

Attachment D

Methodology, Statistical Analyses and Results of GRIT/STAT. Version 5.0 on
Copper and Lead in Groundwater

Summary of Statistical Analyses Results
Copper and Lead in Groundwater

Tests for Normality

	Copper	Lead	Conclusions
<i>Skewness</i>	4.474	3.325	
Critical Value	3.117	1.964 non-normal dist.	
<i>Shapiro-Francia Statistic</i>	0.3324	0.5132	
5% Critical Value	0.976	0.976 non-normal dist.	

	Plume/Source v/s Background		Plume/source v/s Downgradient		Downgradient v/s Background		Conclusions
	Copper	Lead	Copper	Lead	Copper	Lead	
<i>Levene's Test for Distributional Variance</i>							
Computed F	4.11	1.49	9.21	4.47	2.86	4.1	Assumption of equal variances rejected
Tabulated F	2.52	2.52	2.35	2.53	2.36	2.36	
<i>Wilcoxon-Rank Sum (Statistical Significance)</i>							
Test z-statistic	-2.9753	-0.0157	-2.3263	-1.6811	-1.6275	-0.2687	No statistically significant difference in values
Z alpha at 1% Significance	2.3263	2.3263	2.3263	2.3263	2.3263	2.3263	

Calculations performed using GRIT/STAT Verion 5.0

Statistical Analysis Methodology and Results

A statistical analysis was performed with the results of the background, source area and downgradient copper and lead groundwater concentrations. The purpose of the analysis was to determine the significance of the metals concentrations within the source area. If the concentrations within the source area are not significant, then copper and lead should be removed from the sampling plan.

For a background on the statistical tests used and their definitions, please see the *RCRA Facility Investigation Phase II*.

Data Selection

Groundwater analyses have been conducted on groundwater samples collected from the monitoring well network since August 1990. Wells with a sampling history of greater than one year were selected for the statistical analysis. The following wells were selected as background wells: MW-1s, MW-7s, MW-9s and MW-10s. MW-2s, MW-4s, MW-11s, and MW-13s were selected as wells inside the plume or source area and MW-5sk, MW-9sk, CRW-1, CRW-5 and CRW-11 were selected as downgradient wells.

Normality Tests

The skewness and Shapiro-Francia analyses were applied to the data, to determine if the data was normally distributed. The complete data set from all wells was input into the database and skewness of 4.474 for Copper and 3.325 for Lead. The Shapiro-Francia test statistic (W) for copper is 0.3324 with a critical value of 0.9670 and a test statistic (W) of 0.5132 with a critical value of 0.9670.

Based on this data GRIT/STAT Version 5.0 indicated a statistical significant evidence of non-normality. A summary of the skewness values and the test statistics (W) are included in the table at the end of this Attachment.

Statistical Significance Tests

Since the data was determined to non-normally distributed, a Levene's Test for Homogeneity of Variance between two data sets for each of the following comparisons for Copper and Lead. Background v/s source/plume wells; background v/s downgradient; and source/plume wells v/s downgradient. The computed F value for Levene's Test was compared against the tabulated F. In five of the cases, the computed F exceeded the tabulated F and therefore the assumption of equal variances was rejected. Only in the lead data set, where the background wells were compared with the source/plume wells was the assumption of equal variance accepted. Summaries of the F values are included in the table at the end of this Attachment.

Based on the Normality Tests and the test for variance, the Wilcoxon-Rank Sum test was chosen to determine if a statistically significant variance occurs between the data sets. Again, the following comparisons were made for both Copper and Lead. Background v/s source/plume wells; background v/s downgradient; and source/plume wells v/s downgradient. In all cases, the approximate Z-Score was less than the $Z\alpha$ and therefore no significant evidence variance or contamination was determined between the data sets. A summary of the Z-Scores and the $Z\alpha$ are included in the table at the end of this Attachment.

BIOCHLOR Natural Attenuation Decision Support System

Version 1.0

Alcatel
Raleigh, NC
Run Name

Data Input Instructions:

115 → 1. Enter value directly...or
↑ or 2. Calculate by filling in gray cells. Press Enter, then
0.02 Variable* → Data used directly in-model. (C)

(To restore formulas, hit "Restore Formulas" button)

Test if Biotransformation is Occurring → **Natural Attenuation Screening Protocol**

TYPE OF CHLORINATED SOLVENT: Ethenes Ethenes

1. ADVECTION

Seepage Velocity* Vs 434.6 (ft/yr)

Hydraulic Conductivity K 6.0E-03 (cm/sec)

Hydraulic Gradient i 0.021 (ft/ft)

Effective Porosity n 0.3 (-)

5. GENERAL

Simulation Time* 25 (yr)

Modeled Area Width* 600 (ft)

Modeled Area Length* 2400 (ft)

Zone 1 Length* 2400 (ft)

Zone 2 Length* 0 (ft)

Zone 2 = L - Zone 1

2. DISPERSION

Alpha x Calc. Method 40 (ft)

(Alpha y) / (Alpha x) 0.68 (-)

(Alpha z) / (Alpha x) 3.E-02 (-)

Change Alpha x Calc. Method

3. ADSORPTION

Retardation Factor* R

Soil Bulk Density, rho 1.7 (kg/L)

Fraction Organic Carbon, foc 1.0E-4 (-)

Partition Coefficient Koc

TCA	426 (L/kg)	1.2 (-)
DCA	130 (L/kg)	1.1 (-)
CA	125 (L/kg)	1.1 (-)

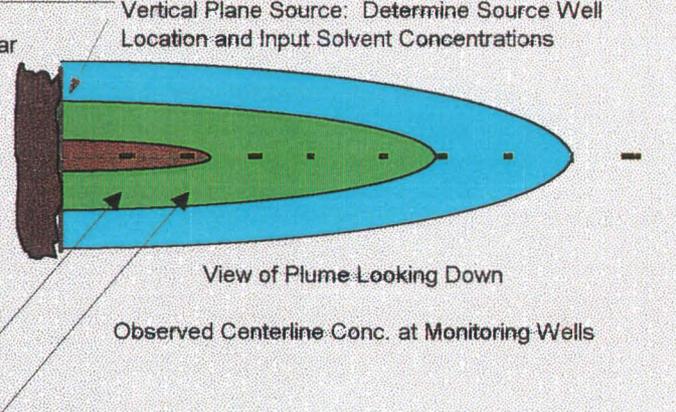
6. SOURCE DATA

Source Options TYPE: Single Planar

Source Thickness in Sat. Zone* 30 (ft)

Width* (ft) 120

Conc. (mg/L)*	C1	C2	C3
TCA	.562		
DCA	.233		
CA	.0		



Common R (used in model)* = 1.1

4. BIOTRANSFORMATION

-1st Order Decay Coef*

Zone 1	λ (1/yr)	half-life (yrs)	Yield*
TCA → DCA	0.990	0.70	0.74
DCA → CA	6.930	0.10	0.65
CA → Ethane	1.733	0.40	0.47

Zone 2	λ (1/yr)	half-life (yrs)
TCA → DCA	0.000	
DCA → CA	0.000	
CA → Ethane	0.000	

7. FIELD DATA FOR COMPARISON

TCA Conc. (mg/L)	.562	.0	.057	.121	.0	.0				
DCA Conc. (mg/L)	.233	.0	.016	.007	.0	.0				
CA Conc. (mg/L)	.0	.0	.0	.0	.0	.0				

Dist. from Source (ft)	0	210	270	390	840	855				
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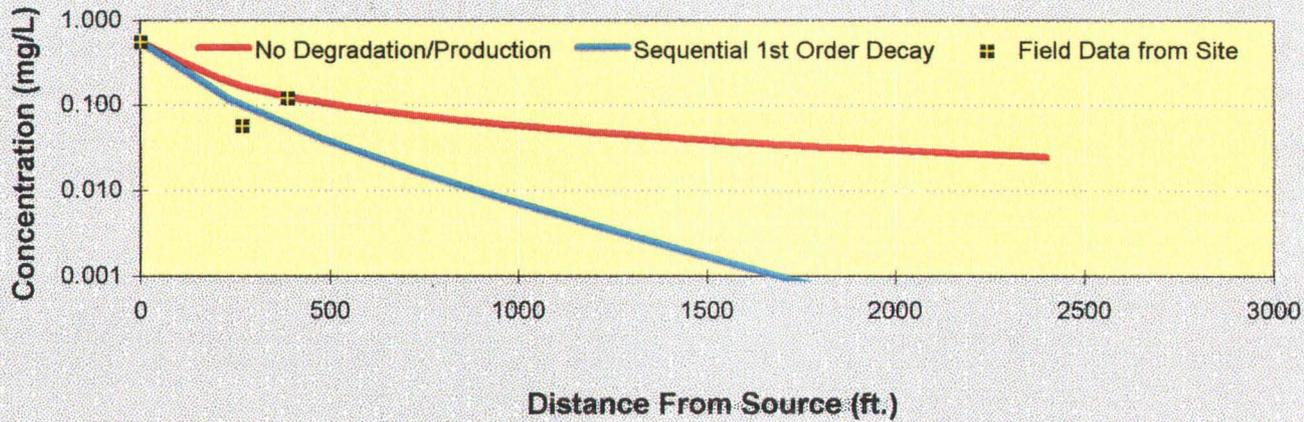
8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE **RUN ARRAY** **Help** **Restore Formulas** **RESET**

SEE OUTPUT **Paste Example**

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

		Distance from Source (ft)										
		0	240	480	720	960	1200	1440	1680	1920	2160	2400
TCA	No-Degradation	0.562	0.187	0.109	0.076	0.059	0.048	0.040	0.035	0.031	0.027	0.025
	Biotransformation	0.562	0.113	0.040	0.017	0.008	0.004	0.002	0.001	0.001	0.000	0.000
		Monitoring Well Locations (ft)										
		0	210	270	390	840	855					
Field Data from Site		0.562	0.000	0.057	0.121	0.000	0.000					



See TCA

See DCA

See CA

Log \longleftrightarrow Linear

Time:

25 Years

Return to
Input

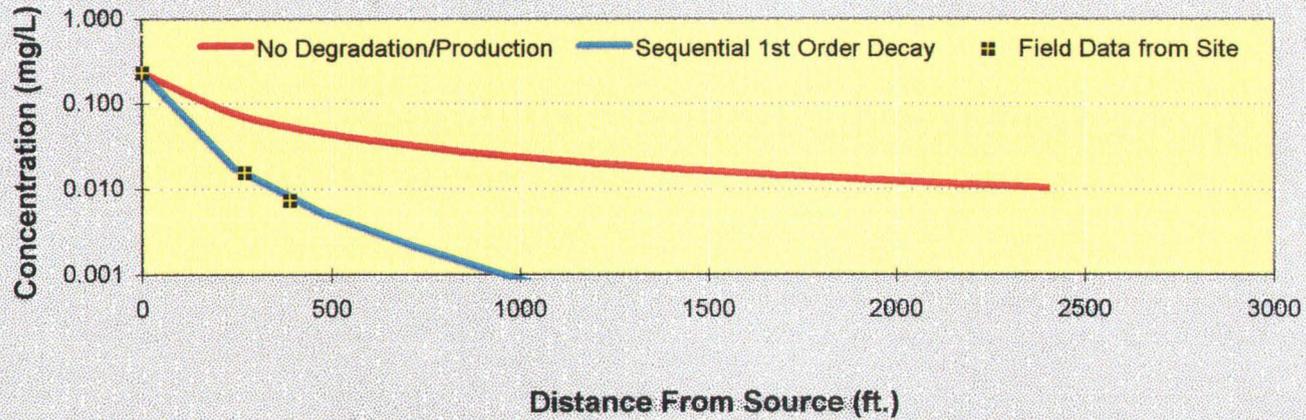
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

DCA	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	0.233	0.077	0.045	0.032	0.024	0.020	0.017	0.014	0.013	0.011	0.010
Biotransformation	0.233	0.018	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Field Data from Site	Monitoring Well Locations (ft)									
	0	210	270	390	840	855				
	0.233	0.000	0.016	0.007	0.000	0.000				



- See TCA
- See DCA
- See CA

Log ↔ Linear

Time: 25 Years

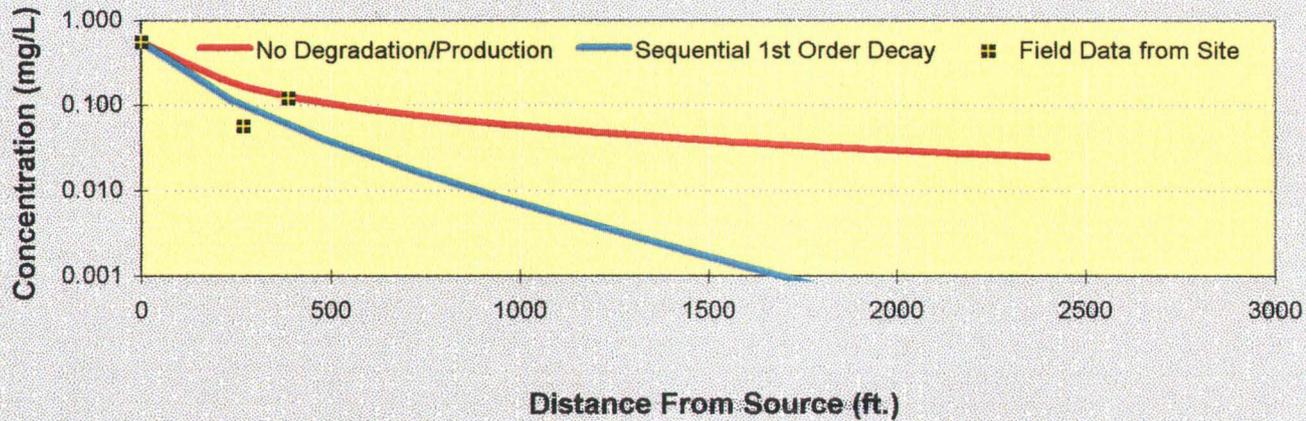
Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

		Distance from Source (ft)										
TCA	Distance from Source (ft)											
	0	240	480	720	960	1200	1440	1680	1920	2160	2400	
No Degradation	0.562	0.187	0.109	0.076	0.059	0.048	0.040	0.035	0.031	0.027	0.025	
Biotransformation	0.562	0.113	0.040	0.017	0.008	0.004	0.002	0.001	0.001	0.000	0.000	
		Monitoring Well Locations (ft)										
		0	210	270	390	840	855					
Field Data from Site	0.562	0.000	0.057	0.121	0.000	0.000						



- See TCA
- See DCA
- See CA

Log ↔ Linear

Time: 75 Years

Return to
Input

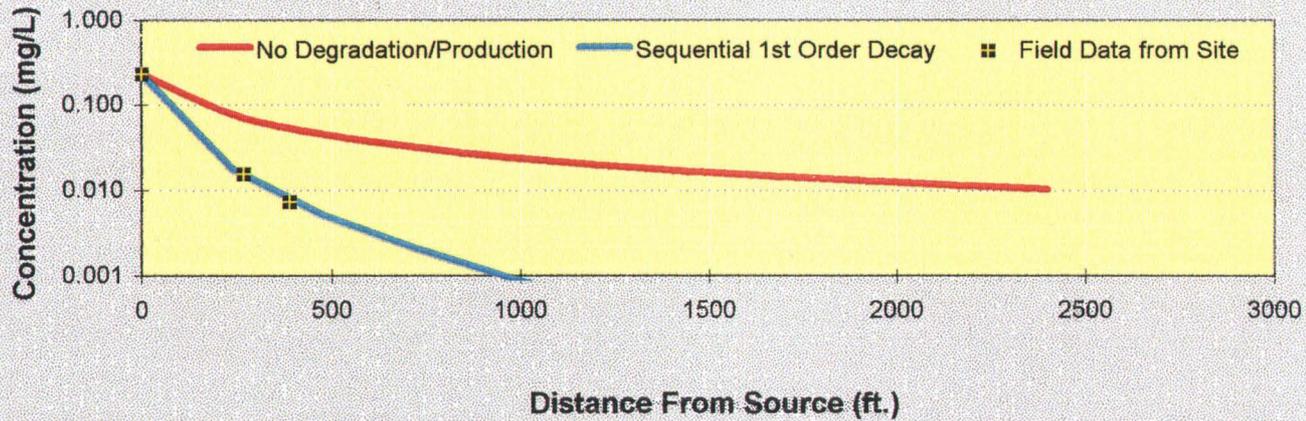
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

DCA	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	0.233	0.077	0.045	0.032	0.024	0.020	0.017	0.014	0.013	0.011	0.010
Biotransformation	0.233	0.018	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Field Data from Site	Monitoring Well Locations (ft)										
	0	210	270	390	840	855					
	0.233	0.000	0.016	0.007	0.000	0.000					



- See TCA
- See DCA
- See CA

Log Linear

Time:

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 1.0

Alcatel
Raleigh, NC
Run Name

Data Input Instructions:

- 115 → 1. Enter value directly...or
↑ or 0.02 → 2. Calculate by filling in gray cells. Press Enter, then
Variable* → Data used directly in model.
- (To restore formulas, hit "Restore Formulas" button)

Test if
Biotransformation
is Occurring →

Natural Attenuation
Screening Protocol

TYPE OF CHLORINATED SOLVENT:

Ethenes
Ethanes

1. ADVECTION

Seepage Velocity* Vs 434.6 (ft/yr)
Hydraulic Conductivity K 6.0E-03 (cm/sec)
Hydraulic Gradient i 0.021 (ft/ft)
Effective Porosity n 0.3 (-)

2. DISPERSION

Alpha x Calc. Method 40 (ft)
(Alpha y) / (Alpha x) 0.68 (-)
(Alpha z) / (Alpha x) 3.E-02 (-)
Change Alpha x Calc. Method

3. ADSORPTION

Retardation Factor* R
Soil Bulk Density, rho 1.7 (kg/L)
Fraction Organic Carbon, foc 1.0E-4 (-)
Partition Coefficient Koc
PCE 426 (L/kg) 1.2 (-)
TCE 130 (L/kg) 1.1 (-)
DCE 125 (L/kg) 1.1 (-)
VC 30 (L/kg) 1.0 (-)
ETH 302 (L/kg) 1.2 (-)
Common R (used in model)* = 1.1

4. BIOTRANSFORMATION

-1st Order Decay Coef*
Zone 1
PCE → TCE 2.772 (1/yr) 0.25 (yrs) 0.79
TCE → DCE 6.930 (1/yr) 0.10 (yrs) 0.74
DCE → VC 1.733 (1/yr) 0.40 (yrs) 0.64
VC → ETH 0.000 (1/yr) 0.45 (yrs)
Zone 2
PCE → TCE 0.000 (1/yr)
TCE → DCE 0.000 (1/yr)
DCE → VC 0.000 (1/yr)
VC → ETH 0.000 (1/yr)
ETH → Ethane 0.000 (1/yr)

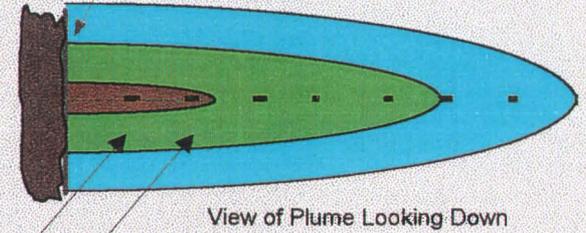
5. GENERAL

Simulation Time* 25 (yr)
Modeled Area Width* 600 (ft)
Modeled Area Length* 2400 (ft)
Zone 1 Length* 2400 (ft)
Zone 2 Length* 0 (ft)
Zone 2 = L - Zone 1

6. SOURCE DATA

Source Options
TYPE: Single Planar
Source Thickness in Sat. Zone* 30 (ft)
Width* (ft) 120
Conc. (mg/L)*
PCE 2.5
TCE .005
DCE 2.61
VC .0
ETH .0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down
Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

Conc. (mg/L)*	C1	C2	C3						
PCE Conc. (mg/L)	1.3	.16	.054	.121	.002	.003			
TCE Conc. (mg/L)	.004	.0	.0	.007	.002	.002			
DCE Conc. (mg/L)	1.74	.0	.0	.434	.001	.01			
VC Conc. (mg/L)	0.0	.0	.0	.0	.0	.0			
ETH Conc. (mg/L)	0.0	.0	.0	.0	.0	.0			
Dist. from Source (ft)	0	210	270	390	840	855			

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE

RUN ARRAY

Help

Restore Formulas

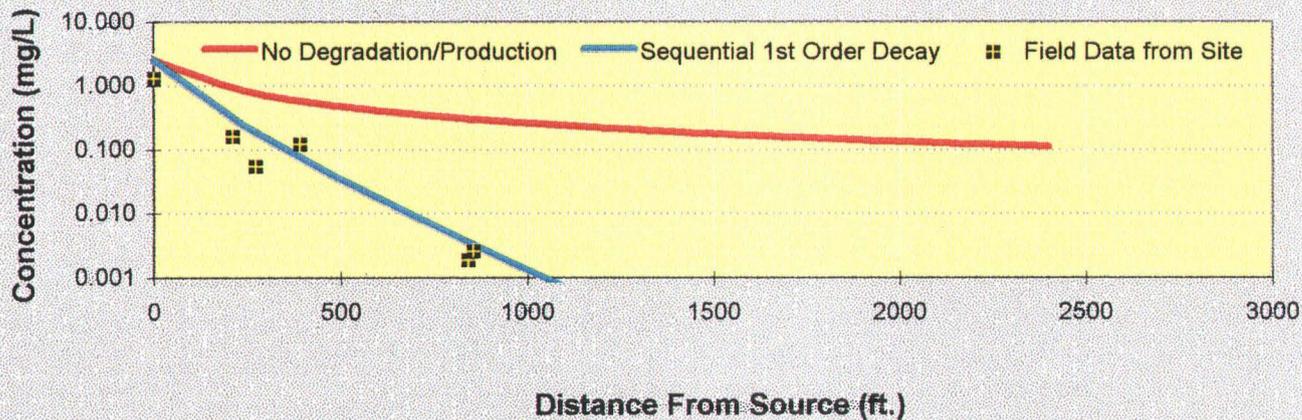
RESET

SEE OUTPUT

Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
PCE											
No Degradation	2.500	0.830	0.483	0.340	0.262	0.213	0.180	0.155	0.137	0.122	0.110
Biodegradation	2.500	0.234	0.039	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Monitoring Well Locations (ft)											
	0	210	270	390	840	855					
Field Data from Site	1.300	0.160	0.054	0.121	0.002	0.003					



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log Linear

Time:

Return to
Input

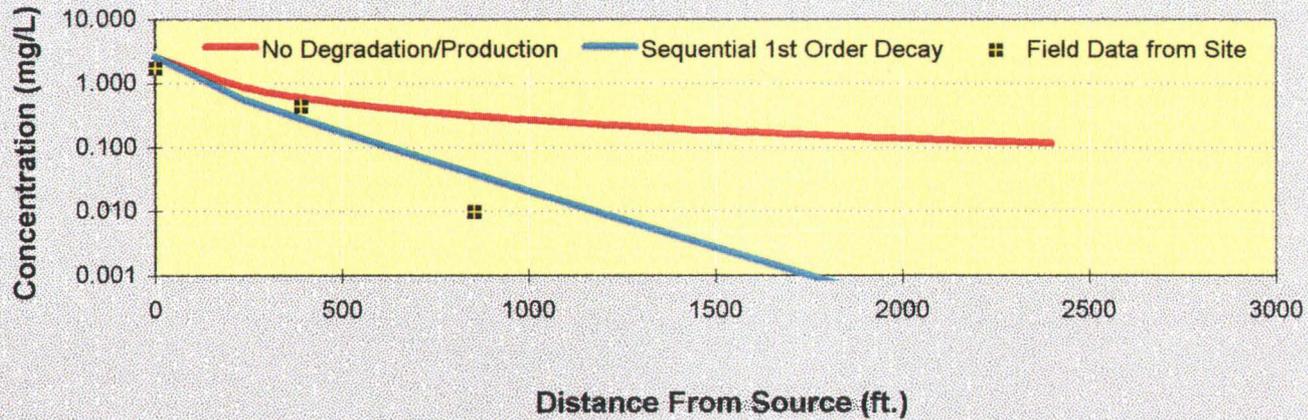
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

DCE	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	2.610	0.867	0.504	0.355	0.274	0.223	0.188	0.162	0.143	0.128	0.115
Biotransformation	2.610	0.542	0.183	0.066	0.024	0.009	0.003	0.001	0.001	0.000	0.000

Field Data from Site	Monitoring Well Locations (ft)										
	0	210	270	390	840	855					
	1.740	0.000	0.000	0.434	0.001	0.010					



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log ↔ Linear

Time: 25 Years

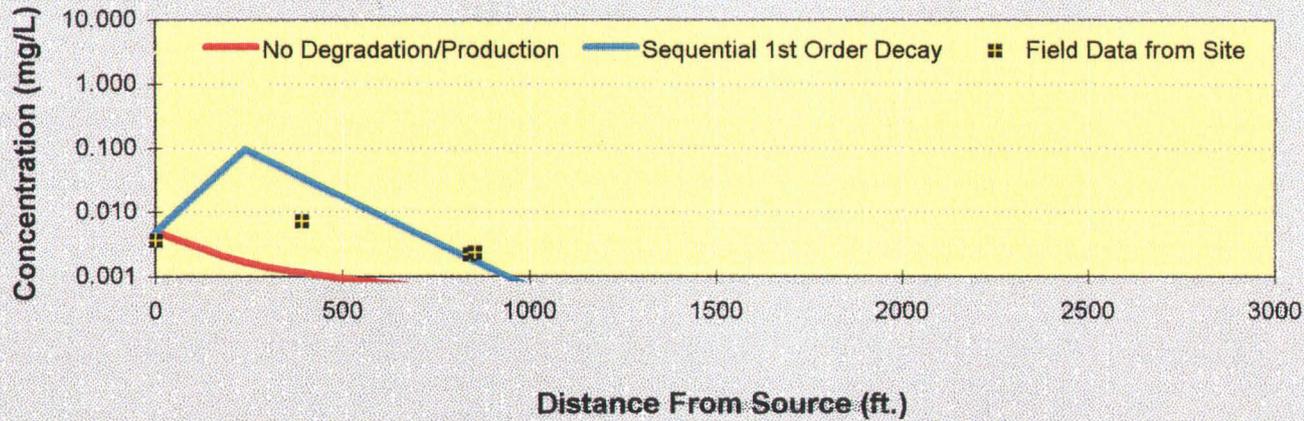
Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
TCE											
No Degradation	0.005	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.005	0.093	0.019	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
	0	210	270	390	840	855					
Field Data from Site	0.004	0.000	0.000	0.007	0.002	0.002					



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log ↔ Linear

Time: 75 Years

Return to
Input

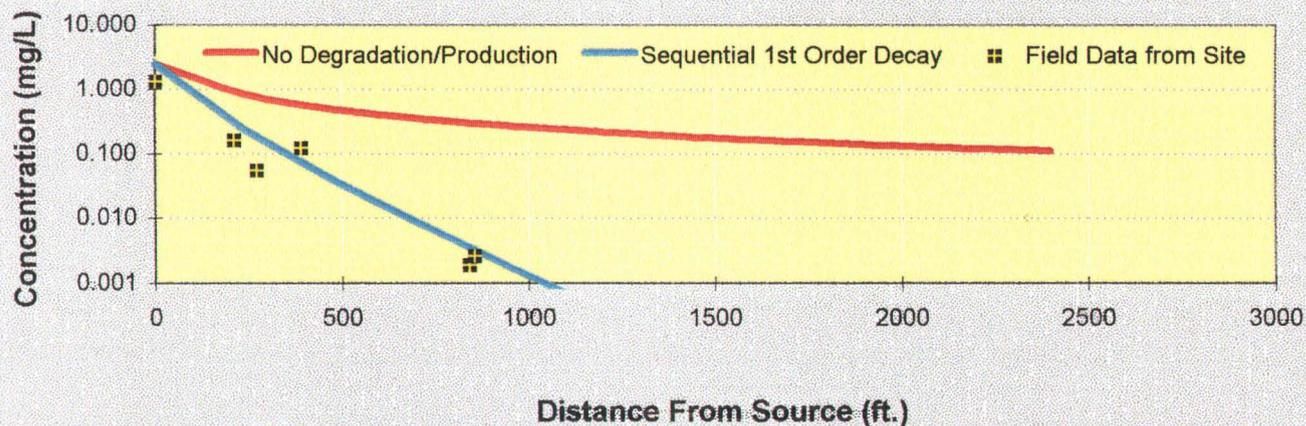
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

PCE	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	2.500	0.830	0.483	0.340	0.262	0.213	0.180	0.155	0.137	0.122	0.110
Biotransformation	2.500	0.234	0.039	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.000

	Monitoring Well Locations (ft)									
	0	210	270	390	840	855				
Field Data from Site	1.300	0.160	0.054	0.121	0.002	0.003				



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log ↔ Linear

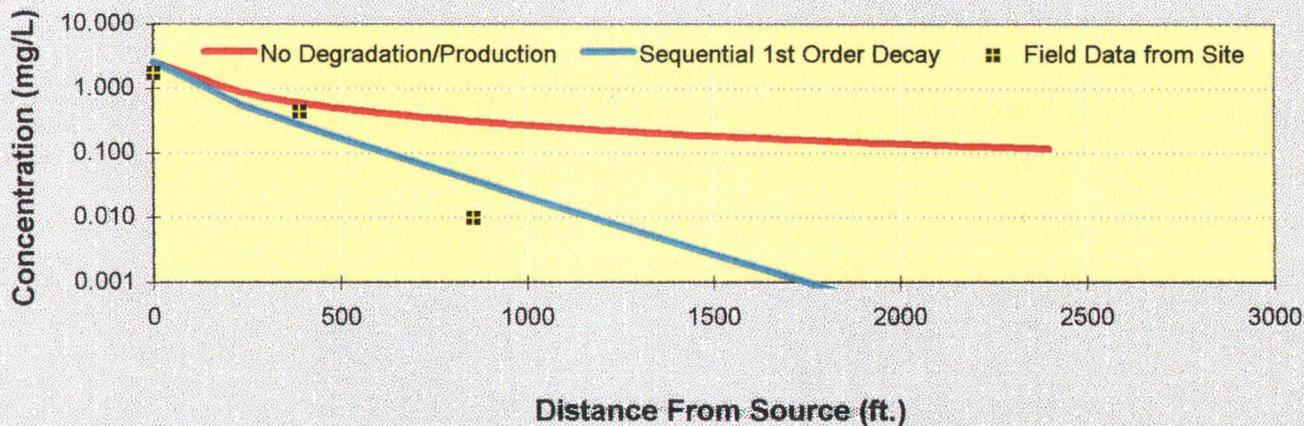
Time: 75 Years

- Return to Input
- To All
- To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

DCE	Distance from Source (ft)										
	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	2.610	0.867	0.504	0.355	0.274	0.223	0.188	0.162	0.143	0.128	0.115
Biotransformation	2.610	0.542	0.183	0.066	0.024	0.009	0.003	0.001	0.001	0.000	0.000

Field Data from Site	Monitoring Well Locations (ft)										
	0	210	270	390	840	855					
	1.740	0.000	0.000	0.434	0.001	0.010					



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log \longleftrightarrow Linear

Time:

Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE

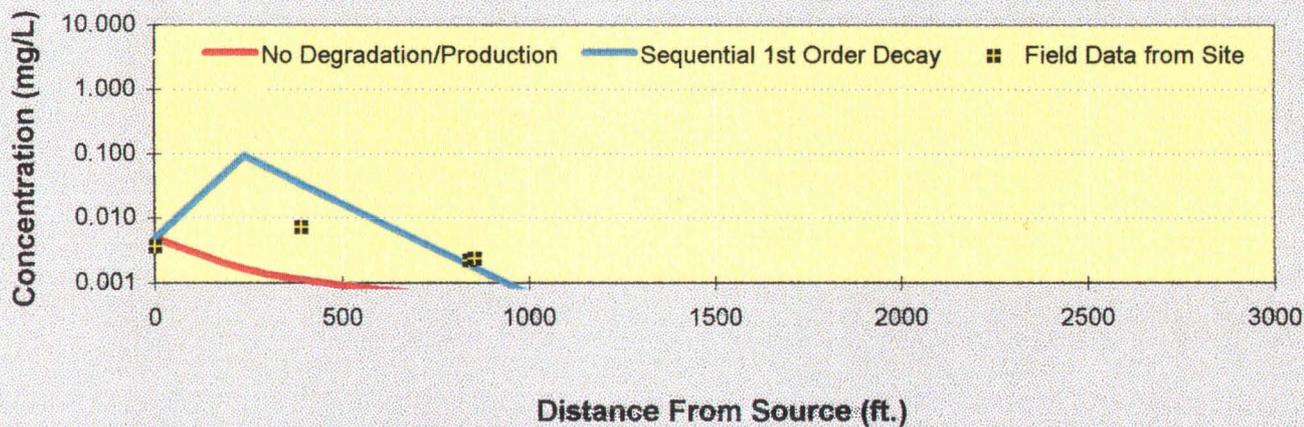
TCE

Distance from Source (ft)

	0	240	480	720	960	1200	1440	1680	1920	2160	2400
No Degradation	0.005	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biodegradation	0.005	0.093	0.019	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	210	270	390	840	855					
Field Data from Site	0.004	0.000	0.000	0.007	0.002	0.002					



- See PCE
- See TCE
- See DCE
- See VC
- See ETH

Log \longleftrightarrow Linear

Time: 25 Years

Return to Input

To All

To Array

Attachment E

NCRAF G3TM Model Input Variables Used and Model Output
Biochlor Model Background Data, Input Variables Used, and Model Output

Model Documentation

A G3TM model was performed. Following is an explanation of the source of many of the input variables.

Name: G3TM

Application to site: This model was used for the unconsolidated surficial unit at the site, based on the assumption that vertical flow is downward at the site and Crabtree Creek is not fed by the bedrock unit. This model cannot be applied to the bedrock unit as described in its documentation.

Values Used: A complete list of input variables is included on the input screen for the model that follows. Values used are identified on the first page of the G2TM model. Values were taken from previous models (BIOSCREEN and MOC3D) with the following exceptions:

Source Concentrations: Taken from highest historical values ever observed in the surficial unit at the site.

Plume Length and Width: Measured from the February 2000 IMR Report isoconcentration map.

7Q10 of Stream: Taken from the NPDES permit application.

Surface Water Chemical Standard: Surface water standards were not available for the target contaminants. Therefore, the NPDES permit limit for the site of 5 ug/l is used. Since this value is the only chemical specific variable, all contaminant models were identical. Therefore only one model run was conducted.

Aquifer Thickness: A value of 50 feet was used rather than the traditional 30 feet that was used in most models to accommodate for potential thickening of the surficial sediments near Crabtree Creek.

North Carolina Department of Environment and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

MODEL INPUT PARAMETERS:

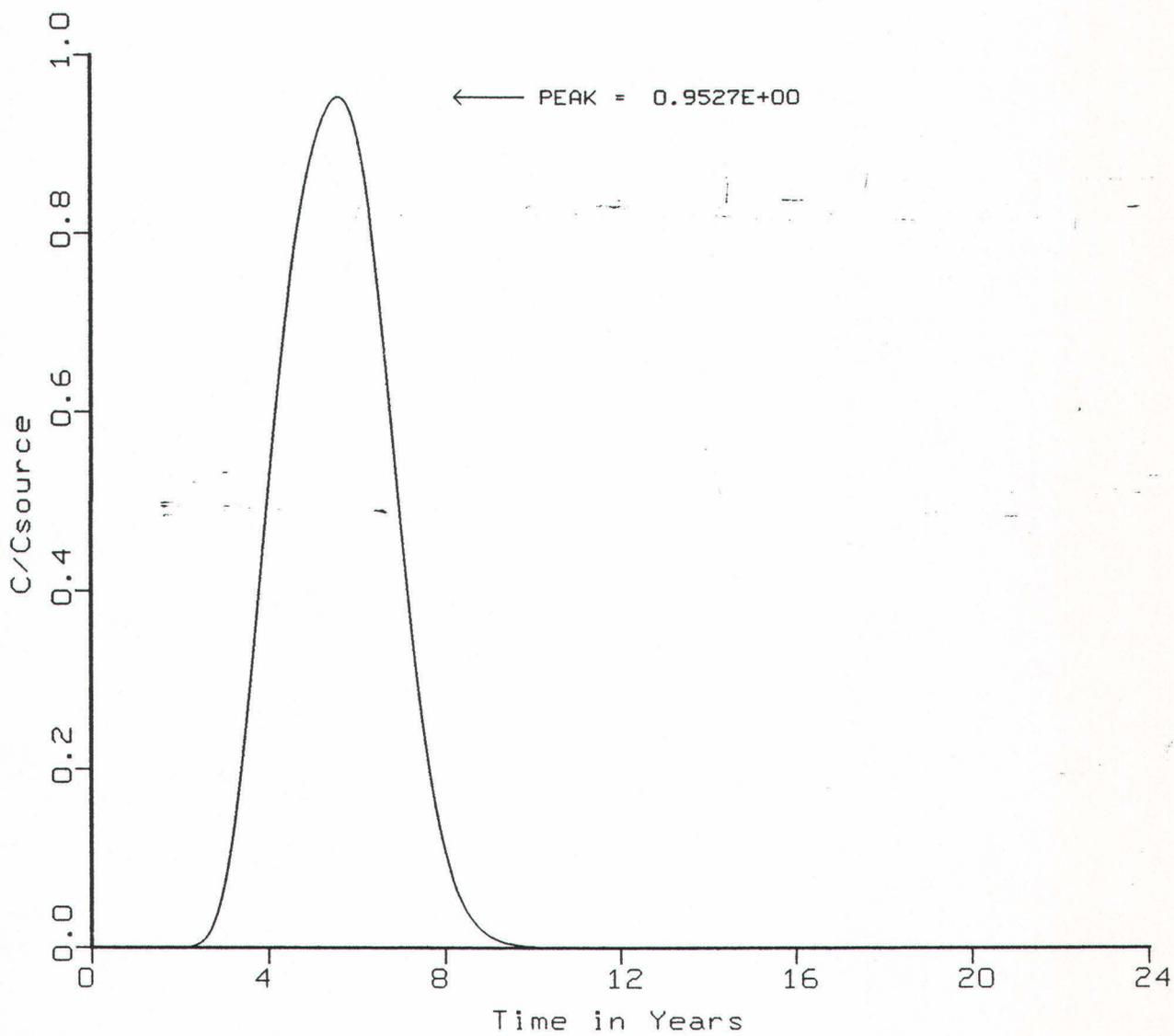
CONTAMINANT CHEMICAL NAME		PCE
SURFACE WATER CHEMICAL STANDARD	(mg/l)	0.005
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (Feet)		1400
(P.L.E. = PLUME LEADING EDGE)		
AQUIFER HYDRAULIC CONDUCTIVITY	(Feet/Day)	17.008
AQUIFER GROUNDWATER GRADIENT	(Feet/Feet)	0.021
AQUIFER EFFECTIVE POROSITY	(unitless)	0.37
AQUIFER DISPERSION COEFFICIENT	(Feet ² /Day)	24.5
CHEMICAL RETARDATION FACTOR	(unitless)	1.0
CHEMICAL BIODEGRADATION DECAY RATE	(1/Day)	0
LENGTH OF CONTAMINANT PLUME	(Feet)	1050
THICKNESS OF SURFICIAL AQUIFER	(Feet)	50
WIDTH OF CONTAMINANT PLUME	(Feet)	600
7Q10 OF RIVER OR STREAM	(Feet ³ /Second)	2.5
UP-STREAM CHEMICAL CONCENTRATION	(mg/l)	0

MODELING RESULTS:

Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 0.5638E+01 years
with Groundwater Concentration C/Csource = 0.9527E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 0.1111E+00 mg/l
for the chemical PCE

Groundwater Concentration at Surface Water
Boundary



Model Documentation

In accordance with the requirement and documentation requirements that are specified in the NCRAF, the following information is provided.

- Name:** BIOCHLOR
- Version:** Version 1.0
- Developer:** Dr Carol Aziz and Charles Newell (Groundwater Services, Inc.)
- Documentation:** Users manual available as EPA document EPA/600/R-00/008 and is available on the following website:
<http://www.epa.gov/ada/biochlor.html>
- Availability:** Fully available in the public domain format at the following website:
<http://www.epa.gov/ada/biochlor.html>
- Peer-review:** Although there is no direct review of BIOCHLOR in professional literature the basic concepts used in the model have been widely written on and are widely used. For a listing of these references see the reference list in the users documentation described under the documentation section described above.
- Application to site:** In the model documentation it describes the model for use at sites where chlorinated solvents have been released. The model is intended for use at sites where remediation by natural attenuation (RNA) is considered. One of its intended uses is quoted as follows to determine "How far will a dissolved chlorinated solvent plume extend if no engineered controls or source area reduction measures are implemented?" Values for the model variables include those for various lithologies including fractured granite and silts and clays.
- Model Assumptions:** BIOCHLOR assumes the following:
- Uniform groundwater flow
 - A vertical plane source
 - First-order decay of contaminants
 - Uniform hydrogeologic conditions
 - Degradation takes place by reductive dechlorination
- Input Assumptions:** During the input, Triangle made the following assumptions:
- Highest historical concentration is the source concentration
 - Crabtree Creek is receiving flow only from the surficial unit
 - Groundwater flow between the various units is downward

Calibration Process:

Input variables were derived from previous site assessment data or assumed values utilized in previous models with the exception of biotransformation constants. These values were varied until the modeled concentrations most closely matched site observed conditions at an elapsed time of 25 years past initial release.

Values Used:

Values used are identified on the first page of the BIOCHLOR model. Values were taken from previous models (BIOSCREEN and MOC3D) with the following exceptions:

Source Concentrations: Taken from highest historical values ever observed in the surficial unit at the site.

Source Area Width: Measured as the distance between MW-14d and MW-2s

Biotransformation Constants: These are the calibration variable using an assumed time of 25 years since initial release.

Sensitivity Analyses:

Most of the input variables will significantly change the output with one order of magnitude of change. The biotransformation constants were varied to calibrate the model over three orders of magnitude. These changes resulted in less than one order of magnitude in output results.

Graphical Representation:

Graphical representation is included at intervals of 25 years from initial release date and 75 years from the initial release date. One printout for ethylenes and a second for ethanes are included. A narrative explanation is included in the text of the response letter.

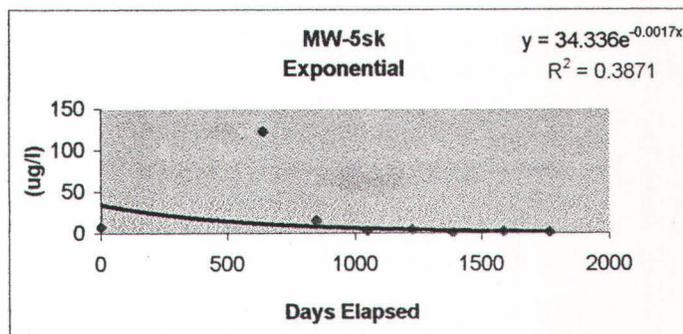
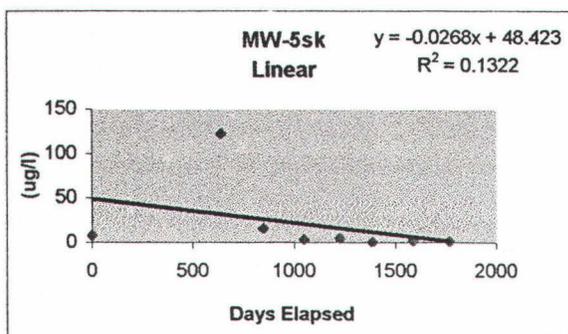
Attachment F

Tabulation of VOC Data from MW-5sk, and Best-fit Lines Using
Linear and Exponential Lines

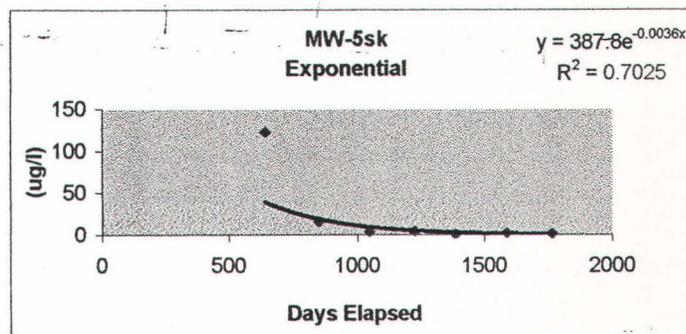
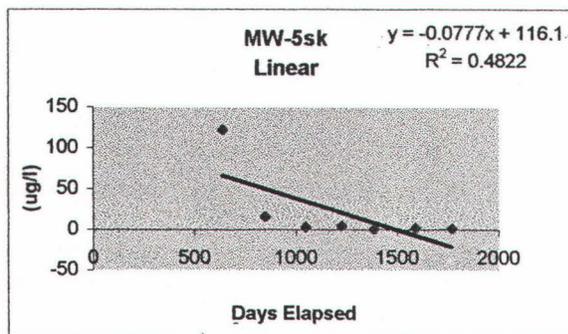
MW-5sk VOC Data and Trend Comparison Lines

Well	Date Sampled	Time (days)	Total VOC Concentration (ug/l)
MW-5sk	12/1/94	0	8.1
	9/13/96	642	122.6
	4/10/97	849	16
	10/30/97	1049	3.5
	4/27/98	1226	4.8
	10/8/98	1387	0.7
	4/28/99	1587	2.5
	10/27/99	1766	1.6

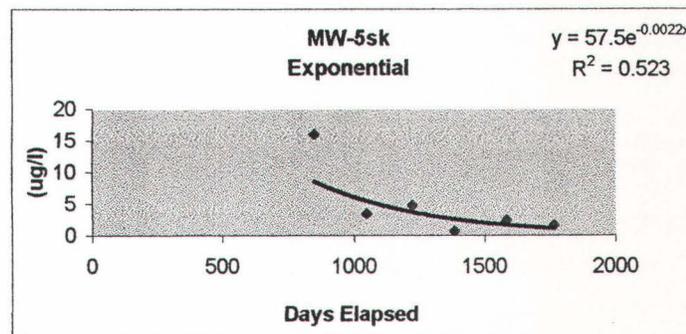
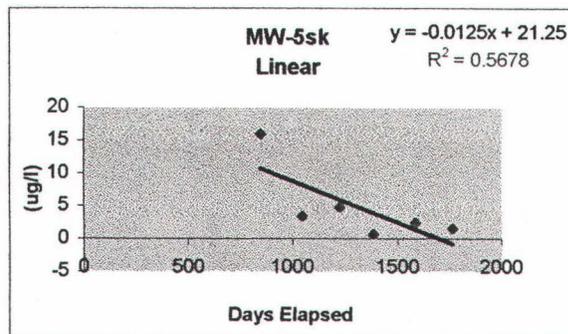
Graphed With All Data Points



Graphed Without First Data Point



Graphed Without First Two Data Points



Best R squared values shown in red