ -- ----- -- ----   --- ---- -|
| VLEACH (Version 2 2a 1996) |
| |
| By |
| Varadhan Ravi and Jeffrey A Johnson |
| (USEPA Contractors) |
| Center for Subsurface Modeling Support |
| Robert S Kerr Environmental Research Laboratory |
| U S Environmental Protection Agency |
| P O Box 1198 |
| Ada OK 74820 |
| |
| Based on the original VLEACH (version 1 0) |
| developed by CH2M Hill Redding California |
for USEPA Region IX

COT-ROW VLEACH Model SVMW -5 PCE contamination
********* ************* *** **** *********** ** *

*********************** ** ** ********** ******* *
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
1	0 37555	0 28812
2	0 4966	0 73724
3	0 55389	1 269
4	0 57986	1 8389
5	0 5913	2 4258
6	0 59604	3 0201
7	0 59768	3 6172
8	0 5979	4 2151
9	0 59746	4 8128
10	0 59672	5 4098
11	0 59585	6 0061
12	0 5949	6 6014
13	0 59393	7 1958
14	0 59295	7 7892
15	0 59196	8 3816
16	0 59098	8 973
17	0 58999	9 5634
18	0 589	10 153
19	0 58802	10 741
20	0 58703	11 329
21	0 58605	11 915
22	0 58507	12 501
23	0 58409	13 085
24	0 58311	13 669
25	0 58213	14 251

COT-ROW VLEACH Model SVMW 5 PCE contamination
** * ******* *****   * * * *** * **** ** ** ** *

************* *********** * **** *   * * ********
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
26	0 58116	14 833
27	0 58019	15 414
28	0 57922	15 993
29	0 57825	16 572
30	0 57728	17 15
31	0 57631	17 727
32	0 57535	18 302
33	0 57439	18 877
34	0 57342	19 451
35	0 57246	20 024
36	0 57151	20 596
37	0 57055	21 167
38	0 5696	21 737
39	0 56864	22 306
40	0 56769	22 874
41	0 56674	23 441
42	0 56579	24 007
43	0 56484	24 573
44	0 5639	25 137
45	0 56295	25 7
46	0 56201	26 263
47	0 56107	26 824
48	0 56013	27 385
49	0 5592	27 944
50	0 55826	28 503
51	0 55733	29 061
52	0 55639	29 618
53	0 55546	30 174
54	0 55453	30 729
55	0 5536	31 283
56	0 55268	31 836
57	0 55175	32 388
58	0 55083	32 939
59	0 54991	33 489
60	0 54899	34 039
61	0 54807	34 587
62	0 54715	35 135
63	0 54623	35 681
64	0 54532	36 227
65	0 54441	36 772
66	0 5435	37 316
67	0 54259	37 859

COT ROW VLEACH Model SVMW 5 PCE contamination
** * *** * *** ** *** * ** * ** *

********* * ** * *** ******* * * ** * * ** *
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
68	0 54168	38 401
69	0 54077	38 942
70	0 53987	39 482
71	0 53896	40 022
72	0 53806	40 56
73	0 53716	41 098
74	0 53626	41 635
75	0 53536	42 17
76	0 53447	42 705
77	0 53357	43 239
78	0 53268	43 772
79	0 53179	44 304
80	0 5309	44 836
81	0 53001	45 366
82	0 52912	45 896
83	0 52824	46 424
84	0 52735	46 952
85	0 52647	47 479
86	0 52559	48 005
87	0 52471	48 53
88	0 52383	49 054
89	0 52295	49 578
90	0 52208	50 1
91	0 52121	50 622
92	0 52033	51 142
93	0 51946	51 662
94	0 51859	52 181
95	0 51772	52 699
96	0 51686	53 217
97	0 51599	53 733
98	0 51513	54 248
99	0 51427	54 763
100	0 51341	55 277

This spreadsheet takes the area dependent out put from VLEACH and calculates GW concentrations
The model (column E) is based on eq 16 of Ground Water Threat Calculations Report for NIBW Area 9
Hydro Geo Chem Inc May 1993

Groundwater Mixing Cell Template
COT ROW PCE Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	364
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0.261	rhob (g/cm3)	1 96
				(Koc foc bulk density) + Porosity	0 531
Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245		
Days/timestep	365 25	GW Flux (ft3/d)	1850		

(These two columns are from VLEACH)

Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
0	0		0 00E+00	0 00E+00	0 000
1	1	0 37555	3 20E 08	3 04E 07	0 011
2	2	0 4966	4 23E-08	5 40E-07	0 019
3	3	0 55389	4 71E-08	6 93E-07	0 024
4	4	0 57986	4 94E 08	7 83E 07	0 028
5	5	0 5913	5 03E-08	8 34E 07	0 029
6	6	0 59604	5 07E-08	8 60E-07	0 030
7	7	0 59768	5 09E-08	8 74E 07	0 031
8	8	0 5979	5 09E-08	8 80E-07	0 031
9	9	0 59746	5 09E-08	8 82E-07	0 031
10	10	0 59672	5 08E 08	8 83E-07	0 031
11	11	0 59585	5 07E 08	8 82E 07	0 031
12	12	0 5949	5 06E-08	8 81E-07	0 031
13	13	0 59393	5 06E-08	8 80E-07	0 031
14	14	0 59295	5 05E-08	8 79E-07	0 031
15	15	0 59196	5 04E-08	8 77E-07	0 031
16	16	0 59098	5 03E-08	8 76E 07	0 031
17	17	0 58999	5 02E-08	8 74E-07	0 031
18	18	0 589	5 01E 08	8 73E-07	0 031
19	19	0 58802	5 01E 08	8 72E 07	0 031
20	20	0 58703	5 00E-08	8 70E-07	0 031
21	21	0 58605	4 99E-08	8 69E-07	0 031
22	22	0 58507	4 98E-08	8 67E-07	0 031
23	23	0 58409	4 97E-08	8 66E-07	0 031
24	24	0 58311	4 96E-08	8 64E-07	0 031
25	25	0 58213	4 96E 08	8 63E-07	0 030
26	26	0 58116	4 95E 08	8 61E-07	0 030
27	27	0 58019	4 94E 08	8 60E-07	0 030
28	28	0 57922	4 93E 08	8 59E-07	0 030
29	29	0 57825	4 92E 08	8 57E 07	0 030
30	30	0 57728	4 91E-08	8 56E 07	0 030
31	31	0 57631	4 91E 08	8 54E 07	0 030
32	32	0 57535	4 90E 08	8 53E 07	0 030
33	33	0 57439	4 89E 08	8 51E 07	0 030
34	34	0 57342	4 88E 08	8 50E-07	0 030
35	35	0 57246	4 87E 08	8 48E 07	0 030
36	36	0 57151	4 86E 08	8 47E-07	0 030
37	37	0 57055	4 86E 08	8 46E-07	0 030
38	38	0 5696	4 85E-08	8 44E 07	0 030
39	39	0 56864	4 84E 08	8 43E-07	0 030
40	40	0 56769	4 83E 08	8 41E 07	0 030
41	41	0 56674	4 82E 08	8 40E-07	0 030
42	42	0 56579	4 82E 08	8 39E 07	0 030

Groundwater Mixing Cell Template
COT ROW PCE Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	364
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96
Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 531
Days/timestep	365 25	GW Flux (ft3/d)	1850		

	(These two columns are from VLEACH)				
Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
43	43	0 56484	4 81E-08	8 37E 07	0 030
44	44	0 5639	4 80E-08	8 36E 07	0 030
45	45	0 56295	4 79E-08	8 34E-07	0 029
46	46	0 56201	4 78E-08	8 33E-07	0 029
47	47	0 56107	4 78E-08	8 32E 07	0 029
48	48	0 56013	4 77E-08	8 30E-07	0 029
49	49	0 5592	4 76E 08	8 29E 07	0 029
50	50	0 55826	4 75E-08	8 27E-07	0 029
51	51	0 55733	4 74E-08	8 26E 07	0 029
52	52	0 55639	4 74E 08	8 25E 07	0 029
53	53	0 55546	4 73E-08	8 23E-07	0 029
54	54	0 55453	4 72E-08	8 22E-07	0 029
55	55	0 5536	4 71E-08	8 21E 07	0 029
56	56	0 55268	4 70E-08	8 19E-07	0 029
57	57	0 55175	4 70E-08	8 18E 07	0 029
58	58	0 55083	4 69E-08	8 16E 07	0 029
59	59	0 54991	4 68E-08	8 15E 07	0 029
60	60	0 54899	4 67E-08	8 14E 07	0 029
61	61	0 54807	4 67E 08	8 12E 07	0 029
62	62	0 54715	4 66E-08	8 11E-07	0 029
63	63	0 54623	4 65E-08	8 10E 07	0 029
64	64	0 54532	4 64E-08	8 08E-07	0 029
65	65	0 54441	4 63E-08	8 07E 07	0 028
66	66	0 5435	4 63E-08	8 06E 07	0 028
67	67	0 54259	4 62E 08	8 04E 07	0 028
68	68	0 54168	4 61E 08	8 03E 07	0 028
69	69	0 54077	4 60E 08	8 02E 07	0 028
70	70	0 53987	4 60E-08	8 00E 07	0 028
71	71	0 53896	4 59E-08	7 99E-07	0 028
72	72	0 53806	4 58E-08	7 98E 07	0 028
73	73	0 53716	4 57E-08	7 96E-07	0 028
74	74	0 53626	4 56E-08	7 95E 07	0 028
75	75	0 53536	4 56E-08	7 94E 07	0 028
76	76	0 53447	4 55E-08	7 92E 07	0 028
77	77	0 53357	4 54E 08	7 91E 07	0 028
78	78	0 53268	4 53E-08	7 90E 07	0 028
79	79	0 53179	4 53E 08	7 88E 07	0 028
80	80	0 5309	4 52E-08	7 87E 07	0 028
81	81	0 53001	4 51E-08	7 86E 07	0 028
82	82	0 52912	4 50E 08	7 84E 07	0 028
83	83	0 52824	4 50E 08	7 83E 07	0 028
84	84	0 52735	4 49E-08	7 82E 07	0 028
85	85	0 52647	4 48E 08	7 80E 07	0 028
86	86	0 52559	4 47E 08	7 79E 07	0 028
87	87	0 52471	4 47E 08	7 78E 07	0 027
88	88	0 52383	4 46E-08	7 76E 07	0 027
89	89	0 52295	4 45E 08	7 75E 07	0 027

Groundwater Mixing Cell Template
COT ROW PCE Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	364
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96

Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 531
Days/timestep	365.25	GW Flux (ft3/d)	1850		

	(These two columns are from VLEACH)				
Time Step (Number)	**Time at end of Time step (Years)**	**Mass from Vadose Zone (g/yr)**	**Mass from Vadose Zone (g/day/ft2)**	**Calculated Concentration (g/ft3)**	**Calculated Concentration (ug/l)**
90	90	0 52208	4 44E-08	7 74E-07	0 027
91	91	0 52121	4 44E-08	7 73E-07	0 027
92	92	0 52033	4 43E 08	7 71E-07	0 027
93	93	0 51946	4 42E-08	7 70E-07	0 027
94	94	0 51859	4 41E-08	7 69E 07	0 027
95	95	0 51772	4 41E-08	7 67E-07	0 027
96	96	0 51686	4 40E-08	7 66E-07	0 027
97	97	0 51599	4 39E-08	7 65E 07	0 027
98	98	0 51513	4 39E-08	7 64E-07	0 027
99	99	0 51427	4 38E-08	7 62E-07	0 027
100	100	0 51341	4 37E-08	7 61E-07	0 027

This spreadsheet calculates total soil concentrations based on soil gas concentrations and Ct/Cg

COT ROW
WELL SVMW 5
CONTAMINANT 1 1 1 TCA

C_T/C_G	0 49	Area (ft2)	32185
		P_b (g/cm3)	1 96

DEPTHS		SOIL GAS (ug/l)			SOIL GAS (ug/l)			TOTAL SOIL (ug/Kg)			MASS (g)		
from (ft)	to (ft)	03/12/1997	05/05/1997	06/23/1997	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX
0	12	0 783	1 157	1 107	1	1	1 157	0	0	0 029	5 4	6 5	6 2
12	31	1 749	2 264	1 861	2	2	2 264	0	1	0 057	16 6	18 9	19 2
31	52	0 043	0 222	0 199	0	0	0 222	0	0	0 06	1 4	2 4	2 1
										TOTALS	**23 5**	**27 8**	**27 4**

NOTE SHADED VALUES ARE THE INPUTS TO VLEACH INPUT FILE

```
COT-ROW VLEACH Model  SVMW-5  1 1 1-TCA contamination
  1
      0 1       100         1         10
     152         540      720      67392
Polygon I
     32185         1        0375      1 96       261        044     000378
       0         -1        -1
   52y       100
    1    12       0 29
   13    31       0 57
   32    52       0 06
```

```
|---------- ---- --------    -- --       --  - -----|
|        VLEACH (Version 2 2a  1996)                |
|                                                   |
|                   By                              |
|    Varadhan Ravi and Jeffrey A  Johnson           |
|          (USEPA Contractors)                      |
|    Center for Subsurface Modeling Support         |
|    Robert S  Kerr Environmental Research Laboratory |
|    U S  Environmental Protection Agency           |
|    P O  Box 1198                                  |
|    Ada  OK 74820                                  |
|                                                   |
|    Based on the original VLEACH (version 1 0)     |
|    developed by CH2M Hill  Redding  California    |
|    for USEPA Region IX                            |
|------------------------------------ -------------|
```

COT-ROW VLEACH Model SVMW -5 1 1 1-TCA contamination
************** ************** ** ** * ********** *

************** ************ **** ** *** * ******* **
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
1	5 69E 02	3 90E 02
2	6 92E-02	0 10418
3	7 20E 02	0 17525
4	7 26E 02	0 24764
5	7 26E 02	0 32024
6	7 24E-02	0 39275
7	7 23E 02	0 4651
8	7 21E 02	0 53727
9	7 19E-02	0 60924
10	7 17E 02	0 68103
11	7 15E 02	0 75263
12	7 13E-02	0 82404
13	7 11E-02	0 89526
14	7 10E-02	0 9663
15	7 08E-02	1 0371
16	7 06E-02	1 1078
17	7 04E-02	1 1783
18	7 02E 02	1 2486
19	7 00E-02	1 3187
20	6 98E 02	1 3886
21	6 96E-02	1 4583
22	6 95E 02	1 5279
23	6 93E 02	1 5972
24	6 91E 02	1 6664
25	6 89E 02	1 7354

COT ROW VLEACH Model SVMW -5 1 1 1 TCA contamination
*   * **   *** * ***** ** *   *** *   **** **

*   ******************** *   * * **** **********
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
26	6 87E-02	1 8042
27	6 86E-02	1 8729
28	6 84E-02	1 9413
29	6 82E-02	2 0096
30	6 80E-02	2 0777
31	6 78E-02	2 1456
32	6 77E-02	2 2133
33	6 75E-02	2 2809
34	6 73E-02	2 3483
35	6 71E-02	2 4154
36	6 69E-02	2 4825
37	6 68E-02	2 5493
38	6 66E 02	2 616
39	6 64E-02	2 6825
40	6 62E-02	2 7488
41	6 61E-02	2 8149
42	6 59E-02	2 8809
43	6 57E-02	2 9467
44	6 55E-02	3 0123
45	6 54E-02	3 0778
46	6 52E-02	3 143
47	6 50E-02	3 2081
48	6 49E-02	3 2731
49	6 47E-02	3 3378
50	6 45E-02	3 4024
51	6 43E-02	3 4668
52	6 42E-02	3 5311
53	6 40E-02	3 5951
54	6 38E-02	3 659
55	6 37E-02	3 7228
56	6 35E 02	3 7863
57	6 33E-02	3 8497
58	6 32E-02	3 913
59	6 30E-02	3 976
60	6 28E-02	4 0389
61	6 27E-02	4 1017
62	6 25E-02	4 1643
63	6 23E-02	4 2267
64	6 22E-02	4 2889
65	6 20E-02	4 351
66	6 18E-02	4 4129
67	6 17E-02	4 4746

** * **** * ** * * * * * * * * *

*** * **** ****************** ** * * * * *

TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
68	6 15E 02	4 5362
69	6 13E 02	4 5976
70	6 12E 02	4 6589
71	6 10E 02	4 72
72	6 09E 02	4 7809
73	6 07E 02	4 8417
74	6 05E 02	4 9023
75	6 04E 02	4 9628
76	6 02E 02	5 0231
77	6 01E 02	5 0832
78	5 99E 02	5 1432
79	5 97E 02	5 203
80	5 96E 02	5 2627
81	5 94E 02	5 3222
82	5 93E 02	5 3815
83	5 91E-02	5 4407
84	5 90E 02	5 4997
85	5 88E-02	5 5586
86	5 87E-02	5 6173
87	5 85E-02	5 6759
88	5 83E-02	5 7343
89	5 82E 02	5 7926
90	5 80E-02	5 8507
91	5 79E 02	5 9086
92	5 77E-02	5 9664
93	5 76E-02	6 0241
94	5 74E-02	6 0816
95	5 73E-02	6 1389
96	5 71E-02	6 1961
97	5 70E-02	6 2532
98	5 68E-02	6 31
99	5 67E-02	6 3668
100	5 65E-02	6 4234

This spreadsheet takes the area dependent out put from VLEACH and calculates GW concentrations
The model (column E) is based on eq 16 of Ground Water Threat Calculations Report for NIBW Area 9
Hydro Geo Chem Inc May 1993

Groundwater Mixing Cell Template
COT ROW 1 1 1 TCA Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	152
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0.261	rhob (g/cm3)	1 96

Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 374
Days/timestep	365 25	GW Flux (ft3/d)	1850		

	(These two columns are from VLEACH)				
Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
0	0		0 00E+00	0 00E+00	0 0000
1	1	5 69E-02	4 85E-09	5 69E-08	0 0020
2	2	6 92E-02	5 89E-09	8 76E-08	0 0031
3	3	7 20E-02	6 13E-09	1 00E-07	0 0035
4	4	7 26E-02	6 18E-09	1 05E-07	0 0037
5	5	7 26E 02	6 18E-09	1 07E 07	0 0038
6	6	7 24E 02	6 17E-09	1 07E-07	0 0038
7	7	7 23E-02	6 15E 09	1 07E-07	0 0038
8	8	7 21E-02	6 14E-09	1 07E-07	0 0038
9	9	7 19E 02	6 12E 09	1 07E 07	0 0038
10	10	7 17E-02	6 10E 09	1 06E-07	0 0038
11	11	7 15E-02	6 09E 09	1 06E-07	0 0037
12	12	7 13E 02	6 07E-09	1 06E-07	0 0037
13	13	7 11E-02	6 06E-09	1 05E 07	0 0037
14	14	7 10E 02	6 04E-09	1 05E 07	0 0037
15	15	7 08E-02	6 02E-09	1 05E-07	0 0037
16	16	7 06E-02	6 01E-09	1 05E-07	0 0037
17	17	7 04E-02	5 99E-09	1 04E-07	0 0037
18	18	7 02E-02	5 98E-09	1 04E 07	0 0037
19	19	7 00E-02	5 96E-09	1 04E-07	0 0037
20	20	6 98E-02	5 94E-09	1 03E 07	0 0037
21	21	6 96E-02	5 93E-09	1 03E-07	0 0036
22	22	6 95E 02	5 91E 09	1 03E 07	0 0036
23	23	6 93E-02	5 90E-09	1 03E-07	0 0036
24	24	6 91E 02	5 88E-09	1 02E-07	0 0036
25	25	6 89E 02	5 87E 09	1 02E 07	0 0036
26	26	6 87E-02	5 85E 09	1 02E 07	0 0036
27	27	6 86E 02	5 84E-09	1 02E 07	0 0036
28	28	6 84E 02	5 82E-09	1 01E-07	0 0036
29	29	6 82E 02	5 80E-09	1 01E 07	0 0036
30	30	6 80E 02	5 79E-09	1 01E 07	0 0036
31	31	6 78E-02	5 77E-09	1 01E-07	0 0035
32	32	6 77E 02	5 76E-09	1 00E-07	0 0035
33	33	6 75E 02	5 74E-09	1 00E-07	0 0035
34	34	6 73E 02	5 73E-09	9 97E 08	0 0035
35	35	6 71E 02	5 71E 09	9 95E-08	0 0035
36	36	6 69E 02	5 70E 09	9 92E 08	0 0035
37	37	6 68E 02	5 68E-09	9 89E 08	0 0035
38	38	6 66E 02	5 67E 09	9 87E 08	0 0035
39	39	6 64E 02	5 65E-09	9 84E 08	0 0035
40	40	6 62E 02	5 64E-09	9 82E 08	0 0035
41	41	6 61E 02	5 62E 09	9 79E 08	0 0035
42	42	6 59E 02	5 61E-09	9 76E-08	0 0034

Groundwater Mixing Cell Template
COT ROW 1 1 1 TCA Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	152
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96

Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 374
Days/timestep	365 25	GW Flux (ft3/d)	1850		

	(These two columns are from VLEACH)				
Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
43	43	6 57E 02	5 59E 09	9 74E-08	0 0034
44	44	6 55E-02	5 58E-09	9 71E 08	0 0034
45	45	6 54E-02	5 56E 09	9 69E 08	0 0034
46	46	6 52E 02	5 55E-09	9 66E-08	0 0034
47	47	6 50E-02	5 54E-09	9 64E 08	0 0034
48	48	6 49E-02	5 52E-09	9 61E 08	0 0034
49	49	6 47E-02	5 51E 09	9 59E-08	0 0034
50	50	6 45E-02	5 49E-09	9 56E-08	0 0034
51	51	6 43E 02	5 48E 09	9 54E 08	0 0034
52	52	6 42E-02	5 46E-09	9 51E 08	0 0034
53	53	6 40E 02	5 45E-09	9 48E 08	0 0033
54	54	6 38E-02	5 43E 09	9 46E-08	0 0033
55	55	6 37E-02	5 42E 09	9 43E 08	0 0033
56	56	6 35E 02	5 40E-09	9 41E-08	0 0033
57	57	6 33E 02	5 39E-09	9 38E 08	0 0033
58	58	6 32E-02	5 38E 09	9 36E 08	0 0033
59	59	6 30E-02	5 36E-09	9 34E 08	0 0033
60	60	6 28E 02	5 35E 09	9 31E 08	0 0033
61	61	6 27E-02	5 33E 09	9 29E-08	0 0033
62	62	6 25E-02	5 32E-09	9 26E 08	0 0033
63	63	6 23E 02	5 31E 09	9 24E 08	0 0033
64	64	6 22E 02	5 29E-09	9 21E 08	0 0033
65	65	6 20E 02	5 28E 09	9 19E 08	0 0032
66	66	6 18E 02	5 26E-09	9 16E 08	0 0032
67	67	6 17E 02	5 25E-09	9 14E-08	0 0032
68	68	6 15E 02	5 24E 09	9 12E-08	0 0032
69	69	6 13E-02	5 22E-09	9 09E-08	0 0032
70	70	6 12E-02	5 21E 09	9 07E 08	0 0032
71	71	6 10E-02	5 19E 09	9 04E 08	0 0032
72	72	6 09E-02	5 18E 09	9 02E 08	0 0032
73	73	6 07E-02	5 17E-09	9 00E 08	0 0032
74	74	6 05E 02	5 15E-09	8 97E 08	0 0032
75	75	6 04E 02	5 14E-09	8 95E 08	0 0032
76	76	6 02E 02	5 13E 09	8 93E-08	0 0032
77	77	6 01E 02	5 11E 09	8 90E 08	0 0031
78	78	5 99E 02	5 10E-09	8 88E 08	0 0031
79	79	5 97E 02	5 09E 09	8 85E-08	0 0031
80	80	5 96E-02	5 07E 09	8 83E 08	0 0031
81	81	5 94E 02	5 06E 09	8 81E 08	0 0031
82	82	5 93E 02	5 05E 09	8 78E 08	0 0031
83	83	5 91E 02	5 03E-09	8 76E 08	0 0031
84	84	5 90E-02	5 02E 09	8 74E 08	0 0031
85	85	5 88E 02	5 01E 09	8 72E 08	0 0031
86	86	5 87E 02	4 99E 09	8 69E 08	0 0031
87	87	5 85E 02	4 98E 09	8 67E 08	0 0031
88	88	5 83E 02	4 97E 09	8 65E-08	0 0031
89	89	5 82E 02	4 95E-09	8 62E 08	0 0030

Groundwater Mixing Cell Template COT ROW 1 1 1 TCA Loading Estimate								
Thickness (ft)	50	K (ft/d)	246	Koc (ml/g)	152
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96

Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 374
Days/timestep	365 25	GW Flux (ft3/d)	1850		

	(These two columns are from VLEACH)				
Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
90	90	5 80E-02	4 94E-09	8 60E-08	0 0030
91	91	5 79E 02	4 93E-09	8 58E-08	0 0030
92	92	5 77E-02	4 91E-09	8 56E-08	0 0030
93	93	5 76E-02	4 90E-09	8 53E-08	0 0030
94	94	5 74E-02	4 89E-09	8 51E-08	0 0030
95	95	5 73E-02	4 88E-09	8 49E-08	0 0030
96	96	5 71E-02	4 86E-09	8 47E 08	0 0030
97	97	5 70E-02	4 85E-09	8 44E-08	0 0030
98	98	5 68E-02	4 84E-09	8 42E 08	0 0030
99	99	5 67E-02	4 82E-09	8 40E-08	0 0030
100	100	5 65E-02	4 81E-09	8 38E-08	0 0030

This spreadsheet calculates total soil concentrations based on soil gas concentrations and Ct/Cg

COT-ROW
WELL SVMW 5
CONTAMINANT TCE

C_T/C_G	0 65	Area (ft2)	32185
		P_b (g/cm3)	1 96

DEPTHS		SOIL GAS (ug/l)			SOIL GAS (ug/l)			TOTAL SOIL (ug/Kg)			MASS (g)		
from (ft)	to (ft)	03/12/1997	05/05/1997	06/23/1997	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX	MEAN	M + 1sd	MAX
0	12	0 067	0 149	0 133	0	0	0 149	0	0	0 06	0 8	1 1	1 1
12	31	0 305	0 349	0 308	0	0	0 349	0	0	0 12	3 6	3 9	3 9
31	52	0 015	0 078	0 055	0	0	0 078	0	0	0 03	0 6	1 0	1 0
										TOTALS	5 0	6 0	5 9

NOTE SHADED VALUES ARE THE INPUTS TO VLEACH INPUT FILE

```
COT-ROW VLEACH Model  SVMW-5  TCE contamınatıon
  1
       0 1      100         1        10
     126         300      1100      68256
Polygon I
     32185         1       0375       1 96       261        044     000378
        0         -1         -1
   52y       100
    1   12      0 05
   13   31      0 12
   32   52      0 03
```

```
|------ ------------- ------ ---     ---------|
|        VLEACH (Version 2 2a  1996)          |
|                                   |
|               By                   |
|     Varadhan Ravi and Jeffrey A  Johnson         |
|          (USEPA Contractors)             |
|     Center for Subsurface Modeling Support        |
|     Robert S  Kerr Environmental Research Laboratory  |
|     U S  Environmental Protection Agency          |
|     P O  Box 1198                        |
|     Ada  OK 74820                         |
|                                   |
|     Based on the original VLEACH (version 1 0)        |
|     developed by CH2M Hill  Redding  California        |
|     for USEPA Region IX                      |
|--------------------------- -- ------------|
```

COT-ROW VLEACH Model SVMW 5 TCE contamination

***** *** *   * ****   * *********** ****** * * *

***** *************************** ***************

TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
1	1 78E-02	1 43E-02
2	2 09E 02	3 42E-02
3	2 18E-02	5 56E-02
4	2 20E-02	7 75E-02
5	2 20E-02	9 96E-02
6	2 20E-02	0 12158
7	2 19E-02	0 14356
8	2 19E-02	0 16546
9	2 18E-02	0 18729
10	2 17E-02	0 20904
11	2 16E-02	0 23072
12	2 16E-02	0 25231
13	2 15E-02	0 27383
14	2 14E-02	0 29528
15	2 13E-02	0 31664
16	2 13E-02	0 33793
17	2 12E-02	0 35915
18	2 11E-02	0 38029
19	2 10E-02	0 40135
20	2 10E-02	0 42234
21	2 09E-02	0 44325
22	2 08E-02	0 46409
23	2 07E-02	0 48485
24	2 07E 02	0 50554
25	2 06E-02	0 52615

COT-ROW VLEACH Model SVMW 5 TCE contamination
* * **** * ***** ** *** *** * * ** ******

* ** * * ** ************* *** *** **** ********

TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
26	2 05E-02	0 54669
27	2 04E 02	0 56716
28	2 04E-02	0 58756
29	2 03E-02	0 60788
30	2 02E-02	0 62813
31	2 01E-02	0 6483
32	2 01E-02	0 66841
33	2 00E-02	0 68844
34	1 99E-02	0 7084
35	1 99E-02	0 72829
36	1 98E-02	0 74811
37	1 97E-02	0 76785
38	1 96E-02	0 78753
39	1 96E-02	0 80714
40	1 95E-02	0 82667
41	1 94E-02	0 84614
42	1 94E-02	0 86554
43	1 93E-02	0 88486
44	1 92E-02	0 90412
45	1 92E-02	0 92331
46	1 91E-02	0 94243
47	1 90E-02	0 96148
48	1 90E-02	0 98047
49	1 89E-02	0 99938
50	1 88E-02	1 0182
51	1 88E-02	1 037
52	1 87E-02	1 0557
53	1 86E-02	1 0744
54	1 86E-02	1 093
55	1 85E-02	1 1115
56	1 84E-02	1 1299
57	1 84E-02	1 1483
58	1 83E-02	1 1666
59	1 82E-02	1 1849
60	1 82E-02	1 203
61	1 81E-02	1 2212
62	1 80E-02	1 2392
63	1 80E-02	1 2572
64	1 79E-02	1 2751
65	1 78E-02	1 293
66	1 78E-02	1 3108
67	1 77E-02	1 3285

COT ROW VLEACH Model SVMW 5 TCE contamination
*** * * * *** * * *** * * * * * ** *

** *** * ** ** * *************** * * * *** *
TOTAL GROUNDWATER IMPACT

Time (yr)	Mass (g/yr)	Cumulative Mass (g)
68	1 76E-02	1 3462
69	1 76E 02	1 3638
70	1 75E-02	1 3814
71	1 75E-02	1 3988
72	1 74E-02	1 4163
73	1 73E-02	1 4336
74	1 73E-02	1 4509
75	1 72E-02	1 4682
76	1 71E-02	1 4853
77	1 71E 02	1 5024
78	1 70E 02	1 5195
79	1 70E 02	1 5365
80	1 69E-02	1 5534
81	1 68E-02	1 5703
82	1 68E 02	1 5871
83	1 67E 02	1 6038
84	1 67E-02	1 6205
85	1 66E 02	1 6371
86	1 65E 02	1 6537
87	1 65E-02	1 6702
88	1 64E 02	1 6867
89	1 64E-02	1 7031
90	1 63E-02	1 7194
91	1 62E 02	1 7357
92	1 62E-02	1 7519
93	1 61E-02	1 768
94	1 61E-02	1 7841
95	1 60E-02	1 8002
96	1 60E 02	1 8162
97	1 59E 02	1 8321
98	1 58E-02	1 848
99	1 58E 02	1 8638
100	1 57E-02	1 8795

This spreadsheet takes the area dependent out put from VLEACH and calculates GW concentrations
The model (column E) is based on eq 16 of Ground Water Threat Calculations Report for NIBW Area 9
Hydro Geo Chem Inc May 1993

Groundwater Mixing Cell Template COT ROW TCE Loading Estimate					
Thickness (ft) Width (ft) Length (ft)	50 151 213	K (ft/d) Gradient (ft/ft) Porosity ( )	245 1 00E 03 0 261	Koc (ml/g) foc( ) rhob (g/cm3)	126 3 78E-04 1 96
Cell Volume (ft3) Days/timestep	1608150 365 25	Darcy Vel (ft/d) GW Flux (ft3/d)	0 245 1850	(Koc foc bulk density) + Porosity	0 354
	(These two columns are from VLEACH)				
Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
0	0		0 00E+00	0 00E+00	0 000000
1	1	1 78E-02	1 52E-09	1 83E-08	0 000647
2	2	2 09E-02	1 78E-09	2 71E-08	0 000956
3	3	2 18E 02	1 85E-09	3 06E-08	0 001082
4	4	2 20E-02	1 87E 09	3 20E 08	0 001129
5	5	2 20E-02	1 88E-09	3 24E 08	0 001145
6	6	2 20E-02	1 87E-09	3 25E 08	0 001149
7	7	2 19E-02	1 87E-09	3 25E 08	0 001147
8	8	2 19E 02	1 86E 09	3 24E 08	0 001144
9	9	2 18E 02	1 86E-09	3 23E 08	0 001141
10	10	2 17E-02	1 85E-09	3 22E 08	0 001137
11	11	2 16E-02	1 84E 09	3 21E 08	0 001133
12	12	2 16E-02	1 84E-09	3 20E-08	0 001129
13	13	2 15E-02	1 83E 09	3 19E 08	0 001125
14	14	2 14E 02	1 82E 09	3 17E-08	0 001121
15	15	2 13E 02	1 82E-09	3 16E-08	0 001117
16	16	2 13E-02	1 81E-09	3 15E 08	0 001113
17	17	2 12E-02	1 80E 09	3 14E 08	0 001109
18	18	2 11E-02	1 80E 09	3 13E-08	0 001105
19	19	2 10E-02	1 79E 09	3 12E 08	0 001101
20	20	2 10E-02	1 78E-09	3 11E-08	0 001097
21	21	2 09E-02	1 78E 09	3 10E-08	0 001093
22	22	2 08E-02	1 77E-09	3 08E-08	0 001089
23	23	2 07E-02	1 76E 09	3 07E 08	0 001085
24	24	2 07E-02	1 76E 09	3 06E 08	0 001081
25	25	2 06E-02	1 75E 09	3 05E 08	0 001077
26	26	2 05E 02	1 75E-09	3 04E-08	0 001074
27	27	2 04E 02	1 74E-09	3 03E 08	0 001070
28	28	2 04E 02	1 73E 09	3 02E-08	0 001066
29	29	2 03E 02	1 73E 09	3 01E 08	0 001062
30	30	2 02E 02	1 72E 09	3 00E 08	0 001058
31	31	2 01E-02	1 71E 09	2 99E-08	0 001055
32	32	2 01E 02	1 71E 09	2 98E-08	0 001051
33	33	2 00E-02	1 70E 09	2 96E 08	0 001047
34	34	1 99E 02	1 70E 09	2 95E-08	0 001043
35	35	1 99E-02	1 69E 09	2 94E-08	0 001040
36	36	1 98E 02	1 68E 09	2 93E 08	0 001036
37	37	1 97E 02	1 68E 09	2 92E 08	0 001032
38	38	1 96E 02	1 67E 09	2 91E 08	0 001028
39	39	1 96E 02	1 67E 09	2 90E 08	0 001025
40	40	1 95E 02	1 66E 09	2 89E 08	0 001021
41	41	1 94E 02	1 65E 09	2 88E 08	0 001017
42	42	1 94E 02	1 65E 09	2 87E 08	0 001014

Groundwater Mixing Cell Template
COT ROW TCE Loading Estimate

Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	126
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96

Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 354
Days/timestep	365 25	GW Flux (ft3/d)	1850		

(These two columns are from VLEACH)

Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
43	43	1 93E-02	1 64E-09	2 86E-08	0 001010
44	44	1 92E-02	1 64E-09	2 85E 08	0 001007
45	45	1 92E 02	1 63E-09	2 84E 08	0 001003
46	46	1 91E 02	1 63E-09	2 83E-08	0 000999
47	47	1 90E 02	1 62E-09	2 82E 08	0 000996
48	48	1 90E 02	1 61E-09	2 81E-08	0 000992
49	49	1 89E 02	1 61E-09	2 80E 08	0 000989
50	50	1 88E 02	1 60E 09	2 79E 08	0 000985
51	51	1 88E 02	1 60E 09	2 78E 08	0 000982
52	52	1 87E 02	1 59E 09	2 77E 08	0 000978
53	53	1 86E-02	1 58E 09	2 76E 08	0 000975
54	54	1 86E-02	1 58E-09	2 75E-08	0 000971
55	55	1 85E 02	1 57E 09	2 74E-08	0 000968
56	56	1 84E 02	1 57E-09	2 73E 08	0 000964
57	57	1 84E 02	1 56E-09	2 72E-08	0 000961
58	58	1 83E 02	1 56E-09	2 71E 08	0 000957
59	59	1 82E 02	1 55E-09	2 70E-08	0 000954
60	60	1 82E-02	1 55E 09	2 69E-08	0 000950
61	61	1 81E-02	1 54E 09	2 68E 08	0 000947
62	62	1 80E 02	1 53E-09	2 67E-08	0 000944
63	63	1 80E 02	1 53E 09	2 66E 08	0 000940
64	64	1 79E 02	1 52E 09	2 65E 08	0 000937
65	65	1 78E 02	1 52E 09	2 64E 08	0 000934
66	66	1 78E 02	1 51E-09	2 63E-08	0 000930
67	67	1 77E-02	1 51E-09	2 62E-08	0 000927
68	68	1 76E 02	1 50E-09	2 62E 08	0 000924
69	69	1 76E-02	1 50E-09	2 61E 08	0 000920
70	70	1 75E 02	1 49E-09	2 60E-08	0 000917
71	71	1 75E-02	1 49E 09	2 59E-08	0 000914
72	72	1 74E 02	1 48E-09	2 58E 08	0 000910
73	73	1 73E 02	1 48E 09	2 57E 08	0 000907
74	74	1 73E 02	1 47E-09	2 56E 08	0 000904
75	75	1 72E 02	1 46E 09	2 55E 08	0 000901
76	76	1 71E 02	1 46E 09	2 54E 08	0 000898
77	77	1 71E 02	1 45E 09	2 53E-08	0 000894
78	78	1 70E 02	1 45E 09	2 52E 08	0 000891
79	79	1 70E 02	1 44E 09	2 51E 08	0 000888
80	80	1 69E-02	1 44E 09	2 51E 08	0 000885
81	81	1 68E 02	1 43E 09	2 50E 08	0 000882
82	82	1 68E 02	1 43E 09	2 49E 08	0 000878
83	83	1 67E 02	1 42E 09	2 48E 08	0 000875
84	84	1 67E 02	1 42E 09	2 47E 08	0 000872
85	85	1 66E 02	1 41E 09	2 46E 08	0 000869
86	86	1 65E 02	1 41E 09	2 45E 08	0 000866
87	87	1 65E 02	1 40E 09	2 44E-08	0 000863
88	88	1 64E 02	1 40E 09	2 43E 08	0 000860
89	89	1 64E 02	1 39E 09	2 43E-08	0 000857

Groundwater Mixing Cell Template COT ROW TCE Loading Estimate					
Thickness (ft)	50	K (ft/d)	245	Koc (ml/g)	126
Width (ft)	151	Gradient (ft/ft)	1 00E 03	foc( )	3 78E 04
Length (ft)	213	Porosity ( )	0 261	rhob (g/cm3)	1 96
Cell Volume (ft3)	1608150	Darcy Vel (ft/d)	0 245	(Koc foc bulk density) + Porosity	0 354
Days/timestep	365.25	GW Flux (ft3/d)	1850		

(These two columns are from VLEACH)

Time Step (Number)	Time at end of Time step (Years)	Mass from Vadose Zone (g/yr)	Mass from Vadose Zone (g/day/ft2)	Calculated Concentration (g/ft3)	Calculated Concentration (ug/l)
90	90	1 63E-02	1 39E 09	2 42E-08	0 000854
91	91	1 62E 02	1 38E-09	2 41E 08	0 000851
92	92	1 62E-02	1 38E-09	2 40E-08	0 000848
93	93	1 61E 02	1 37E-09	2 39E-08	0 000844
94	94	1 61E-02	1 37E-09	2 38E 08	0 000841
95	95	1 60E-02	1 36E-09	2 37E 08	0 000838
96	96	1 60E-02	1 36E-09	2 37E-08	0 000835
97	97	1 59E-02	1 35E-09	2 36E 08	0 000832
98	98	1 58E-02	1 35E-09	2 35E-08	0 000829
99	99	1 58E-02	1 34E-09	2 34E-08	0 000827
100	100	1 57E-02	1 34E-09	2 33E-08	0 000824

J&E Output Files

Subsite	City of Tempe Right of Way
Model	Infinite Source
SVMW(s)	5

Compound(s) Modeled	1 1 1 Trichloroethane Tetrachloroethylene Trichloroethylene

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CALCULATE RISK BASED SOIL CONCENTRATION (enter X in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter X in YES' box and initial soil conc below)

YES [X]

ENTER Chemical CAS No (numbers only no dashes)	**ENTER** Initial soil conc C_R (µg/kg)	Chemical
71556	1	1 1 1 Trichloroethane

ENTER Depth below grade to bottom of enclosed space floor L_F (15 or 200 cm)	**ENTER** Depth below grade to top of contamination L_t (cm)	**ENTER** Average soil temperature T_S (C)	**ENTER** Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	**ENTER** User defined vadose zone soil vapor permeability k (cm^2)
15	1584 96	19 4	S		

ENTER Vadose zone soil dry bulk density ρ_b^A (g/cm^3)	**ENTER** Vadose zone soil total porosity n^V (unitless)	**ENTER** Vadose zone soil water filled porosity θ_w^V (cm^3/cm^3)	**ENTER** Vadose zone soil organic carbon fraction f_{oc}^V (unitless)
1 957123077	0 26146299	0 045	0 000377904

ENTER Averaging time for carcinogens AT_C (yrs)	**ENTER** Averaging time for noncarcinogens AT_{NC} (yrs)	**ENTER** Exposure duration ED (yrs)	**ENTER** Exposure frequency EF (days/yr)	**ENTER** Target risk for carcinogens TR (unitless)	**ENTER** Target hazard quotient for noncarcinogens THQ (unitless)
70	30	30	350	1 0E 06	1

Used to calculate risk based soil concentration

RESULTS SHEET

RISK BASED SOIL CONCENTRATION CALCULATIONS

Indoor exposure soil conc carcinogen (µg/kg)	Indoor exposure soil conc noncarcinogen (µg/kg)	Risk based indoor exposure soil conc (µg/kg)	Soil saturation conc C (µg/kg)	Final indoor exposure soil conc (µg/kg)
NA	NA	NA	1 68E+05	NA

INCREMENTAL RISK CALCULATIONS

Incremental risk from vapor intrusion to indoor air carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air noncarcinogen (unitless)
NA	3 0E 04

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CALCULATE RISK BASED SOIL CONCENTRATION (enter X in 'YES' box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter X in YES" box and initial soil conc below)

YES [X]

ENTER Chemical CAS No (numbers only no dashes)	ENTER Initial soil conc C_R (µg/kg)	Chemical
127184	1	Tetrachloroethylene

ENTER Depth below grade to bottom of enclosed space floor L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination L_t (cm)	ENTER Average soil temperature T_S (C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)		ENTER User defined vadose zone soil vapor permeability k (cm^2)
				OR	
15	1584 96	19 4	S		

ENTER Vadose zone soil dry bulk density ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity n^V (unitless)	ENTER Vadose zone soil water filled porosity θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction f_{oc}^V (unitless)
1 957123077	0 26146299	0 045	0 000377904

ENTER Averaging time for carcinogens AT_C (yrs)	ENTER Averaging time for noncarcinogens AT_{NC} (yrs)	ENTER Exposure duration ED (yrs)	ENTER Exposure frequency EF (days/yr)	ENTER Target risk for carcinogens TR (unitless)	ENTER Target hazard quotient for noncarcinogens THQ (unitless)
70	30	30	350	1 0E 06	1

Used to calculate risk based soil concentration

RESULTS SHEET

RISK BASED SOIL CONCENTRATION CALCULATIONS

Indoor exposure soil conc carcinogen (µg/kg)	Indoor exposure soil conc noncarcinogen (µg/kg)	Risk based indoor exposure soil conc (µg/kg)	Soil saturation conc C_{sat} (µg/kg)	Final indoor exposure soil conc (µg/kg)
NA	NA	NA	2 88E+04	NA

INCREMENTAL RISK CALCULATIONS

Incremental risk from vapor intrusion to indoor air carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air noncarcinogen (unitless)
6 1E 08	NA

CALCULATE RISK BASED SOIL CONCENTRATION (enter X in "YES" box)

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YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter X in "YES" box and initial soil conc below)

YES [X]

ENTER Chemical CAS No (numbers only no dashes)	ENTER Initial soil conc C_R (µg/kg)	Chemical
79016	1	Trichloroethylene

ENTER Depth below grade to bottom of enclosed space floor L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination L_t (cm)	ENTER Average soil temperature T_S (C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User defined vadose zone soil vapor permeability k (cm^2)
15	1584 96	19 4	S		

ENTER Vadose zone soil dry bulk density ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity n^V (unitless)	ENTER Vadose zone soil water filled porosity θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)
1 957123077	0 26146299	0 045	0 000377904

ENTER Averaging time for carcinogens AT_C (yrs)	ENTER Averaging time for noncarcinogens AT_{NC} (yrs)	ENTER Exposure duration ED (yrs)	ENTER Exposure frequency EF (days/yr)	ENTER Target risk for carcinogens TR (unitless)	ENTER Target hazard quotient for noncarcinogens THQ (unitless)
70	30	30	350	1 0E 06	1

Used to calculate risk based soil concentration

RESULTS SHEET

RISK BASED SOIL CONCENTRATION CALCULATIONS

Indoor exposure soil conc carcinogen (µg/kg)	Indoor exposure soil conc noncarcinogen (µg/kg)	Risk based indoor exposure soil conc (µg/kg)	Soil saturation conc C_{t} (µg/kg)	Final indoor exposure soil conc (µg/kg)
NA	NA	NA	1 34E+05	NA

INCREMENTAL RISK CALCULATIONS

Incremental risk from vapor intrusion to indoor air carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air noncarcinogen (unitless)
1 3E 07	NA