A COMPARISON OF TESTED AND ESTIMATED PARAMETERS IN A RISK ASSESSMENT OF AND WATER QUALITY ANALYSIS OF A LUST SITE IN THE PERMIAN GARBER SANDSTONE

By

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NOMENCLATURE

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AT123D	Analytical Transport: One, Two, and Three Dimensional Model
BGS	Below Ground Surface
BP	British Petroleum
CEC	Cation Exchange Capacity
DSS	Decision Support System
DTW	Depth To Water
F&T	Fate and Transport Parameters
FPR	Free Product Recovery
GSI	Groundwater Services, Inc.
ISGC	Investigation for Soil and Groundwater Clean-up
LUST	Leaking Underground Storage Tank
OCC	Oklahoma Corporation Commission
ORBCA	Oklahoma Risk-Based Corrective Action
OWRB	Oklahoma Water Resources Board
POE	Point Of Exposure
RBCA	Risk-Based Corrective Action
RBSL	Risk-Based Screening Level
RISC	Risk-Integrated Software for Clean-ups
SSTL	Site Specific Target Level
TDS	Total Dissolved Solids
TOC	Top Of Casing
USGS	United States Geological Survey
VADSAT	Vadose Zone/Saturated Zone Model

CHAPTER I

Introduction

Overview

More than 2000 documented leaking underground storage tanks (LUSTs) are in Oklahoma, and each of these sites will be closed or cleaned up depending on the results from a risk analysis. The Oklahoma Corporation Commission (OCC) has adopted the American Society for Testing and Materials (ASTM) standards for risk-based clean-ups and developed software to calculate acceptable chemical concentrations that can be left in the ground. One LUST site is a truck stop in Oklahoma City, Oklahoma; where the Permian Garber Sandstone is exposed (Figure 1). The OCC confirmed the release on March 10, 1998, and assigned the release as OCC LUST Case #064-2040. This case is the focus for this study.

The purpose of the of this study is to compare variations in results between American Petroleum Institute's Decision Support System (API DSS), British Petroleum's Risc-Integrated Software for Clean-ups (BP RISC), and Groundwater Services Incorporated's Risk-Based Corrective Action Tier 2 Tool Kit (GSI RBCA). The comparison was expanded to evaluating the effect of entering estimated values that are acceptable by the environmental industry versus entering values that were derived in a state-certified laboratory or measured in the field.

In five monitoring wells at OCC LUST Case #064-2040 the elevation of groundwater is at least five feet higher than the other 27 wells. The water quality analyses from the set of the five wells and from the set of the 27 wells were gathered to determine whether the waters are connected. This is a secondary purpose of this study.

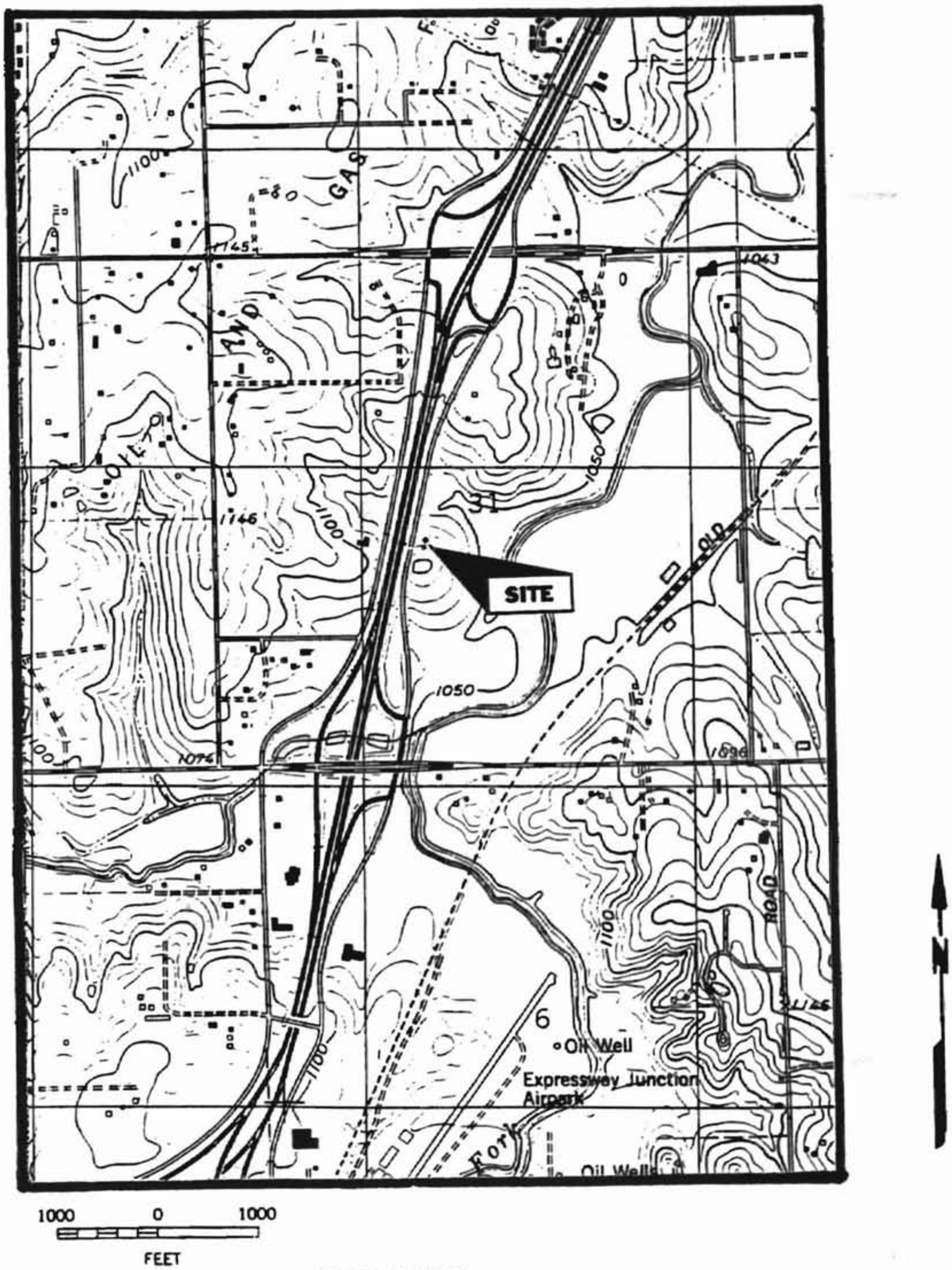
Case History

OCC LUST Case #064-2040 opened March 10, 1998 with the confirmed release. Average depth to water (DTW) is approximately 30 feet below ground surface (BGS). Free product (non-aqueous-phase hydrocarbons) is in the subsurface. In the monitoring wells, the free product column has been as long as 10 feet. Thirty-two monitoring wells have been drilled at this site to delineate the free product plume that is floating on the groundwater (Figure 2) (ORBCA 1998).

The on-site truck stop does not have access to city water and uses a water well located on-site approximately 25 feet from the observed edge of the free product plume. There is no Oklahoma Water Resources Board (OWRB) well record of this water well. The water well is 62 feet deep, the screened interval is unknown, and the top of groundwater is approximately 37 feet BGS. The well was sampled for dissolved hydrocarbons in April and May 1998. The results were 0.0051 mg/L of benzene, 0.0007 mg/L of toluene, 0.0012 mg/L of xylenes, and amounts less than detection limits of ethylbenzene and total petroleum hydrocarbons, in both the diesel and gasoline range. A carbon canister was installed on the well as a

Figure 1 - Site Location Map

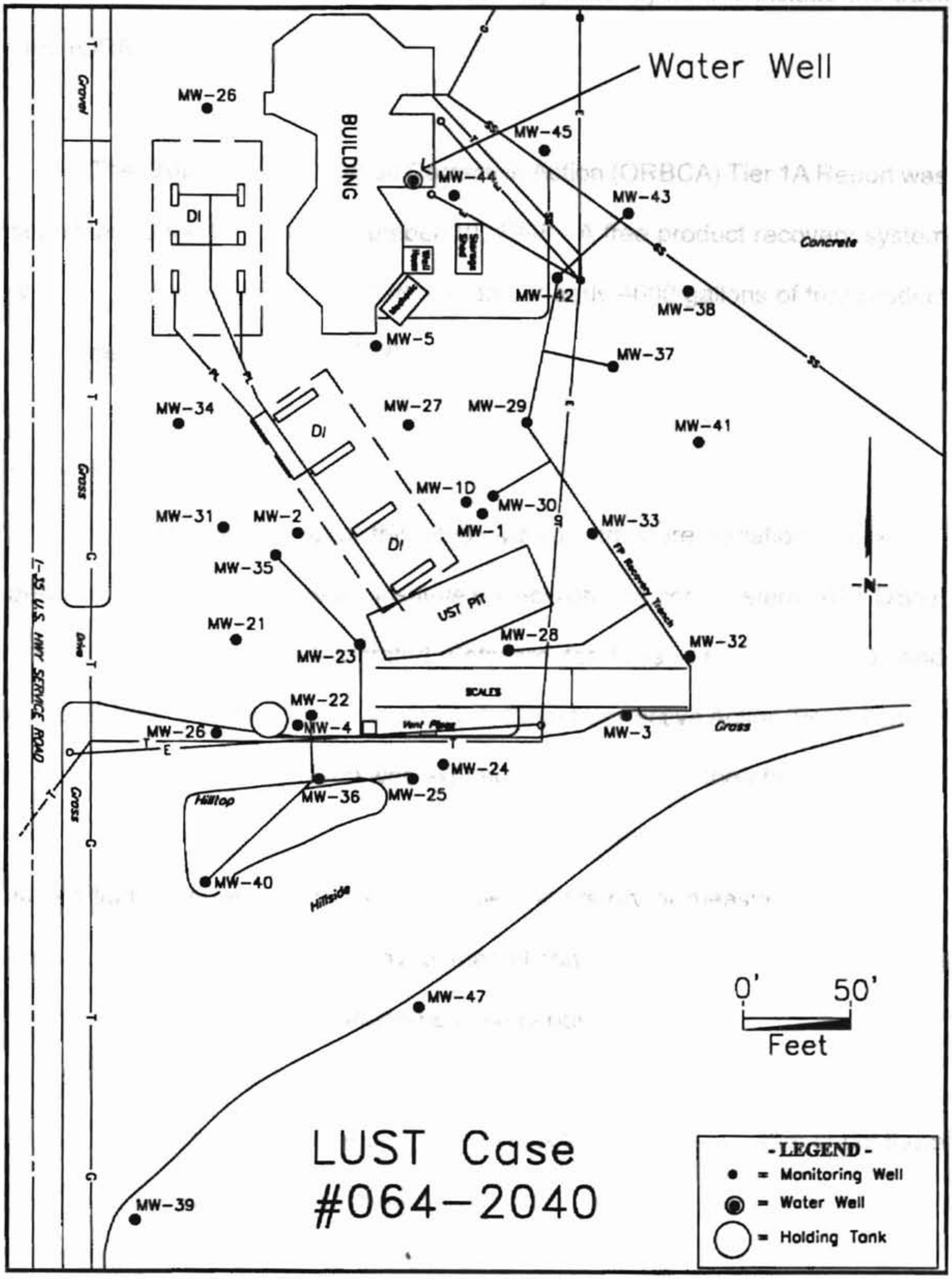
SPENCER QUADRANGLE
OKLAHOMA–OKLAHOMA CO.



FFP-OKC
Case #064-2040

Topographic Map

Figure 2 - Site Map



temporary measure until a city-water line is extended to the site. Plans have been submitted to Oklahoma City to extend the city water system to include the truck stop (ORBCA 1998).

The Oklahoma Risk-Based Corrective Action (ORBCA) Tier 1A Report was submitted to the OCC on September 10, 1998. A free product recovery system was installed on October 19, 1998. To date, nearly 4000 gallons of free product have been recovered (FPR 1999).

<u>Objectives</u>

The purpose of the of this study was to compare variations in results between American Petroleum Institute's Decision Support System (API DSS), British Petroleum's Risc-Integrated Software for Clean-ups (BP RISC), and Groundwater Services Incorporated's Risk-Based Corrective Action Tier 2 Tool Kit (GSI RBCA). The comparison was expanded to evaluating the effect of entering estimated values that are acceptable by the environmental industry versus entering values that were derived in a state-certified laboratory or measured in the field. This study should be useful to environmental consultants who make decisions in risk assessments and risk management every day.

The secondary purpose of this study was to determine whether or not there is a perched aquifer in the local subsurface.

CHAPTER II

Review of the Garber Aquifer

Review of Literature

The Garber aquifer is a well studied sandstone because water is drawn from it to supply the largest city in Oklahoma, Oklahoma City. Many papers have been written and many conferences held concerning the water quality and local contamination of the aquifer.

The OWRB has conducted studies and subcontracted for studies. Pettyjohn and White (1986) prepared a report on water resources in Oklahoma for the OWRB. In this report, sources of water were discussed as well as how to treat the water to make it potable. The report gives general overviews about hardness, total dissolved solids (TDS), and major ions in water from the Garber Sandstone and other aquifers that are in Oklahoma. (Pettyjohn and White 1986)

The aquifer's groundwater quality has been compared to the aquifer's lithology by authors G. N. Breit and J. L. Schlottmann (1994) of the United States Geological Survey (USGS). They concluded that water chemistry could be related directly to how the clay-rich rocks are distributed. Two main water types are correlated to the subsurface matrix; where sandstone is more than 50% of the Garber aquifer the water type is Ca-Mg-HCO_3, but where sandstone is less than 50% the water is the type Na-HCO_3 (Breit and Schottmann 1994)

Personnel associated with Tinker Air Force Base have studied the Garber Sandstone and developed a conceptual model that divides the groundwater into four zones; perched, top of regional, regional, and producing zone. Table 1 lists the water quality of the main zones (ISGC 1996).

Table 1 - Background Averages of Groundwater Quality (mg/L)

Source: PES 1996	Perched	Regional	Producing Zone
Aquifer Type	unconfined	unconfined	unconfined
Depth to Water (feet)	15-30	110-175	250-700
arsenic	0.010	0.002	0.002
barium	1.11	0.663	<0.500
cadmium	0.010	<0.0075	<0.0075
chromium	0.046	<0.010	<0.010
lead	0.057	0.048	0.033
mercury	<0.0004	<0.0004	<0.0004
selenium	0.0021	0.0005	0.0021
silver	0.010	<0.010	<0.010
nickel	0.101	0.033	0.019
zinc	0.11	0.12	0.44
chloride	297.4	42.1	4.9
sulfate	82.8	21.0	5.8
conductivity μmhos/cm	684.0	718.0	442.0
pH S.U.	7.10	9.80	7.17
TOC	3.9	5.3	2.2
cyanide	<0.20	<0.20	<0.20
alpha pc/L	55.2	3.7	4.2
beta pc/L	106.8	9.3	9.0

The Tinker Air Force Base studies also show that strata of shale have influenced the water-bearing zones. These shales are very sandy, with 25% - 40% sand grains, and are lean, with liquid limits of 30% - 35% (ISGC 1996).

The shales are composed of clays that react with calcium in the groundwater; this reaction is known as ion exchange or natural softening. The following equation demonstrates this process.

$$2\ Na\text{-}clay + Ca^{2+} \rightarrow Ca\text{-}clay + Na^{+}$$

When dolomite is dissolved, Ca^{2+} and Mg^{2+} are liberated and these ions react with clays (Henderson 1984). Different types of clays have different cation exchange capacities (CEC). The values for CEC respective to different clays are not exact, the variation in pH and ions present can affect the CEC (Table 2).

Table 2 - Cation Exchange Capacities (meq/100g)

Clay Type	Henderson 1984	Drever 1997
Kaolinite	3-15	1-10
Glauconite	11-20	no data
Illite	10-40	10-40
Smectites (montmorillonite)	80-150	80-150
Vermiculites	100-150	120-200
Mn(IV) and Fe(III) oxyhydroxides	100-740	no data

Sequence of Stratigraphy

The combined Garber Sandstone - Wellington Formation is approximately 900 feet thick in the study area. The Garber stratigraphic unit consists of approximately 60% lenticular and interbedded sandstone with the lower 250 feet consisting of mostly reddish brown shales and siltstone, sandy and lean. The Garber Sandstone is from the Permian Period, Sumner Group. Formations overlying the Garber are the Fairmont Shale and the Salt Plains Formation of the Hennessey Group and above that lies the Duncan Sandstone of the El Reno Group. Below the Garber is the Wellington Formation also of the Sumner Group. Below the Wellington Formation is the Pennsylvanian Oscar Group (Figure 3) (Bingham and Moore 1991 and ISGC 1996).

Structural Geology

The Garber Sandstone outcrops in Central Oklahoma with the majority of the recharge area being in the eastern halves of Logan, Oklahoma, and Cleveland Counties. The regional formation dips westward about 15 feet per mile (Figure 4) (Bingham and Moore 1991).

Mineralogy

The Garber Sandstone is reddish orange to reddish brown, very fine-grained, and poorly cemented with a clay matrix, and some silica and dolomite. Grains are subangular to subrounded, and are mostly quartz. Most of the clay is montmorillonite (Breit 1994 and ISGC 1996).

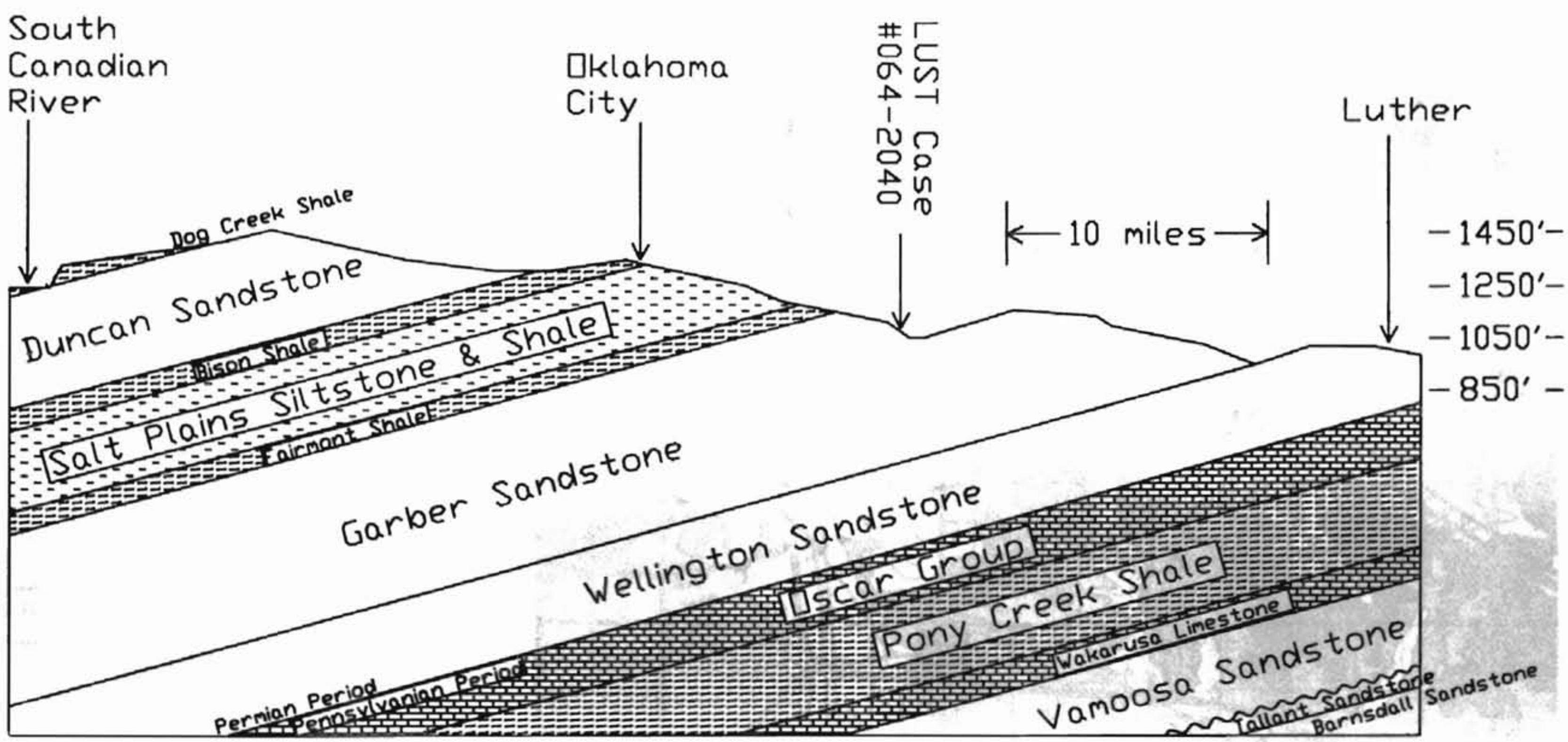
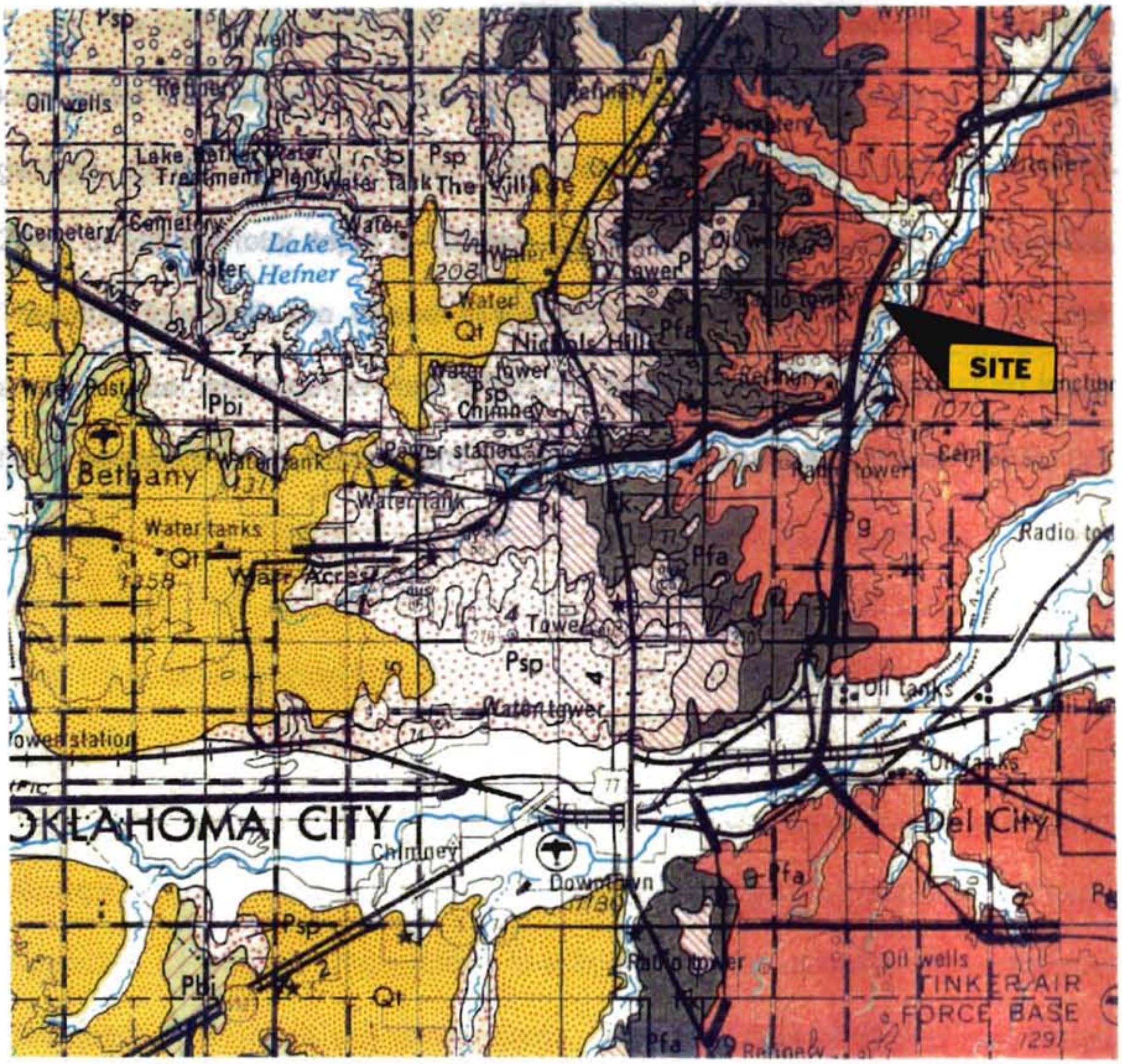
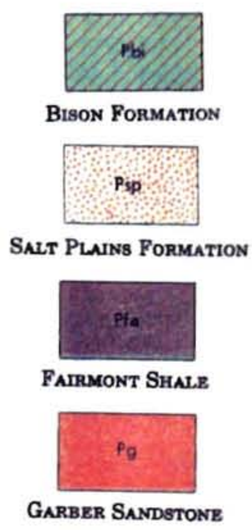


Figure 3 - Stratigraphic Cross-Section (Bingham and Moore 1991)

Figure 4 - Geologic Map (Bingham and Moore 1991)





ROY H. BINGHAM and ROBERT L. MOORE **1991**

Hydrology

The Garber Sandstone is one the major aquifers in Oklahoma. Data from local water wells indicate that the aquifer's yield rate is in the range of 150 to 300 gal/min. Of the eight water wells in the near vicinity of OCC LUST Case #064-2040, in half the total depth is 100 feet and the water level is 30 to 75 feet BGS. The other four wells are deeper in the Garber; total depths are about 700 feet, and the water levels range from 100 to 280 feet BGS. The regional groundwater flows westward to southwestward in this region (Bingham and Moore 1991).

CHAPTER III

Analysis of Local Aquifer

Purpose of Water-Quality Study

The secondary purpose of this study was to determine whether is a perched aquifer is in the local subsurface. Since OCC LUST Case #064-2040 began and the 32 monitoring wells were drilled, five monitoring wells have consistently been anomalous. In these five monitoring wells, elevation of groundwater is over five feet higher than in the other 27 monitoring wells (Figure 5), suggesting that there is a local perched aquifer above the main shallow unconfined Garber aquifer. Other principal characteristics of the site are described below.

1.) Gasoline recovered from monitoring wells was tested in a state-certified laboratory for degradation, the tests indicated that this product could still be used in gasoline as long as it was added to a fresh gasoline mixture. This evidence indicates that the plume is a young plume. The given date of release was March 1998, and the length of the plume is approximately 250 feet (Figure 6). The free product is or has been present in four of the five anomalous wells, and in 20 other wells. This fact indicates that the 24 wells are interconnected

2.) One of the anomalous wells is MW-2, which is 8.5 feet upgradient from MW-35. On January 21, 1999, traceable dye was injected in MW-2 (Figure 5, left central part of site). The dye appeared in MW-35 seven days later.

Figure 5 - Groundwater Elevation Map

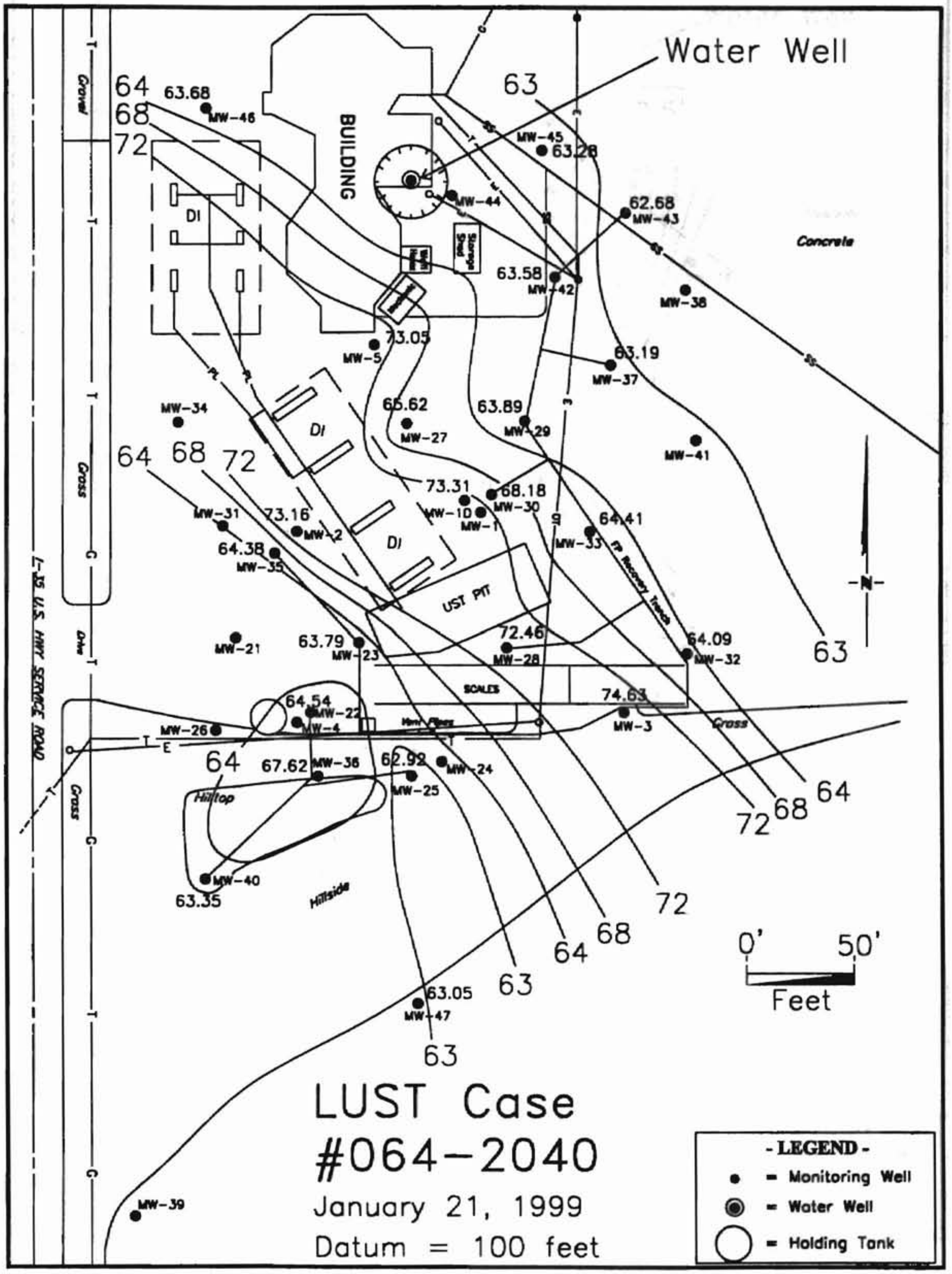
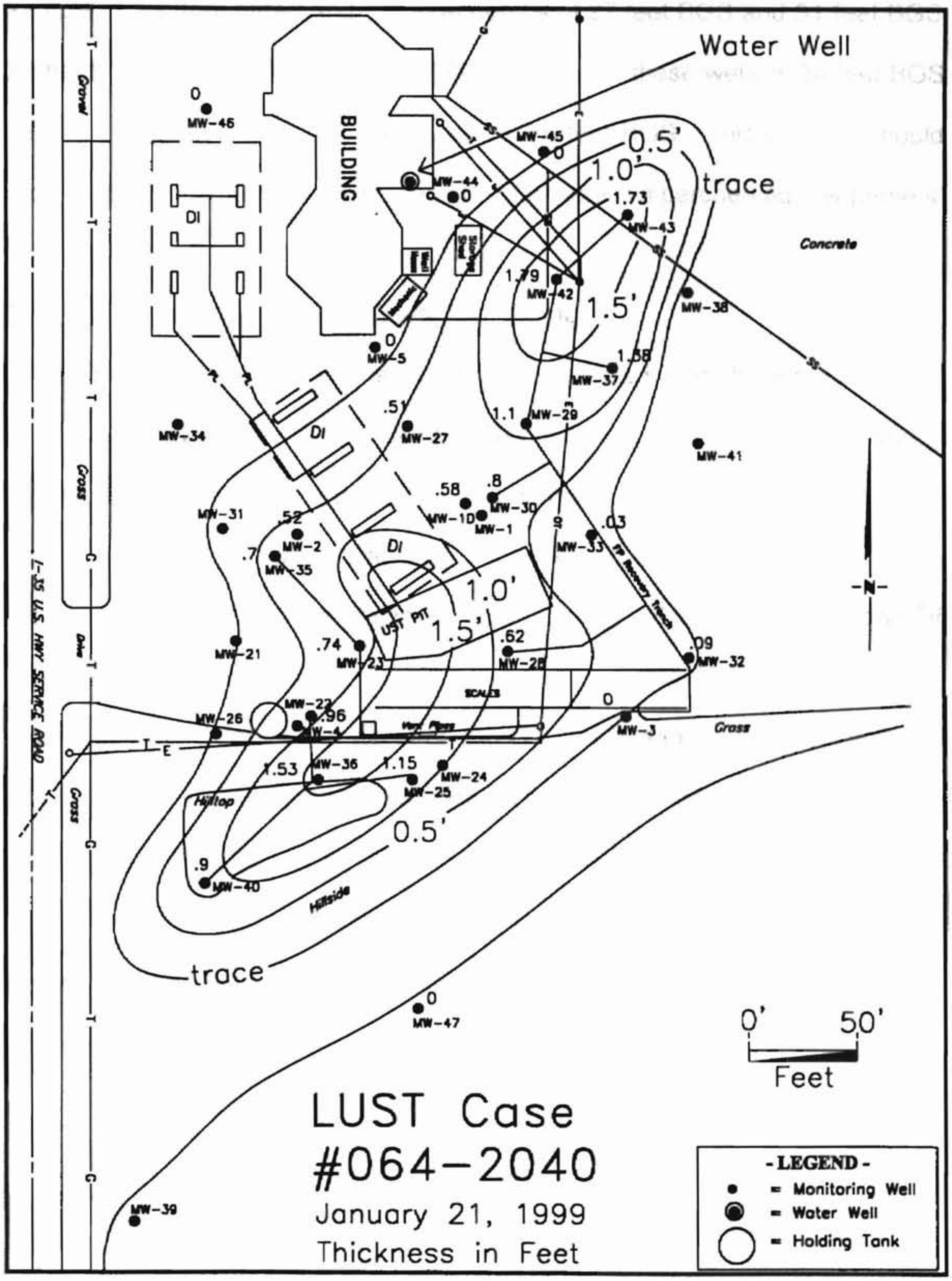


Figure 6 - Estimated Thickness of Gasoline at Site



3.) The only indication of an impermeable barrier was derived from the sample cores from MW-2 and MW-5 at depths of 27 feet BGS and 31 feet BGS respectively. The average corrected DTW in both of these wells is 24 feet BGS whereas in nearby wells corrected DTW is 30 feet BGS. This evidence could indicate the waters are not connected and that there is a perched aquifer present.

Methodology for Collection of Water-Quality Data

To determine whether the waters are connected, samples were collected from MW-1D (where average corrected DTW is 23 feet) and from MW-30 (where average corrected DTW is 29 feet). The samples were collected adherent to Appendix E of "Sampling Handling Protocol for Low, Medium, and High Concentration of Hazardous Waste" of ER 1110-1-263 of the U.S. Army Corps of Engineers. MW-1D is approximately 11 feet southwest of MW-30 (see central part, Figure 5). The difference in top-of-casing (TOC) elevation is 0.25 feet with the TOC at 6 inches below ground in each well. The groundwater samples were analyzed for the major ions. Results were entered into WATEVAL - a water equilibrium computer model that runs reliability checks and gives a "first cut" deduction about the source rock (Hounslow 1995). Table 3 shows the results of the analyses.

Table 3 - Results of Water-Quality Analyses.

	MW-1D - 23' BGS				MW-30 - 29' BGS			
Ion or Parameter	mg/L	mmol/L	meq/L	% meq/L	mg/L	mmol/L	meq/L	%meq/L
Na^+	162	7.05	7.05	53.3	74	3.22	3.22	21
Ca^{2+}	64	1.60	3.19	24.2	118	2.94	5.89	38.5
Mg^{2+}	35	1.44	2.88	21.8	75	3.08	6.17	40.3
K^+	4	0.10	0.1	0.8	1	0.03	0.03	0.2
cation sum	265		13.22		268		15.31	
NO_3^-	<1	<.02	<.02	0	<1	<.02	<.02	0
Cl^-	50	1.41	1.41	11.4	141	3.98	3.98	28.8
SO_4^{2-}	9	0.09	0.19	1.5	14	0.15	0.29	2.1
CO_3^{2-}	0	0.00	0	0	0	0.00	0	
$CO_3^{2-}{}_{calculated}$	2.2				1.6			
HCO_3^-	656	10.75	10.75	87.7	583	9.55	9.55	69.1
$HCO_3^-{}_{calculated}$	651.6				579.8			
anion sum	715		12.71		738		14.12	
SiO_2	21.42	0.36	0.36		18	0.30	0.3	
pH	8				7.9			
EC	1140				1249			
Estimated EC	1322				1530			
TSS	980				1006			
Total Diss. $Solids_{calc}$	1001.42				1024			
Total Diss. $Solids_{180}$	668				728			
Total Hardness	303.7				603			
Total $Hardness_{calc}$	303.88				603.4			
Langelier Index	0.74				0.82			
SAR	4				1.3			
Alkalinity	538				478			
$Alkalinity_{calc}$	537.98				477.93			

Reliability Checks

Both samples are acceptable with respect to the proportions of the major ions. A list of the reliability checks from Hounslow (1995) are in Appendix D. The only major difference in the reliability checks is the sodium / chloride ratio which will be discussed in the source rock deductions.

Deductions About Source Rock

The source rock is a quarzose sandstone. The cement is mostly clay with some silica and dolomite. The sandstone was observed when the monitoring wells were drilled; additional evidence is silica in the groundwater. The dolomite cement is indicated by the ratio of magnesium to calcium - the values in both samples are almost equal. The equation from Drever (1997) for dissolution of the dolomite cement is as follows.

$$CaMg(CO_3)_2 = Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$$

Ion exchange, by removal of calcium and magnesium from groundwater and concurrent release of sodium into groundwater, is strongly suggested by the high amount of sodium in relation to the amount of chloride. Sodium could also have been be released from montmorillonite clay, however there would be very little clay since the sand grains are fine-grained and sub-angular to sub-rounded.

The bicarbonate source is dolomite dissolution. Hardness of groundwater is temporary; and the water is over-saturated with respect to calcite, according to the positive value of the Langelier Index.

CHAPTER IV

Risk Assessment of Local Aquifer

Risk Assessment Methodology and Software Overview

Risk assessment has evolved from simply noting the dangers of environmental pollutants to in-depth studies of de minimus risk, lengthy procedures, and large data requirements. The risk assessment process includes four steps which are Hazard Identification, Dose-Response assessment, Exposure Assessment, and Risk Characterization (EPA 1989 - Risk Assessment).

The last step - Risk Characterization is the stage in which the software models are utilized. The software packages that were studied consists of two phases; fate and transport of the chemical to the receptor and the exposure pathway that the receptor will have to the chemical. The required parameters for the software can be quite detailed and costly to acquire, therefore estimations of the parameters are used extensively in the environmental industry. It is difficult to compare risk assessments when there are several users each using different models and different estimated parameters. Both Lynn Spence (1997) and Sheldon Reaven (1990) advise that risk assessments should be used as a "first-cut" tool towards risk management and not as the final word since the estimations used in risk assessments offer a false sense of precision and accuracy (Spence 1997 and Reaven 1990).

The three software models that were studied are American Petroleum Institute's Decision Support System (API DSS), British Petroleum's Risc-Integrated Software for Clean-ups (BP RISC), and Groundwater Services Incorporated's Risk-Based Corrective Action Tier 2 Tool Kit (GSI RBCA).

API's DSS models one receptor that can be exposed to a maximum of 6 pathways. DSS requires the user to enter chemical concentrations and site data. The user also has the option to enter some or all of the required data as a Monte Carlo Analysis, the Monte Carlo Analysis is beyond the scope of this study. The model will calculate the Point-of-Exposure (POE) concentration and the receptor's risks. DSS does not perform back calculations (Spence 1998).

RISC operates similar to DSS but also has a RBCA Tier 1 Spreadsheet to calculate RBSLs. The focus of this study was tier 2 analyses where SSTLs are generated, therefore the Tier 1 Spreadsheet for RBSLs was not utilized. BP's RISC allows for 1 or 2 receptors with each one being exposed to a maximum of 9 pathways. RISC has an option to deterministically calculate clean-up levels for one receptor per run. RISC does allow uncertainty analysis (e.g. Monte Carlo analysis). RISC can back calculate SSTLs by converting user input of the Target Risk to a Target Concentration at the source (Spence 1997).

API's DSS and BP's RISC were both written by Lynn Spence. They are essentially the same suite of models although DSS is more robust because the user can choose the specific fate and transport model to be used; whereas in RISC, the models' computer codes have been combined into different media equations (i.e. unsaturated zone to groundwater). Both DSS and RISC have shower models. RISC has an indoor air model where as DSS does not. The second version of DSS (currently in beta testing) is used in this study and contains an updated version of AT123D, while RISC uses the first version of AT123D. RISC will include an ecological pathway (e.g. vegetable and fish consumption) in a future version. RISC can calculate risks from surface water, but cannot model contaminant transport to a surface water body (Spence 1997 and 1998).

GSI's RBCA Tier 2 Tool Kit permits consideration of multiple receptors and pathways but the outputs are SSTLs for each environmental media. A shower model is not included in RBCA. Receptors and pathways are listed for each media and only the lowest clean-up level of all receptors is shown. RBCA uses the identical fate and transport equations found in the ASTM Standard. GSI's RBCA does not allow uncertainty analysis. The user chooses the receptors (but cannot have an onsite and offsite receptor in the same run), site data, and receptors' exposure factors to the chemical. The user enters a value of acceptable risk (i.e. from 10E-6 to 10E-4) and then the RBCA Tier 2 Tool Kit uses fate and transport equations to back calculate the equivalent POE concentration (GSI 1997).

Purpose of the Model Comparison

The purpose of the of this study is to compare variations in results between American Petroleum Institute's Decision Support System (API DSS), British Petroleum's Risc-Integrated Software for Clean-ups (BP RISC), and Groundwater Services Incorporated's Risk-Based Corrective Action Tier 2 Tool Kit (GSI RBCA). The comparison was expanded to evaluating the effect of entering estimated values of fate and transport and exposure parameters that are accepted by the environmental industry versus entering values that were tested in a state-certified laboratory or measured in the field. The analysis did not include Monte Carlo or biodegradation due to the need for high concentrations and risks to compare across several models. Biodegradation greatly affects the risk assessment as evidenced by Klinchuch (1995).

Methodology for Selection of Model Parameters

Eighteen pathways shown on Table 4 are completed by four receptors: residential adult and child, commercial worker, and truck driver. The completed pathways were ran in each of the three software models with estimated or "default" values for most of the parameters and measured or best estimated for those parameters where estimations can not work (i. e., depth to water). The eighteen completed pathways were ran again in each of the software models with only measured values where possible. See Figures 5 and 6 for the parameters used.

Table 4 - Completed Pathways

Completed Pathways That Were Modeled	
Residential Child	Dermal Exposure to Groundwater in Shower
	Inhalation of Vapors in Shower
	Ingestion of Groundwater
	Indoor Inhalation of Groundwater Emissions
	Outdoor Inhalation of Groundwater Emissions
Residential Adult	Dermal Exposure to Groundwater in Shower
	Inhalation of Vapors in Shower
	Ingestion of Groundwater
	Indoor Inhalation of Groundwater Emissions
	Outdoor Inhalation of Groundwater Emissions
Truck Driver	Dermal Exposure to Groundwater in Shower
	Inhalation of Vapors in Shower
	Ingestion of Groundwater
	Indoor Inhalation of Groundwater Emissions
	Outdoor Inhalation of Groundwater Emissions
Commercial Worker	Ingestion of Groundwater
	Indoor Inhalation of Groundwater Emissions
	Outdoor Inhalation of Groundwater Emissions

Table 5 - Fate and Transport Parameters

Fate & Transport Parameter	unit	Estimate	Measured/ Best Estimate	Source
Type of Source		constant		
Depth to Groundwater	m		7.14	Observed
Vadose Zone Thickness	m		7.01	Observed
Capillary Fringe Thickness	m		0.13	Observed
Aquifer Thickness (assume infinite width)	m		100	Bingham 1991
Thickness of Soil Above Contamination	m	5.14	6.6	Observed
Source Length	m		80	Observed
Source Width	m		37	Observed
Source Depth	m	2	0.54	Observed
Vadose Porosity	unitless	0.35	0.364	Laboratory
Vadose Volumetric Water Content	unitless	0.2	0.08	Laboratory
Vadose Volumetric Air Content	unitless	0.15	0.284	Laboratory
Vadose Soil Dry Bulk Density	g/cm^3	1.7	1.68	Laboratory
Vadose Fraction Organic Carbon	g C/g soil	0.01	0.00077	Laboratory
Vadose Infiltration Rate	m/day		0.002	Bingham 1991
Aquifer Porosity	unitless	0.35	0.407	Laboratory
Aquifer Volumetric Water Content	unitless	0.2	0.311	Laboratory
Aquifer Volumetric Air Content	unitless	0.15	0.096	Laboratory
Aquifer Soil Dry Bulk Density	g/cm^3	1.7	1.59	Laboratory
Aquifer Fraction Organic Carbon	g C/g soil	0.01	0.00085	Laboratory
Van Genucten's "n" Parameter for Aquifer	unitless		2.68	Spence 1997
Hydraulic Conductivity	m/day	0.021	0.2	Slug Tests
Groundwater Darcy Velocity	ft/yr	1.9	18	Slug Tests
Groundwater Flow Velocity	ft/yr	4.68	43.8	Slug Tests
Hydraulic Gradient	ft/ft	0.1	0.074	Observed
Longitudinal Dispersivity	m		1/10 the POE	Spence 1998
Transverse Dispersivity	m		1/10 Long. Dis.	Spence 1998
Vertical Dispersivity	m		1/10 Trans. Dis.	Spence 1998
Wind Speed	cm/sec	225		Spence 1998
Length of Box for Outdoor Air Inhalation	m	10		Spence 1998
Air Exchange Rate - Comm. Worker	1/hr	20		Spence 1998
Building Length	m	15	45	Observed
Building Width	m	15	23	Observed
Building Ceiling Height	m	3	3	Observed
Air Exchange Rate - Resident	1/hr	0.25	0.3	Spence 1998
House Length	m		24	Default
House Width	m		18	Default
House Ceiling Height	m		3	Default
Basement Wall Thickness	m	0.15		Default
Fraction of Area Exposed by Cracks	unitless	0.01		Default
POE Distance to Station Building	m		21	Observed
POE Distance to Residents	m		490	Observed
X coordinate to water well	m		0	Observed
Y coordinate to water well	m		21	Observed
Z coordinate to top of screen	m		10	Observed
Z coordinate to bottom of screen	m		19	Observed

Table 6 - Exposure Parameters

Exposure Parameter	unit	Estimate	Measured/ Best Estimate	Source
Body Weight for Adult	Kg	70		EPA 1989
Body Weight for Child	Kg	15		EPA 1989
Lifetime for Adult	years	70		EPA 1989
Lifetime for Child	years	6		EPA 1989
Exposure Frequency -Resident	day/yr	350		EPA 1989
Exposure Frequency - Comm. Worker	day/yr	250	310	Observed
Exposure Frequency - Truck Driver	day/yr	52		Default
Exposure Duration - Resident Adult	years	30	12	EPA 1989
Exposure Duration - Resident Child	years	30	12	EPA 1989
Exposure Duration - Comm. Worker	years	9	5	EPA 1989
Exposure Duration - Truck Driver	years	5		Default
Water Ingestion Rate - Resident	L/day	2	1.4	EPA 1989
Water Ingestion Rate - Comm. Worker & Truck Driver	L/day	2	1.4	EPA 1989
Indoor Inhalation Rate - Resident	m^3/hr	0.937	0.833	EPA 1989
Indoor Inhalation Rate - Comm. Worker & Truck Driver	m^3/hr	2	0.833	EPA 1989
Skin Surface Area - arms and hands	cm^2	3160		EPA 1989
Total Skin Surface Area - Adult	cm^2	23000		Spence 1998
Total Skin Surface Area - Child	cm^2	7280		Spence 1998
Indoor Exposure Time - Resident Adult	hr/day	16	19	Default
Indoor Exposure Time - Resident Child	hr/day	16		EPA 1989
Indoor Exposure Time - Comm. Worker	hr/day	8		EPA 1989
Indoor Exposure Time - Truck Driver	hr/day	2		Default
Outdoor Exposure Time - Resident Adult	hr/day	16	5	EPA 1989
Outdoor Exposure Time - Resident Child	hr/day	16	8	EPA 1989
Outdoor Exposure Time -Comm. Worker	hr/day	8	3	EPA 1989
Outdoor Exposure Truck Driver	hr/day	0.5		Default
Soil Skin Adherence Factor	mg/cm^2	1	0.5	Default
Bioavailability	unitless	1	0.5	Default
Exposure Time in Shower	hr/day	0.333		Default
Fraction of Chemical Volatized in Shower	unitless	1		EPA 1989
Temperature of Shower Water	C	45		Spence 1998
Shower Flow Rate	L/min	10		EPA 1989
Volume of Shower	m^3	3		Spence 1998
Water Droplet Diameter	cm	0.1		Spence 1998
Water Droplet Drop Time	sec	2		Spence 1998
Soil ppm - Benzene 11, Toluene 240, Ethylbenzene 91, Xylene 430, TPH-D 2500				
Free Product is present on GW, ppm effective solubilities are used, Bz 44.39, Tol 26.54, EBz 2.87, Xyl 46.56				

The measured Fate and Transport (F&T) data was collected during site investigations for OCC LUST Case #064-2040. The vadose and aquifer data was tested in a state-certified laboratory from samples collected during drilling events. The estimated exposure parameters were taken from the ORBCA Guidelines and the EPA's Exposure Factors Handbook. The exposure parameters are estimated more frequently than the fate and transport parameters because they are more expensive to measure and collect.

A fate and transport parameter that is often estimated and merits some discussion is volumetric water content. Though not the case in this study since the measured value is within an acceptable range, volumetric water content is often the source of much debate and many incorrect Site Specific Target Levels (SSTLs). According to Fetter (1993) "One must be careful in measuring volumetric water content since in many soils (especially those with fine textures) the volume changes as the water is imbibed or drained. This is due to the interaction between the charged soil particles and the polar water molecules.", it is quite common to have soil data that is oversaturated with respect to volumetric water content. When this happens, a good remedy taken from Driscoll (1986) is to calculate volumetric water content from representative specific yield rates for various soils and the reported porosity. The equation is: % Porosity - % Specific yield = % Volumetric Water Content (Fetter 1993 and Driscoll 1986).

The measured dimensions for the station building were collected during site investigations. The measured exposure frequency for the commercial worker came from conversations with station personnel. The best estimate exposure frequency for the truck driver was derived from the following assumptions. There are many truck drivers who shower, eat, and fill their diesel tanks. The frequency and duration for each of these activities vary with the job assignment of the trucker. It was assumed that one trucker would take a shower once/week when he or she stopped for fuel. It was further assumed the trucker drove the same weekly route for a duration of five years.

The estimated hydraulic conductivity was derived by making a conservative assumption that the release occurred 50 years ago and has spread 80 meters since the release date. The resulting hydraulic conductivity was calculated at .021 m/day. The measured hydraulic conductivity was collected from four LUST Sites that are within five miles of the subject site and within the same lithologic zone as the subject site (Table 7).

Table 7 - Measured Hydraulic Conductivities (m/day)

LUST Case Number	Hydraulic Conductivity
064-2123	.1
064-1446	.2
064-1621	.3
064-QH	.2

The average (0.2 m/day) of the four data points was used. This hydrologic data was calculated from slug tests. The procedure for conducting a slug test is to record the static water level in a single borehole. Then remove over half of the water column. At time zero, record the new water level, then record the water level often until the water level returns to within 37% of the static water level. The slug test was conducted following the guidelines outlined in "EPA Method 9100 3.4 Single Well Tests" (EPA 1985). The hydraulic conductivity equation is the Hvorslev Slug Test Method, see below. (Fetter 1994 and Freeze 1979)

$$K = \frac{r^2 \ln(Le/R)}{2\ Le\ T_o}$$

Where K = hydraulic conductivity
r = radius of well casing
Le = Length of the gravel pack
R = radius of the borehole
T_o = Time elapsed until water level returned to within 37% of static level

Procedure for Model Comparison

Eighteen completed pathways were ran in each of the software models using estimated or "default" values for most of the parameters and using measured or best estimated values for those parameters where estimations cannot work (i.e., depth to water). Then the eighteen completed pathways were ran again in each of the software models using only best estimate or measured values. To evaluate the effect of estimated versus measured parameters, the RISC software output for benzene was compared across the 18 pathways. To evaluate the performance of the three software packages, software output from the measured runs was compared across the 18 pathways. Table 8 summarizes the models' output for benzene. Output from all runs is listed by pathway in Appendix F.

Table 8 - Model Output Summary (benzene)

Receptor	Pathway	Output	API DSS	GSI RBCA	BP RISC
Resident Child	Dermal Exposure to Groundwater in Shower	Risk	3.12E-06	can not model	2.20E-06
		SSTL			0.775
		Concentration	0.0165		0.135
	Inhalation of Vapors in Shower	Risk	5.66E-04	can not model	1.90E-04
		SSTL			0.775
		Concentration	0.55		0.135
	Ingestion of Groundwater	Risk	8.58E-05	0.0003	5.90E-05
		SSTL		0.31	0.775
		Concentration	0.0165		0.135
	Indoor Inhalation of Groundwater Emissions	Risk	can not model	0.0003	1.20E-05
		SSTL		0.044	0.775
		Concentration			0.006
	Outdoor Inhalation of Groundwater Emissions	Risk	can not model	0.0003	4.40E-10
		SSTL		6.1	0.775
		Concentration			4.18E-07
Resident Adult	Dermal Exposure to Groundwater in Shower	Risk	1.81E-07	can not model	1.50E-06
		SSTL			0.775
		Concentration	0.0165		0.14
	Inhalation of Vapors in Shower	Risk	1.04E-05	can not model	4.00E-05
		SSTL			0.775
		Concentration	0.55		0.135
	Ingestion of Groundwater	Risk	1.58E-06	0.0003	1.30E-05
		SSTL		0.31	0.775
		Concentration	0.0165		0.135
	Indoor Inhalation of Groundwater Emissions	Risk	can not model	0.0003	3.10E-06
		SSTL		0.044	0.775
		Concentration			0.006
	Outdoor Inhalation of Groundwater Emissions	Risk	can not model	0.0003	5.90E-11
		SSTL		6.1	0.775
		Concentration			4.18E-07
Truck Driver	Dermal Exposure to Groundwater in Shower	Risk	7.56E-08	can not model	1.20E-06
		SSTL			1.02
		Concentration	0.112		1.73
	Inhalation of Vapors in Shower	Risk	4.34E-06	can not model	3.20E-05
		SSTL			1.02
		Concentration	0.112		1.73
	Ingestion of Groundwater	Risk	6.58E-07	0.00054	1.00E-05
		SSTL		0.17	1.02
		Concentration	0.112		1.73
	Indoor Inhalation of Groundwater Emissions	Risk	can not model	0.00054	7.40E-09
		SSTL		48	1.02
		Concentration			0.002
	Outdoor Inhalation of Groundwater Emissions	Risk	can not model	0.00054	8.90E-12
		SSTL		98	1.02
		Concentration			1.01E-05
Commercial Worker	Ingestion of Groundwater	Risk	3.92E-06	0.0032	6.10E-05
		SSTL		0.028	0.727
		Concentration	0.112		1.73
	Indoor Inhalation of Groundwater Emissions	Risk	can not model	0.003	1.80E-07
		SSTL		8.1	0.727
		Concentration			0.002
	Outdoor Inhalation of Groundwater Emissions	Risk	can not model	0.003	3.20E-10
		SSTL		16	0.727
		Concentration			1.01E-05

Software Comparison

The first comparison between the three software packages are the pathways that each package is capable of modeling. Eighteen pathways were completed in OCC LUST Case #064-2040, these are denoted on Table 9. GSI's RBCA can not model exposure during showers. API DSS can not model exposure from emissions from groundwater. The only completed pathway in OCC LUST Case #064-2040 that all three software packages can model is groundwater ingestion.

Table 9 - Possible Exposure Pathways

Medium	Pathway	API DSS	BP RISC	GSI RBCA
Surficial Soil				
	Dermal contact	*X	X	X
	Ingestion	*X	X	X
	Leaching to surface water			
Subsurface Soil				
	Dermal contact	*X	X	X
	Ingestion	*X	X	X
	Vadose zone to groundwater	X	X	X
	Phreatic zone to groundwater	X	X	
	Leaching to surface water			
Surface Water				
	Dermal contact		X	
	Ingestion		X	
Groundwater				
	Dermal contact (trench)			
Resident, Truck Driver	Dermal contact during shower	X	X	
Resident, Truck Driver, Commercial Worker	Ingestion	X	X	X
Indoor Air				
	Emissions from surficial soil		X	
	Emissions from subsurface soil			X
	Particulates			
Resident, Truck Driver, Commercial Worker	Emissions from groundwater		X	X
Resident, Truck Driver	Emissions during shower	X		
Outdoor Air				
	Emissions from surficial soil	X	X	X
	Emissions from subsurface soil			X
	Particulates	X		
	Emissions from surface water			
Resident, Truck Driver, Commercial Worker	Emissions from groundwater		X	X
Food				
	Ingestion		future version	
	Dermal contact		future version	

***X = No Fate & Transport Models are utilized, just enter concentrations.**

Consider the following saturated zone equations.

RISC: $R(C/t) = (D_x(C/x^2)) + (D_y(C/y^2)) + (D_z(C/z^2)) - (\delta(C/x)) - \mu C + (M/\theta)$

RBCA: $C = \exp\left\{(x/2D_x)\left(1-\sqrt{1+(4\,\mu D_x R/\delta)}\right)\right\} \mathrm{erf}\left\{S_w/\left(4\sqrt{D_y x}\right)\right\} \mathrm{erf}\left\{S_d/\left(4\sqrt{D_z x}\right)\right\}$

where

- C = Concentration
- C_i = Initial concentration
- x = Distance down-gradient from source to receptor well
- y = Distance cross-gradient from source to receptor well
- z = Vertical distance from top of well screen to bottom of well screen
- t = Time
- R = Retardation Factor
- D_x = Longitudinal Dispersivity
- D_y = Transverse Dispersivity
- D_z = Vertical Dispersivity
- δ = Groundwater Seepage Velocity
- μ = First-order decay rate
- M = Mass flux
- θ = Effective porosity
- S_w = Source width
- S_d = Source depth

DSS VADSAT: $R(C_i/t) = (D_x(C_i/x^2)) + (D_y(C_i/y^2)) + (D_z(C_i/z^2)) - (\delta(C_i/x)) - \mu C_i + (M/\theta)$

where $C_i = (C_i^w)\exp\left(-\left(q_u W_H S_i/\rho_b L_w F_H W_i\right) + \left(D_i^v H_i W_H S_i/\rho_b L_d L_w F_H W_i\right) t\right)$

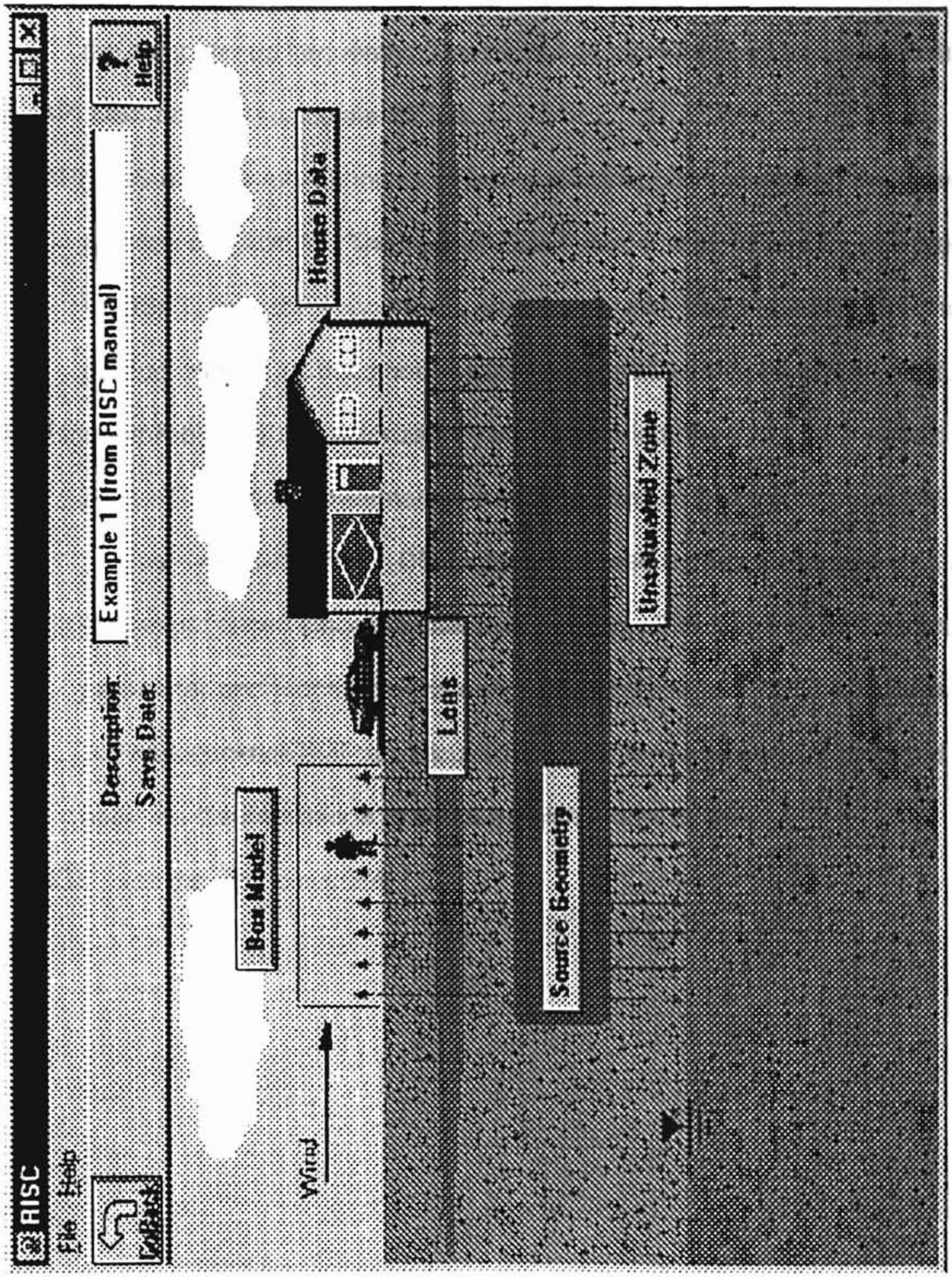
where

- C_i^w = Initial Aqueous Concentration
- q_u = net recharge rate
- W_H = average molecular weight of hydrocarbon
- S_i = aqueous solubility of pure component i
- ρ_b = soil bulk density in the waste zone
- L_d = Diffusion path length
- L_w = thickness of the waste zone
- F_H = mass of hydrocarbon per mass of soil in the waste zone
- D_i^v = effective diffusion coefficient of component i in the soil
- H_i = dimensionless form of Henry's constant for component i
- W_i = Molecular weight of i

Limitations and Attributes of BP RISC

1. RISC calculated higher SSTLs than RBCA for the measured ingestion pathways because the RISC saturated zone model includes cross-gradient distance to the receptor well and considers the depth of well screen.
2. For most pathways, RISC calculated risks between the RBCA and DSS calculations. The risks are lower than RBCA for the previous reasons. The risks and concentrations are higher than DSS because the VADSAT model in DSS allows more of the source concentration to volatilize.
3. RISC successfully back-calculated the POE concentration on every run.
4. The main disadvantage in using RISC in this study was that it could not save a file and perform calculations on the file after the save. Saving a file was attempted several times during this study and each time the software could not locate the saved file to perform calculations. This would make the computer lock up.
5. The user does not specify a certain model to run. There is only one option for the chosen media pathway. The user simply chooses "vadose soil to groundwater model" for example. This is not a discredit to RISC, it certainly makes modeling a lot easier for people to conduct.
6. The required parameters are common in site characterization data.
7. RISC was very user friendly and has on line example parameters for various media. The graphical user interface is appealing. (See captured screen for entering site data in RISC (Figure 7)).
8. RISC uses the metric system.

Figure 7 - Example of RISC Interface (Spence 1997)



Limitations and Attributes of API DSS

1. The main disadvantage with the first version of API DSS was that it would lock the computer up frequently. This did not occur in the Beta Version 2.0 runs.
2. API DSS does not calculate SSTLs.
3. API DSS has the most choices of fate and transport models with the newest addition of VADSAT. The new VADSAT model was utilized for this study. VADSAT can correctly model partitioning and mass loading from free product although it does not simulate subsurface transport of free product.
4. If the available site characterization data is detailed, then API DSS should be used. The intricate parameters that the models in DSS require are difficult and costly to determine. DSS should be used by risk assessors who are very experienced since the user may not know the definition of a particular parameter and jeopardize the entire risk assessment. DSS is a detailed software package that can calculate acceptable concentrations provided the user has the knowledge to choose which model to use.
5. DSS uses the metric system.

Limitations and Attributes of GSI RBCA Tier 2 Tool Kit

1. GSI's RBCA Tier 2 Tool Kit consistently calculated higher risks than DSS or RISC since it calculates down-gradient concentrations only, (not cross-gradient), and does not account for depth of well screen.
2. For the estimated residential pathways, neither DSS or RISC calculated the source concentration to be transported to the POE. GSI's RBCA calculated a risk of 2.4E-4 for the estimated residential ingestion pathways.
3. Back calculation was attempted several times in RBCA during the study, but it does not give data (an equation error would pop up).
4. The main disadvantage associated with RBCA is that the saved files are extensive and require approximately 1400 KB of disk space for each file.
5. GSI's RBCA does not appear to be as robust as the other risk assessment software packages that were studied. It does not use models or code but instead uses one equation for each media.
6. RBCA uses the English system.

Parameter Comparison

In most pathways the measured values were less conservative so the software package calculated lower concentrations at the receptor. Since the measured values' concentrations decreased from the estimated values' concentrations the measured risks were lower too. The SSTLs for the measured values were generally higher than the estimated values' SSTLs. The exceptions can be attributed to the software's performance and equations.

The measured petrophysical values for the vadose and phreatic zones were the main reason that the concentrations decreased from the estimated values. Most important of these is the volumetric water content. This parameter is very sensitive in risk assessment models. If the value for volumetric water content is near the porosity value (within 10%) then the value of the SSTL will be higher than it should be, which is not conservative. If the volumetric water content in the laboratory analysis is near the porosity value, then the following equation from Driscoll (1986) should be applied: % Porosity - % Specific yield = % Volumetric Water Content.

CHAPTER V

Conclusions

Summary of Objectives

The core objective of this study was to compare variations in the results between three risk assessment software packages: American Petroleum Institute's Decision Support System (API DSS), British Petroleum's Risc-Integrated Software for Clean-ups (BP RISC), and Groundwater Services Incorporated's Risk-Based Corrective Action Tier 2 Tool Kit (GSI RBCA).

The second objective was to compare the output when estimated values (accepted by the environmental industry) of fate and transport and exposure parameters were entered to when measured values were entered into the risk assessment software.

The final purpose of this study determined whether a local perched aquifer exists and if the waters are connected.

Results of Software Comparison

Software output from the measured runs was compared across the 18 pathways to evaluate the results of the three software packages. The first comparison was the available pathway options. GSI's RBCA could not model exposure during showers. API DSS could not model exposure from emissions from groundwater. The only completed pathway in OCC LUST Case #064-2040 that all three software packages could model is groundwater ingestion.

<u>The limitations and attributes of BP RISC that were found are as follows.</u>

RISC calculated higher SSTLs than RBCA for the measured ingestion pathways because the RISC saturated zone model includes cross-gradient distance to the receptor well and considers the depth of well screen.

For most pathways, RISC calculated risks between the RBCA and DSS calculations. The risks were lower than RBCA for the previous reasons. The risks and concentrations were higher than DSS because the VADSAT model in DSS allows more of the source concentration to volatilize.

The main disadvantage in using RISC in this study was that it could not save a file and perform calculations on the file after the save. Saving a file was attempted several times and each time the software could not locate the saved file to perform calculations. This would make the computer lock up.

The user could not specify a certain model to run. There was only one option for the chosen media pathway. The user simply chose "vadose soil to groundwater model" for example.

RISC was very user friendly and had on line example parameters for various media. The graphical user interface was appealing.

The limitations and attributes of API DSS that were found are as follows.

The main disadvantage with the first version of API DSS was that it would lock the computer up frequently. This did not occur in the Beta Version 2.0 runs. Also, API DSS could not calculate SSTLs.

API DSS had the most choices of fate and transport models with the newest addition of VADSAT. The new VADSAT model was utilized for this study. VADSAT correctly models partitioning and mass loading from free product although it does not simulate subsurface transport of free product.

The intricate parameters that the models in DSS require were difficult and would have been costly to determine. DSS is a detailed software package that can calculate acceptable concentrations provided the user has the knowledge to choose which model to use.

The limitations and attributes of GSI RBCA that were found are as follows.

GSI's RBCA Tier 2 Tool Kit consistently calculated higher risks than DSS or RISC since it calculates down-gradient concentrations only, (not cross-gradient), and does not account for depth of well screen.

For the estimated residential pathways, neither DSS or RISC calculated the source concentration to be transported to the POE. GSI's RBCA calculated a risk of 2.4E-4 for the estimated residential ingestion pathways.

The main disadvantage associated with RBCA was that the saved files were extensive and require approximately 1400 KB of disk space for each file.

GSI's RBCA did not appear to be as robust as the other risk assessment software packages that were studied. It does not use models or code but instead uses one equation for each media.

Results of Parameter Comparison

The RISC software output for benzene was compared across the 18 pathways to evaluate the effects of estimated and measured parameters. In most pathways the measured values were less conservative so the software package calculated lower concentrations at the receptor. Since the measured values' concentrations decreased from the estimated values' concentrations the measured risks were lower too. The SSTLs for the measured values were generally higher than the estimated values' SSTLs due to the lower risks.

The measured petrophysical values for the vadose and phreatic zones were the main reason that the concentrations decreased from the estimated values. The most important of the petrophysical parameters was the volumetric water content.

If the value for volumetric water content was near the porosity value (within 10%) then the value of the SSTL was higher than it should have been, which is not conservative. If the volumetric water content in the laboratory analysis is near the porosity value, then the following equation from Driscoll (1986) should be applied: % Porosity - % Specific yield = % Volumetric Water Content.

Results of Water Analysis

Out of the 32 monitoring wells at OCC LUST Case #064-2040, five have consistently been anomalous. In these five monitoring wells, elevation of groundwater have ranged from five to ten feet higher than in the other 27 monitoring wells suggesting that there is a local perched aquifer above the main shallow unconfined Garber aquifer. There were four facts considered in this study.

Free-phase hydrocarbons recovered from monitoring wells were tested in a state-certified laboratory for degradation, the tests indicated that the plume is young. The free-phase hydrocarbon plume has spread approximately 250 feet and has been observed in 24 monitoring wells, including 4 of the anomalous five. This evidence indicated that the 24 wells were interconnected. A traceable dye was injected in MW-2 (One of the anomalous wells) which was 8.5 feet upgradient from MW-35 (which was a normal well) on January 21, 1999. The dye appeared seven days later in MW-35.

The only indication that a local perched aquifer could be present was an impermeable barrier that was observed in the sample cores from MW-2 and MW-5. The average corrected DTW in both wells was 24 feet BGS whereas in nearby wells corrected DTW was 30 feet BGS.

Groundwater samples were collected from MW-1D (average corrected DTW was 23 feet) and from MW-30 (average corrected DTW was 29 feet) to be tested for the major ions. The water quality analyses were similar.

The observed facts and water quality analyses that were studied in this thesis indicate that there could be a local aquifer present, but it is hydrologically connected to the main shallow unconfined Garber aquifer.

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Appendix A
Partial ORBCA Tier 1A Report

ORBCA

Tier 2 Analysis

as required by:
OAC 165:25-3-76

FFP
8402 NE Expressway
Oklahoma City, Oklahoma County, Oklahoma

Case # 064-2040
Facility #55-08256

prepared by:
Applied Geoscience Environmental Services, Inc.
3408 French Park Drive, Suite C
Edmond, Oklahoma
(405) 348-5332

February 1999

LUST ID: 064-2040

FACILITY ID: 55-08256

PRIORITY NUMBER: 1.4

FACILITY NAME: Driver's Travel Mart #411

FACILITY ADDRESS: 8402 NE Expressway

FACILITY CITY & COUNTY: Oklahoma City, Oklahoma County

RESPONSIBLE PARTY: Dale Roberts

CERTIFIED UST CONSULTANT: Kathy Lippert

TIER EVALUATION: **I-A**

I certify that all work has been conducted under my supervision and in accordance with the underground Storage Tank Rules and that I am aware that my misrepresentation of any of the information submitted herein is a violation of OAC 165:25-3-90.

____________________	________	#421 December 2000
Certified UST Consultant Signature Date	**Date Signed**	**Certification No. & Expiration**

Kathy Lippert
Certified UST Consultant

By signature below, I certify that I have reviewed this report for completeness

____________________	Dale Roberts	________
Responsible Party Signature	**Responsible Party**	**Date Signed**

EXECUTIVE SUMMARY

REPORT INFORMATION

Section #1 - Facility Information
Section #2 - Site Description
Section #3 - Underground Storage Tank Type
Section #4 - Land Use Summary
Section #5 - Chronology of Events
Section #6 - Release Characterization
Section #7 - UST/Piping Removal Characterization
Section #8 - Site Stratigraphy and Hydrogeology
Section #9 - Water Use
Section #10 - Site Conceptual Exposure Scenario
Section #11 - Tier1a.xls Input/Output & Fate and Transport Parameters with Justifications
Section #12 - Conclusions and Recommendations

REFERENCES & PROTOCOLS

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Vicinity Map
Site Map
Aerial Photo showing Land Use & Zoning
Area Geologic Map
Water Well Map
Points of Exposure Map
Groundwater Gradient Map
Impacted Soil Contour Map
Free Product Plume Map

TABLES & GRAPHS

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Soil Analytical Data
Groundwater Analytical Data
Time vs Concentration Graphs

FIGURES

Soil Boring Logs

APPENDIX

Site Physical Properties Laboratory Reports
Laboratory Analytical Reports
Attachments
OWRB Water Well Search
Driscoll Reference for Volumetric Water Content

LUST: 064-2040 **FACILITY ID: 55-08256**

Date Form Completed: 8/19/98 **Form Completed by:** Rachal Roberts

PRIORITIZATION INDEX NUMBER: 1.4
FACILITY NAME AND ADDRESS: Driver's Travel Mart #411, 8402 NE Expressway
FACILITY LOCATION DESCRIPTION: East of Interstate-35 and north of Wilshire Boulevard
STATUS OF FACILITY: Operating
GROUND SURFACE CONDITION: Paved
ESTIMATED VOLUME RELEASED: 2100 gallons
IS NATIVE SOIL IMPACTED ON-SITE: Yes
IS NATIVE SOIL IMPACTED OFF-SITE: No
IS GROUNDWATER IMPACTED ON-SITE: Yes
IS GROUNDWATER IMPACTED OFF-SITE: Yes
HAS THE SOURCE OF THE RELEASE BEEN IDENTIFIED: Yes
HAS FREE PRODUCT ASSOCIATED WITH THIS RELEASE BEEN FOUND: Yes
HAS SURFACE WATER BEEN IMPACTED BY THIS RELEASE: No
SHALLOWEST DEPTH TO GROUNDWATER ENCOUNTERED: 23.44 feet
AVERAGE DEPTH TO GROUNDWATER: 30 feet
HAS A DRINKING WATER SUPPLY BEEN IMPACTED BY THIS RELEASE: Yes

RECOMMENDATION: (X in front)

__ CLOSURE UNDER TIER 1-A
X REMEDIATE AND CLOSE UNDER TIER 1-A
X GO TO TIER 2
__ CLOSE UNDER TIER 2
__ REMEDIATE AND CLOSE UNDER TIER 2
__ GO TO TIER 3
__ REMEDIATE AND CLOSE UNDER TIER 3
__ MONITOR FOR CLOSURE THROUGH NATURAL ATTENUATION

EXPLANATION OF RECOMMENDATION:

RBSLs are exceeded and free product is present at this site. We recommend recovering all available free product, after this the case will be evaluated for remediation of dissolved phase constituents in the groundwater with the possibility of conducting a Tier 2 analysis.

1. Current land use of the site if no longer an active UST/AST facility:

Site is an active UST facility.

2. Soil stratigraphy and analytical data summary:

The subsurface matrix is the Garber Sandstone. The sandstone is red, fine-grained, and well-cemented. Maximum soil contamination found was in MW-2 at a depth of 26 feet on 4/8/98, ppm levels were: Benzene 11; Toluene 240; Ethylbenzene 91; Xylene 430; TPH-G 920; TPH-D 5457.

3. Aquifer characteristics & groundwater data summary:

The aquifer is approximately 30 feet BGS with a gradient of .074 to the northeast and .049 to the southwest. There is a mounding effect at the tank pit and the water table slopes off to either side. Hydraulic conductivity is calculated to be .07 ft/day. Free product is present at this site with a maximum thickness over 10 feet in MW-42.
Only 9 wells out of 32 do not have free product. Effective solubilities were used in place of maximum concentration values, they are as follows (in ppm):
Benzene 44.39; Toluene 26.54; Ethylbenzene 2.87; Xylene 46.56.

4. Risk assessment analysis:

Current pathways include commercial worker inhalation of vapors from deep groundwater and commercial worker ingestion of deep groundwater. A water well is on site and in use by the station and restaurant. A carbon canister has been placed on the well to filter out hydrocarbons and the responsible party is in the process of extending the city water main to the site. After the city water main has been installed, the current groundwater ingestion pathway will be removed from this analysis.

Future pathways include commercial worker ingestion of deep groundwater via a possible water well that could be drilled 300 feet away from the groundwater plume, and residential inhalation of vapors from and ingestion of deep groundwater. The pathway of dermal contact with deep groundwater by the commercial worker and resident will be modeled in the Tier 2 analysis. The future possible pathway of commercial worker inhalation of vapors from the deep groundwater was considered but not modeled since it is also current, (the current pathway is a more conservative number).

All of the soil RBSLs are exceeded.

There is over ten (10) feet of free product floating on the water table, therefore the groundwater concentrations listed are the effective solubilities. Only 9 wells out of 32 do not have free product. If these 9 were sampled, they would not accurately depict the groundwater contamination, therefore groundwater sampling of the 9 wells was not necessary.

The dissolved groundwater concentrations listed as effective solubilities exceed only the benzene and toluene RBSLs.

5. Overall recommendations of risk assessment:

Based on this Tier 1A analysis, we recommend recovering all available free product. After the free product has been removed, the case will be evaluated for remediation of dissolved phase constituents in the groundwater with the possibility of conducting a Tier 2 analysis.

LUST ID: 064-2040 **FACILITY ID:** 55-08256

Date Form Completed: 8/19/98 **Form Completed by:** Rachal Roberts

FACILITY INFORMATION

Prioritization Index No.: 1.4

Facility Name: Driver's Travel Mart #411

Facility Address: 8402 NE Expressway
Facility City: Oklahoma City
Facility County: Oklahoma County

Facility Location Description: East of Interstate-35 and north of Wilshire Boulevard
Facility Latitude/Longitude: 35° 33' 41" / 97° 27' 22"
Legal Location: NE NE SW Sec. 31 T13N R2W

Facility Owner: Clement Trust
Owner Phone No.: 800-890-3551
Owner Address: P.O. Box 575
Owner City/State/Zip: Burkburnett, TX 76354

Facility Operator: FFP Partners, LP
Facility Phone No.: 817-838-4786

List Previous names of this facility
1. Trucker's Village #2
2.
3.

List Previous Owner(s) of this Facility with Address(es)
1. Red Rock Petroleum
2. Texaco
3.

Has this site ever had an emergency response? No

If yes, then was it: __ State Lead __ Owner/Operator Lead (Discuss under Additional notes, below)

Additional Notes:

SITE DESCRIPTION

Site Status: Operating

Ground Surface Conditions: Paved

Material: Concrete / Asphalt

Degree of cracking (X in front): _Minimal X Low _Moderate _High

Utilities: Designate each utility as - Conduit **(C)**, Potential Conduit **(P)**, or Not a Conduit **(N)**

N	Sanitary Sewer:	Depth: 6 feet	Flow Direction: SE
__	Storm Sewer:	Depth: -----	Flow Direction: -----
N	Electric Lines are overhead		
N	Telephone Line	Depth: 2 feet	
N	Gas line	Depth: 2 feet	
__	Water Line	Depth: ____	Flow Direction: ____

	Yes	No	Dates
Have the utilities been inspected	__	X	____
Are utilities uncovered	__	X	____

IMMEDIATE LAND USE (within 500 feet):

North: Wooded / Ravine
Northeast: Pasture / Wooded

Northwest: Interstate-35
South: Vacant
Southeast: Pasture / Deep Fork Creek

Southwest: Interstate-35
West: Interstate-35
East: Pasture / Deep Fork Creek

Surface Drainage:	Direction(s): NE	Grade (ft/ft): .017
Drainage Discharge:	Stream Yes	If YES, name: Deep Fork
	Lake -----	If YES, name: ________________

Groundwater recharge/discharge area: Yes   If YES, aquifer name: Garber Sandstone

Additional Notes:

UNDERGROUND STORAGE TANK TYPE

Tank No.	Product Type	Capacity (gal)	Active (Y/N)	Installation Date	Out of Use,O/Close,C/Remove,R Date (s)
1	Diesel	12,000	Yes	1985	
2	Diesel	12,000	Yes	1985	
3	Diesel	4,000	Yes	1985	
4	Gasoline	8,000	Yes	1985	
5	Gasoline	8,000	Yes	1985	
6	Gasoline	5,000	Yes	1985	
7	Gasoline	10,000	Yes	1985	

Additional Notes:

LAND USE SUMMARY

The purpose of this section is to identify existing and reasonable beneficial uses for land.

CURRENT LAND USE

	Current (Y/N)	Prior (Y/N)	COMMENTS
Residential	___	___	___
Non-residential	X	X	___
Sensitive/special	---	---	-----
Other	---	---	-----

Distance and direction to the nearest residence (feet):
1600 feet southwest

Distance and direction to any environmentally sensitive area (feet) **within a 1/2 mile** (Define in Notes):
Site is over the Garber Sandstone.
Deep Fork Creek 800 feet east.

Distance and direction to the nearest school, hospital, day care, retirement home, etc., (feet) (specify):
Over 1 mile away.

Distance and direction to the nearest commercial/industrial site (feet) (specify):
600 feet west Statuary Shop

Additional Notes:

FUTURE LAND USE

	Potential (Y/N)	COMMENTS
Residential	___	-----
Non-residential	X	-----
Sensitive/special	---	-----
Other	---	-----

Additional Notes:

CHRONOLOGY OF EVENTS

Date	Event
3/10/98	Release Confirmed, assigned Case #064-2040
3/30/98	72 & 73 Reports submitted.
3/31/98	72 & 73 Reports approved by OCC.
4/8/98	Four (4) monitoring wells installed (MW-1D, MW-1, MW-2, & MW-3)
4/17/98	Two (2) monitoring wells installed (MW-4 and MW-5) Free product found, initiated free product removal.
5/13/98	Free Product Report (FPR) submitted.
5/26/98	Carbon canister attached to water flow from the on-site water well. This is a temporary measure until a permanent drinking water source can be assigned.
6/8-12/98	Nineteen (19) 4" free product recovery wells installed (MW-21 through MW-39)
7/14/98	Five (5) 4" free product recovery wells installed (MW-39 through MW-43)
7/27/98	Free Product Recovery System Workplan submitted.
7/29/98	DEQ meeting to discuss alternate drinking water sources.
8/14/98	FPR submitted
8/18/98	Four (4) 4" free product recovery wells installed (MW-44 through MW-47)
8/19/98	ORBCA Tier 1A Report begun.
9/2/98	Recovery System Workplan resubmitted as a purchase order.

RELEASE CHARACTERIZATION

Release discovered during/by (X in front all that apply):

---	UST Removal	---	Closure in Place
---	Release Detection Equipment	___	Property Transaction
X	Inventory Control	___	System Tightness Testing
---	Citizen Complaint	---	Spill Incident
--	Unknown	---	Other (specify):

Pumping Mechanism (X in front):

X	Pressure	_	Suction	---	Unknown

Sources of Release(s) (X in front all that apply):

---	Spills/overfills	---	Piping
---	Dispenser	X	Tank
___	Unknown	---	Other (specify):------

Substance Released (X in front all that apply):

X	Gasoline	X	Diesel
---	Used Oil	---	AV Gas
---	Jet Fuel	---	Hydraulic Fluid
---	Other: ______		

Has the source of release been identified?:	Yes
Has the release been eliminated?:	Yes
Is groundwater impacted?:	Yes
Is surface water impacted?:	No
Is native soil impacted?:	Yes

DISSOLVED PHASE EXTENT:

Has free product been found at this site (YES/NO)? Yes

If YES, does free product extend off-site?: Yes

If YES, denote greatest thickness (to the nearest 1/100 foot):

Maximum: 12.5 feet

Current: 10.64 feet

If YES, has free product removal been initiated? Yes Method: Manual Bailing/Recovery System

If NO, cite reason: -----

DETAILS OF THE RELEASE(S):

Date Discovered:	**Location:**	**Quantity:**
3/9/98	Inventory Records, tank pit	2100 gallons

TANKS ARE IN PLACE AND ACTIVE

UST/PIPING REMOVAL CHARACTERIZATION

NOTE: A separate SECTION # 7 must be filled out for each UST/AST system removal

Date of removal: **Tank No.:** ----- **Capacity(ies):** -----

EXCAVATED SOIL **Date:** ----- **Quantity:** -----

Details of Excavated Soil:

	Date	Quantity	Location
Stockpiled on-site	-----	-----	-----
Disposed off-site*	-----	-----	-----
Used (as fill material...) on-site	-----	-----	-----
Used as road base*	-----	-----	-----
Soil farm*	-----	-----	-----

Confirmatory soil samples collected after excavation in native soil? Yes / No
(Include the data in Worksheet # 10)

Sampling of excavated soil? Yes / No
(Include the data in Worksheet # 10 only if disposed on-site)

Groundwater sampling during excavation? Yes / No

Status of excavation: (X in front of all that apply)

--- Open with water
--- Open/dry
--- Barricaded
--- Backfilled
 --- with excavated soil --- with clean fill
 --- Pervious cover --- Impervious cover
--- Other: -----

Depth BGS to base of UST pit: -----
Was UST pit over-excavated? ____
If YES, cite dimensions (in feet) and give direction(s): -----
Was piping trench over-excavated? ____
If YES, cite dimensions (in feet) and give direction(s): ____

* Provide as attachments all copies of letters, permits, etc., for off-site removal.

Additional Notes:

SITE STRATIGRAPHY AND HYDROGEOLOGY

Is groundwater impacted by release?: Yes

STRATIGRAPHY

Unconsolidated:

Depth	Unified Soil Classification	General Description of Soil
0'-1'	N/A	Pavement
1'-1.5'	SW	Red Sand

Predominant Soil Type: Vadose - Sand **Saturated** - N/A

Consolidated (Lithified):

Depth	Type of Bedrock & Geologic Formation	Rock properties, features & fractures
1.5'-?	Garber Sandstone, Red, fine-grained, well-cemented.	

Predominant Bedrock Type: Vadose -Sandstone **Saturated** -Sandstone

Average depth at which groundwater was first encountered (ft.): 30
Shallowest depth to water table/piezometer (ft.): 23.44
Flow Direction: NE & SW
Hydraulic Gradient (i) [ft./ft.]: .074 NE & .049 SW

	Vadose Zone 4-6'	Saturated Zone 37-38'
Porosity (q) [cm3/cm3]:	.364	.407
Water Content [cm3/cm3]:	.08	.311
Dry Bulk Density [g/cm3]:	1.68	1.59
Fraction Organic Carbon [g carbon/g soil]	.00077	.00085
Hydraulic Conductivity (K) [ft./day]:		.07

Hydraulic Conductivity test method (X in front): ___ grain size/sieve analysis ___ slug test

___ pump test, period (hours): ___ X other (specified in notes)

Darcy Velocity (Ki): 1.9 ft/yr
Is this a perched aquifer?: No
Is the first groundwater encountered confined?: No
Groundwater level fluctuations (± ft.) (cite greatest known from 1 well): 7 feet
Aquifer name: Garber Sandstone
Annual precipitation, 30-yr avg. (in/yr): 32
Identify any hydrogeologically sensitive areas that are either in, or within 1 mile of the COC's plume:
Site is over the Garber Sandstone. Deep Fork Creek is 800 feet east of the site.

Additional Notes:
The hydraulic conductivity was derived by calculations based on the assumption that the station is 50 years old and the plume has been mobile since the station began. This is a most conservative assumption and will result in a hydraulic conductivity that is lower than actual conditions. The free product plume has traveled 234 feet over 50 years. The Flow velocity is 4.68 ft/yr, the Darcy velocity is flow velocity x porosity = 1.9 ft/yr. The hydraulic conductivity is Darcy velocity / gradient (.074) = 26 ft/yr or .07 ft/day. The northeast gradient was used because the receptor is north of the tank pit.

WATER USE

NOTE: Denote all wells within 1/2 mile radius of the site on Topographic Map

GROUNDWATER RESOURCES

	Y / N Current	Y / N Potential	(e.g. Distance from source to POE) Comments
Domestic Drinking	Yes	___	_____
Irrigation (Non-Agri.)	___	___	_____
Public/Municipal Supply	___	___	_____
Industrial Supply	___	___	_____
Agriculture	___	___	_____
Other (Define in Notes)	Yes	___	Restaurant on site uses water well.
Within Wellhead Protection Area	Yes	___	_____

Likelihood of use of groundwater in the future (X in front):
___None/Extremely Unlikely ___Low X Medium ___**High**

Water Quality (PPM):

TDS: 320	Specific Conductance: -----	Chlorides: 14
Hardness: 156	Nitrates: 1	Iron: -----
Sulfates: 17	Pesticides (specify): -----	Other (specify): -----

Is the site and surrounding area supplied by a public/municipal/rural water district system?: No Responsible party is in the process of extending the city water main to service the station and restaurant.

SURFACE WATER RESOURCES - Not relevant

	Current	Potential	Comments
Domestic supply	___	___	_____
Public/Municipal Supply	___	___	_____
Recreational	___	___	_____
Other	___	___	_____

Likelihood of use of surface water in the future (X in front):
X None/Extremely unlikely ___ Low ___ Medium ___ High

If a stream is, or may potentially be, impacted by COC's, does the stream have:
___ Intermittent water flow X Continuous water flow

Additional Notes:

SITE CONCEPTUAL EXPOSURE SCENARIO - CURRENT CONDITIONS

List all completed exposure pathways and reason(s) for inclusion.
List all questionable exposure pathways and reason(s) for exclusion.
Remove any NOT COMPLETE pathways

Potentially Exposed Receptor	Exposure route, medium, and point of exposure	Justification of inclusion or exclusion of pathways
Resident:		
	No residents within 1600 feet.	
Commercial Worker:		
No	Indoor inhalation of vapors from sub-surficial soil	Soil is not impacted under the building.
Yes	Indoor inhalation of vapors from deep groundwater	Groundwater is impacted under building.
Yes	Ingestion of deep groundwater	Station uses an on site water well, the carbon canister may quite working before the city water line is installed.
Construction Worker:		
	Contamination is too deep for exposure.	

SITE CONCEPTUAL EXPOSURE SCENARIO - FUTURE CONDITIONS

List all completed exposure pathways and reason(s) for inclusion.
List all questionable exposure pathways and reason(s) for exclusion.
Remove any NOT COMPLETE pathways

Potentially Exposed Receptor	Exposure route, medium, and point of exposure	Justification of inclusion or exclusion of pathways
Resident:		
Yes	Ingestion of deep groundwater	Residents are 1600' downgradient.
Yes	Inhalation of deep groundwater	Residents are 1600' downgradient.
Pathways to be evaluated under Tier 2/3		
Yes	Dermal contact with deep groundwater	Residents are 1600' downgradient.
Commercial Worker:		
Yes	Ingestion of deep groundwater	A future water well is possible.
Yes	Indoor inhalation of vapors from deep groundwater	Evaluated under current conditions.
Pathways to be evaluated under Tier 2/3		
Yes	Dermal contact with deep groundwater	A future water well is possible.
Construction Worker:		
	Contamination is too deep for exposure.	

TIER1A.XLS INPUT/OUTPUT

Insert at this point in the report all the input and output spreadsheets from the tier1a.xls file. If you need to make more than one run based on varying site conceptual exposure scenarios or fate and transport parameters, you need to clearly describe those scenarios or parameter changes and section off each run. If a fate and transport factor used is not the default, laboratory analysis or derived from direct field observation, then you need to describe below why you are justified in using that particular value.

Current Tier 1A

In the first analysis, the commercial worker inhalation of vapors from the free product plume was modeled.
POE distance was set to 1 foot since MW-42 has over 10 feet of free product and the building is downgradient from MW-42.

In the second analysis, the commercial worker ingestion of deep groundwater was modeled. Although there is a carbon canister on the current water well, it may quite working before the city water main is installed. Once the water main has been installed, the RBSLs from this pathway will be removed.

Future Tier 1A

In the first future analysis, residential ingestion of deep groundwater was modeled. The POE distance was set at 1600 feet.

In the second future analysis, residential inhalation of deep groundwater was modeled using the same POE distance of 1600 feet.

For the third future analysis, a water well could be drilled near this site. The POE distance was set to 300 feet to reflect current OWRB regulations that a water well can not be drilled within 300 feet of a known contaminant plume. Commercial worker ingestion of groundwater was modeled.

The pathway of dermal contact with deep groundwater by the residents and commercial worker was considered but not modeled since the Tier 1A model is not designed for this particular pathway. When the Tier 2 is completed, the future dermal contact pathway will be modeled with a different software package.

PARAMETER, Units	Tier 1	Tier 2/Tier 3	Source
Source parameters			
Depth to groundwater, cm	714	-----	on-site
Depth to surficial soil sources, cm	30.48	-----	-----
Depth to subsurface soil sources, cm	304.8	-----	-----
Thickness of vadose zone, cm	701	-----	on-site
Building parameters			
Height of the indoor space (Building)			
On/Off-site Resident (adult and child), cm	300	-----	-----
On-site Commercial Worker, cm	300	-----	-----
Construction Worker, cm	300	-----	-----
Width of the indoor space (Building), cm	2256	-----	on-site
Length of the indoor space (Building), cm	4481	-----	on-site
Fraction of area exposed by cracks, %	0.01	-----	-----
Enclosed space air exchange rate			
On/Off-site Resident (adult), 1/day	12	-----	-----
On/Off-site Resident (child), 1/day	12	-----	-----
On/Off-site Commercial Worker, 1/day	18	-----	-----
Averaging time for vapor flux			
On/Off-site Resident (adult), sec	946080000	-----	-----
On/Off-site Resident (child), sec	189216000	-----	-----
On/Off-site Commercial Worker, sec	788400000	-----	-----
Construction Worker, sec	31536000	-----	-----
Groundwater parameters			
Groundwater Darcy velocity, cm/year	57.9	-----	equation
Groundwater mixing zone (source) thickness, cm	457	-----	well log
Source width parallel to flow direction , cm	7925	-----	on-site
Thickness of capillary fringe, cm	13	-----	well log
Soil parameters			
Total soil porosity, cc/cc	0.364	-----	petro
Volumetric water content in vadose zone soils, cc/cc	0.08	-----	petro
Volumetric air content in vadose zone soils, cc/cc	0.15	-----	petro
Soil bulk density, g/cc	1.68	-----	petro
Fraction organic carbon content in soil , g-C/g-soil	0.00077	-----	petro
Other parameters			
Particulate emission rate, g/cm^2-s	6.9E-09	-----	-----
Wind speed over gr. surface in ambient mixing zone, cm/s	225	-----	-----
Width of source parallel to wind direction, cm/yr	2500	-----	-----
Ambient air mixing zone height, cm	200	-----	-----
Infiltration Rate (see Table 5-4)			
West Zone County, cm/yr	7	-----	-----
Central Zone County, cm/yr	10	-----	-----
East Zone County, cm/yr	13	-----	-----

Other parameter(s) specifically for Tier 2/Tier 3

Tier 2/Tier 3 parameter: **Depth to Groundwater**
Justification: observed on site. The shallowest known water level was used, (23.44 feet below ground surface)

Tier 2/Tier 3 parameter: **Vadose Zone and Capillary Fringe Thicknesses**
Justification: observed while drilling, see well logs. The sandstone has a low capillary fringe of 5".

Tier 2/Tier 3 parameter: **Width and Length of Building**
Justification: The on site building measured 74 x 147 feet. For the resident 1600 feet downgradient, the default was used of 2000 x 2000 cm or 66 x 66 ft.

Tier 2/Tier 3 parameter: **Darcy Velocity and Hydraulic Conductivity**
Justification: The hydraulic conductivity was derived by calculations based on the assumption that the station is 50 years old and the plume has been mobile since the station began. This is a most conservative assumption and will result in a hydraulic conductivity that is lower than actual conditions. The free product plume has traveled 234 feet over 50 years. The Flow velocity is 4.68 ft/yr, the Darcy velocity is flow velocity x porosity = 1.9 ft/yr. The hydraulic conductivity is Darcy velocity / gradient (.074) = 26 ft/yr or .07 ft/day. The northeast gradient was used because the receptor is north of the tank pit.

Tier 2/Tier 3 parameter: **Mixing Zone Thickness in Groundwater**
Justification: observed while drilling, see well logs (15 feet)

Tier 2/Tier 3 parameter: **Source Width and Depth**
Justification: observed during field activities. 260 feet long x 10 feet thick.

Tier 2/Tier 3 parameter: **Soil Petrophysical Parameters**
Justification: measured in laboratory

Tier 2/Tier 3 parameter: **Point of Exposure**
Justification: The building is 70 feet downgradient of MW-42 which has over 10 feet of free product in it. Groundwater contamination is known to be under the building, therefore a distance of 14 feet was used.
The future possible commercial worker's water well must be 300 feet away from known contaminant plumes.
The residents are 1600 feet downgradient of the site.

Tier 2/Tier 3 parameter: **Hydraulic Gradient**
Justification: observed during field acitivities. There is a mounding effect at the tank pit with the water table sloping off either side. The gradient on the southwest side is .049 ft/ft. The northeast side's gradient is .074 ft/ft

Comparison of Concentration Levels with the RBSLs (ppm)

Soil	Benzene	Toluene	Ethylbenzene	Xylene
Current				
Comm. soil to protect G.W.	0.0	28.47	14.24	55.71
Future				
Res. soil to protect G.W.	6.93	104.56	166.24	55.71
Comm. soil to protect G.W.	1.19	237.15	118.58	55.71
Minimum soil RBSL	**0.0**	**28.47**	**14.24**	**55.71**
Max. On site level	**11.**	**240.**	**91.**	**430.**
MW-2 26' 4/8/98				

Groundwater				
Current				
Comm. inh deep G.W.	.503	530.739	152.	198.
Comm. ing deep G.W.	.01	20.45	10.22	198.
Future				
Res. Child inh deep G.W.	22.833	57.799	138.468	47.828
Res. Adult inh deep G.W.	21.311	269.726	152.	198.
Res. ing deep G.W.	47.693	508.07	152.	198.
Comm. ing deep G.W.	8.22	170.3	85.15	198.
Minimum G.W. RBSL	**.01**	**20.45**	**10.22**	**47.828**
Max. On site level	**44.39**	**26.54**	**2.87**	**46.56**

The effective solubilities were listed because free product is present at the site.

Res. = Residential
ing = ingestion
G.W. = groundwater

Comm = commercial worker
inh = inhalation

CONCLUSIONS AND RECOMMENDATIONS OF TIER 1-A ANALYSES

Maximum chemical-of-concern (C-O-C) concentrations compared with minimum modified Risk-Based Screening Levels (RBSLs) for all completed pathways, excluding cross- or down-gradient groundwater ingestion receptors. Comparisons should only be made with soil that still exists in the area or groundwater data that is no more than two years old. If free product exists list maximum solubility concentrations.

Maximum Soil C-O-C Concentration		Min. Allowable Mod. RBSL	Exceed/Nonexceeded
Benzene	----- mg/Kg	----- mg/Kg	-----
Toluene	----- mg/Kg	----- mg/Kg	-----
Ethylbenzene	----- mg/Kg	----- mg/Kg	-----
Xylenes	----- mg/Kg	----- mg/Kg	-----

Max. Groundwater C-O-C Concentration		Minimum Mod. RBSL	Exceed/Nonexceeded
Benzene	44.39 mg/L	.503 mg/L	exceeded
Toluene	26.54 mg/L	57.799 mg/L	not exceeded
Ethylbenzene	2.87 mg/L	138.468 mg/L	not exceeded
Xylenes	46.56 mg/L	47.828 mg/L	not exceeded

Are there any cross- or down-gradient groundwater ingestion receptors?: Yes
If YES, what is the direction and distance to the nearest receptor?: Well is in the groundwater plume.
If YES, complete the next summary:

GROUNDWATER INGESTION TARGET LEVEL TABLES

Maximum Soil C-O-C Concentration		Minimum Mod. RBSL	Exceed/Nonexceeded
Benzene	11.00 mg/Kg	0.0 mg/Kg	exceeded
Toluene	240.00 mg/Kg	28.47 mg/Kg	exceeded
Ethylbenzene	91.00 mg/Kg	14.24 mg/Kg	exceeded
Xylenes	430.00 mg/Kg	55.71 mg/Kg	exceeded

Max. Groundwater C-O-C Concentration		Min. Allowable Mod. RBSL	Exceed/Nonexceeded
Benzene	44.39 mg/L	0.01 mg/L	**exceeded**
Toluene	26.54 mg/L	20.45 mg/L	exceeded
Ethylbenzene	2.87 mg/L	10.22 mg/L	**not exceeded**
Xylenes	46.56 mg/L	198.00 mg/L	not exceeded

CONCLUSIONS:

Current pathways include commercial worker inhalation of vapors from deep groundwater and commercial worker ingestion of deep groundwater. A water well is on site and in use by the station and restaurant. A carbon canister has been placed on the well to filter out hydrocarbons and the responsible party is in the process of extending the city water main to the site. After the city water main has been installed, the current groundwater ingestion pathway will be removed from this analysis.

Future pathways include commercial worker ingestion of deep groundwater via a possible water well that could be drilled 300 feet away from the groundwater plume, and residential inhalation of vapors from and ingestion of deep groundwater. The pathway of dermal contact with deep groundwater by the commercial worker and resident will be modeled in the Tier 2 analysis. The future possible pathway of commercial worker inhalation of vapors from the deep groundwater was considered but not modeled since it is also current, (the current pathway is a more conservative number).

All of the soil RBSLs are exceeded.

There is over ten (10) feet of free product floating on the water table, therefore the groundwater concentrations listed are the effective solubilities. Only 9 wells out of 32 do not have free product. If these 9 were sampled, they would not accurately depict the groundwater contamination, therefore groundwater sampling of the 9 wells was not necessary.

The dissolved groundwater concentrations listed as effective solubilities exceed only the benzene and toluene RBSLs.

RECOMMENDATIONS:

Based on this Tier 1A analysis, we recommend recovering all available free product. After the free product has been removed, the case will be evaluated for remediation of dissolved phase constituents in the groundwater with the possibility of conducting a Tier 2 analysis.

LIMITING CONDITIONS

All findings in this report are based on facts and circumstances as they existed during the Assessment. A change in the facts and circumstances upon which this report was based may affect the findings.

In addition, AGES has relied on information derived from OCC prescribed procedures and secondary sources. We have made limited independent investigation to determine the accuracy of these procedures and have assumed that the information is reliable and complete.

The Oklahoma Based Corrective Action Assessment (ORBCA) is an evaluation of the currently identified and perceived future pathways and their completed receptors. The ORBCA is not a guarantee or warranty that the property evaluated is free of all defects with regard to the environmental condition of the property. AGES conclusions and recommendations are based on regulations in force at the time of the assessment. Changes in laws, regulations, jurisdiction, or regulatory procedures could affect the findings of the.report. Furthermore, this Assessment is not a comprehensive engineering study. Residual uncertainty and risk always remain when information is limited

In the future, if any petroleum levels are discovered to exceed those determined appropriate for the site, then the case could be reopened according to OCC UST Rules and Regulations.

SUMMARY OF GROUNDWATER DATA							
Sample ID	Sampled	Benzene	Toluene	Ethylbenzene	Xylene	TPH-G	TPH-D
MW-5	4/20/98	10	33	3.6	12	71	ND
Water Well	4/20/98	0.0051	ND	ND	ND	ND	ND
Water Well, spigot	5/12/98	0.0006	0.0007	ND	0.0012		
Water Well	5/28/98	ND	ND	ND	ND	ND	ND
Water Well, spigot	5/28/98	ND	ND	ND	ND	ND	ND

SUMMARY OF SOIL DATA										
WELL	Sampled	Depth	Benzene	Toluene	Ethylbenzene	Xylene	TPH-G	TPH-D	Naphthalene	MtBE
MW-1	4/8/98	16'	2.8	0.31	0.43	5.6	62	13402		
MW-1D	4/8/98	25-27'	2.2	98	0.76	96	470	2526		
MW-2	4/8/98	26'	11	240	91	430	920	5457		
MW-3	4/8/98	30'	0.018	0.17	0.18	1.2	4.9	ND		
MW-4	4/17/98	25'	ND	0.24	0.46	2.4	9.4	43		
MW-5	4/17/98	2'	ND	ND	ND	ND	ND	ND		
MW-5	4/17/98	25'	ND	ND	ND	ND	ND	ND		
MW-24	6/8/98	40'	0.083	2.5	3.2	19	56	ND	4.2	705
MW-31	6/10/98	30'	ND	ND	ND	ND	0.18	ND		

SOIL BORING LOG .

AGES	FFP - OKC	LOCATION	BORING NUMBER MW-1 D

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	vfg rubyred SS uncon.									weathered
	fg SS uncon. white pink									
	SAA pink red				13					
5	SAA									
	vfg SS uncon. Pink-orange									
	SAA dk red									
	SAA pink red									
	Clayey SS Red slightly cons.									
10	vfg SS uncon. white									
	fg SS orangered uncon.									
	vfg SS Red uncon. w/ chunks of consol.				52					
15	Silty SS white w/ organic matter				173					
	fg SS uncon. orange, organic w/ layer				224					odor, 4" Red SS fg, Black stains
	vfg SS uncon. Red pink organic				75					odor
20	SAA white w/red slight cons.									odor
	fg SS litered, friable w/ caliche thin layer				258					Odor
25	vfg SS white-red slightly cons. w/ hard Layers				309			25-27'		Odor
					473					
	SAA crumbly dry many hard pieces				37					
	TD = 28'									
	.02 Screen 20-28 Blank 0-20									
	No Sand above screen									
	No hole drilled in Sand point									

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND: CLAY; SILT; SAND; GRAVEL; SILTY CLAY; CLAYEY SILT; DEBRIS FILL; MOIST ORGANIC (PEAT); SANDY CLAY; CLAYEY SAND; caliche

DATE DRILLED	4-8-98
PAGE	of
DRILLING METHOD	Hollow Stem
DRILLED BY	Davis Drilling
LOGGED BY	R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	4' N, 7.5' W of MW-1

SOIL BORING LOG .

AGES	FFP: OkC	LOCATION	BORING NUMBER MW-2

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	dk red siltstone w/ clay									slight uncons.
	SAA				4					
5	SAA									
	SAA, med. red color				3					
	No return									
10	med-lite Red fg SS gy white Layers									consolidated
					6					
	SAA									
	Blush-white SS vfg				4					
15	white, Lite red vfg SS thin bedded				10					
	Lite Red vfg SS unconsolid.				74					
20	med Red vfg SS unconsolidated									
	sucrosic coarse grain SS				9					well cemented mineralized.
	dk red fg SS friable unconsolid				10					wet at 25'
25	Orange Red mg SS unconsol.				208		■	26'		moist, slight odor
	3" Caliche layer in gray clay									
	Red sandy silt				184					
30	Shale, Lite red									
	TD = 30'.									
	10' Screen .02 slot									
	20' Blank									
	hole drilled in Sand point									
	Sanded 2' above screen									

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID — Photoionization Detection (ppm)
- NO. — Identifies Sample by Number
- TYPE — Sample Collection Method
- SPLIT-BARREL / AUGER / ROCK CORE / THIN-WALLED TUBE / CONTINUOUS SAMPLER / NO RECOVERY
- DEPTH — Depth Top and Bottom of Sample
- REC. — Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY, SILT, SAND, GRAVEL, SILTY CLAY, CLAYEY SILT, DEBRIS FILL, HIGHLY ORGANIC (PEAT), SANDY CLAY, CLAYEY SAND, caliche, Shale

DATE DRILLED: 4-8-98	PAGE ___ of ___
DRILLING METHOD: Hollow Stem	
DRILLED BY: Davis Drilling	
LOGGED BY: R. Roberts	
EXISTING GRADE ELEVATION (FT. AMSL):	
LOCATION OR GRID COORDINATES: 36' W of cement deisel i	

SOIL BORING LOG .

AGES . FFP - OKC

LOCATION

BORING NUMBER MW-3

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Orange-Red fg SS unconsolid.									
	SAA, white/pink				9					
5	SAA w/a layer 3" dk red fg SS well-cemented									3" had organic matter and was hard
	SAA, red				5					
	SAA, pink									
	SAA white-pink									
10	Dk red clayey sand unconsol									
	mottled white and pink SS w/3" dk red mottle and organics				4					
	Hard Layer at 14'									a thin layer of white vfg SS
15	Orange fg SS				75					
	SAA, Liter color, friable									"wet layer"-"mud"
	Shale, friable, white/red Layers				5					
	white-pink SS fg slightly consol				18					moist
20	SAA, orange red, Friable				47					moist, slight odor
	SAA w/ organics				17					slight odor
	w/ 5" Layer colored yellow at 23'									
	med-lite Red fg SS slightly consolic				145					wet, odor
25	white-yellow vfg SS friable.				253					odor
	Red fg friable SS				309					Odor
	orange SS vfg friable				235					odor
	SAA, orange-red				459					odor
30	SAA, more consolidated				557		■	30'		Odor
	TD = 30'									
	15' screen .02 slot									
	15' = Blank									
	drilled hole in sand point									
	Sanded 2' above screen									

EXPLANATION

▼ Water Table (24 Hour)

▽ Water Table (Time of Boring)

PID Photoionization Detection (ppm)

NO. Identifies Sample by Number

TYPE Sample Collection Method

SPLIT-BARREL | AUGER | ROCK CORE

THIN-WALLED TUBE | CONTINUOUS SAMPLER | NO RECOVERY

DEPTH Depth Top and Bottom of Sample

REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY | DEBRIS FILL

SILT | HIGHLY ORGANIC (PEAT)

SAND | SANDY CLAY

GRAVEL | CLAYEY SAND

SILTY CLAY | shale

CLAYEY SILT | ______

DATE DRILLED 4-8-98

PAGE of

DRILLING METHOD Hollow Stem

DRILLED BY Davis Drilling

LOGGED BY R. Roberts

EXISTING GRADE ELEVATION (FT. AMSL)

LOCATION OR GRID COORDINATES 44'E, 4'N of south tel

SOIL BORING LOG

AGES	FFP-OKC	LOCATION	BORING NUMBER MW-5

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Fill, Concrete									
	Clayey fg SS red uncon.				19					No odor
	fg SS pink uncon				3					
5	SAA slightly cons.				13					
	SAA blushred, friable 6" clayey SS				16					
	SAA pink-white, orn				14					
10	No Recovery									
	Clayey SS Red w/ white hard pieces				13					6' clayey SS white Layer
	vfg SS orange red				10					
15	fg SS conso. pinkish white									
	SAA uncon. orange red				11					slight odor
	SAA pink white									slight odor
	clayey SS dk red, thin white clay Layer				9					odor
20	fg SS yellow + pink uncon.				8					
	SAA red orn SAA orange				3					
	SAA pinkish yellow				15					odor
25	Vfg clayey SS uncon. Red, white Layers				104					odor, dry, crumbly
	fg SS uncon yellow-pink ▽				123					odor, wet
30	SAA				227					has a dirty Blk Layer
	gravely Brown mud				156					hard, wet
	Red clay w/ white pieces				162					wet
	white SS fg uncon.				41					
35	No Recovery.									
	plugged to 32									
	screened 20-32'									
	hole in sand point									
	Sanded 1' above screen									

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND: CLAY; SILT; SAND; GRAVEL; SILTY CLAY; CLAYEY SILT; DEBRIS FILL; HIGHLY ORGANIC (PEAT); SANDY CLAY; CLAYEY SAND

DATE DRILLED	4-17-98
PAGE	of
DRILLING METHOD	Hollow Stem
DRILLED BY	Davis Drilling
LOGGED BY	R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	8' due S of SE corner of Bldg

SOIL BORING LOG

A.G.E.S.	FFP-OKC	LOCATION	BORING NUMBER MW-23

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Concrete									
	Red fg Sandstone									
5	pinkish-white fg SS				24					
										TD= 40 screened 20'-40' 4" well
10	Red fg SS				12					
								No Sample		
15	SAA				14					Hole drilled in Sandpoint
20	SAA				33					
25	SAA				77					Strong hydrocarbon odor
30	SAA				112					
35	SAA with orangish yellow layers ▼				132					
40	SAA				92					SAA

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND: CLAY; SILT; SAND; GRAVEL; SILTY CLAY; CLAYEY SILT; DEBRIS FILL; HIGHLY ORGANIC (PEAT); SANDY CLAY; CLAYEY SAND

DATE DRILLED: 6-8-98
PAGE: 1 of 1
DRILLING METHOD: Solid Stem
DRILLED BY: Davis Drilling
LOGGED BY: R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL):
LOCATION OR GRID COORDINATES:

SOIL BORING LOG

A.G.E.S	FFP-OKC	LOCATION	BORING NUMBER MW-27

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	pavement				10					TD=40' Screened 20-40' hole in Sandpoint 4" well
5	Red, fg Sandstone				7					
10	SAA				7			No sample		Slight hydrocarbon odor
15	SAA with white siltstone layers				9					
20	med-brown fg SS, silt layers				13					Om present
25	Red fg SS				22					very hard
30	SAA, white siltstone layers ▼				11					
35	SAA				7					SAA
40	SAA				13					Wet

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; SILT; SAND; GRAVEL; SILTY CLAY; CLAYEY SILT; DEBRIS FILL; HIGHLY ORGANIC (PEAT); SANDY CLAY; CLAYEY SAND; om organic matter

DATE DRILLED: 6-10-98
PAGE ___ of ___
DRILLING METHOD: Solid Stem
DRILLED BY: Davis Drilling
LOGGED BY: R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL)
LOCATION OR GRID COORDINATES

SOIL BORING LOG

A.G.E.S.	FFP-OKC	LOCATION	BORING NUMBER MW-28

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Concrete									TD= 40 screen 20'-40' 4" well hole in sand point
5	Pink fg-vfg SS				9					
10	Red fg SS				10					faint odor
15	SAA, with white siltstone layers				67			No sample		moderate Hydrocarbon odor
20	Brown + white siltstone + SS vfg				251					strong HC odor
25	Brown fg SS				236					
30	SAA				149					very hard, wet
35	SAA				231					SAA
40	SAA TD:40 20' screen				185					SAA

EXPLANATION

Water Table (24 Hour)
Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL | AUGER | ROCK CORE
THIN-WALLED TUBE | CONTINUOUS SAMPLER | NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY | DEBRIS FILL
SILT | HIGHLY ORGANIC (PEAT)
SAND | SANDY CLAY
GRAVEL | CLAYEY SAND
SILTY CLAY | ____
CLAYEY SILT | ____

DATE DRILLED: 6-10-98
PAGE: 1 of 1
DRILLING METHOD: Solid Stem
DRILLED BY: Davis Drilling
LOGGED BY: R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL):
LOCATION OR GRID COORDINATES:

SOIL BORING LOG

A.G.E.S.	FFP-OKC	LOCATION (4" twin of MW 1-0)	BORING NUMBER MW-30

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0	pavement									
5	Red fg SS				13					TD=40 Screen 20-40' 4" well hole in sandpoint
10	SAA, with white siltstones				212					
	SAA							No Sample		
15	Brown fg SS				192					
20	SAA, with white siltstones				212					
25	Brown fg SS				340					
30	Red fg SS				181					very hard; Strong hydrocarbon odor
35	SAA				226					Wet
40	SAA				265					SAA; SAA

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND: CLAY; SILT; SAND; GRAVEL; SILTY CLAY; CLAYEY SILT; DEBRIS FILL; HIGHLY ORGANIC (PEAT); SANDY CLAY; CLAYEY SAND

DATE DRILLED: 6-10-98

PAGE: 1 of 1

DRILLING METHOD: Solid Stem

DRILLED BY: Davis Drilling

LOGGED BY: R. Roberts

EXISTING GRADE ELEVATION (FT. AMSL):

LOCATION OR GRID COORDINATES:

SOIL BORING LOG

		LOCATION	BORING NUMBER
A.G.E.S.	FFP-OKC	(4" twin of MW-2)	MW-35

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Concrete									
										TD=40'
5	Brownish-red fg SS				9					screen 20'-40'
	Lite tan fg SS									4" Well
										hole in Sandpoint
10	Red fg-vfg SS				19					
15	SAA				13					
	SAA									
20	Lite tan fg SS				9			No sample		
25	Reddish-Brown fg SS				345					moderate hydrocarbon odor
30	SAA, with white siltstone layers				397					faint HC odor
35	SAA				172					
40	SAA				138					Soupy wet

EXPLANATION

Water Table (24 Hour)
Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL
AUGER
ROCK CORE
THIN-WALLED TUBE
CONTINUOUS SAMPLER
NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY — DEBRIS FILL
SILT — HIGHLY ORGANIC (PEAT)
SAND — SANDY CLAY
GRAVEL — CLAYEY SAND
SILTY CLAY
CLAYEY SILT

DATE DRILLED: 6-11-98
PAGE: 1 of 1
DRILLING METHOD: Solid Stem
DRILLED BY: Davis Drilling
LOGGED BY: R. Roberts
EXISTING GRADE ELEVATION (FT. AMSL):
LOCATION OR GRID COORDINATES:

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA 77 Exp. 06/30/99

Area Offices

9200 KING ARTHUR DRIVE	DALLAS, TX 75247	(214) 631-4372
902 TRAILS WEST LOOP	ENID, OK 73703	(405) 237-3130
900 S.E. SECOND	LAWTON, OK 73501	(405) 353-0872
5806 S. 129 EAST AVE.	TULSA, OK 74134	(918) 459-2700

Acct. No: 2AG56 File No: AG56-55
Report Date: 4/27/98
Project: FFP
Location: MW-4 Vadose (4-6')
Arch./Engr:
Contractor: AGES

Date Sampled: 04/17/98
Sampled By: R. Boberts
By Order Of: K. Lippert
Order No:
Quantity Represented: See Below

REPORT: See Below
Specification:

LAB NO: E-1052
Test Method: ASTM D2216, D2937, D854

TEST RESULTS

Sample ID	MW-4
Natural Water Content, (g weight of water/g weight of dry soil)	0.048
Dry Bulk Density, (g/cc)	1.68
Specific Gravity	2.637
Organic Matter, (g organic matter/g soil)	
Walkley Black, Fractional Organic Carbon (g carbon/g soil)	0.00077
Volumetric Water Content (cc volume of water/cc total sample volume)	0.080
Porosity, (cc volume of void/cc total sample volume)	0.364
Soil Description	Light Pink Sandstone

Charge: AGES
Orig. & 1-cc same
1-cc Laboratory

Respectfully submitted,
STANDARD TESTING AND ENGINEERING CO.

Farid Ahmad, MSCE, EI, Laboratory Manager
4-27-98

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA 77 Exp. 06/30/99

Area Offices

9200 KING ARTHUR DRIVE	DALLAS, TX 75247	(214) 631-4372
902 TRAILS WEST LOOP	ENID, OK 73703	(405) 237-3130
900 S.E. SECOND	LAWTON, OK 73501	(405) 353-0872
5806 S. 129 EAST AVE.	TULSA, OK 74134	(918) 459-2700

Acct. No: 2AG56 File No: AG56-55
Report Date: 4/27/98
Project: FFP
Location: MW-4 (37-38') Saturated
Arch./Engr:
Contractor: AGES

Date Sampled: 04/17/98
Sampled By: R. Boberts
By Order Of: K. Lippert
Order No:
Quantity Represented: See Below

REPORT: See Below
Specification:

LAB NO: E-1053
Test Method: ASTM D2216, D2937, D854

TEST RESULTS

Sample ID	MW-4 (37-38') Saturated
Natural Water Content, (g weight of water/g weight of dry soil)	0.196
Dry Bulk Density, (g/cc)	1.59
Specific Gravity	2.674
Organic Matter, (g organic matter/g soil)	
Walkley Black, Fractional Organic Carbon (g carbon/g soil)	0.00085
Volumetric Water Content (cc volume of water/cc total sample volume)	0.311
Porosity, (cc volume of void/cc total sample volume)	0.407
Soil Description	Light Pink Loose Sandstone

Charge: AGES
Orig. & 1-cc same
1-cc Laboratory

Respectfully submitted,
STANDARD TESTING AND ENGINEERING CO.

Farid Ahmad, MSCE, EI, Laboratory Manager
4-27-98

StanTech — # CHAIN - OF - CUSTODY RECORD — **STANDARD TESTING AND ENGINEERING COMPANY**

Page ______ of ______

PROJECT NAME: TFP-OKC

SAMPLER (Print Name): Rachel Roberts

PROJECT NUMBER: ______

SIGNATURE: ______

SAMPLE CONTAINER DESCRIPTION CODES
A. 40-ml VOA Vial — B. Glass Liter — C. Plastic 500-ml — D. Plastic Liter — E. 250-ml Soil Jar — G. Other

SAMPLE DESCRIPTION CODES
A. Ground Water — B. Waste Water — C. Leachate — D. Asbestos — E. Soil/Sediment — F. Air — G. Waste — H. Blank/Spike — I. Other ______

LABORATORY USE ONLY — LAB NO. ______

DATE	TIME	SAMPLE ID	SAMPLE CONTAINER CODE	SAMPLE DESCRIPTION CODE	NUMBERS OF CONTAINERS AND PRESERVATION: UNPRESERVED	HNO_3			G = GRAB C = COMPOSITE	Dry Bulk Density ASTM D2937	Volumetric Moisture ASTM D2216	Specific Gravity ASTM D854	Porosity (By Calculation)	Hydraulic Conductivity ASTM D5084	Grain Size Analysis ASTM D422	F.O.C. Walkley Black	pH of Soil ASTM D4972	Resistivity ASTM G57	Hydraulic Conductivity ASTM D2434	SAMPLE STORED AT 4°C (Please Initials)	NOTES	LAB SAMPLE NUMBER	SAMPLE CONDITION UPON RECEIPT
[illegible]		MW-4 (3-6')							G	✓	✓	✓	✓			✓						[illegible]	[illegible]
[illegible]	[illegible]	MW-4 (37-38')							G	✓	✓	✓	✓			✓						[illegible]	[illegible]

NOTES/MISCELLANEOUS	METHOD OF SHIPMENT	RELINQUISHED BY: (SIGNATURE)	RECEIVED BY: (SIGNATURE)	TIME	DATE
	[illegible]	[illegible]	[signature]	15:03	4/17/98
	DESCRIPTION OF SHIPPING CONTAINER	RELINQUISHED BY: (SIGNATURE)	RECEIVED BY LABORATORY (SIGNATURE)	TIME	DATE
		[signature]	[signature]	1518	4/17/98

SEND RESULTS TO:
Name [illegible] Company [illegible]
Address [illegible]
Phone [illegible] Fax [illegible]

SEND INVOICE TO:
Company [illegible]
Address ______
Phone ______ P.O. NO. ______

RESULTS NEEDED BY: ______
VERBAL NEEDED BY: ______

STANTECH ANALYTICAL SERVICES ■ 3400 NORTH LINCOLN BOULEVARD ■ OKLAHOMA CITY, OKLAHOMA 73105
TELEPHONE (405) 528-0541 ■ FAX (405) 528-0559

Original - Return with Results • Yellow - Lab Copy • Pink - Client Copy

Appendix B
Partial February 1999 Free Product Report

Applied
Geoscience
Environmental
Services, Inc.

Free Product Recovery Report

February 1999

Case #064-2040, Facility #55-08256

FFP, Oklahoma City, Oklahoma

As required by rule 3-75

Site History

After the confirmed release on March 10, 1998, five 2-inch monitoring wells (MW-1D through MW-5) were installed. Upon gauging these wells, free product was discovered in four of them (MWs 1D, 2, 3, and 4). Over the next several months, 27 delineation/recovery wells (4-inch) were installed, MW-20 through MW-47 (MW-6 through MW-19 do not exist at this site). During this investigative period, free product removal and gauging was conducted in a variety of ways. A vacuum truck was hired in April, 1998 to remove free product from the wells, with marginal success. This event was followed by manual weekly free product recovery. In June, 1998 free product recovery events were increased to bi-weekly using a portable pump due to the large volume of product encountered. A total of 350 gallons of fuel were recovered from April to August 1998. All free product was stored in 55-gallon drums on site for later removal by a waste disposal company. (See attached recovery table.)

This site now has a total of 32 monitoring/recovery wells with the last four (4) being drilled August 18, 1998 (see attached soil boring logs). Out of the 32 monitoring wells, MW-31 has trace amounts of free product, 12 wells do not have any free product, and the remaining 19 have measurable thicknesses of free product.

The Free Product Recovery System Proposal was submitted to the OCC on July 30, 1998. After negotiations the proposal was later submitted as a purchase order on September 2, 1998 and approved two days later. The proposed recovery system consisted of 11 ferret pumps connected to a central air compressor which was later changed to 12 ferret pumps. Product lines drain into a 3000-gallon double-walled holding tank. System installation was partially completed in October 1998 and installation was completed in January 1999.

Drinking Water Supply Status

The on-site water well is impacted. There is currently a carbon canister filtering the water which is monitored on a regular basis. The tap water was last sampled January 1, 1999; all chemicals of concern were non-detect (see attached lab results). The OCC has approved the extension of the city water main from Wilshire Boulevard north to the station. An engineer was contracted to complete the water line plans and take bids to perform the work. The water main extension plans were submitted to the City of Oklahoma City on January 29, 1999. Following the city's approval, the engineer will collect bids for installation.

Free Product Recovery

Static free product and water level measurements were taken on January 21 & 22, 1999. The average free product thickness in the system wells is 4.86' and average depth to water at the site is 32'. The greatest static free product thickness was in MW-42 at 9.47' on January 21, 1999; although the pump usually keeps the product thickness pumped down to less than one inch.

The total amount of free product recovered at this site is:

1.) From inception 3/10/98 - 8/4/98	350 gallons
2.) From 8/4/98 -10/19/98	no recovery events
3.) From 10/19/98 - 11/12/98	1323 gallons
4.) From 11/12/98 - 2/9/99	2267 gallons

The thickness of the free product plume has not decreased much since system start-up, although considerable quantities have been removed. The only noticeable decrease has been MW-25 (from 7.09 feet to 5.75 feet); MW-28 (from 8.33 feet to 3.12 feet); MW-37 (from 7.69 feet to 6.88 feet); and MW-40 (from 6.03 feet to 4.51 feet).

The electrical breaker tripped and was discovered January 6th due to the air compressor shorting out. The air compressor was repaired on January 25th. Four "Alpha" ferret pumps were installed January 25 & 26, 1999 in MW-22, MW-32, MW-29, and MW-43. The observed product thickness in MW-33 has been less than one foot, therefore we installed a 4" soakease "sock" for recovery. The Alpha Ferret pump was relocated to MW-35. On February 9, 1999, 1½ gallons of free product was squeezed from the "sock" in MW-33 and 0.4' of free product was present in the well.

We have yet to install the pump in MW-35 due to an hydraulic conductivity test we are conducting in that area of the groundwater. On January 22, 1999, when MW-35 was checked, 1½ gallons of free product was manually bailed and disposed of in the holding tank located on site. Since then, less than 2 inches has returned.

From the discovery of the release to the system installation, the free product plume had migrated down gradient to the east and northeast as demonstrated by the recorded appearance of product in MW-43 and the decline in free product thickness in MW-33 and MW-32 (see attached well graphs). This was partly due to the increased water level in MW-42 caused by the removal of free product. We believe this migration has been mitigated since a pump was installed in MW-43 and MW-32 in January 1999.

Conclusions

The ORBCA Tier 1A Report was completed and submitted to the OCC on September 10, 1998. The Ferret® Free Product Recovery System is steadily removing free product. We continue to check the system at least once a week for optimum performance, and remove free product off site on a regular basis.

Prepared by: Rachal Roberts
Hydrologist

Approved by: Kathy Lippert
UST Consultant #421

Free Product Recovery Table (since 11/20/98)

Well #		10/12	11/20	12/1	12/10	12/11	12/15	12/28	12/31	1/6/99	1/7/99	1/21/99	1/28/99	2/9/99
MW-22	FP	33.65	34.37	34.4	34.52		34.17		33.65		34.29	33.48		35.17
began 1/25	WL	38.72	38.78	38.78	38.78		38.8		38.6		38.76	38.27		38.5
TD=39	thickness	5.07	4.41	4.38	4.26		4.63		4.95		4.47	4.79		3.33
short	pumping?													no
MW-23	FP	32.92	33.32	34.58	33.49	34.4	34.4		33.5		34.45	33.43		33.58
began 10/19	WL	37.24	37.22	34.85	37.33	35.85	35.4		35.4		34.88	37.13		37.3
TD=37.25	thickness	4.32	3.9	0.27	3.84	1.45	1		1.9		0.43	3.7		3.72
short	pumping?		no	yes	no	yes	yes		yes		yes			no
MW-25	FP	45.21	45.84	45.9	45.83	45.72	45.5		45.42		46.48	45.9		46.02
began 10/29	WL	52.3	47.76	51.65	51.75	51.63	51.7		51.57		48.86	51.65		52
TD=52.3	thickness	7.09	1.92	5.75	5.92	5.91	6.2		6.15		2.38	5.75		5.98
long	pumping?		yes	no	no	no	no		no		yes			no
MW-28	FP	24.85	24.95	25.12	25.56	25.8	25.52		25.6		25.58	25.3		25.88
began 10/29	WL	33.18	29.78	27.86	26.45	26.17	26.02		26.25		26.65	28.42		26.37
TD=38' 5"	thickness	8.33	4.83	2.74	0.89	0.37	0.5		0.65		1.07	3.12		0.49
long	pumping?		slowly	yes	yes	yes	yes		yes		yes			yes
MW-29	FP	31.72	31.86	31.97	32.13		31.73				31.83	31.2		32.6
began 1/28	WL	37.11	37.13	37.1	37.05		36.95				37.08	36.7		33.96
TD=37	thickness	5.39	5.27	5.13	4.92		5.22				5.25	5.5		1.36
short	pumping?													yes
MW-30	FP	28.77	28.12	28.07	28.06	28.1	27.9		28.8		27.95	27.88		27.9
began 10/20	WL	31.96	29.72	30.64	31.76	29.37	31.54		29.9		29.38	31.86		31.7
TD=38	thickness	3.19	1.6	2.57	3.7	1.27	3.64		1.1		1.43	3.98		3.8
long	pumping?		yes	no	slowly	yes	yes		yes		yes			no
MW-32	FP	33.55	33.94	33.95	33.94		33.75				33.86	33.44		34.66
began 1/28	WL	34.92	34.61	34.53	34.61		34.25				34.52	33.88		34.7
TD=39' 2"	thickness	1.37	0.67	0.58	0.67		0.5				0.66	0.44		0.04
short	pumping?													yes
MW-33	FP	31.87	32.2	32.2	32.12		32.05				32.1	31.66		32.95
installed 1/28	WL	35.28	33.93	33.95	33.74		33.07				32.8	31.8		33.35
TD=38' 1"	thickness	3.41	1.73	1.75	1.62		1.02				0.7	0.14		0.4
sock	gallons													1.5
MW-35	FP	32.9	33.15	33.21	33.31		33.25				33.05	32.52		33.72
	WL	35.92	36.04	36.23	36.38		36.25				36.35	36.02		33.87
TD=38	thickness	3.02	2.89	3.02	3.07		3				3.3	3.5		0.15
long	gallons											1.5		
MW-36	FP	45.27	45.33	45.21	45.25	45.27	46.2				44.97	45.24		45.12
began 10/20	WL	52.17	53.19	53.17	53.1	53.25	47.6		46.4		50.81	52.9		51.6
TD=57' 4"	thickness	6.9	7.86	7.96	7.85	7.98	1.4		0		5.84	7.66		6.48
long	pumping?		no	no	no	no	yes		yes		no			no
MW-37	FP	30.35	31.15	31	32.27	32.44	32		31.96		31.38	30.88		32.55
began 10/19	WL	38.04	38	38.08	32.97	32.68	33.02		32.84		36.45	37.76		32.96
TD=38	thickness	7.69	6.85	7.08	0.7	0.24	1.02		0.88		5.07	6.88		0.41
long	pumping?		no	no	yes	yes	yes		yes		no			yes
MW-40	FP	50.75	52.68	53.05	53.26	53.12	52.97		52.37		52.85	51.94		53.22
began 10/20	WL	56.78	54.78	53.72	53.5	53.5	53.52		53.36		53.6	56.45		53.5
TD=61' 9"	thickness	6.03	2.1	0.67	0.24	0.38	0.55		0.99		0.75	4.51		0.28
long	pumping?		yes	yes	yes	yes	yes		yes		yes			yes
MW-42	FP	30.47	30.78	32.57	32.49	32.42	30.45				32.1	29.63		32.42
began 10/27	WL	38.83	38.95	32.8	32.8	32.45	38.6		30.18		32.85	39.1		32.45
TD=39.26	thickness	8.36	8.17	0.23	0.31	0.03	8.15		0		0.75	9.47		0.03
long	pumping?		no	yes	yes	yes	no		yes		yes			yes
MW-43	FP	31.21	31.6	29.95	29.85		29.48		29.09		29.63	29.67		30.97
began 1/28	WL	32.1	35.2	38.2	38.37		38.3		38.07		38.35	38.32		34.12
TD=39.26	thickness	0.89	3.6	8.25	8.52		8.82		8.98		8.72	8.65		3.15
long	pumping?													yes
Tank	FP	8.31	3.54	3.05	6.2	6.12	5.66	4.71	4.06	3.91	3.71	3.57	2.75	5.25
ft x 376 = gal	WL	8.41	7.68	7.57	7.52	7.44	7.4	froze	froze	froze	froze	7.12	6.92	6.74
1" = 31.33 gal	gallons	37.6	1556.64	1699.52	496.32	496.32	658	1011.44	1259.6	1312.24		1334.8	1567.92	560.24
Recovery Rate (gal/day)		32	16	4.25	38.8	0	40.42	32	49.8	8.8			77.7	31
Total gal. Removed		38		1700	2146								3218	**3590**
History of Events		10/12/98 Baseline	11/20/98 true thickness		12/4/98 1650 gal hauled off				1/6/99 breaker tripped		1/10/99 [illegible]	1/25/99 air back on true thickness	2/2/99 1380 gal hauled off	

Project: FFP-OKC
Case: 064-2040

WELL	CASING ELEV.	Screen Interval	DEPTH TO GROUNDWATER after 8/18/98 (ft)									Corrected Water Depth	WL ELEV.
			8/27/98	9/4/98	9/11/98	9/17/98	9/24/98	11/12/98	11/20/98	1/21/99			
MW-1	97.26	10-20'											
MW-1D	97.11	20-28'	25.86	25.71			26.12		25.6	26.1		23.80	73.31
MW-2	97.41	20-30'	25.43	25.55			25.56			26.32		24.25	73.16
MW-3	99.06	15-30'	23.86	23.74			23.81	24.58		24.43			74.63
MW-4	99.29	29-39'	38.85				38.85						
MW-5	96.64	20-32'	24.87	24.82	24.83	24.77	24.72	24.16		23.59			73.05
MW-21	97.79	20-40'				33.42	33.53	34.07					
MW-22	98.98	20-40'	38.28	38.3	38.74	38.8	38.75	38.45	38.78	38.27		34.44	64.54
MW-23	97.96	20-40'	37.13	37.22	37.32	37.33	37.29	34.68	37.22	37.13		34.17	63.79
MW-24	108.72	20-50'	43.82	43.9			44.21	45.35	46.50				
MW-25	109.97	25-55'		46.5			52.24	47.65	47.76	51.65		47.05	62.92
MW-26	98.12	21-41'					32.1						
MW-27	97.9	20-40'	34.29	34.2	34.24	34.23	34.22	34.80	35.12	34.30		32.28	65.62
MW-28	98.38	20-40'	33.35		33.24	33.15	33.14	27.98	29.78	28.42		25.92	72.46
MW-29	96.19	17-37'	37.15	37.11	37.16	37.17	37.17	37.14	37.13	36.70		32.30	63.89
MW-30	96.86	20-40'	32.1	32.05	32.08	32.05	32.1	30.03	29.72	31.86		28.68	68.18
MW-31	97.19	20-40'				31.48	31.59	32.13	32.28				
MW-32	97.62	20-40'	39.31	39.35	39.3	38.57	37.98	35.63	34.61	33.88		33.53	64.09
MW-33	96.1	17-37'	34.73	34.65	34.57	34.54	34.38	33.77	33.93	31.80		31.69	64.41
MW-34	96.02	20-40'	28.17	28.16	28.58	28.71	28.91	29.78	29.95				
MW-35	97.6	20-40'	35.63	35.81	35.95	35.88	35.71		36.04	36.02		33.22	64.38
MW-36	114.39	29-59'	52		52	52.14	52.05	49.05	53.19	52.90		46.77	67.62
MW-37	95.45	20-40'		38	38.04	38.04	38.01	32.7	38	37.76		32.26	63.19
MW-38	95.39	20-40'					32.13	33.2					
MW-39	97.61	25-45'					34.21						
MW-40	116.19	40-60'	56.92	56.9	56.82	56.78	56.8	54.1	54.78	56.45		52.84	63.35
MW-41	94.95	20-40'	32.1	32.16	32.4	32.54	32.67						
MW-42	95.55	20-40'	39.41	39.39	39.42	39.42	39.42	32.45	38.95	39.13		31.97	63.58
MW-43	94.08	20-40'				30.85	31	38.27	35.2	38.32		31.40	62.68
MW-44	95.46	22-42'	30.26	30.38	30.42	31.29	31.19	28.84	27.93				
MW-45	94.56	19.5-39.5'	30.59	30.7	30.87	31.21	31.4	31.72	31.8	31.28			63.28
MW-46	95.22	25-45'	31.27	31.4			31.93	31.85		31.54			63.68
MW-47	98.9	25-45'	35.34	35.28	35.58	35.65	35.73	36.26		35.85			63.05

Appendix C
Water Quality Analyses and Chains-of-Custody

OKLAHOMA COOPERATIVE EXTENSION SERVICE

SOIL, WATER & FORAGE ANALYTICAL LABORATORY

Division of Agricultural Sciences and Natural Resources • Oklahoma State University
Plant and Soil Sciences • 048 Agricultural Hall • Stillwater, OK 74078

WATER QUALITY REPORT

RACHEL ROBERTS

RT 1 BOX 78U
CHANDLER, OK 74834
405-258-0064

Name:

Location:

Lab I.D. No.:	194562
Customer Code:	1460
Sample No:	1
Received:	02/19/99
Report Date:	03/03/99
Test No:	1

TEST RESULTS

Cations		Anions		Other	
Sodium (ppm)	162	Nitrate-N (ppm)	<1	pH	8.0
Calcium (ppm)	64	Chloride (ppm)	50	EC (µmhos/cm)	1140
Magnesium (ppm)	35	Sulfate (ppm)	9		
Potassium (ppm)	4	Carbonate (ppm)	0	Boron (ppm)	0.09
		Bicarbonate (ppm)	656		

Derived Values		Derived Values (cont'd)	
Total Soluble Salts (TSS in ppm)	980	Sodium Percentage	53.7
Sodium Adsorption Ratio (SAR)	4.0	Hardness (ppm)	303.7
Potassium Adsorption Ratio (PAR)	0.1	Hardness Class	Very Hard
Residual Carbonates meq	4.68	Alkalinity (ppm as $CaCO_3$)	538

INTERPRETATIONS FOR *Irrigation Water*

This water is generally of sufficiently low quality that its use is considerably restricted. It may be used safely only on very well-drained permeable soils and on salt tolerant crops. It requires careful irrigation practices, including applications of excess irrigation water to keep the soil leached of salt when rain fall is insufficient.
Good soil management practices must be used to maintain good physical structure in the soil and to maintain a high level of fertility. Use of this water on medium textured soils may result in problems if care is not exercised. This water is not recommended for heavy textured soils.
If this water is used extensively, it is recommended that a soil sample be obtained every few years from the irrigated fields to determine the extent to which sodium or salts are accumulating and the need for special management practices.
Residual carbonates are present in excess amounts, lowering water quality to unsiutable. Waters with excess residual carbonates may contain more effective sodium than indicated by the sodium percentage of the water. The calcium and magnesium may precipitate out as lime, increasing the percentage of sodium.

Signature

90

Soil, Water & Forage Analytical Laboratory

WATER TEST REQUEST FORM

Mark one test:
____ LIVESTOCK
____ HOUSEHOLD
__✓__ IRRIGATION

Address Code 1460 Sender Number 1

County ________ Sample Location ________

Name MW-1D Shallow

Address ________

2-18-99

Comments ________

Return to: SWFAL, 048 Ag Hall, O.S.U., Stillwater, OK 74078 (405) 744-6630

Apply bar-code here for:
Address Code + Sender Number

Apply bar-code here for:
Test Type

S194562$ fertility lab#

OKLAHOMA COOPERATIVE EXTENSION SERVICE

SOIL, WATER & FORAGE ANALYTICAL LABORATORY

Division of Agricultural Sciences and Natural Resources • Oklahoma State University
Plant and Soil Sciences • 048 Agricultural Hall • Stillwater, OK 74078

WATER QUALITY REPORT

RACHEL ROBERTS

RT 1 BOX 78
CHANDLER, OK 74834
405-258-0064

Name:

Location:

Lab I.D. No.: 194563
Customer Code: 1460
Sample No: 2
Received: 02/19/99
Report Date: 03/03/99
Test No: 1

TEST RESULTS

Cations		Anions		Other	
Sodium (ppm)	74	Nitrate-N (ppm)	<1	pH	7.9
Calcium (ppm)	118	Chloride (ppm)	141	EC (μmhos/cm)	1249
Magnesium (ppm)	75	Sulfate (ppm)	14		
Potassium (ppm)	1	Carbonate (ppm)	0	Boron (ppm)	0.28
		Bicarbonate (ppm)	583		

Derived Values		Derived Values (cont'd)	
Total Soluble Salts (TSS in ppm)	1006	Sodium Percentage	21.1
Sodium Adsorption Ratio (SAR)	1.3	Hardness (ppm)	603.0
Potassium Adsorption Ratio (PAR)		Hardness Class	Very Hard
		Alkalinity (ppm as CaCO3)	478

INTERPRETATIONS FOR ***Irrigation Water***

This water is suitable for use on most crops under most conditions. A problem may arise with continued use on very heavy soils where essentially no leaching occurs. If rainfall is sufficient, it will dilute the salts and reduce any negative effect. If sodium is the main problem, gypsum can be used to reduce the problem.

Signature

Soil, Water & Forage Analytical Laboratory

WATER TEST REQUEST FORM

Mark one test:

____ LIVESTOCK
__✓__ HOUSEHOLD
____ IRRIGATION

Address Code 1460 Sender Number 2

County ____________ Sample Location ____________

Name MW-30 Deep

Address ____________

____

Comments ____________

Return to: SWFAL, 048 Ag Hall, O.S.U., Stillwater, OK 74078 (405) 744-6630

Apply bar-code here for:
Address Code + Sender Number

Apply bar-code here for:
Test Type

S194563$ fertility lab#

SOUTHWELL LABORATORY, INC.
P.O. BOX 25001
1838 S.W. 13th STREET
OKLAHOMA CITY, OKLAHOMA 73125
(405) 232-1966 or (800) 872-5669
FAX (405) 235-8234
ODEQ CERT #7218

To: KATHY LIPPERT
AGES INC
3408 FRENCH PARK DR STE C
EDMOND OK 73034

Project #:
Project Name: RACHAL

PO Number:

Date Received: 02/23/1999
Report Date: 02/23/1999

- CERTIFICATE OF ANALYSIS -

Lab Number	Sample Identification	Matrix	Date Sampled	PARAMETER	Result	MDL	Method
SL9903618	MW-10	WATER	02/23/1999	SILICON DIOXIDE (SILICA)	21.42 mg/l	0.036	200.7/6010
SL9903619	MW-30	WATER	02/23/1999	SILICON DIOXIDE (SILICA)	18 mg/l	0.036	200.7/6010

Laboratory Authorized Signature

mg/l = Milligrams per Liter, equivalent to parts-per-million.

SOUTHWELL LABORATORY, INC.
1838 S. W. 13th Street
Oklahoma City, OK 73108-3404
(405) 232-1966 or (800) USA-KNOW
Fax (405) 235-8234
E-mail: lab@southwell.com
Website: http://www.southwell.com

CHAIN-OF-CUSTODY FORM

Report To: A.G.E.S.	Invoice To (if Different): For Rachal
Address:	
City: State: Zip:	Project Number: Rachal
Telephone: FAX#:	Project Name: Rachal
Report To: Sampler:	Purchase Order #:

Turnaround Time: Normal____ Rush____ Priority Rush ____ Fax____ Custody Seal: Y N Intact: Y N

CHANGES MUST BE FAXED NO VERBAL CHANGES

Client Sample ID	Date/Time Sampled	Matrix	Grab/ Comp	No./Type of Containers: VOA	1 LTR	500 ML	250 ML	OTHER		Analysis Requested: SiO2								Remarks	Southwell Lab #
MW-1D	2-23-99 4:00	GW	G			X				X									
MW-30	" "	GW	G			X				X									

Relinquished By:	Date:	Time:	Received By:
Rachel Roberts	2-23-99	5:00	
Relinquished By:	Date:	Time:	Received By:
Relinquished By:	Date: 2-23-99	Time: 17:00	Received at Laboratory By: S McDonald

Special Instructions:

Temperture at or below 4° C when received: Y N

Appendix D
WATEVAL Data and Reliability Checks

Sample MW-1D

TempC =	0.0	pH =	8.0
TDS =	1001.4	COND =	1140.0
HARD =	303.7	DENS =	0.0
x-cor =	0.0	y-cor =	0.0
Units =	mg/L	rock =	0.0

	mg/L	mmole/L	meq/L	% meq/L
Na+	162.0	7.0462	7.0462	53.3
K +	4.0	0.1023	0.1023	0.8
Ca++	64.0	1.5968	3.1936	24.2
Mg++	35.0	1.4396	2.8792	21.8
Cl-	50.0	1.4103	1.4103	11.4
SO4--	9.0	0.0937	0.1874	1.5
HCO3-	656.0	10.7513	10.7513	87.1
CO3--	0.0	0.0000	0.0000	0.0
SiO2	21.4	0.3565	0.0000	0.0
Li+	0.0	0.0000	0.0000	0.0
Sr++	0.0	0.0000	0.0000	0.0
Ba++	0.0	0.0000	0.0000	0.0
Fe++	0.0	0.0000	0.0000	0.0
NO3-	0.0	0.0000	0.0000	0.0
F-	0.0	0.0000	0.0000	0.0
Br-	0.0	0.0000	0.0000	0.0
B	0.0	0.0000	0.0000	0.0

LANGELIER INDEX = 0.74 SAR = 4.0
Conductivity = 1140 umho Est. Cond. = 1322 umho

Analytical checks and comparisons

Sum cations = 13.2214 Sum anions = 12.3490
BALANCE = 3.41 %

TDS entered = 1001 mg/L
TDS calc = 1001 mg/L TDS(180) calc = 668 mg/L
Entered TDS - TDS(calc) diff= 0.0 % Entered TDS - TDS(180) diff= 33.3 %

Conductivity = 1140 umho
TDS(entered)/Cond ratio = 0.88 Usual range = 0.55 to 0.75
TDS(calc)/Cond = 0.88 Usual range = 0.55 to 0.75
Conductivity/Sum-cations = 86 Usual range = 90 - 110

Entered and calculated density
Meas. Density = 0.0000 Calc. Density = 1.0008

Entered and calculated hardness
Meas. hardness= 303.7 mg/L CaCO3 Calc. hardness= 303.9 mg/L CaCO3

Element ratios
Na/(Na+Cl) = 83.3 % Usually > 50%

Ca/(Ca + SO4) = 94.5 % Usually > 50%
K/(Na + K) = 1.4 % Usually < 20%

Mg/(Mg+Ca) = 47.4 % Usually < 40%

Carbonate/bicarbonate at pH = 8
Meas HCO3 = 656.0 mg/L Meas CO3 = 0.0 mg/L
Calc HCO3 = 651.6 mg/L Calc CO3 = 2.2 mg/L

REDOX EQUILIBRIA

NOTE

Concentrations not activities are used
25 degrees C and 1 atmosphere assumed

```
pH =  8          SO4 =  9  mg/L

               REDOX CALCULATIONS
                                                          pe
1. Dissolved Oxygen   0.0   mg/L
2. Ferrous iron       0.000 mg/L
     Ferric iron      0.001 mg/L
     Ferric iron      0.100 mg/L
  3. Ferric iron      0.000 mg/L
     Solid Fe(OH)3
     Solid FeOOH
4. Manganous (Mn++)   0.000 mg/L
     Solid MnO2
5. Nitrate            0.000 mg/L
     Ammonium         0.001 mg/L
     Ammonium         0.100 mg/L
  6. Ammonium         0.000 mg/L
     If H2S PESENT
        For PH2S of 1E-3 atmos or  3.1763 mg/L      -4.4
        For PH2S of 1E-8 atmos or  0.0000 mg/L      -3.8
     If CH4 PESENT
        For 1% CH4                                  -4.9
        For 99% CH4                                 -5.4


       ****************************************
       * Concentration ESTIMATES for given pe *
       ****************************************

               For given pe =  0

O2 / H2O system                pO2   =   0.77E-27  atmos
                               DO    =   0.00   mg/L

Fe++ / Fe+++ system            Fe++ = 100.00 mole %
Fe++ / Fe(OH)3 system          Fe++ =   0.64E-03 mg/L
Fe++ / limonite system         Fe++ =   0.53E-03 mg/L

Mn++ / MnO2 system             Mn++ =   0.22E+15 mg/L

NO3- / N2 system               NO NO3 ENTERED

NO3- / NH4+ system             NH4  = 100.00 mole %

H2S / SO4= system              pH2S =   0.94E-38 atmos
                               H2S  =   0.00 mg/L

CH4 / CO2 system               CH4  =   0.00 %
```

Sample MW-1D

SOURCE ROCK ESTIMATE

SiO2 (mmol/L)	=	0.36	
HCO3/SiO2	=	30.16	Carbonate weathering
SiO2/(Na+K-Cl)	=	0.06	Cation exchange
(Na+K-Cl)/(Na+K-Cl+Ca)	=	0.78	Plagioclase weathering possible
Na/(Na + Cl)	=	0.83	Albite or ion exchange
Mg/(Mg+Ca)	=	0.47	Limestone-dolomite weathering
Ca/(Ca + SO4)	=	0.94	Ca source other than gypsum carbonates or silicates
(Ca + Mg)/SO4	=	32.4	Dedolomitization unlikely
TDS calculated	=	1001 mg/L	Carbonate weathering, brine, evaporites or sea water
Cl/sum anions	=	0.11	Silicate or carbonate weathering
HCO3/sum anions	=	0.87	Silicate or carbonate weathering
Langelier Index	=	0.74	Oversaturated with respect to calcite

Mass Balance Calculation

Carbonate option

Mineral	Dissolves	Precipitates
HALITE	1.410	
CALCITE	2.881	
DOLOMITE	1.440	
GYPSUM	0.094	
ION EXCH	2.818	
CO2 GAS	4.991	

Silicate option

Mineral	Dissolves	Precipitates
HALITE	1.410	
ALBITE(K)	5.636	
ANORTHIT(K)	0.063	
DIOPSIDE	1.440	
GYPSUM	0.094	
CO2 GAS		-0.770

Analysed silica = 21 Silica from albite and diopside = 512 - 850

TEMPERATURE ESTIMATES IN DEGREES C

Good for temperatures 20 - 350 C

Mg-Li	-->	0
Na-Li	-->	0
Na-K-Ca (Mg corrected)	-->	51

Good for low temperatures 30 - 70 C

Chalcedony	-->	34

Good for temperatures > 70 C

Quartz-no steam loss	-->	66
Quartz-maximum steam loss	-->	71

Do not use for oil-field waters

May not be useful below 150 C

Na-K (Fournier)	-->	121
Na-K (Truesdell)	-->	86
Na-K-Ca (t < 100 C)	-->	51
Na-K-Ca (t > 100 C)	-->	107

Sample MW-30

TempC =	0.0	pH =	7.9
TDS =	1024.0	COND =	1249.0
HARD =	603.0	DENS =	0.0
x-cor =	0.0	y-cor =	0.0
Units =	mg/L	rock =	0.0

	mg/L	mmole/L	meq/L	% meq/L
Na+	74.0	3.2187	3.2187	21.0
K +	1.0	0.0256	0.0256	0.2
Ca++	118.0	2.9441	5.8882	38.5
Mg++	75.0	3.0849	6.1698	40.3
Cl-	141.0	3.9771	3.9771	28.8
SO4--	14.0	0.1457	0.2915	2.1
HCO3-	583.0	9.5549	9.5549	69.1
CO3--	0.0	0.0000	0.0000	0.0
SiO2	18.0	0.2996	0.0000	0.0
Li+	0.0	0.0000	0.0000	0.0
Sr++	0.0	0.0000	0.0000	0.0
Ba++	0.0	0.0000	0.0000	0.0
Fe++	0.0	0.0000	0.0000	0.0
NO3-	0.0	0.0000	0.0000	0.0
F-	0.0	0.0000	0.0000	0.0
Br-	0.0	0.0000	0.0000	0.0
B	0.0	0.0000	0.0000	0.0

LANGELIER INDEX = 0.82 SAR = 1.3
Conductivity = 1249 umho Est. Cond. = 1530 umho

Analytical checks and comparisons

Sum cations = 15.3022 Sum anions = 13.8235
BALANCE = 5.08 %
TDS entered = 1024 mg/L
TDS calc = 1024 mg/L TDS(180) calc = 728 mg/L
Entered TDS - TDS(calc) diff= 0.0 % Entered TDS - TDS(180) diff= 28.9 %

Conductivity = 1249 umho
TDS(entered)/Cond ratio = 0.82 Usual range = 0.55 to 0.75
TDS(calc)/Cond = 0.82 Usual range = 0.55 to 0.75
Conductivity/Sum-cations = 82 Usual range = 90 - 110

Entered and calculated density
Meas. Density = 0.0000 Calc. Density = 1.0008

Entered and calculated hardness
Meas. hardness= 603.0 mg/L CaCO3 Calc. hardness= 603.4 mg/L CaCO3

Element ratios
Na/(Na+Cl) = 44.7 % Usually > 50%

Ca/(Ca + SO4) = 95.3 % Usually > 50%
K/(Na + K) = 0.8 % Usually < 20%

Mg/(Mg+Ca) = 51.2 % Usually < 40%

Carbonate/bicarbonate at pH = 7.9
Meas HCO3 = 583.0 mg/L Meas CO3 = 0.0 mg/L
Calc HCO3 = 579.8 mg/L Calc CO3 = 1.6 mg/L

Sample MW-30
SOURCE ROCK ESTIMATE

SiO2 (mmol/L)	=	0.30	
HCO3/SiO2	=	31.90	Carbonate weathering
SiO2/(Na+K-Cl)	=		Cl > (Na+K)
(Na+K-Cl)/(Na+K-Cl+Ca)	=		Cl > (Na+K)
Na/(Na + Cl)	=	0.45	Reverse softening, sea water
Mg/(Mg+Ca)	=	0.51	Dolomite dissoln and calcite pptn or sea water
Ca/(Ca + SO4)	=	0.95	Ca source other than gypsum carbonates or silicates
(Ca + Mg)/SO4	=	41.4	Dedolomitization unlikely
TDS calculated	=	1024 mg/L	Carbonate weathering, brine, evaporites or sea water
Cl/sum anions	=	0.29	Sea water, brine or evaporites possible
HCO3/sum anions	=	0.69	
Langelier Index	=	0.82	Oversaturated with respect to calcite

Mass Balance Calculation

Carbonate option

Mineral	Dissolves	Precipitates
HALITE	3.977	
CALCITE		-0.666
DOLOMITE	3.085	
GYPSUM	0.146	
ION EXCH		-0.379
CO2 GAS	4.051	

Silicate option
Mineral

REDOX EQUILIBRIA

NOTE
Concentrations not activities are used
25 degrees C and 1 atmosphere assumed

pH = 7.9 SO4 = 14 mg/L

REDOX CALCULATIONS

			pe
1. Dissolved Oxygen	0.0 mg/L		
2. Ferrous iron	0.000 mg/L		
Ferric iron	0.001 mg/L		
Ferric iron	0.100 mg/L		
3. Ferric iron	0.000 mg/L		
Solid Fe(OH)3			
Solid FeOOH			
4. Manganous (Mn++)	0.000 mg/L		
Solid MnO2			
5. Nitrate	0.000 mg/L		
Ammonium	0.001 mg/L		
Ammonium	0.100 mg/L		
6. Ammonium	0.000 mg/L		
If H2S PESENT			
For PH2S of 1E-3 atmos or		3.1763 mg/L	-4.2
For PH2S of 1E-8 atmos or		0.0000 mg/L	-3.6
If CH4 PESENT			
For 1% CH4			-4.8
For 99% CH4			-5.3

```
****************************************
* Concentration ESTIMATES for given pe *
****************************************

                    For given pe =  0

O2 / H2O system                 pO2  =   0.77E-27  atmos
                                DO   =   0.00  mg/L

Fe++ / Fe+++ system             Fe++ = 100.00 mole %
Fe++ / Fe(OH)3 system           Fe++ =   0.13E-02 mg/L
Fe++ / limonite system          Fe++ =   0.11E-02 mg/L

Mn++ / MnO2 system              Mn++ =   0.55E+15 mg/L

NO3- / N2 system                NO NO3 ENTERED

NO3- / NH4+ system              NH4  = 100.00 mole %

H2S / SO4= system               pH2S =   0.15E-36 atmos
                                H2S  =   0.00 mg/L

CH4 / CO2 system                CH4  =   0.00 %
```

Temperature Estimates in Degrees C

MW-30

Good for temperatures 20-350 C

Mg-Li →

Na-Li →

Na-K-Ca (Mg corrected) → 3

Good for low temperatures 30-70 C

Chalcedony → 27

Good for temperatures > 70 C

Quartz - No steam loss → 60

Quartz - maximum steam loss → 66

Do NOT use for oil-field waters

May NOT be useful below 150 C

Na-K (Fournier) → 90

Na-K (Truesdell) → 52

Na-K-Ca (T < 100 C) → 3

Na-K-Ca (T > 100 C) → 74

Sample MW-30
SOURCE ROCK ESTIMATE

SiO2 (mmol/L)	=	0.30	
HCO3/SiO2	=	31.90	Carbonate weathering
SiO2/(Na+K-Cl)	=		Cl > (Na+K)
(Na+K-Cl)/(Na+K-Cl+Ca)	=		Cl > (Na+K)
Na/(Na + Cl)	=	0.45	Reverse softening, sea water
Mg/(Mg+Ca)	=	0.51	Dolomite dissoln and calcite pptn or sea water
Ca/(Ca + SO4)	=	0.95	Ca source other than gypsum carbonates or silicates
(Ca + Mg)/SO4	=	41.4	Dedolomitization unlikely
TDS calculated	=	1024 mg/L	Carbonate weathering, brine, evaporites or sea water
Cl/sum anions	=	0.29	Sea water, brine or evaporites possible
HCO3/sum anions	=	0.69	
Langelier Index	=	0.82	Oversaturated with respect to calcite

Mass Balance Calculation

Carbonate option

Mineral	Dissolves	Precipitates
HALITE	3.977	
CALCITE		-0.666
DOLOMITE	3.085	
GYPSUM	0.146	
ION EXCH		-0.379
CO2 GAS	4.051	

Silicate option

Mineral		
Halite	3.977	
Albite(k)		-.758
Anorthite(k)		-.287
Diopside	3.085	
Gypsum	0.146	
CO_2 Gas		-1.453

Analysed silica = 18   Silica from Albite and diopside = 325-280

Figure #9 - Piper Plot for MW-1D and MW-30

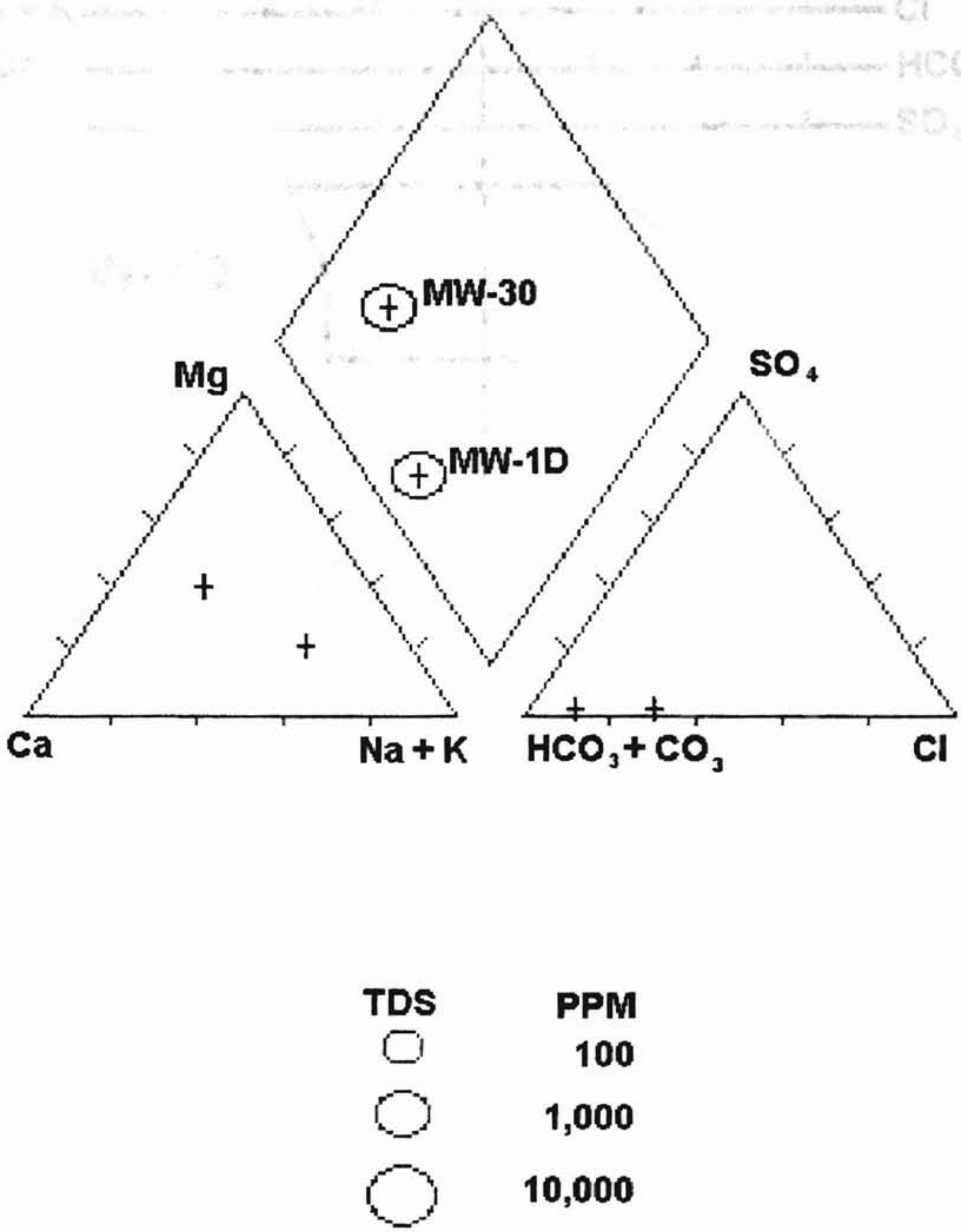
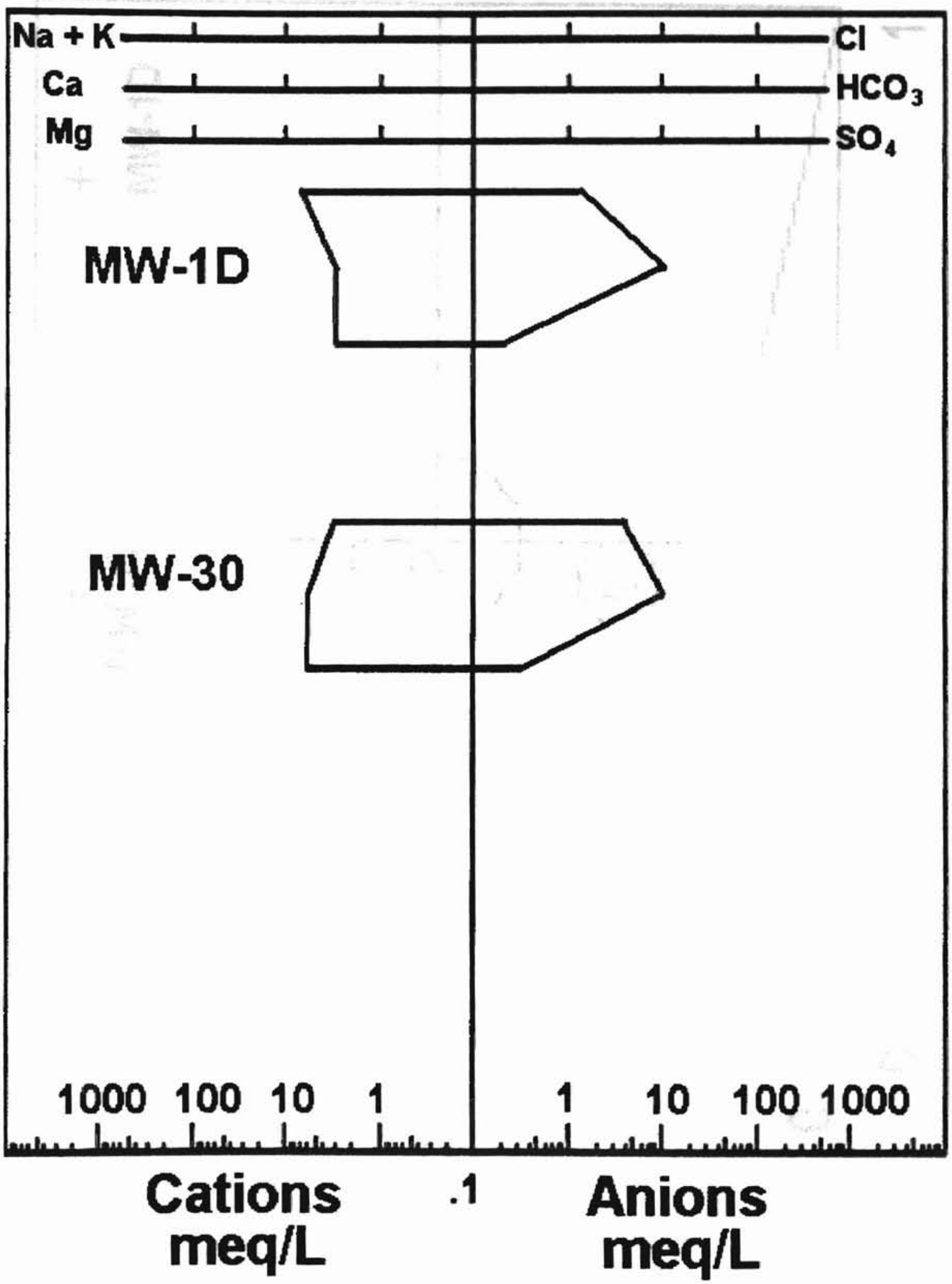
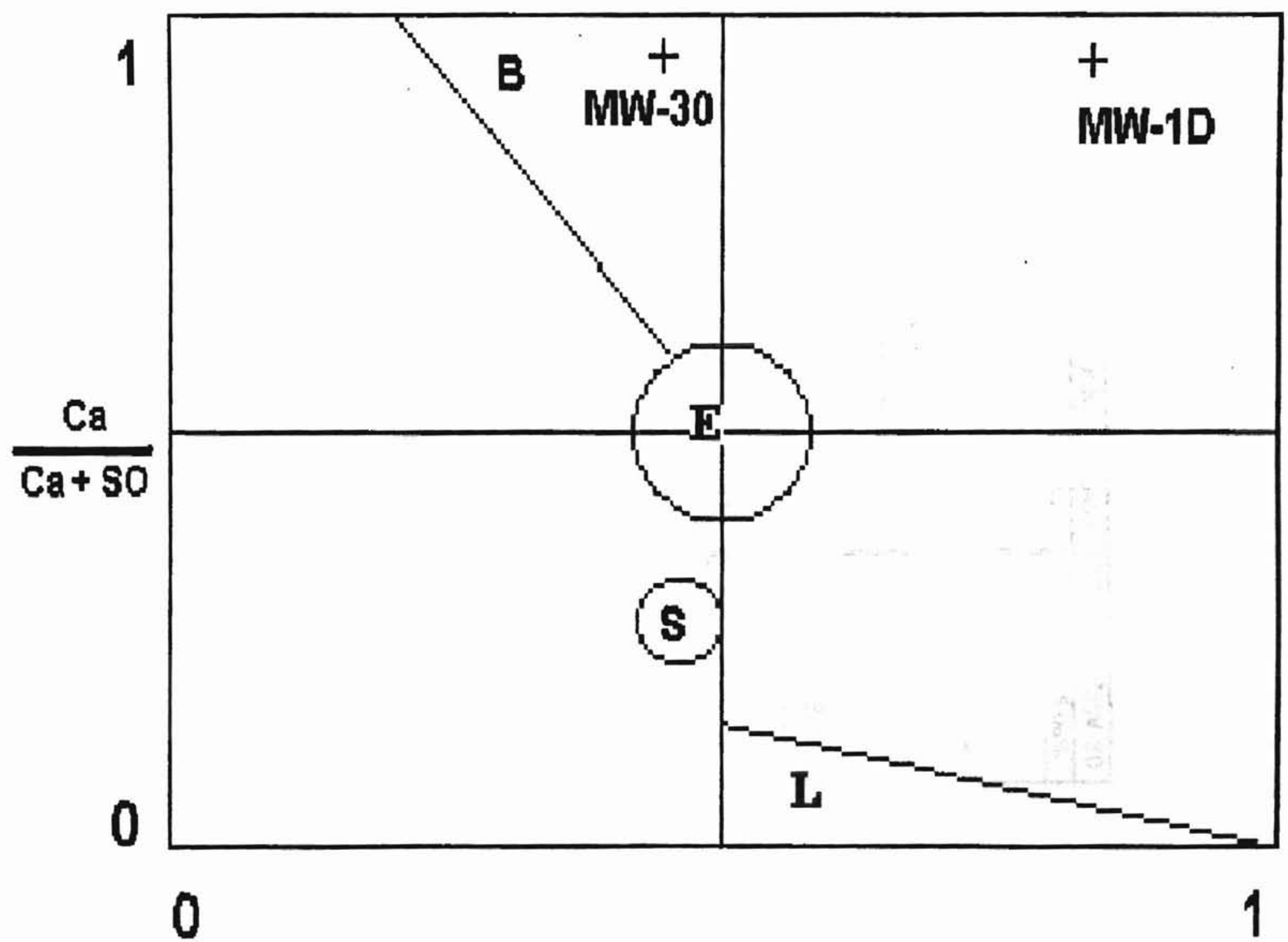


Figure #10 - Stiff Diagram for MW-1D and MW-30





1
0
Ca
Ca + SO
0
1
B
MW-30
MW-1D
E
S
L

Table #4 - Reliability Checks

Reliability Check	is usually	MW-1D	MW-30
Ion Balance	< 5%	3.41%	5.08%
Hardness $\frac{\text{Entered - Calculated}}{\text{Entered}}$	< 5%	0.06%	0.07%
Total Diss. Solids $\frac{\text{Entered - Calculated}}{\text{Entered}}$	< 5%	0.00%	0.00%
Total Diss. $Solids_{180}$ $\frac{\text{Entered - Calculated}}{\text{Entered}}$	< 5%	33.33%	28.90%
$TDS_{entered}$ / EC	.55 - .75	0.88	0.82
TDS_{calc} / EC	.55 - .75	0.88	0.82
EC / cation sum	90 - 110	86.23	81.58
$\frac{K^+}{Na^+ + K^+}$	< 20%	1.40%	0.80%
$\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}$	< 40%	47.40%	51.16%
$\frac{Ca^{2+}}{Ca^{2+} + SO_4^{2-}}$	> 50%	94.50%	95.30%
$\frac{Na^+}{Na^+ + Cl^-}$	> 50%	83.33%	44.72%
Conclusion		accept	accept

Appendix E
Examples of the Software Outputs

DEVELOPMENT OF RISK SCENARIO

The following chemicals were selected:
Benzene

The following exposure routes were selected:
Drinking Water
Dermal Intake During Shower
Inhalation During Shower

RECEPTOR POINT CONCENTRATIONS

Data for Fate and Transport Models

Models Selected:	
VADSAT	
Simulation Time (max=100) [years]:	50
Simulation Title:	DSS Fate and Transport
Date and Time of Simulation:	03/24/99 18:04

---------- VADSAT Model ----------

Model Control Parameters

Allowing Volatilization?	Yes
Solid Phase Degradation?	No
Code-calculated dispersivities?	No

Source Zone Parameters

Saturated conductivity of waste zone [m/day]	0.2
Thickness of waste zone [m]	0.54
Waste zone area [m^2]	2960
Length to width ratio [m/m]	2.16
Thickness of soil cover [m]	6.6
Fraction organic carbon [-]	0.00085

Vadose Zone Soil Parameters

Fraction organic carbon [-]	0.00077
Saturated conductivity [m/day]	0.2
Depth to groundwater [m]	7.14
Effective porosity [-]	0.364
van Genucten's n parameter [-]	2.68
Residual moisture content [-]	0.08
Net recharge rate [m/day]	0.002

Saturated Zone (Aquifer) Parameters

Effective porosity [-]	0.407
Fraction organic carbon [-]	0.00085
Saturated conductivity [m/day]	0.2

Hydraulic gradient [m/m]	0.074
Aquifer thickness [-]	100
Location of well-downgradient [m]	0
Location of well--cross-gradient [m]	21
Depth of well [m]	19

TPH Data

Concentration of TPH mixture [mg/kg]	2500
Molecular Weight of TPH [g/mole]	100
Density of TPH [g/cm^3]	0.95

VADSAT Chemical Specific Parameters

Benzene

Total Concentration in Soil [mg/kg]	11
Diffusion Coeff. in Air [cm^2/s]	8.80E-02
Diffusion Coeff. in Water [cm^2/s]	9.80E-06
Henrys Law Constant [(mg/L)/(mg/L)]	2.28E-01
Koc [ug/gOC/ug/ml]	5.89E+01
Solubility [mg/l]	1.75E+03
Degradation Rate in Vadose Zone [1/days]	0.00E+00
Degradation Rate in Aquifer [1/days]	0.00E+00
Molecular Weight [g/mole]	78

INTAKE PARAMETERS

Analysis Type: Deterministic

Body Weight and Lifetime

Average Weight (kg)	70
Lifetime (yrs)	70

Drinking Water

Exposure Frequency [days/yr]	52
Exposure Duration [years]	5
Ingestion Rate [liters/day]	1.4

Drinking Water Chemical Specific Parameters

Benzene

Bioavailability [fraction]	1.00E+00

Dermal Intake During Shower

Exposure Frequency [days/yr]	52
Exposure Duration [years]	5
Total Skin Surface Area [cm^2]	23000
Time in Shower [hours/day]	0.333

Dermal Intake Chemical Specific Parameters

Benzene

Permeability Coef [cm/hour]	2.10E-02

Inhalation During Shower	
Exposure Frequency [days/yr]	52
Exposure Duration [years]	5
Inhalation Rate [m^3/hr]	0.833
Time in Shower [hours/day]	0.333
Fraction Volatilized [-]	0.5
Shower Flow Rate [l/min]	10
Volume of Bathroom [m^3]	3
Temperature of the Water [C]	45
Droplet Diameter [cm]	0.1
Droplet Drop Time [s]	2
Liquid Mass Trans. Coeff. [cm/hr]	20
Gas Mass Trans. Coeff. [cm/hr]	3000

Inhalation During Shower Chemical Specific Parameters	
Benzene	
Henry's Constant [(mg/L)/(mg/L)	2.28E-01
Bioavailability [fraction]	1.00E+00
Oral Toxicity Parameters	
Benzene	
Slope Factor [1/(mg/kg-day)]	2.90E-02
Reference Dose [mg/kg-day]	1.70E-03
Inhalation Toxicity Parameters	
Benzene	
Slope Factor [1/(mg/kg-day)]	2.90E-02
Reference Dose [mg/kg-day]	1.70E-03
Dermal Toxicity Parameters	
Benzene	
Slope Factor [1/(mg/kg-day)]	2.90E-02
Reference Dose [mg/kg-day]	1.70E-03

Chemicals in the analysis:

Benzene
Ethylbenzene
Toluene
Xylenes

Chemical Intake Analysis

Deterministic Run

PARAMETER NAME	UNITS	VALUE
Body Weight	kg	7.00E+01
Life Time	yr	7.00E+01
Exposure Duration Groundwater	yr	5.00E+00
Exposure Frequency Ingestion	dy/yr	5.20E+01
Water Ingestion Rate	l/day	1.40E+00
Exposure Duration Groundwater	yr	5.00E+00
Exposure Frequency Shower	dy/yr	5.20E+01
Shower Duration	hr	3.33E-01
Total Skin Surface Area	cm^2	2.30E+04
Exposure Duration Groundwater	yr	5.00E+00
Exposure Duration Groundwater	yr	5.20E+01
Shower Duration	hr	3.33E-01
Inhalation Rate in Shower	m^3/hr	8.33E-01
Fraction Volatilized	(-)	5.00E-01
Shower Flow Rate	l/hr	1.00E+01
Volume of Bathroom	m^3	3.00E+00

Benzene

PARAMETER NAME	UNITS	VALUE
Water Ingestion Bioavailibility	(-)	1.00E+00
Permeability Coefficient	cm/hr	2.10E-02
Henrys constant	(mg/L)/(mg/L)	2.28E-01
Molecular Weight	g/mol	7.80E+01
Inhal Shower Bioavailibility	(-)	1.00E+00
Oral Slope Factor	kg-dy/mg	2.90E-02
Oral Reference Dose	mg/kg-dy	1.70E-03
Inhalation Slope Factor	kg-dy/mg	2.90E-02
Inhalation Reference Dose	mg/kg/dy	1.70E-03
Dermal Slope Factor	kg-dy/mg	2.90E-02
Dermal Reference Dose	mg/kg-dy	1.70E-03

Ethylbenzene

PARAMETER NAME	UNITS	VALUE
Water Ingestion Bioavailibility	(-)	1.00E+00
Permeability Coefficient	cm/hr	7.40E-02
Henrys constant	(mg/L)/(mg/L)	3.23E-01
Molecular Weight	g/mol	1.06E+02

Inhal Shower Bioavailibility	(-)	1.00E+00
Oral Slope Factor	kg-dy/mg	ND
Oral Reference Dose	mg/kg-dy	1.00E-01
Inhalation Slope Factor	kg-dy/mg	ND
Inhalation Reference Dose	mg/kg/dy	2.90E-01
Dermal Slope Factor	kg-dy/mg	ND
Dermal Reference Dose	mg/kg-dy	1.00E-01

Toluene

PARAMETER NAME	UNITS	VALUE
Water Ingestion Bioavailibility	(-)	1.00E+00
Permeability Coefficient	cm/hr	4.50E-02
Henrys constant	(mg/L)/(mg/L)	2.72E-01
Molecular Weight	g/mol	9.21E+01
Inhal Shower Bioavailibility	(-)	1.00E+00
Oral Slope Factor	kg-dy/mg	ND
Oral Reference Dose	mg/kg-dy	2.00E-01
Inhalation Slope Factor	kg-dy/mg	ND
Inhalation Reference Dose	mg/kg/dy	1.14E-01
Dermal Slope Factor	kg-dy/mg	ND
Dermal Reference Dose	mg/kg-dy	2.00E-01

Xylenes

PARAMETER NAME	UNITS	VALUE
Water Ingestion Bioavailibility	(-)	1.00E+00
Permeability Coefficient	cm/hr	8.00E-02
Henrys constant	(mg/L)/(mg/L)	2.90E-01
Molecular Weight	g/mol	1.06E+02
Inhal Shower Bioavailibility	(-)	1.00E+00
Oral Slope Factor	kg-dy/mg	ND
Oral Reference Dose	mg/kg-dy	2.00E+00
Inhalation Slope Factor	kg-dy/mg	ND
Inhalation Reference Dose	mg/kg/dy	2.00E-01
Dermal Slope Factor	kg-dy/mg	ND
Dermal Reference Dose	mg/kg-dy	2.00E+00

SUMMARY OF THE OUTPUTS
****

CDI: Chronic Daily Intake
LADI: Lifetime Average Daily Intake

DRINKING WATER

	Daily Intake (mg/kg-dy)	CDI (mg/kg-dy)	LADI (mg/kg-dy)	Risk (-)	Hazard Quotient (-)
Benzene	2.23E-03	3.18E-04	2.27E-05	6.58E-07	1.87E-01
Ethylbenzene	4.75E-03	6.76E-04	4.83E-05	ND	6.76E-03
Toluene	2.80E-02	3.98E-03	2.85E-04	ND	1.99E-02

Xylenes	2.69E-02	3.83E-03	2.74E-04	ND	1.92E-03

DERMAL INTAKE DURING SHOWER

	Daily Intake (mg/kg-dy)	CDI (mg/kg-dy)	LADI (mg/kg-dy)	Risk (-)	Hazard Quotient (-)
Benzene	2.56E-04	3.65E-05	2.61E-06	7.56E-08	2.15E-02
Ethylbenzene	1.92E-03	2.74E-04	1.96E-05	ND	2.74E-03
Toluene	6.88E-03	9.81E-04	7.00E-05	ND	4.90E-03
Xylenes	1.18E-02	1.68E-03	1.20E-04	ND	8.39E-04

INHALATION DURING SHOWER

	Daily Intake (mg/kg-dy)	CDI (mg/kg-dy)	LADI (mg/kg-dy)	Risk (-)	Hazard Quotient (-)
Benzene	1.47E-02	2.10E-03	1.50E-04	4.34E-06	1.23E+00
Ethylbenzene	3.13E-02	4.46E-03	3.19E-04	ND	1.54E-02
Toluene	1.84E-01	2.63E-02	1.88E-03	ND	2.31E-01
Xylenes	1.77E-01	2.53E-02	1.81E-03	ND	1.26E-01

Receptor Point Concentrations

Groundwater Concentrations:	Max. 5-year ave (non-carcinogens)	Ave. over ED (carcinogens)
Benzene	.112	.112
Ethylbenzene	.237	.237
Toluene	1.40	1.40
Xylenes	1.35	1.35

Shower Air Concentrations:	Max. 5-year ave (non-carcinogens)	Ave. over ED (carcinogens)
Benzene	3.71	3.71
Ethylbenzene	7.90	7.90
Toluene	46.6	46.6
Xylenes	44.8	44.8

Site Name: Truck Stop | Site Location: Oklahoma City | Completed By: Rachal Roberts | Date Completed: 3/1/1999

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

GROUNDWATER EXPOSURE PATHWAYS ■ **(CHECKED IF PATHWAY IS ACTIVE)**

SOIL: LEACHING TO GROUNDWATER/ GROUNDWATER INGESTION

Constituents of Concern	Exposure Concentration 1) Source Medium Soil Concentration (mg/kg)	2) NAF Value (L/kg) Receptor On-Site Commercial		3) Exposure Medium Groundwater: POE Conc. (mg/L) (1)/(2) On-Site Commercial		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (L/kg-day) On-Site Commercial		5) Average Daily Intake Rate (mg/kg-day) (3) x (4) On-Site Commercial	
Benzene	1.1E+1	1.2E-1		9.2E+1		2.0E-4		1.9E-2	
Ethylbenzene	9.1E+1	1.8E-1		4.9E+2		5.7E-4		2.8E-1	
Toluene	2.4E+2	2.1E-1		1.2E+3		5.7E-4		6.7E-1	
Xylene (mixed isomers)	4.3E+2	3.0E-1		1.5E+3		5.7E-4		8.3E-1	

NOTE: ABS = Dermal absorption factor (dim) BW = Body Weight (kg) EF = Exposure frequencey (days/yr) POE = Point of exposure
AF = Adherance factor (mg/cm^2) CF = Units conversion factor ET = Exposure time (hrs/day) SA = Skin exposure area (cm^2/day)
AT = Averaging time (days) ED = Exposure duration (yrs) IR = Intake rate (L/day)

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-507-WJX-400

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.1**

Site Name: Truck Stop | Site Location: Oklahoma City | Completed By: Rachal Roberts | Date Completed: 3/1/1999 | *9 OF 9*

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

GROUNDWATER EXPOSURE PATHWAYS ■ **(CHECKED IF PATHWAY IS ACTIVE)**

GROUNDWATER: INGESTION

Constituents of Concern	Exposure Concentration 1) Source Medium Groundwater Conc. (mg/L)	2) NAF Value (dim) Receptor On-Site Commercial		3) Exposure Medium Groundwater: POE Conc. (mg/L) (1)/(2) On-Site Commercial		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (L/kg-day) On-Site Commercial		5) Average Daily Intake Rate (mg/kg-day) (3) x (4) On-Site Commercial		MAX. PATHWAY INTAKE (mg/kg-day) *(Maximum intake of active pathways soil leaching & groundwater routes.)* On-Site Commercial	
Benzene	FP	1.0E+0		#VALUE!		2.0E-4		#VALUE!		1.9E-2	
Ethylbenzene	FP	1.0E+0		#VALUE!		5.7E-4		#VALUE!		2.8E-1	
Toluene	FP	1.0E+0		#VALUE!		5.7E-4		#VALUE!		6.7E-1	
Xylene (mixed isomers)	FP	1.0E+0		#VALUE!		5.7E-4		#VALUE!		8.3E-1	

NOTE:
ABS = Dermal absorption factor (dim)
AF = Adherence factor (mg/cm^2)
AT = Averaging time (days)
BW = Body weight (kg)
CF = Units conversion factor
ED = Exposure duration (yrs)
EF = Exposure frequency (days/yr)
ET = Exposure time (hrs/day)
IR = Intake rate (L/day)
POE = Point of exposure
SA = Skin exposure area (cm^2/day)

RBCA SITE ASSESSMENT	Tier 2 Worksheet 8.2

Site Name: Truck Stop | Site Location: Oklahoma City | Completed By: Rachal Roberts | Date Completed: 3/1/1999 | *4 OF 4*

TIER 2 PATHWAY RISK CALCULATION

GROUNDWATER EXPOSURE PATHWAYS ■ **(CHECKED IF PATHWAYS ARE ACTIVE)**

	CARCINOGENIC RISK						TOXIC EFFECTS				
Constituents of Concern	(1) EPA Classification	(2) Total Carcinogenic Intake Rate (mg/kg/day) On-Site Commercial		(3) Oral Slope Factor (mg/kg-day)^-1	(4) Individual COC Risk (2) x (3) On-Site Commercial		(5) Total Toxicant Intake Rate (mg/kg/day) On-Site Commercial		(6) Oral Reference Dose (mg/kg-day)	(7) Individual COC Hazard Quotient (5) / (6) On-Site Commercial	
Benzene	A	1.9E-2		2.9E-2	5.4E-4						
Ethylbenzene	D						2.8E-1		1.0E-1	2.8E+0	
Toluene	D						6.7E-1		2.0E-1	3.3E+0	
Xylene (mixed isomers)	D						8.3E-1		2.0E+0	4.1E-1	

Total Pathway Carcinogenic Risk = 5.4E-4 | 0.0E+0

Total Pathway Hazard Index = 6.6E+0 | 0.0E+0

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-507-WJX-400

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 9.3**

Site Name: Truck Stop — Completed By: Rachal Roberts

Site Location: Oklahoma City — Date Completed: 3/1/1999

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-6 — ☐ MCL exposure limit? — Calculation Option: 3

Target Risk (Class C) 1.0E-5 — ☐ PEL exposure limit?

Target Hazard Quotient 1.0E+0

SSTL Results For Complete Exposure Pathways ("x" if Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	X Groundwater Ingestion			X Groundwater Volatilization to Indoor Air		X Groundwater Volatilization to Outdoor Air		Applicable SSTL	SSTL Exceeded ?	Required CRF
CAS No.	Name	(mg/L)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)	Residential: (on-site)	Commercial: (on-site)	Residential (on-site)	Commercial: (on-site)	(mg/L	"■" if yes	Only if "yes" left
71-43-2	Benzene	FP	NA	1.7E-1	NA	NA	4.8E+1	NA	9.8E+1	1.7E-1	■	#VALUE!
100-41-4	Ethylbenzene	FP	NA	>Sol	NA	NA	>Sol	NA	>Sol	>Sol	☐	<1
108-88-3	Toluene	FP	NA	3.5E+2	NA	NA	>Sol	NA	>Sol	3.5E+2	■	#VALUE!
1330-20-7	Xylene (mixed isomers)	FP	NA	>Sol	NA	NA	>Sol	NA	>Sol	>Sol	☐	<1

>Sol Indicates risk-based target concentration greater than constituent solubility

Software: GSI RBCA Spreadsheet — Serial: G-507-WJX-400

Version: 1.0.1

Saturated zone model (dissolved phase source) BP RISC
Indoor air model with volatile emissions from groundwater
Outdoor air concentration estimated from gw concentration

Title: New Project
Simulation time (years)........... 100
Unsaturated Zone Properties
Total Porosity in vadose zone (cm3/cm3) .364
Residual water content (cm3/cm3)........ 8.000E-02
Fraction organic carbon (g oc/g soil)... 7.700E-04
Soil bulk density (g/cm3).............. 1.68
Infiltration Rate (cm/yr).............. 730.
Saturated conductivity (m/d)............ .200
Van Genuchten"s N....................... 2.68
Thickness of vadose zone (m)............ 7.01
Water content under house(cm3/cm3)...... 8.000E-02
Thickness of capillary fringe (cm)...... 13.0
Air content in capillary fringe(cm3/cm3) 9.600E-02
(Water cont. in cap. fringe(cm3/cm3))... .268
Air content in capillary fringe(cm3/cm3) 9.600E-02

OUTDOOR AIR PARAMETERS
Height of box (breathing zone) (m)...... 2.00
Length of box (m)....................... 10.0
Wind speed (m/s)........................ 2.25

Basement and House Data
Distance from source to basement (m).... 7.14
Cross-sect. area of basement (m2)....... 1.035E+03
Volume of house (m3).................... 3.100E+03
Number of air changes per day........... 480.
Foundation thickness (m)................ .150
Fraction of cracks (cm3/cm3)............ 1.000E-02

Saturated Zone Model Source

Pulse Source:
Length of pulse (yr)................... 50.0
Total thickness of source (m).......... .540
Length of source (m)................... 80.0
Width of source (m).................... 37.0

Aquifer Properties
Effective porosity (cm3/cm3)............ .407
Fraction organic carbon (g oc/g soil)... 8.500E-04
Hydraulic conductivity (m/d)............ .200

Soil bulk density (g/cm3)............... 1.59
Hydraulic gradient (m/m)................ 7.400E-02
Longitudinal dispersivity (m)........... 2.10
Transverse dispersivity (m)............ .210
Vertical dispersivity (m).............. 2.100E-02

Receptor Well Location

Distance downgradient (m)............... .300
Distance cross-gradient (m)............. 21.0
Depth to top of well screen (m)......... .000
Depth to bottom of well screen(m)....... 9.70
Number of points used to calc. conc..... 2

CHEMICAL DATA INPUT: Benzene

Diffusion coeff. in air (cm2/s)..... 8.800E-02
Diffusion coeff. in water (cm2/s)... 9.800E-06
Solubility (mg/l)................... 1.750E+03
KOC (ml/g).......................... 58.9
Henry"s Law Coefficient (-)......... .228
Molecular Weight (g/mol)............ 78.0
Density of chemical (g/cm3)......... .877
Degradation rate sat. zone (1/d).... .000
Degradation rate unsat. zone (1/d).. .000
Source conc. for GW model (mg/l).................. 44.4

Routes:
INGESTION OF GROUNDWATER
DERMAL CONTACT DURING SHOWER
INHALATION DURING SHOWER
INHALATION OF OUTDOOR AIR
INHALATION OF INDOOR AIR

SUMMARY OF INPUT PARAMETERS

Body Weight (kg)	70.00
Lifetime (years)	70.00

INGESTION OF GROUNDWATER

Ingestion rate (l/day)	1.40
Exp. Freq Groundwater (events/year)	52.00
Exp. Duration Groundwater (years)	5.00
Absorption Adjustment Factor for Ingestion of water (-)	
Benzene	1.0

INHALATION OF INDOOR AIR

Inhalation rate (m^3/hr)	0.83
Time indoors (hours/day)	2.00
Lung Retention Factor (-)	0.50
Exp. Freq. Indoor Air (events/yr)	52.00
Exp. Duration Indoor Air (yr)	5.00
Absorption Adjustment Factor for Inhalation (-)	1.0

MEDIA CONCENTRATIONS

Concentration in Groundwater (mg/l)
Obtained from Fate and Transport output
AVERAGE Concentration (over exposure duration)
(used to calculate carcinogenic risk)
Exposure Duration (years) 5.0
Benzene 1.7

Concentration used to calculate hazard index
(Minimum of 7 years or exposure duration)
Exposure Duration (years) 5.0
Benzene 1.7

Concentration in Indoor Air (mg/m^3)
Obtained from Fate and Transport output
AVERAGE Concentration (over exposure duration)
(used to calculate carcinogenic risk)
Exposure Duration (years) 5.0
Benzene 2.10E-03

Concentration used to calculate hazard index
(Minimum of 7 years or exposure duration)
Exposure Duration (years) 5.0
Benzene 2.10E-03

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]	2.90E-02
Ingestion Reference Dose (mg/kg-day)	1.70E-03
Inhalation Slope Factor [1/(mg/kg-day)]	2.90E-02
Inhalation Reference Dose (mg/kg-day)	1.70E-03
Dermal Slope Factor [1/(mg/kg-day)]	2.90E-02
Dermal Reference Dose (mg/kg-day)	1.70E-03

SUMMARY OF RESULTS
INGESTION OF GROUNDWATER

Benzene

CDI (mg/kg-day)	4.93E-03
LADD (mg/kg-day)	3.52E-04
Cancer Risk (-)	1.02E-05
Hazard Index (-)	2.90E+00

INHALATION OF INDOOR AIR

Benzene

CDI (mg/kg-day)	3.56E-06
LADD (mg/kg-day)	2.54E-07
Cancer Risk (-)	7.36E-09
Hazard Index (-)	2.09E-03

SUMMARY OF CARCINOGENIC RISK
CASE 1:
Worker - Typical

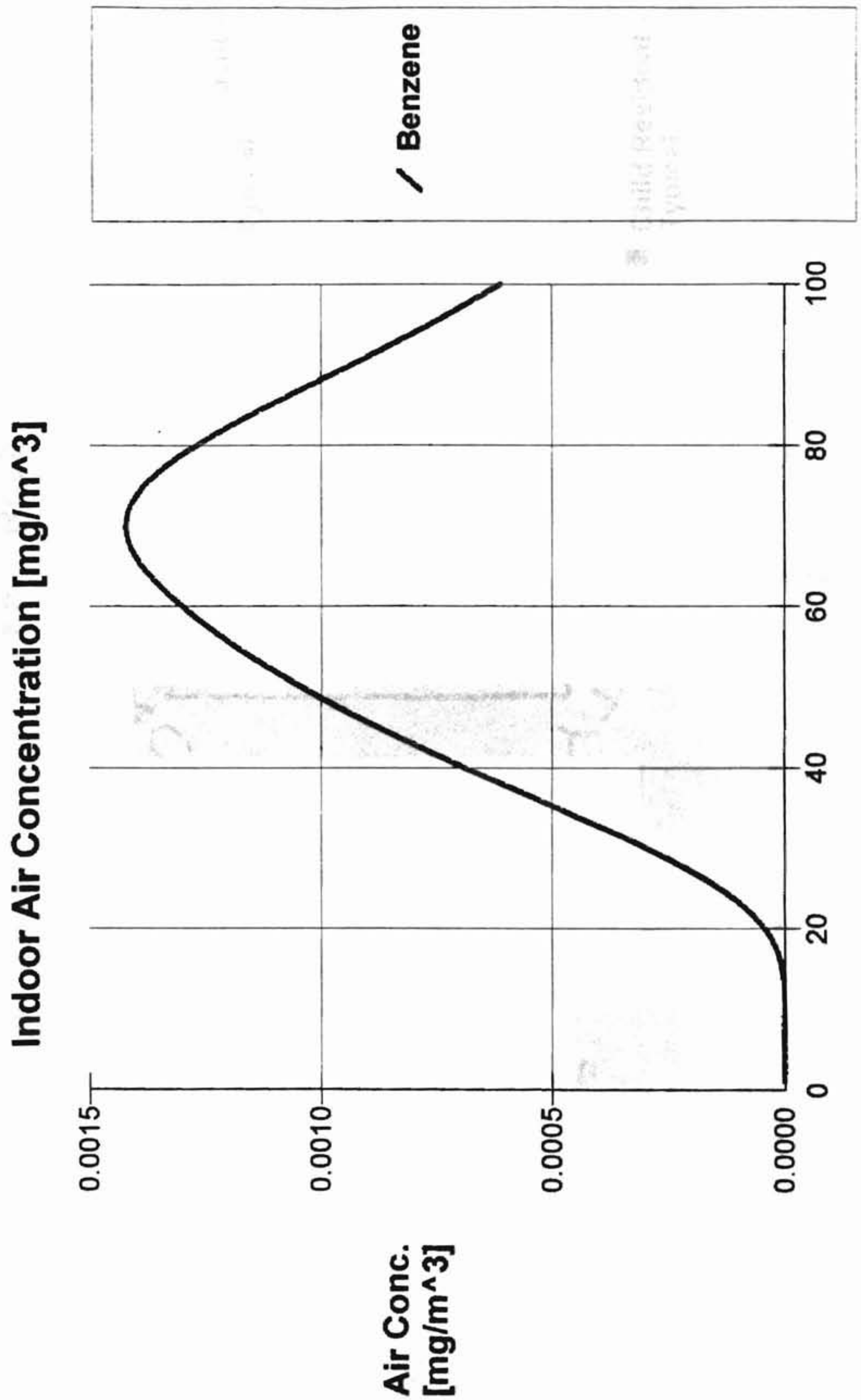
	Ingestion of Groundwater	Dermal Contact Shower	Inhalation During Shower	Inhalation of Outdoor Air	Inhalation of Indoor Air	TOTAL
Benzene	1.0E-05	1.2E-06	3.2E-05	8.9E-12	7.4E-09	4.3E-05
TOTAL	1.0E-05	1.2E-06	3.2E-05	8.9E-12	7.4E-09	4.3E-05

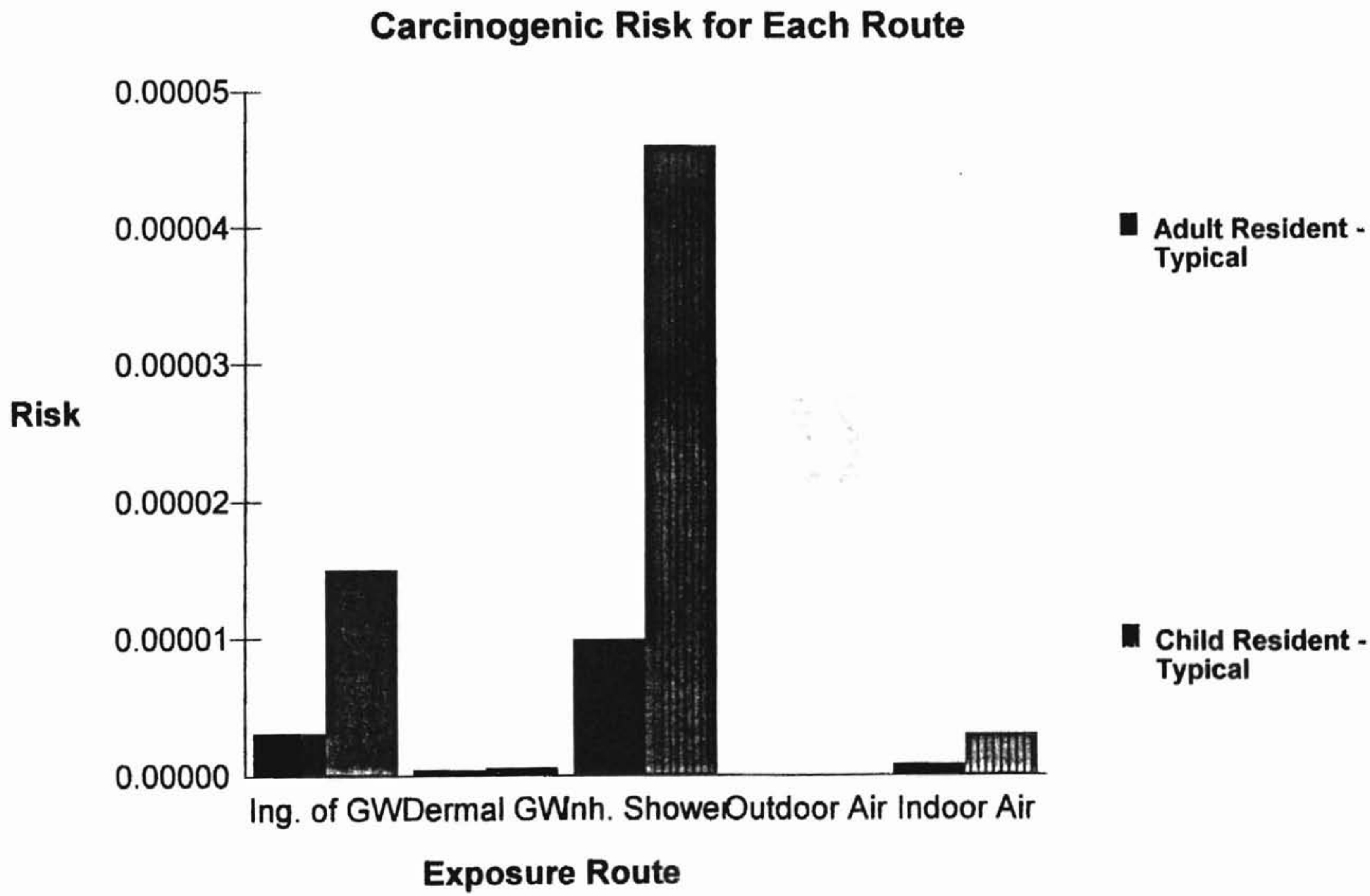
SUMMARY OF HAZARD QUOTIENTS

	Ingestion of Groundwater	Dermal Contact Shower	Inhalation During Shower	Inhalation of Outdoor Air	Inhalation of Indoor Air	TOTAL
Benzene	2.9E+00	3.3E-01	9.1E+00	2.5E-06	2.1E-03	1.2E+01
Ethylbenzene	3.2E-03	1.3E-03	3.1E-03	1.2E-09	1.2E-07	7.6E-03
Toluene	.5E-02	3.6E-03	7.7E-02	2.6E-08	2.7E-06	9.5E-02
Xylenes	2.6E-03	1.1E-03	7.3E-02	2.3E-08	2.3E-06	7.7E-02
TOTAL	2.9E+00	3.4E-01	9.3E+00	2.6E-06	2.1E-03	1.3E+01

Clean-up Levels (RBSLs) in Saturated Zone Source [mg/l}

Benzene	1.02
Ethylbenzene	.0662
Toluene	.612
Xylenes	1.07


Indoor Air Concentration [mg/m^3]
Air Conc. [mg/m^3]
0.0015
0.0010
0.0005
0.0000
0
20
40
60
80
100
Years
Benzene


Carcinogenic Risk for Each Route
Risk
0.00005
0.00004
0.00003
0.00002
0.00001
0.00000
Ing. of GW
Dermal GW
Inh. Shower
Outdoor Air
Indoor Air
Exposure Route
Adult Resident - Typical
Child Resident - Typical

Appendix F
Model Output by Pathways

Residential Child - Dermal Exposure to Groundwater in Shower											
		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	0.0	0.0		0.0	0.0	3.12E-06	3.22E-02		0.0168	0.0165
	Ethylbenzene	0.0	0.0		0.0	0.0		7.02E-04		0.0061	0.0044
	Toluene	0.0	0.0		0.0	0.0		6.75E-03		0.1930	0.1670
	Xylene	0.0	0.0		0.0	0.0		7.62E-04		0.1230	0.0968
GSI RBCA	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	2.20E-06	2.60E-01	7.75E-01		1.35E-01
	Ethylbenzene	0.0	0.0	1.13E+02	0.0	0.0		6.80E-04	5.01E-02	5.93E-03	
	Toluene	0.0	0.0	1.05E+03	0.0	0.0		2.40E-03	4.63E-01	0.0688	
	Xylene	0.0	0.0	1.84E+03	0.0	0.0		6.90E-04	8.13E-01	0.112	

Residential Child - Inhalation of Vapors in Shower											
		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	0.0	0.0		0.0	0.0	5.66E-04	5.84E+00		0.559	0.550
	Ethylbenzene	0.0	0.0		0.0	0.0		1.25E-02		0.204	0.146
	Toluene	0.0	0.0		0.0	0.0		1.00E+00		6.440	5.550
	Xylene	0.0	0.0		0.0	0.0		3.63E-01		4.090	3.220
GSI RBCA	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	1.90E-04	2.20E+01	7.75E-01		1.35E-01
	Ethylbenzene	0.0	0.0	1.13E+02	0.0	0.0		5.20E-03	5.01E-02	5.93E-03	
	Toluene	0.0	0.0	1.05E+03	0.0	0.0		1.60E-01	4.63E-01	0.0688	
	Xylene	0.0	0.0	1.84E+03	0.0	0.0		1.40E-01	8.13E-01	0.112	

Residential Child - Ingestion of Groundwater											
		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	0.0	0.0		0.0	0.0	8.58E-05	0.884		0.0168	0.0165
	Ethylbenzene	0.0	0.0		0.0	0.0		0.005		0.0061	0.0044
	Toluene	0.0	0.0		0.0	0.0		0.087		0.1930	0.1670
	Xylene	0.0	0.0		0.0	0.0		0.006		0.1230	0.0968
GSI RBCA	Benzene	2.40E-04		0.086			3.00E-04		0.310		
	Ethylbenzene		0.760	110.000				1.300	> sol		
	Toluene		0.750	210.000				1.500	> sol		
	Xylene		0.078	> sol				0.190	> sol		
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	5.90E-05	7.100	0.775		0.135
	Ethylbenzene	0.0	0.0	113.00	0.0	0.0		0.005	0.050	0.006	
	Toluene	0.0	0.0	1050.00	0.0	0.0		0.031	0.463	0.0688	
	Xylene	0.0	0.0	1840.00	0.0	0.0		0.005	0.813	0.112	

Residential Child - Indoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	2.40E-04		0.018			3.00E-04		0.044		
	Ethylbenzene		0.760	54.000				1.300	140.000		
	Toluene		0.750	24.000				1.500	59.000		
	Xylene		0.078	> sol				0.190	> sol		
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	1.20E-05	1.40E+00	0.775		0.006
	Ethylbenzene	0.0	0.0	113.00	0.0	0.0		5.40E-05	0.050	3.67E-05	
	Toluene	0.0	0.0	1050.00	0.0	0.0		1.60E-03	0.463	4.16E-04	
	Xylene	0.0	0.0	1840.00	0.0	0.0		1.30E-03	0.813	5.98E-04	

Residential Child - Outdoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	2.40E-04		3.50			3.00E-04		6.100		
	Ethylbenzene		0.760	> sol				1.300	> sol		
	Toluene		0.750	> sol				1.500	> sol		
	Xylene		0.078	> sol				0.190	> sol		
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	4.40E-10	5.20E-05	0.776		4.18E-07
	Ethylbenzene	0.0	0.0	113.00	0.0	0.0		1.60E-08	0.050	2.21E-08	
	Toluene	0.0	0.0	1050.00	0.0	0.0		4.70E-07	0.463	2.51E-07	
	Xylene	0.0	0.0	1840.00	0.0	0.0		3.80E-07	0.813	3.60E-07	

Residential Adult - Dermal Exposure to Groundwater in Shower

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	0.0	0.0		0.0	0.0	1.81E-07	0.022		0.0168	0.0165
	Ethylbenzene	0.0	0.0		0.0	0.0		0.000		0.0061	0.0044
	Toluene	0.0	0.0		0.0	0.0		0.005		0.1930	0.1670
	Xylene	0.0	0.0		0.0	0.0		0.001		0.1230	0.0968
GSI RBCA	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	1.50E-06	0.170	0.776		0.14
	Ethylbenzene	0.0	0.0	113.00	0.0	0.0		0.000	0.050	0.006	
	Toluene	0.0	0.0	1050.00	0.0	0.0		0.002	0.463	0.0688	
	Xylene	0.0	0.0	1840.00	0.0	0.0		0.000	0.813	0.112	

Residential Adult - Outdoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	2.40E-04		3.50			3.00E-04		6.100		
	Ethylbenzene		0.760	> sol				1.300	> sol		
	Toluene		0.750	> sol				1.500	> sol		
	Xylene		0.078	> sol				0.190	> sol		
BP RISC	Benzene	0.0	0.0	> sol	0.0	0.0	5.90E-11	7.00E-06	0.775		4.18E-07
	Ethylbenzene	0.0	0.0	113.00	0.0	0.0		2.20E-09	0.050	2.21E-08	
	Toluene	0.0	0.0	1050.00	0.0	0.0		6.30E-08	0.463	2.51E-07	
	Xylene	0.0	0.0	1840.00	0.0	0.0		5.10E-08	0.813	3.60E-07	

Truck Driver - Dermal Exposure to Groundwater In Shower

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	2.30E-08	0.007		0.034	0.034	7.56E-08	0.0215		0.112	0.112
	Ethylbenzene		6.96E-11		6.00E-09	6.00E-09		0.0027		0.237	0.237
	Toluene		8.02E-06		0.0023	0.0023		0.0049		1.400	1.400
	Xylene		3.80E-08		6.10E-05	6.10E-05		0.0008		1.350	1.350
GSI RBCA	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
BP RISC	Benzene	1.20E-06	0.3500	0.25		1.84	1.20E-06	0.3300	1.02		1.73
	Ethylbenzene		0.0001	0.02	0.009			0.0013	0.066	0.112	
	Toluene		0.0010	0.15	0.30			0.0036	0.612	1.03	
	Xylene		0.0002	0.26	0.33			0.0011	1.070	1.81	

Truck Driver - Inhalation of Vapors in Shower

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	3.17E-06	0.899		0.034	0.034	4.34E-06	1.23		0.112	0.112
	Ethylbenzene		9.39E-10		6.00E-09	6.00E-09		0.0154		0.237	0.237
	Toluene		9.06E-04		0.0023	0.0023		0.2310		1.400	1.400
	Xylene		1.38E-05		6.10E-05	6.10E-05		0.1260		1.350	1.350
GSI RBCA	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
BP RISC	Benzene	1.60E-04	46.0	0.25		1.84	3.20E-05	9.1	1.02		1.73
	Ethylbenzene		0.0012	0.02	0.009			0.0031	0.066	0.112	
	Toluene		0.1000	0.15	0.30			0.0770	0.612	1.03	
	Xylene		0.0630	0.26	0.33			0.0730	1.070	1.81	

Truck Driver - Ingestion of Groundwater

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	2.9E-07	8.1E-02		0.034	0.034	6.58E-07	0.187		0.112	0.112
	Ethylbenzene		2.5E-10		6.00E-09	6.00E-09		0.007		0.237	0.237
	Toluene		4.7E-05		0.0023	0.0023		0.020		1.400	1.400
	Xylene		1.2E-07		6.10E-05	6.10E-05		0.002		1.350	1.350
GSI RBCA	Benzene	1.80E-04		0.120			5.40E-04		0.170		
	Ethylbenzene		0.670	120				2.80	> sol		
	Toluene		0.650	250				3.30	350		
	Xylene		0.068	> sol				0.410	> sol		
BP RISC	Benzene	1.50E-05	4.40E+00	2.47E-01		1.84	1.00E-05	2.900	1.020		1.73
	Ethylbenzene		3.60E-04	1.59E-02	0.009			0.003	0.066	0.112	
	Toluene		5.90E-03	1.47E-01	0.30			0.015	0.612	1.03	
	Xylene		6.60E-04	2.59E-01	0.33			0.003	1.070	1.81	

Truck Driver - Indoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	1.80E-04		27.000			5.40E-04		48.000		
	Ethylbenzene		0.670	> sol				2.800	> sol		
	Toluene		0.650	> sol				3.300	> sol		
	Xylene		0.068	> sol				0.410	> sol		
BP RISC	Benzene	1.30E-08	0.0036	0.247		7.62E-04	7.40E-09	2.10E-03	1.020		0.002
	Ethylbenzene		8.10E-10	0.0159	3.00E-08			1.20E-07	0.066	1.97E-05	
	Toluene		7.50E-08	0.147	1.07E-06			2.70E-06	0.612	1.78E-04	
	Xylene		4.70E-08	0.259	1.18E-06			2.30E-06	1.070	2.76E-04	

Truck Driver - Outdoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	1.80E-04		66.00			5.40E-04		98.000		
	Ethylbenzene		0.670	> sol				2.800	> sol		
	Toluene		0.650	> sol				3.300	> sol		
	Xylene		0.068	> sol				0.410	> sol		
BP RISC	Benzene	1.20E-12	3.40E-07	0.247		2.84E-07	8.90E-12	2.50E-06	1.020		1.01E-05
	Ethylbenzene		7.60E-12	0.0159	1.13E-09			1.20E-09	0.066	7.88E-07	
	Toluene		7.00E-10	0.147	4.05E-08			2.60E-08	0.612	7.13E-06	
	Xylene		4.40E-10	0.259	4.46E-08			2.30E-08	1.070	1.10E-05	

Commercial Worker - Ingestion of Groundwater

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene	2.5E-06	0.4		0.034	0.034	3.92E-06	1.110		0.112	0.112
	Ethylbenzene		1.2E-09		6.02E-09	6.00E-09		0.040		0.237	0.237
	Toluene		2.2E-04		0.0023	0.0023		0.119		1.400	1.400
	Xylene		6.0E-07		6.06E-05	6.10E-05		0.011		1.350	1.350
GSI RBCA	Benzene	0.0015		0.014			0.0032		0.028		
	Ethylbenzene		5.800	14				17.00	29.0		
	Toluene		5.600	28				20.00	59		
	Xylene		0.590	> sol				2.500	> sol		
BP RISC	Benzene	1.30E-04	21.000	0.33		1.84	6.10E-05	17.000	0.727		1.73
	Ethylbenzene		0.002	0.28	0.009			0.019	0.047	0.112	
	Toluene		0.028	0.17	0.30			0.088	0.435	1.03	
	Xylene		0.003	0.44	0.33			0.015	0.763	1.81	

Commercial Worker - Indoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	0.0015		3.200			0.003		8.100		
	Ethylbenzene		5.800	> sol				17.000	> sol		
	Toluene		5.600	> sol				20.000	> sol		
	Xylene		0.590	> sol				2.500	> sol		
BP RISC	Benzene	4.40E-07	0.07	0.333		7.62E-04	1.80E-07	0.050	0.727		0.002
	Ethylbenzene		1.50E-08	0.277	3.00E-08			2.70E-06	0.047	1.97E-05	
	Toluene		1.40E-06	0.166	1.07E-06			6.30E-05	0.435	1.78E-04	
	Xylene		8.80E-07	0.444	1.18E-06			5.60E-05	0.763	2.76E-04	

Commercial Worker - Outdoor Inhalation of Groundwater Emissions

		Estimated					Measured				
			Hazard		Air Concentration			Hazard		Air Concentration	
Model	Chemical	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen	Risk	Quotient	SSTL	Non-Carcinogen	Carcinogen
API DSS	Benzene										
	Ethylbenzene		Can not be modeled					Can not be modeled			
	Toluene										
	Xylene										
GSI RBCA	Benzene	0.002		7.60			0.003		16.000		
	Ethylbenzene		5.800	> sol				17.000	> sol		
	Toluene		5.600	> sol				20.000	> sol		
	Xylene		0.590	> sol				2.500	> sol		
BP RISC	Benzene	1.60E-10	2.60E-05	0.3330		2.84E-07	3.20E-10	9.00E-05	0.727		1.01E-05
	Ethylbenzene		5.80E-10	0.2770	1.13E-09			4.10E-08	0.047	7.88E-07	
	Toluene		5.40E-08	0.1660	4.05E-08			9.50E-07	0.435	7.13E-06	
	Xylene		3.30E-08	0.4440	4.46E-08			8.40E-07	0.763	1.10E-05	

VITA

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