

# **HUMAN HEALTH RISK ASSESSMENT**

**Erdle Perforating Company  
NYSDEC Site #828072**

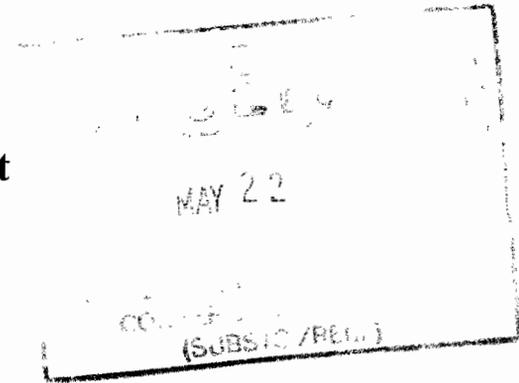
**Prepared for:  
Mr. Michael E. Rick  
Vice President of Engineering  
Erdle Perforating Company  
100 Pixley Industrial Parkway  
Rochester, New York 14603**

**Prepared by:  
Radian Engineering Inc.  
Rochester, New York**

**May 19, 1998**

## Human Health Risk Assessment

**Erdle Perforating Company**  
**NYSDEC Site #828072**



Prepared for:  
Mr. Michael E. Rick  
Vice President of Engineering  
Erdle Perforating Company  
100 Pixley Industrial Parkway  
Rochester, New York 14603

Prepared by:  
Radian Engineering Inc.  
Rochester, New York

May 19, 1998

## Table of Contents

<b>1.0 INTRODUCTION.....</b>	<b>1-1</b>
<b>2.0 ESTIMATION OF GROUNDWATER CONCENTRATIONS.....</b>	<b>2-1</b>
2.1 GROUNDWATER FATE AND TRANSPORT DATA.....	2-1
2.2 MASS INPUT .....	2-2
<b>3.0 ESTIMATION OF INDOOR AIR CONCENTRATIONS.....</b>	<b>3-1</b>
<b>4.0 RISK CHARACTERIZATION AND RISK ASSESSMENT RESULTS.....</b>	<b>4-1</b>
4.1 ESTIMATION OF INTAKE (DOSE).....	4-1
4.2 DAILY INTAKE FOR INHALATION OF VAPORS IN INDOOR AIR EXPOSURE PATHWAY.....	4-1
4.3 DETERMINATION OF CARCINOGENIC RISKS .....	4-2
4.4 RISK ASSESSMENT RESULTS .....	4-3

### APPENDIX

<b>A</b>	<b>GROUNDWATER MODELING DATA</b>
<b>B</b>	<b>CALCULATION OF INDOOR AIR CONCENTRATIONS</b>
<b>C</b>	<b>RISK ASSESSMENT CALCULATIONS</b>

## List of Tables

TABLE 1. PARAMETERS USED TO ESTIMATE INDOOR AIR CONCENTRATIONS OF TRICHLOROETHENE FROM GROUNDWATER EMISSIONS ASTM RISK-BASED CORRECTIVE ACTION (RBCA) EQUATIONS .....	3-2
TABLE 2. TOXICOLOGICAL DATA FOR TRICHLOROETHENE .....	4-2
TABLE 3. RISK ASSESSMENT RESULTS, EXPOSURE TO TCE IN INDOOR AIR .....	4-3



## 1.0 Introduction

The purpose of this health risk assessment (HRA) is to evaluate potential risks from exposure to trichloroethene (TCE) in groundwater to residents living downgradient of the Erdle Perforating Site. Specifically, this HRA quantifies potential cancer risks to residents living 500 feet downgradient of the Erdle property who may inhale TCE vapors assumed to enter homes from ground water. The estimation of these potential risks involves the following:

- Estimation of the groundwater concentration 500 feet downgradient of the property by means of a groundwater model. In this HRA, groundwater modeling is performed by the RISKPRO AT123D groundwater model. Details of the groundwater modeling are provided in Section 2.
- Estimation of indoor air concentrations based on the projected groundwater concentrations. The indoor air concentrations are estimated by models of the American Society for Testing and Materials, Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites, E 1739-95, December 1996 (RBCA). A description of the RBCA modeling is provided in Section 3.
- Quantification of potential cancer risks from inhalation of TCE vapors. The estimation of risk is performed according to guidelines of the U.S. EPA's Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), USEPA, December, 1989(RAGS-A). Details of the risk assessment methodology are provided in Section 4.

This risk assessment follows guidance provided in the following documents:

- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), USEPA, December, 1989(RAGS-A).
- U.S. Environmental Protection Agency, OSWER Directive 9285.6-03, Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual Supplemental Guidance, "Standard Default Exposure Factors", Interim Report, March 25, 1991.
- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), USEPA, December 1991(RAGS-B).
- U.S. EPA Region IX Preliminary Remediation Goals, 1997
- Soil Screening Guidance, Office of Solid Waste and Emergency Response, USEPA, December 1996.

- American Society for Testing and Materials, Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites, E 1739-95, December 1996.
- RISKPRO Environmental Pollution Modeling System, Analytical Transient 1-2-3 Dimensional Model (AT123D), General Sciences Corporation, 1994.



## 2.0 Estimation of Groundwater Concentrations

The groundwater concentration of TCE downgradient of the Site was estimated by the Analytical Transient 123 Dimensional Model (AT123D) of the RISKPRO environmental modeling system. The AT123D model is used in risk assessments by the U.S. EPA to evaluate a chemical's behavior when released into a groundwater system. The model has also been used by a number of state environmental departments, including Louisiana, Mississippi, Wisconsin, Pennsylvania, Illinois, New Jersey, by other Federal government agencies, by large corporations, by environmental consulting firms, and by other national governments, such as Environment Canada. The AT123D model produces results which estimate chemical groundwater concentrations (mg/L) at times (days), distances (meters), and depths (meters) specified by the user.

Appendix A provides printouts of the complete input and output data of the AT123D model.

The following sections present and discuss the data used in the AT123D model to estimate groundwater concentrations.

### 2.1 Groundwater Fate and Transport Data

Since the purpose of AT123D model is to predict groundwater concentrations, data which affect groundwater flow and contaminant movement in the saturated zone are required by the model. Among these are porosity of the saturated zone, hydraulic conductivity, hydraulic gradient, dispersivity, potential chemical decay or attenuation, density of soil and water, and the mass of each chemical entering the aquifer. The following are the default fate and transport parameters used by the AT123D model:

- Porosity of Saturated Zone - 0.20 (estimated)
- Hydraulic Conductivity – 6.1 meter/hour (site-specific measurement)
- Hydraulic Gradient - 0.001 (site-specific measurement)
- Longitudinal Dispersivity – 15.2 meters (Derived according to ASTM, E 1739)
- Lateral Dispersivity - 5 meters (Derived according to ASTM, E 1739)
- Vertical Dispersivity – 0.76 meter (Derived according to ASTM, E 1739)
- Molecular Diffusion - No molecular diffusion was assumed.

- Dimensions of groundwater source – 10 m x 10 m ft x 3 m (30 x 30 x 10 ft<sup>3</sup>)
- Decay Constant - The decay constant was set to zero, the model's default. This is considered as a conservative approach since it assumes that chemicals do not decay or are attenuated.

## 2.2 Mass Input

The AT123D model requires an initial chemical release rate in order to estimate groundwater concentrations. This rate is expressed in kg/hour and assumes a continuous release rate of chemicals into the saturated zone.

The source of the TCE mass input term uses the concentration of TCE in Monitoring Well MW-6D, 1.0 mg/L. This concentration is multiplied by the site-specific volumetric flow rate through the source of 4.7 m<sup>3</sup>/day.

The following is the calculation of the mass loading rate:

$$\begin{aligned} & 1.0 \text{ mg/L} \times 4.7 \text{ m}^3/\text{day} \times 1,000 \text{ L/m}^3 \times 10^{-6} \text{ kg/mg} \times \\ & 1 \text{ day}/24 \text{ hour} = 1.96 \times 10^{-4} \text{ kg/hour} \end{aligned}$$

For this risk assessment, the highest downgradient TCE concentration predicted by the model and the estimated concentration at 150 meters (the distance to the nearest residence) were used to estimate potential cancer risks from inhalation of vapors indoors.



### 3.0 Estimation of Indoor Air Concentrations

Indoor air exposure point concentrations were estimated by the Risk-Based Corrective Action (RBCA) equations developed by the American Society for Testing and Materials (ASTM). The indoor air models assume that vapors of constituents of concern are emitted from groundwater and pass through the capillary and vadose zones, through cracks in building foundations, floors and carpeting, and into residences or commercial buildings. The product of the RBCA equations for indoor air is a Groundwater to Enclosed Space Volatilization Factor (VFwesp) for each constituent of concern. VFwesp has units of milligrams per cubic meter of air per milligram per cubic meter of water ( $\text{mg}/\text{m}^3\text{-air}/\text{mg}/\text{L}\text{-water}$ ) and when multiplied by the groundwater concentration of a constituent produces a vapor concentration in air. The equations describing the RBCA models and calculations of VFwesp and indoor air concentrations are presented in Appendix B. Table 1 presents parameters and values used to estimate the indoor air concentrations. The estimated indoor air concentrations and calculations for each constituent of concern are included in Appendix B.

**Table 1. Parameters Used to Estimate Indoor Air Concentrations Of Trichloroethene From Groundwater Emissions ASTM Risk-Based Corrective Action (RBCA) Equations**

Parameter	Value
Henry's Law Constant ( $\text{cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-air}$ ) –Dimensionless	0.422
Depth to ground water (cm)	90
Enclosed-space air exchange rate (1/sec)- Residential	0.00014
Enclosed space volume/infiltration area ratio (cm) – Residential	200
Thickness of capillary fringe (cm)	30
Thickness of vadose zone (cm)	60
Diffusion coefficient in air ( $\text{cm}^2/\text{sec}$ )	0.079
Volumetric air content in capillary fringe soils ( $\text{cm}^3\text{-air}/\text{cm}^3\text{-soil}$ )	0.043
Total soil porosity ( $\text{cm}^3\text{-pore space}/\text{cm}^3\text{-soil}$ )	0.43
Diffusion coefficient in water ( $\text{cm}^2/\text{sec}$ )	$9.10 \times 10^{-6}$
Volumetric water content in capillary fringe soils ( $\text{cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-soil}$ )	0.387
Volumetric air content in vadose zone soils ( $\text{cm}^3\text{-air}/\text{cm}^3\text{-soil}$ )	0.3
Volumetric water content in vadose zone soils ( $\text{cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-soil}$ )	0.13
Volumetric air content in foundation/wall cracks ( $\text{cm}^3\text{-air}/\text{cm}^3\text{-total volume}$ )	0.12
Volumetric water content in foundation/wall cracks ( $\text{cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-total volume}$ )	0.26
Total soil porosity in foundation wall cracks ( $\text{cm}^3\text{-pore space}/\text{cm}^3\text{-soil}$ )	0.38
Foundation or wall thickness (cm)	15
Areal fraction of cracks in walls	0.01



## 4.0 Risk Characterization and Risk Assessment Results

This section represents the final step in the risk assessment process. In the risk characterization stage exposure and toxicity data are combined to produce quantitative expressions of health risk. The steps involved in the risk characterization follow.

### 4.1 Estimation of Intake (Dose)

This section explains the methodology for estimating daily intake or dose which is the amount of a chemical that enters the body on a daily basis. In this HRA, the factors used to determine daily intake were obtained from the U.S. EPA's Standard Default Exposure Factors, 1991. The generic equation for calculating chemical intake is:

$$\text{Daily Intake, or Dose (I)} = (C \times CR \times EFD) \div (BW \times AT)$$

where:

- I = Daily chemical intake or dose (mg/kg/day)
- C = Constituent concentration
- CR = Contact rate
- EFD = Exposure frequency and duration
- BW = Body weight
- AT = Time over which exposure is averaged

The following equation was used to compute doses for the indoor inhalation scenario evaluated in this HRA.

### 4.2 Daily Intake for Inhalation of Vapors in Indoor Air Exposure Pathway

$$\text{Intake} = (CA \times IR \times EF \times ED) / (BW \times AT)$$

where:

- CA = Constituent concentration in air (mg/m<sup>3</sup>)
- IR = Inhalation rate
  - = 20 m<sup>3</sup>/day for residents
- EF = Exposure frequency (days/year)
  - = 350 days per year for residents

- ED = Exposure duration (years)  
= 30 years for residents
- BW = Body weight  
= 70 kg for adults
- AT = Averaging time (period over which exposure is averaged)  
= 70 x 365 = 25,550 days for noncarcinogenic effects

### 4.3 Determination of Carcinogenic Risks

Carcinogenic risks are expressed as a probability of contracting cancer. This probability is defined as an "incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen". Incremental refers to the cancer risk in excess of the individual's normal risk without this exposure. The means by which daily intake is converted to a probability of carcinogenic risk is the Carcinogenic Slope Factor (CSF). Oral and inhalation Carcinogenic Slope Factors (CSFs) are values published by U.S.EPA which assess the carcinogenic potential of a compound. They are used with the exposure data to quantify potential carcinogenic risks. CSFs are expressed in  $(\text{mg/kg-day})^{-1}$ , denoting a numerical risk per  $\text{mg/kg-day}$  of intake dose for each constituent. The inhalation CSF for TCE used in this HRA was obtained from U.S. EPA Region III's, Risk-Based Concentration Table, 1997. The following table lists the toxicological data provided by Region III.

**Table 2. Toxicological Data for Trichloroethene**

Constituent	Oral Reference Dose (RfDo) (mg/kg-day)	Oral Slope Factor (SFo) (mg/kg-day) <sup>-1</sup>	Inhalation Slope Factor (SFi) (mg/kg-day) <sup>-1</sup>
Trichloroethene	0.006	0.011	0.006

To compute the probability of contracting cancer, the daily intakes described above is multiplied by the chemical-specific CSFs listed in Table 2. Therefore,

$$\text{Carcinogenic Risk} = \text{Dose} \times \text{CSF}$$

For this HRA the carcinogenic goal is  $1 \times 10^{-6}$  where a carcinogenic risk of  $10^{-6}$  is equivalent to one excess incidence of cancer in 1,000,000 persons. The U.S. EPA states that its

carcinogenic goal range for the U.S. population is  $10^{-6}$  to  $10^{-4}$  (RAGS-A, 1989), where a carcinogenic risk of  $10^{-6}$  is equivalent to one excess incidence of cancer in 1,000,000 persons and a  $10^{-4}$  risk is equivalent to a risk of one in 10,000.

Carcinogenic risks quantified in this HRA are presented in Section 4 and calculations of the daily intakes and cancer risks are presented Appendix D.

Table 3 presents the potential cancer risks incurred by a resident who inhales the TCE in indoor air at the rate of  $20 \text{ m}^3/\text{day}$ , 24 hours a day, 350 days a year for 30 years. These exposure factors are those recommended by the U.S. EPA (RAGS-A, 1989 and U.S. EPA Standard Default Exposure Factors, 1991) for quantifying residential risks by the inhalation pathway.

#### 4.4 Risk Assessment Results

Table 3 summarizes the results of the risk assessment. As shown in the table, the predicted excess lifetime cancer risks from exposure to TCE in air are  $5.9 \times 10^{-7}$  for the worst case situation and  $1.8 \times 10^{-7}$  for the nearest downgradient receptor located 150 meters from the source. These risks are below the U.S. EPA's remediation goal range of  $10^{-6}$  to  $10^{-4}$ .

**Table 3. Risk Assessment Results, Exposure to TCE in Indoor Air**

Location	Estimated Ground Water Concentration (mg/L)	Estimated Indoor Air Concentration (mg/m <sup>3</sup> )	Excess Lifetime Cancer Risk
Highest Predicted Concentration and Risk - 50 m from Source	0.11	$8.4 \times 10^{-4}$	$5.9 \times 10^{-7}$
Predicted Concentrations and Risks - 150 m from source	0.035	$2.6 \times 10^{-4}$	$1.8 \times 10^{-7}$

The predicted air concentrations are also below the risk-based residential remediation goal for TCE published by U.S.EPA Regions 3 and 9 ( $1.1 \times 10^{-3} \text{ mg/m}^3$ ).

Note that the U.S. EPA in Soil Screening Guidance Technical Background Document published in 1996 states "EPA has selected a default DAF (dilution-attenuation factor) of 20 to account for contaminant dilution during transport through the saturated zone to a compliance point", and "A DAF of 20 is protective of sources up to 0.5 acres in size". The dilutions

projected by the AT123D model in this assessment (10X to 28X) from source to receptor correspond well with the EPA guidance for this source size.





**APPENDIX A**  
**GROUND WATER MODELING DATA**



0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Z = 5.00

					X	
Y	0.	50.	100.	150.	200.	250.
30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Z = 10.00

					X	
Y	0.	50.	100.	150.	200.	250.
30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Z = 20.00

					X	
Y	0.	50.	100.	150.	200.	250.
30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Z = 30.00

					X	
Y	0.	50.	100.	150.	200.	250.
30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.4380E+05 HRS  
 (ADSORBED CHEMICAL CONC. = 0.0000E+00 \* DISSOLVED CHEMICAL CONC.)

Z = 0.00

					X	
Y	0.	50.	100.	150.	200.	250.
30.	0.200E-01	0.357E-01	0.305E-01	0.249E-01	0.204E-01	0.172E-01
15.	0.637E-01	0.833E-01	0.445E-01	0.318E-01	0.244E-01	0.198E-01
0.	0.914E-01	0.112E+00	0.510E-01	0.347E-01	0.260E-01	0.208E-01
-15.	0.637E-01	0.833E-01	0.445E-01	0.318E-01	0.244E-01	0.198E-01
-30.	0.200E-01	0.357E-01	0.305E-01	0.249E-01	0.204E-01	0.172E-01

Z = 5.00

Y	X					
	0.	50.	100.	150.	200.	250.
30.	0.158E-01	0.302E-01	0.279E-01	0.234E-01	0.195E-01	0.166E-01
15.	0.474E-01	0.663E-01	0.403E-01	0.298E-01	0.233E-01	0.191E-01
0.	0.673E-01	0.874E-01	0.460E-01	0.325E-01	0.248E-01	0.201E-01
-15.	0.474E-01	0.663E-01	0.403E-01	0.298E-01	0.233E-01	0.191E-01
-30.	0.158E-01	0.302E-01	0.279E-01	0.234E-01	0.195E-01	0.166E-01

Z = 10.00

Y	X					
	0.	50.	100.	150.	200.	250.
30.	0.841E-02	0.194E-01	0.216E-01	0.196E-01	0.171E-01	0.149E-01
15.	0.210E-01	0.366E-01	0.304E-01	0.247E-01	0.203E-01	0.172E-01
0.	0.286E-01	0.460E-01	0.344E-01	0.269E-01	0.216E-01	0.180E-01
-15.	0.210E-01	0.366E-01	0.304E-01	0.247E-01	0.203E-01	0.172E-01
-30.	0.841E-02	0.194E-01	0.216E-01	0.196E-01	0.171E-01	0.149E-01

Z = 20.00

Y	X					
	0.	50.	100.	150.	200.	250.
30.	0.169E-02	0.543E-02	0.871E-02	0.100E-01	0.102E-01	0.984E-02
15.	0.261E-02	0.787E-02	0.115E-01	0.123E-01	0.120E-01	0.113E-01
0.	0.306E-02	0.899E-02	0.127E-01	0.133E-01	0.127E-01	0.118E-01
-15.	0.261E-02	0.787E-02	0.115E-01	0.123E-01	0.120E-01	0.113E-01
-30.	0.169E-02	0.543E-02	0.871E-02	0.100E-01	0.102E-01	0.984E-02

Z = 30.00

Y	X					
	0.	50.	100.	150.	200.	250.
30.	0.328E-03	0.121E-02	0.255E-02	0.379E-02	0.464E-02	0.512E-02
15.	0.433E-03	0.157E-02	0.317E-02	0.452E-02	0.538E-02	0.581E-02
0.	0.479E-03	0.172E-02	0.342E-02	0.482E-02	0.567E-02	0.607E-02
-15.	0.433E-03	0.157E-02	0.317E-02	0.452E-02	0.538E-02	0.581E-02
-30.	0.328E-03	0.121E-02	0.255E-02	0.379E-02	0.464E-02	0.512E-02

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.8760E+05 HRS  
 (ADSORBED CHEMICAL CONC. = 0.0000E+00 \* DISSOLVED CHEMICAL CONC.)

Z = 0.00

Y	X					
	0.	50.	100.	150.	200.	250.
30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-15.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-30.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Z = 5.00

X



**APPENDIX B**

**CALCULATION OF INDOOR AIR CONCENTRATIONS**

**Calculation of Volatilization Factor from Groundwater  
from Risk-Based Corrective Action (RBCA) Equations**

Trichoroethene

**VFwesp = Groundwater to Enclosed Space Volatilization Factor (mg/m<sup>3</sup>-air/mg/L-H<sub>2</sub>O)**

H = Henry's Law Constant (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -air) -Dimensionless	4.22E-01
Lgw = Depth to ground water (cm)	90
ER Enclosed-space air exchange rate (1/sec)- Residential	0.00014
Lb = Enclosed space volume/infiltration area ratio (cm) - Residential	200
D(eff)ws = Effective diffusivity above water table (cm <sup>2</sup> /sec)	5.07E-05
<b>(D(eff)ws/Lgw)/(ER x Lb)- Residential</b>	<b>2.01E-05</b>
<b>Numerator - Residential</b>	<b>8.49E-03</b>

**Calculation of D(eff)ws**

hcap = Thickness of capillary fringe (cm)	30
hv = Thickness of vadose zone (cm)	60
D(eff)cap = Effective diffusivity in the capillary zone - calculated (cm <sup>2</sup> /sec)	1.70E-05
D(eff)s = Effective diffusivity in vadose zone soils - calculated (cm <sup>2</sup> /sec)	7.75E-03

**D(eff)ws = 5.07E-05**

**Calculation of D(eff)cap**

Dair = Diffusion coefficient in air (cm <sup>2</sup> /sec)	0.079
THacap = Volumetric air content in capillary fringe soils (cm <sup>3</sup> -air/cm <sup>3</sup> -soil)	0.043
THt = Total soil porosity (cm <sup>3</sup> -pore space/cm <sup>3</sup> -soil)	0.43
Dwat = Diffusion coefficient in water (cm <sup>2</sup> /sec)	9.10E-06
H = Henry's Law Constant (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -air) -Dimensionless	4.22E-01
THwcap = Volumetric water content in capillary fringe soils (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -soil)	0.387
<b>D(eff)cap =</b>	<b>1.70E-05</b>

**Calculation of D(eff)s**

Dair = Diffusion coefficient in air (cm <sup>2</sup> /sec)	0.079
THas = Volumetric air content in vadose zone soils (cm <sup>3</sup> -air/cm <sup>3</sup> -soil)	0.3
THt = Total soil porosity (cm <sup>3</sup> -pore space/cm <sup>3</sup> -soil)	0.43
Dwat = Diffusion coefficient in water (cm <sup>2</sup> /sec)	9.10E-06
H = Henry's Law Constant (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -air) -Dimensionless	4.22E-01
THws = Volumetric water content in vadose zone soils (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -soil)	0.13
<b>D(eff)s =</b>	<b>7.75E-03</b>

**Calculation of D(eff)crack**

Dair = Diffusion coefficient in air (cm <sup>2</sup> /sec)	0.079
THacrack = Volumetric air content in foundation/wall cracks (cm <sup>3</sup> -air/cm <sup>3</sup> -total volume)	0.26
THt = Total soil porosity (cm <sup>3</sup> -pore space/cm <sup>3</sup> -soil)	0.38
Dwat = Diffusion coefficient in water (cm <sup>2</sup> /sec)	9.10E-06
H = Henry's Law Constant (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -air) -Dimensionless	4.22E-01
THwcrack = Volumetric water content in foundation/wall cracks (cm <sup>3</sup> -H <sub>2</sub> O/cm <sup>3</sup> -total volume)	0.12
<b>D(eff)crack =</b>	<b>6.16E-03</b>

**(D(eff)s / Lgw) / (D(eff)crack / Lcrack)**

D(eff)ws =	5.07E-05
Lgw =	90
D(eff)crack =	6.16E-03
Foundation or wall thickness (cm) - Lcrack =	15
areal fraction of cracks in walls - h =	0.01
<b>(D(eff)s / Lgw) / (D(eff)crack / Lcrack) h =</b>	<b>1.37E-01</b>

**Calculation of VFwesp**

Numerator (Residential)=	8.49E-03
(D(eff)ws/Lgw)/(ER x Lb) =	2.01E-05
(D(eff)s / Lgw) / (D(eff)crack / Lcrack) h =	1.37E-01
<b>VFwesp (Residential)=</b>	<b>7.46E-03</b>

**Calculation of Indoor Air Concentrations  
50 Meters Downgradient**

CONSTITUENT	VFWesp (mg/m <sup>3</sup> -air)/ (mg/L-H <sub>2</sub> O)	Water Concentration (mg/L-H <sub>2</sub> O)	Air Concentration (mg/m <sup>3</sup> -air)
Trichoroethene	7.46E-03	1.12E-01	8.36E-04

**Calculation of Indoor Air Concentrations  
150 Meters Downgradient**

CONSTITUENT	VFWesp (mg/m <sup>3</sup> -air)/ (mg/L-H <sub>2</sub> O)	Water Concentration (mg/L-H <sub>2</sub> O)	Air Concentration (mg/m <sup>3</sup> -air)
Trichoroethene	7.46E-03	3.47E-02	2.59E-04



**APPENDIX C**  
**RISK ASSESSMENT CALCULATIONS**

**RISK ASSESSMENT CALCULATIONS - OFF-SITE RESIDENTIAL EXPOSURES**  
**INHALATION OF INDOOR AMBIENT AIR**  
**50 Meters Downgradient**

**Residential**

COMPOUND	Air Concentration mg/m <sup>3</sup>	Inhalation Rate m <sup>3</sup> /day	Exposure Frequency days	Exposure Duration years	Body Weight kg	Averaging Time Cancer days	Dose Cancer (mg/kg/day)	CSF inhalation (mg/kg/day) <sup>-1</sup>	Cancer Risk
Trichloroethene	8.36E-04	20	350	30	70	25,550	9.82E-05	6.00E-03	5.89E-07

**RISK ASSESSMENT CALCULATIONS - OFF-SITE RESIDENTIAL EXPOSURES**  
**INHALATION OF INDOOR AMBIENT AIR**  
**150 Meters Downgradient**

**Residential**

COMPOUND	Air Concentration mg/m <sup>3</sup>	Inhalation Rate m <sup>3</sup> /day	Exposure Frequency days	Exposure Duration years	Body Weight kg	Averaging Time Cancer days	Dose Cancer (mg/kg/day)	CSF inhalation (mg/kg/day) <sup>-1</sup>	Cancer Risk
Trichloroethene	2.59E-04	20	350	30	70	25,550	3.04E-05	6.00E-03	1.82E-07