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PGDP Trichloroethene Biodegradation Investigation
Summary Report
Regional Gravel Aquifer & Northwest Plume

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Prepared by

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through
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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

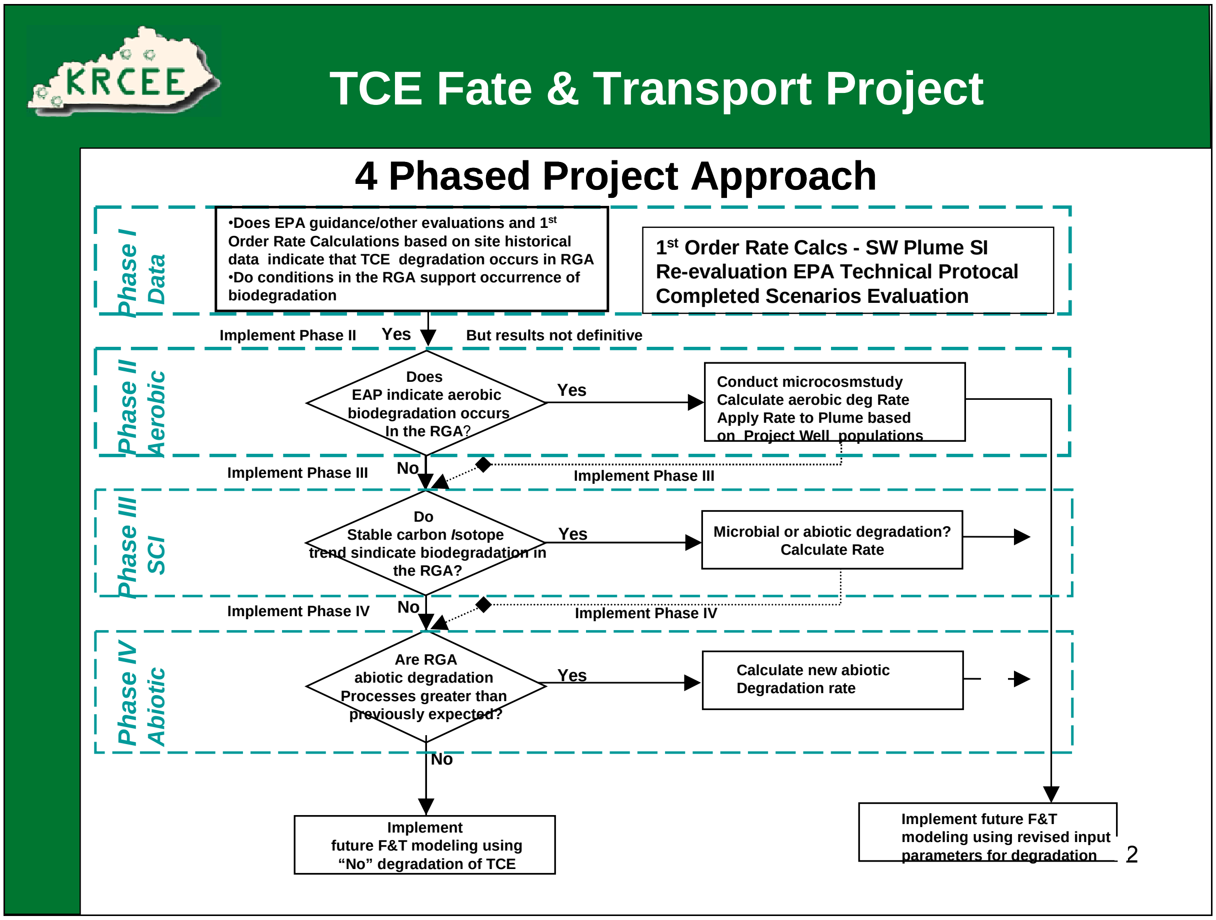
ARAR – Applicable Relevant and Appropriate Requirement
AT123D – Analytical Transient One, Two, Three Dimensional Transport Model
bgs – below ground surface
BTEX- Benzene, Toluene, Ethylbenzene, and Xylenes
CAH – Chlorinated Aromatic Hydrocarbon
CERCLA – Comprehensive Environmental Response Compensation and Liability Act
CSIA – Compound Specific Isotope Analysis
DCE - Dichloroethene
DES – Decision Estimation Statement
DNAPL – Dense NonAqueous Phase Liquid
DO – Dissolved Oxygen
DOC - Dissolved Organic Carbon
DOE – United States Department of Energy
DOE-EM – United States Department of Energy Environmental Management (Headquarters)
DOE-PPPO – United States Department of Energy Portsmouth Paducah Project Office
DNA – Deoxyribonucleic Acid
DQO – Data Quality Objectives
DWGIS – Data Warehouse and Geographic Information System
EA – Enhanced Attenuation
EAP – Enzyme Activity Probe
EPA – United States Environmental Protection Agency
GC – Gas Chromatography
GC-IRMS - gas chromatograph–isotope ratio mass spectrometers
GWOU – Groundwater Operable Unit
GMS – United States Army Corps of Engineers Groundwater Modeling System
INL – Idaho National Laboratory
ITRC – Interstate Technology and Regulatory Council
KRCEE – Kentucky Research Consortium for Energy and Environment
LCD – Lower Continental Deposits
LDR – Land Disposal Restriction
LRGA – Lower Regional Gravel Aquifer
MCLs – Maximum Contaminant Levels
MEPAS – Multi Environmental Pollutant Assessment System numerical model
MNA – Monitored Natural Attenuation
MODFLOW – MODular three-dimensional finite difference groundwater FLOW model
MQO – Measurement Quality Objective
MRGA – Middle Regional Gravel Aquifer
NAS – National Academy of Sciences
NEP – Northeast Plume
NWP – Northwest Plume
ORD – United States Environmental Protection Agency Office of Research and Development
ORP – Oxidation-Reduction Potential
OSWER – United States Environmental Protection Agency Office of Solid Waste and Emergency Response
P & T – Purge and trap method
PA – Phenylacetylene
PCE – Perchloroethene
PCR - polymerase chain reaction
PGDP – Paducah Gaseous Diffusion Plant
PTS – Pump and treat system
RCRA – Resource Conservation Recovery Act
RGA – Regional Groundwater Aquifer
ROD – Record of Decision
SAP – Sampling and Analysis Plan

SCI – Stable Carbon Isotope
SCIR – Stable Carbon Isotope Ratio
SESOIL – Seasonal Soil numerical model
SHI – Stable Hydrogen Isotopes
SI – Site Investigation
sMMO – soluble methane mono oxygenase
SRNL – Savannah River National Laboratory
SWMU – Solid Waste Management Unit
SWP – Southwest Plume
^{99}Tc – technetium-99
TAN – Idaho National Environmental and Engineering Laboratory Test Area North
TCE - Trichloroethylene
Technical Protocol – Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater
TOC – Total Organic Carbon
TOD – Toluene Dioxygenase
TMO – Toluene Monooxygenase
T-RFLP – terminal restriction fragment length polymorphism
TVA – Tennessee Valley Authority
USEPA – United States Environmental Protection Agency
UCRS – Upper Continental Recharge System
URGA – Upper Regional Gravel Aquifer
USAFCEE – United States Air Force Center for Environmental Excellence
UCD – Upper Continental Deposits
UIC – Underground Injection Control Program
VC – Vinyl Chloride
VOC – Volatile Organic Compound
VPDB – Vienna Pee Dee Belemnite
WAG – Waste Area Group
WKWMA – Western Kentucky Wildlife Management Area
3HPA – 3-hydroxyphenylacetic acid

Executive Summary

The evaluation of biological degradation processes addressed by this report are part of a broad trichloroethene (TCE) Fate and Transport Investigation that includes four (4) topics of phased investigation *(*Table ES1) relative to degradation and/or attenuation of TCE in the Regional Gravel Aquifer (RGA) underlying the United States Department of Energy Paducah Gaseous Diffusion Plant (PGDP). In order of implementation the project phases are: (1) derivation of a TCE first-order rate constant by normalization of TCE values against technetium-99 (^{99}Tc) and chloride. 2) identification of the presence of microbes capable of aerobic co-metabolic TCE biodegradation using enzyme activity probes (this report); 3) Compound-specific isotope analysis (CSIA) to support prevalence of biotic and/or abiotic degradation processes; and 4) evaluation of potential abiotic RGA-TCE attenuation mechanisms including sorption.

Table ES1. TCE Fate and Transport Project Phases



TCE Fate & Transport Project

4 Phased Project Approach

Phase I Data

•Does EPA guidance/other evaluations and 1st Order Rate Calculations based on site historical data indicate that TCE degradation occurs in RGA
•Do conditions in the RGA support occurrence of biodegradation

1st Order Rate Calcs - SW Plume SI
Re-evaluation EPA Technical Protocal
Completed Scenarios Evaluation

Implement Phase II Yes But results not definitive

Phase II Aerobic

Does EAP indicate aerobic biodegradation occurs In the RGA?

Yes: Conduct microcosmstudy
Calculate aerobic deg Rate
Apply Rate to Plume based on Project Well populations

Implement Phase III No Implement Phase III

Phase III SCI

Do Stable carbon /sotope trend sindicate biodegradation in the RGA?

Yes: Microbial or abiotic degradation? Calculate Rate

Implement Phase IV No Implement Phase IV

Phase IV Abiotic

Are RGA abiotic degradation Processes greater than previously expected?

Yes: Calculate new abiotic Degradation rate

No: Implement future F&T modeling using “No” degradation of TCE

Implement future F&T modeling using revised input parameters for degradation

2

This report summarizes the Phase II activities related to the identification and evaluation of biological degradation processes that may be actively influencing TCE fate and transport in the RGA contaminant plumes at the United States Department of Energy (DOE) PGDP and its environs (Figure ES1)**.** The goals of these activities were to identify active biological degradation mechanisms in the RGA through multiple lines of evidence and to provide DOE with recommendations for future TCE biological degradation investigations.

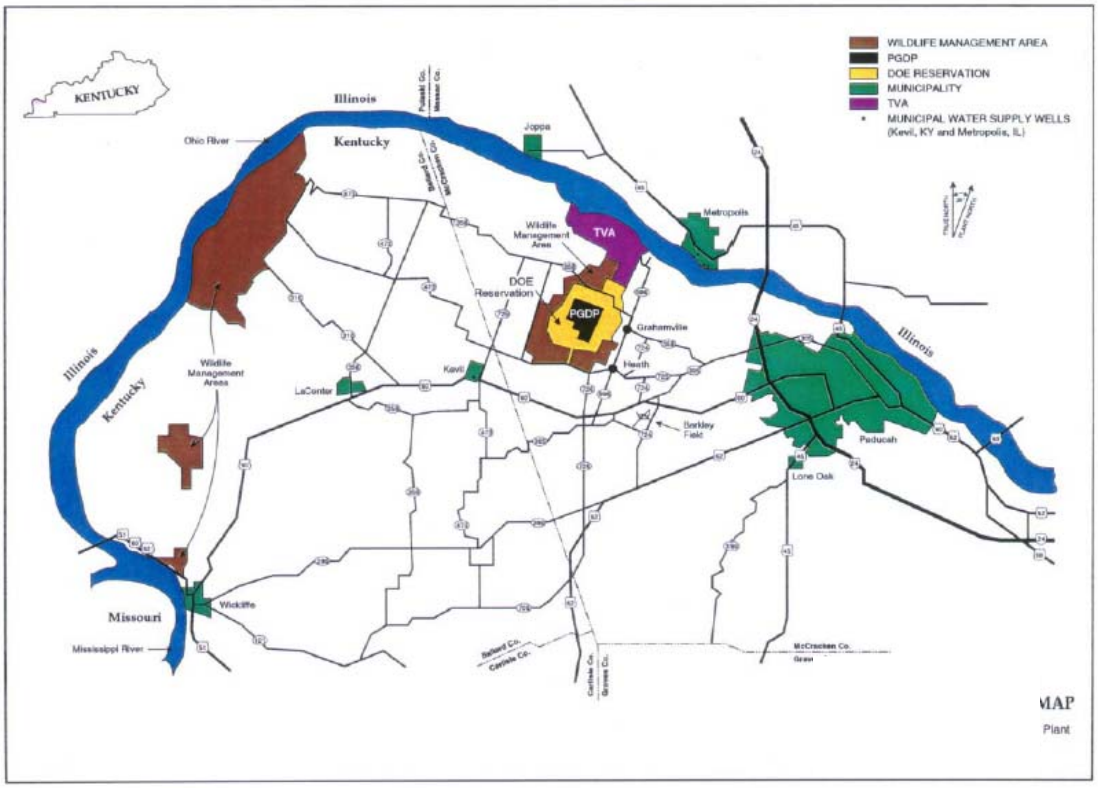


Figure ES1. PGDP Location Map (DOE, 2001a)

Groundwater beneath the PGDP is contaminated by two principal constituents, the chlorinated solvent trichloroethene and a soluble form of the radioisotope ^{99}Tc. TCE was released as a dense non-aqueous phase liquid (DNAPL) to subsurface soils and groundwater as a result of routine PGDP industrial activities. Technetium-99 was introduced to the PGDP through industrial re-processing of spent reactor materials from other DOE facilities. The introduction of TCE and ^{99}Tc to shallow subsurface soils and the underlying sands and gravels of the RGA resulted in the evolution of three (3) groundwater contaminant plumes; the Northeast Plume, Northwest Plume, and Southwest Plume (Figure ES2**)**. The plumes generally originate from the C-400 Building and are impacted along their on-site flowpaths by additional sources of contamination including burial grounds and disposal areas.

The field activities, analytical work, and evaluations conducted for this project centered on a portion of the Northwest Plume (NWP) (Figures ES2 and ES3). Three RGA horizons, upper, middle, and lower, were sampled at locations along the plume axis from upgradient source areas at the C-400 Building to downgradient areas in the dissolved phase portion of the plume. Field sampling, analysis, and evaluation activities for this project focused on:

1. The identification of the presence of microbes capable of aerobic co-metabolic TCE biodegradation using enzyme activity probes and additional lines of evidence to evaluate microbial population diversity;
2. Evaluation of current and historical RGA geochemical data relative to the occurrence and sustenance of microbial activity; and
3. Evaluation of stable-carbon isotope sampling data relative to degradation of TCE along the core of the NWP.

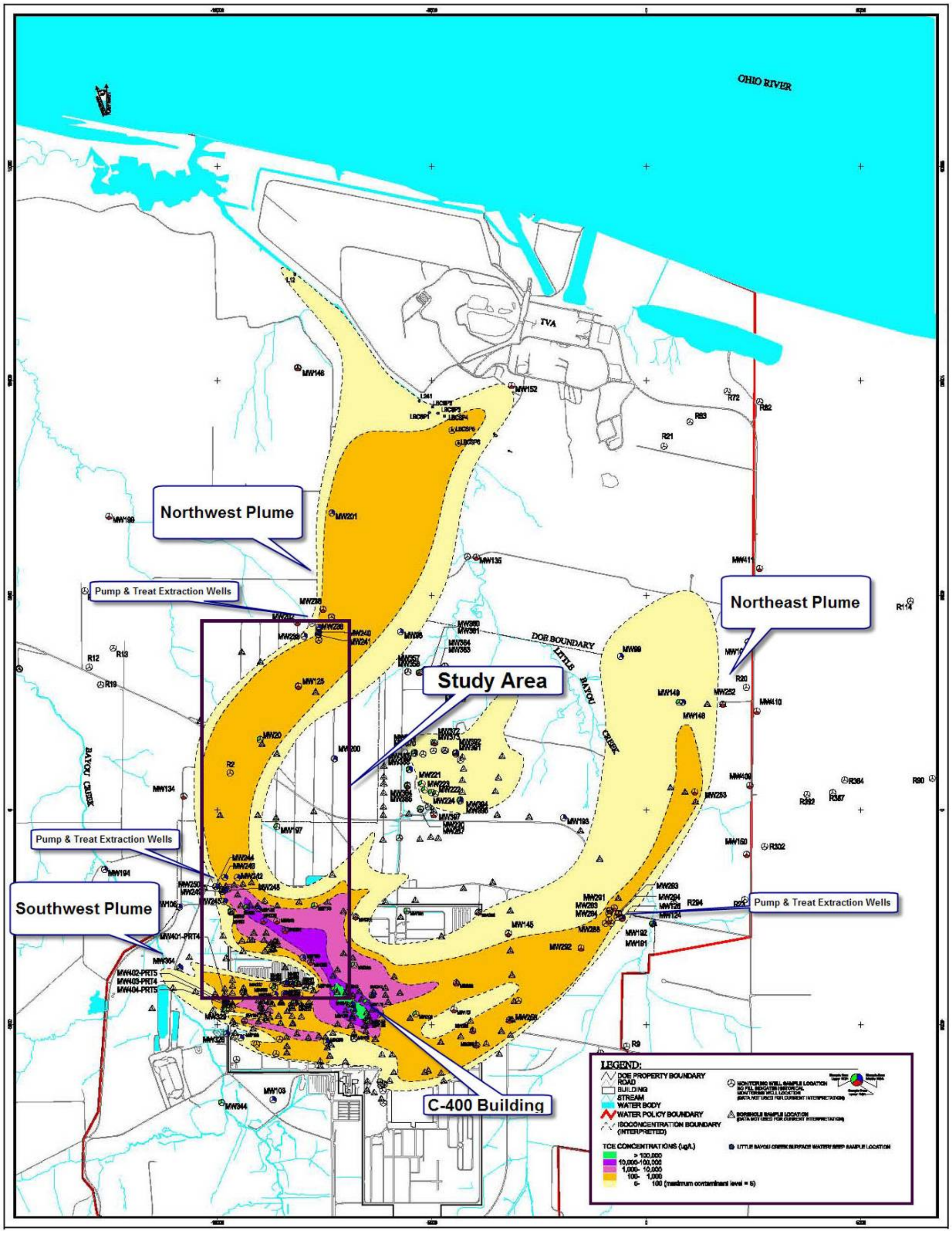


Figure ES2. 2005 TCE Contaminant Plumes in the Regional Gravel Aquifer at the PGDP (PRS, 2007)

The RGA geochemical data evaluation included data collected in the study area for this project and historical geochemical data from on-site and off-site RGA sampling locations. Analytical data for this project were generated from samples collected at ten (10) wells screened in the upper, middle and lower horizons of the RGA along the approximate NWP core and two (2) control wells outside of the NWP

(Figure ES3). A Data Quality Objectives (DQO) process was employed to ensure that project activities identified questions, problems, and relevant information necessary to address questions about the identification and occurrence of aerobic co-metabolic biological degradation of TCE.

Historical field and analytical activities have been conducted to identify and characterize natural attenuation processes that affect the fate of TCE and other contaminants in the RGA. Those natural attenuation processes include advection, dispersion, sorption, and volatilization. Results of historical efforts provided the basic information necessary to identify that appropriate conditions existed in the RGA to support the occurrence of aerobic oxidation of organic compounds and co-metabolic degradation of TCE. However, the state of the science, as well as available technical and regulatory guidance, was not such at the time of the historical investigations, that degradation of TCE via microbial processes would have been identified as occurring in an aerobic (oxygenated) aquifer.

Recent Savannah River National Laboratory technical guidance, *Scenarios Evaluation Tool for Chlorinated Solvent MNA* (SRNL, 2006) provided an approach for the evaluation of existing and historical site conditions that prompted the implementation of a formal evaluation of aerobic biodegradation processes in the RGA. The *Scenarios Evaluation Tool* along with information obtained from the 1998 EPA technical guidance document "*Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*" (Technical Protocol) provided PGDP investigators with the approaches and tools necessary to evaluate and characterize microbial degradation in the PGDP's aerobic groundwater environment.

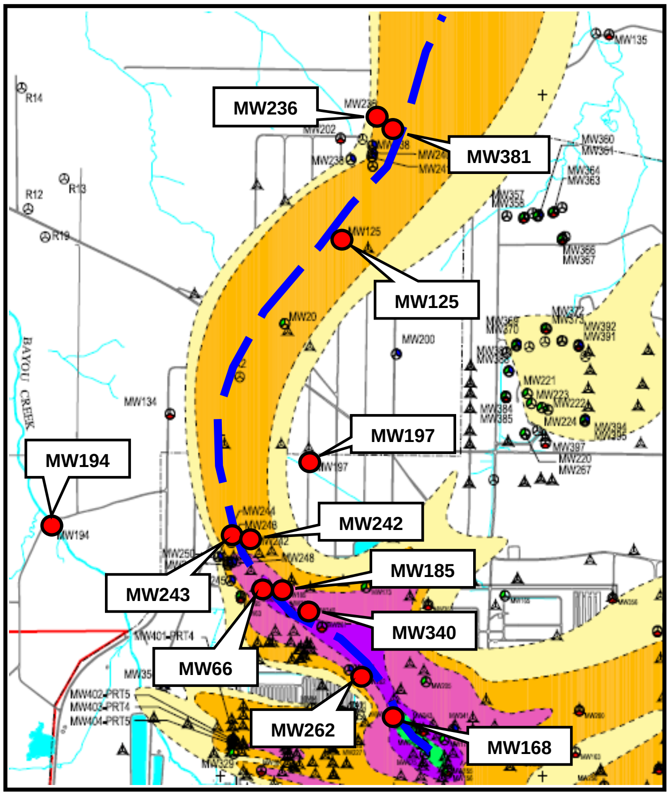


Figure ES3. Location of Study AreaMonitoring Wells Along the Core of the Northwest Plume

First-order rate constant calculations are the first of three lines of evidence identified by the United States Environmental Protection Agency Technical Protocol to demonstrate that microbial processes are actively achieving TCE or other contaminant degradation. The second line of evidence addressed by this investigation was the identification of the actual processes responsible for TCE degradation and the existence of geochemical conditions capable of supporting the process(es). Enzyme Activity Probes and genetic profiling were utilized to address the second line of evidence along with evaluation of current and historical RGA geochemical trends. The third line of evidence addressed by this investigation was the utilization of compound specific isotope analyses (CSIA), specifically stable carbon isotopes (SCI), to independently provide verification of the first and second lines of evidence.

Past site investigations generated first-order rate constant estimations that mathematically describe the amount of time required for one-half of the dissolved phase TCE in the PGDP plumes to be removed by natural attenuation processes. Methods used for the derivation of first-order rate constants included a mass balance evaluation across plume cross-sections and tracer-corrected methods identified in the Technical Protocol that utilize the TCE co-contaminant ^{99}Tc and chloride as tracers. The first-order degradation rate calculation methods resulted in TCE half-lives ranging from 3 to 16 years.

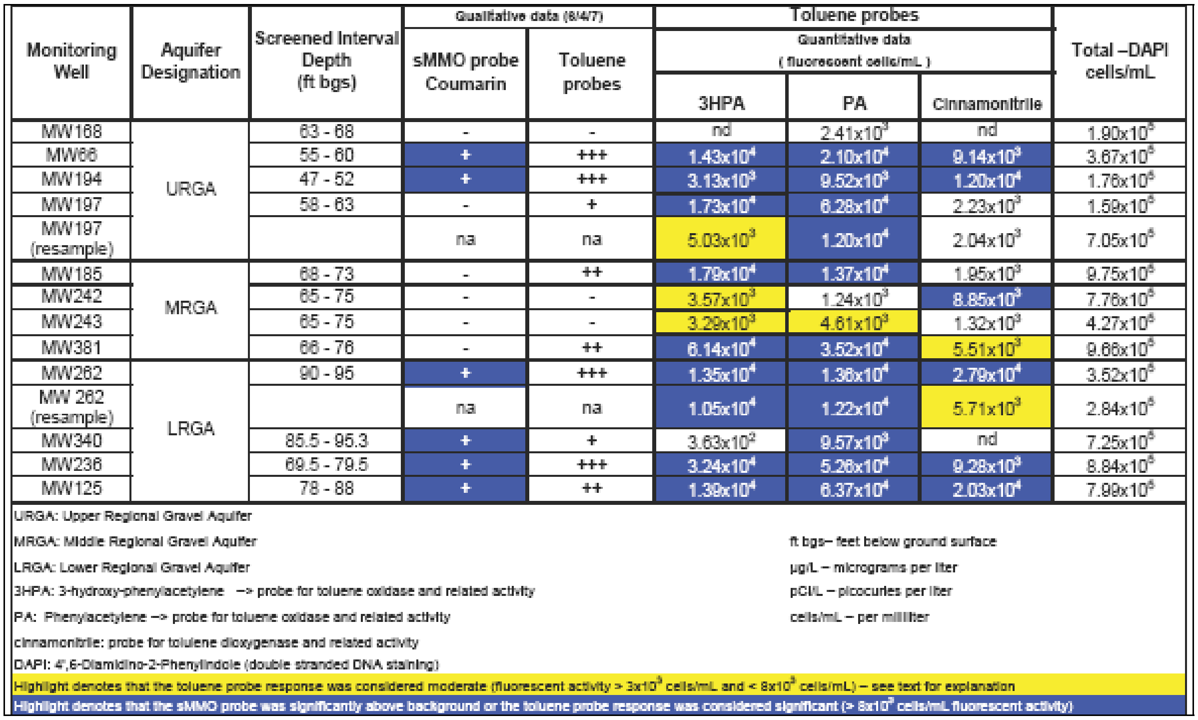
TCE is not directly degraded by microbial respiration processes in aerobic groundwater environments. Instead, destruction of TCE occurs when indigenous microbes produce enzymes that are directly involved in the metabolism, or direct aerobic oxidation, of aromatic substances such as toluene, ethene, phenol, benzene, and chlorinated aliphatic compounds that are less chlorinated than TCE. The enzymes produced for aerobic oxidation of these targeted aromatic substances are non-specific and fortuitously initiate the destruction of TCE to short-lived, non-toxic end products. The destruction of TCE by enzymes in aerobic environments is referred to as aerobic co-metabolic degradation.

The identification of microbes producing the co-metabolic enzymes capable of TCE destruction was accomplished via application of qualitative and quantitative Enzyme Activity Probe (EAP) analyses and genetic profiling. EAPs are laboratory tools that fluoresce when bacteria producing the enzyme of interest or samples containing enzymes of interest are encountered. DNA evaluations were conducted to ensure that the genetic information for production of co-metabolic enzymes was present in local microbial populations.

The EAPs applied in this study target several of the co-metabolic enzymes of interest, soluble methane monooxygenase (sMMO) and three (3) toluene enzymes (cinnamontrile, phenylacetylene (PA), and 3-hydrophenylacetylene (3HPA)). The enzyme-specific probes were utilized to identify the presence of the enzymes in samples and to enumerate the microorganisms producing the enzymes. Results of the EAP analyses indicate that microbes producing the co-metabolic enzymes of interest are present in sufficient numbers to satisfy minimum population criteria of 1 x 10^3 cells/mL. Minimum population criteria for this project was based on the expected minimum number of bacteria necessary to effectively destruct TCE in one mL of groundwater. More stringent population requirements of 8 x 10^3 cells/mL were utilized by investigators for final microbial activity determinations and were based on evaluation of recent population data collected at other Federal Facility sites where large aerobic groundwater contaminant plumes are being investigated (Table ES2).

Terminal-restriction fragment length polymorphism (T-RFLP) analyses were conducted to determine whether microbial populations in study-area samples were representative of populations indigenous to the plume or representative of biofouling populations observed on PGDP well screens. The T-RFLP analyses provided evidence that samples from each of the study area wells were representative of distinctly unique micro-communities and not biofouling populations that would have been similar from one well location to another. EAP and T-RFLP analyses were jointly conducted by Savannah River National Laboratory (SRNL) and Idaho National Laboratory (INL) - North Wind Environmental. SRNL and INL participation are part of a nationwide assessment of large organic-solvent contaminant plumes in aerobic groundwater environments. The nationwide assessments will result in the development of standard protocols for investigation, characterization and monitoring of microbial degradation processes in aerobic groundwater settings.

Table ES2. Summary results from EAP quantitative and qualitative analyses (SRNL, 2008)



Monitoring Well	Aquifer Designation	Screened Interval Depth (ft bgs)	Qualitative data (8/4/7)		Toluene probes			Total –DAPI cells/mL
					Quantitative data (fluorescent cells/mL)			
			sMMO probe Coumarin	Toluene probes	3HPA	PA	Cinnamonitrile	
MW168	URGA	63 - 68	-	-	nd	2.41x10^3	nd	1.90x10^5
MW66		55 - 60	+	+++	1.43x10^4	2.10x10^4	9.14x10^3	3.67x10^5
MW194		47 - 52	+	+++	3.13x10^3	9.52x10^3	1.20x10^4	1.76x10^5
MW197		58 - 63	-	+	1.73x10^4	6.28x10^4	2.23x10^3	1.59x10^5
MW197 (resample)			na	na	5.03x10^3	1.20x10^4	2.04x10^3	7.05x10^5
MW185	MRGA	68 - 73	-	++	1.79x10^4	1.37x10^4	1.95x10^3	9.75x10^5
MW242		65 - 75	-	-	3.57x10^3	1.24x10^3	8.85x10^3	7.76x10^5
MW243		65 - 75	-	-	3.29x10^3	4.61x10^3	1.32x10^3	4.27x10^5
MW381		66 - 76	-	++	6.14x10^4	3.52x10^4	5.51x10^3	9.66x10^5
MW262	LRGA	90 - 95	+	+++	1.35x10^4	1.36x10^4	2.79x10^4	3.52x10^5
MW 262 (resample)			na	na	1.05x10^4	1.22x10^4	5.71x10^3	2.84x10^5
MW340		85.5 - 95.3	+	+	3.63x10^2	9.57x10^3	nd	7.25x10^5
MW236		69.5 - 79.5	+	+++	3.24x10^4	5.26x10^4	9.28x10^3	8.84x10^5
MW125		78 - 88	+	++	1.39x10^4	6.37x10^4	2.03x10^4	7.99x10^5

URGA: Upper Regional Gravel Aquifer
MRGA: Middle Regional Gravel Aquifer
LRGA: Lower Regional Gravel Aquifer
3HPA: 3-hydroxy-phenylacetylene –> probe for toluene oxidase and related activity
PA: Phenylacetylene –> probe for toluene oxidase and related activity
cinnamonitrile: probe for toluene dioxygenase and related activity
DAPI: 4',6-Diamidino-2-Phenylindole (double stranded DNA staining)

ft bgs– feet below ground surface
µg/L – micrograms per liter
pCi/L – picocuries per liter
cells/mL – per milliliter

Highlight denotes that the toluene probe response was considered moderate (fluorescent activity > 3x10^3 cells/mL and < 8x10^3 cells/mL) – see text for explanation
Highlight denotes that the sMMO probe was significantly above background or the toluene probe response was considered significant (> 8x10^3 cells/mL fluorescent activity)

Current and historical RGA geochemical conditions were evaluated relative to the occurrence and potential for sustenance of aerobic microbial activity in the RGA. Table ES4 summarizes historical RGA analyses by providing detection frequencies and concentration ranges of degradation-related geochemical parameters within the study area for this project and across the PGDP. Dissolved oxygen (DO), oxidation reduction potential (ORP), and sources of carbon necessary for microbial respiration were evaluated along with compounds that are the result of anaerobic degradation or incomplete anaerobic TCE degradation including cis-1,2-DCE, vinyl chloride, and Fe^{2+}. Dissolved Oxygen was evaluated because its presence is critical for the existence and sustenance of aerobic microbial communities. ORP was evaluated as an indicator of redox conditions capable of supporting microbes responsible for aerobic degradation processes. DO, ORP, Fe^{2+}, and TCE degradation products were evaluated as indicators of anaerobic conditions that would predicate other biotic and abiotic degradation processes.

Presence of dissolved oxygen is necessary for the occurrence and sustenance of the microbes responsible for aerobic oxidation and aerobic co-metabolic degradation processes. RGA DO concentrations range from 30 to 9240 ug/L in on-site and off-site monitoring wells. Many RGA wells exhibit stable or decreasing DO trends. Wells with concurrently decreasing TCE and DO trends may indicate widespread occurrence of aerobic co-metabolic TCE degradation. However, wells with DO concentrations less than 1.0 mg/L and ORP approaching or less than zero indicate that conditions capable of supporting aerobic microbial activity are not ubiquitous to on-site and near-site portions of the RGA. Based on DO, ORP, and presence of anaerobic TCE degradation products (cis-1,2-DCE and 1,1-TCE), anaerobic degradation processes are impacting on-site and near-site portions of the RGA. Detections of Fe^{2+} in study area and historical groundwater samples are an additional indication that reducing environments supportive of anaerobic degradation processes are impacting on-site and near site portions of the RGA.

Naturally-occurring carbon compounds (toluene, benzene, phenol) and lesser-chlorinated (than TCE) organic compounds which serve as substrates for aerobic microbial oxidation processes have not been regularly analyzed in PGDP groundwater samples. However, total organic carbon (TOC) representing the sum of anthropogenic and naturally-occurring carbon sources has been detected with some regularity in RGA groundwater at concentrations exceeding 1 mg/L. TOC is routinely detected in soils overlying the RGA and in the RGA matrix.

Dissolved organic carbon (DOC) measurements are representative of soluble organic compounds that are readily available for microbial respiration. DOC was detected in two (2) of 12 samples collected for this investigation. Based on published descriptions of the carbon cycle, DOC concentrations in aquifer recharge can generally be expected to be present at concentrations less than 1 mg/L. Sixteen (16) historical groundwater DOC analyses resulted in 10 detections of DOC at concentrations ranging from 1 to 6 mg/L. Although the detections identify relatively low concentrations of DOC in the RGA, the DOC concentrations are typical of oligotrophic "low nutrient" groundwater environments that have been evaluated in other large aerobic groundwater plumes where biodegradation processes have been identified (SRNL, 2008). Although DOC has not been analyzed routinely, sufficient quantities of organic carbon must be available in the RGA to sustain the microbial populations identified in the EAP analyses (SRNL, 2008).

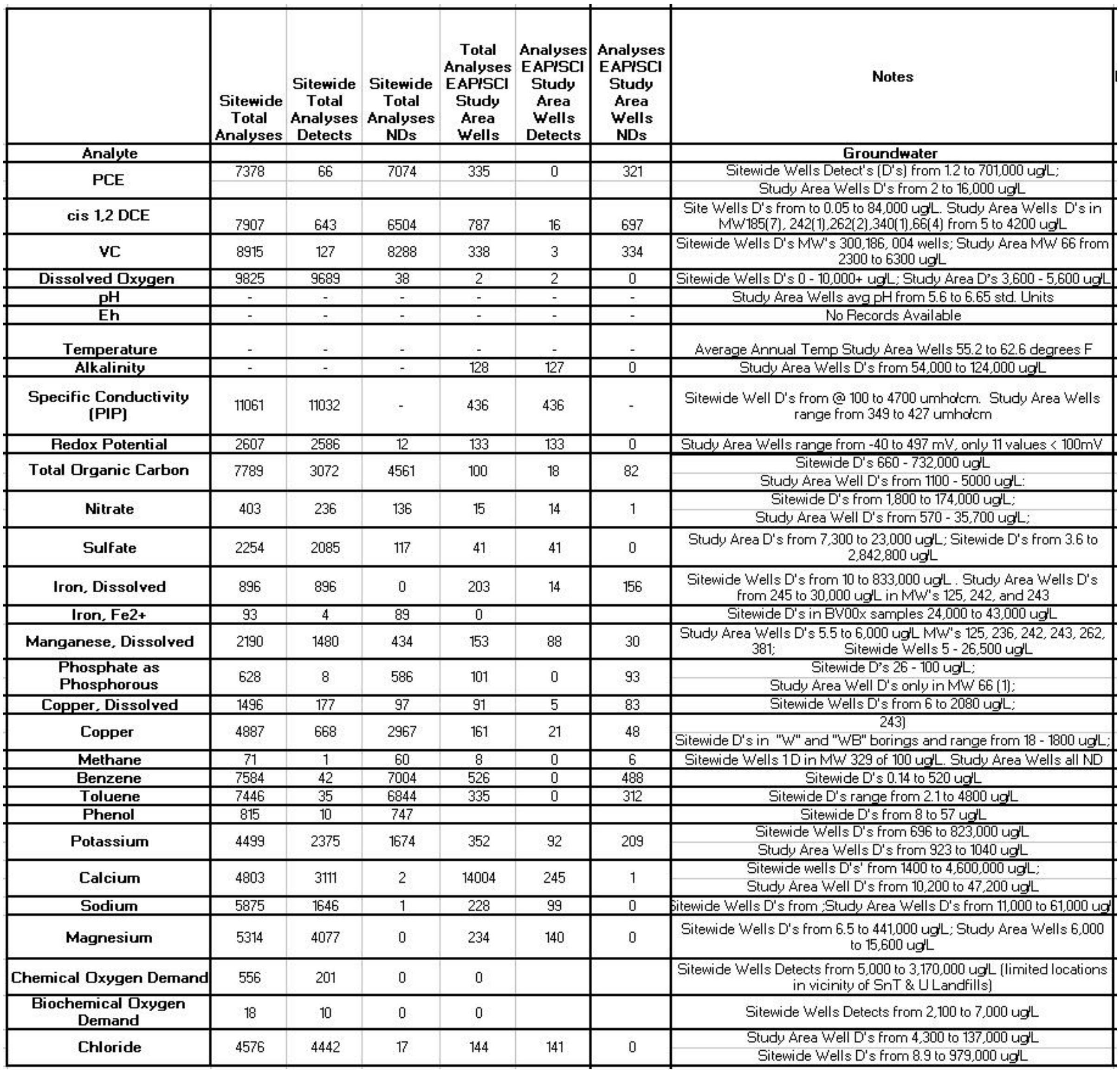
As a result of in-situ TCE degradation processes that include aerobic microbial degradation processes, ^{12}C in TCE molecules is preferentially utilized relative to ^{13}C along NWP study area flowpaths. SCIs in study-area dissolved-phase TCE were evaluated as the third independent line of evidence to support occurrence of microbial co-metabolic TCE degradation. SCI analyses and comparative evaluation of stable carbon isotope ratio (SCIR) upgradient/downgradient well-pair data indicate that ^{13}C is being enriched by preferential microbial utilization of ^{12}C along the core of the NWP.

Changes in TCE stable-carbon isotope ratios caused by biodegradation along study-area flowpaths were evaluated by comparison of upgradient well versus downgradient well SCIRs. Table ES3 summarizes the study well-pair stable carbon isotope ratio comparisons that support the occurrence of aerobic degradation in the study area. In the SCIR evaluation of the published enrichment factor of -1.1, eight (8) of 10 well-pair comparisons indicate that aerobic degradation processes are occurring and six (6) of the SCIR evaluations indicate that that the rate of transformation is significant. The SCIR evaluation of the 90% one-tailed confidence interval ϵ value of -1.4 identifies eight (8) of 10 well-pair comparisons that indicate the occurrence of aerobic-degradation processes and that the rate of transformation is significant in five (5) of the evaluated well pairs. The evaluation of the 95% one-tailed confidence interval on epsilon value of -1.68 seven (7) of 10 well pairs indicate that aerobic degradation is occurring and the rate of transformation is significant in five (5) of the evaluated well pairs. In summary, application of SCI decision/estimation statements and decision rules to well-pair comparisons of SCI analytical results provides support for the occurrence of aerobic co-metabolic degradation through a range of enrichment factor values.

Table ES3. SCIR study area well-pair evaluation summary

Enrichment Factor (ε)	**Total Up/Downgradient Comparisons Possible**	**Favorable Result Comparisons**	**Significant Result Comparisons**
-1.1	10	8	6
-1.4	10	8	5
-1.68	10	7	5

Table ES4. Summary of PGDP geochemical parameters evaluated for this investigation



	Sitewide Total Analyses	Sitewide Total Analyses Detects	Sitewide Total Analyses NDs	Total Analyses EAP/SCI Study Area Wells	Analyses EAP/SCI Study Area Wells Detects	Analyses EAP/SCI Study Area Wells NDs	Notes
Analyte							**Groundwater**
PCE	7378	66	7074	335	0	321	Sitewide Wells Detect's (D's) from 1.2 to 701,000 ug/L; Study Area Wells D's from 2 to 16,000 ug/L
cis 1,2 DCE	7907	643	6504	787	16	697	Site Wells D's from to 0.05 to 84,000 ug/L. Study Area Wells D's in MW185(7), 242(1),262(2),340(1),66(4) from 5 to 4200 ug/L
VC	8915	127	8288	338	3	334	Sitewide Wells D's MW's 300,186, 004 wells; Study Area MW 66 from 2300 to 6300 ug/L
Dissolved Oxygen	9825	9689	38	2	2	0	Sitewide Wells D's 0 - 10,000+ ug/L; Study Area D's 3,600 - 5,600 ug/L
pH	-	-	-	-	-	-	Study Area Wells avg pH from 5.6 to 6.65 std. Units
Eh	-	-	-	-	-	-	No Records Available
Temperature	-	-	-	-	-	-	Average Annual Temp Study Area Wells 55.2 to 62.6 degrees F
Alkalinity	-	-	-	128	127	0	Study Area Wells D's from 54,000 to 124,000 ug/L
Specific Conductivity (PIP)	11061	11032	-	436	436	-	Sitewide Well D's from @ 100 to 4700 umho/cm. Study Area Wells range from 349 to 427 umho/cm
Redox Potential	2607	2586	12	133	133	0	Study Area Wells range from -40 to 497 mV, only 11 values < 100mV
Total Organic Carbon	7789	3072	4561	100	18	82	Sitewide D's 660 - 732,000 ug/L Study Area Well D's from 1100 - 5000 ug/L:
Nitrate	403	236	136	15	14	1	Sitewide D's from 1,800 to 174,000 ug/L; Study Area Well D's from 570 - 35,700 ug/L;
Sulfate	2254	2085	117	41	41	0	Study Area D's from 7,300 to 23,000 ug/L; Sitewide D's from 3.6 to 2,842,800 ug/L
Iron, Dissolved	896	896	0	203	14	156	Sitewide Wells D's from 10 to 833,000 ug/L . Study Area Wells D's from 245 to 30,000 ug/L in MW's 125, 242, and 243
Iron, Fe2+	93	4	89	0			Sitewide D's in BV00x samples 24,000 to 43,000 ug/L
Manganese, Dissolved	2190	1480	434	153	88	30	Study Area Wells D's 5.5 to 6,000 ug/L MW's 125, 236, 242, 243, 262, 381; Sitewide Wells 5 - 26,500 ug/L
Phosphate as Phosphorous	628	8	586	101	0	93	Sitewide D's 26 - 100 ug/L; Study Area Well D's only in MW 66 (1);
Copper, Dissolved	1496	177	97	91	5	83	Sitewide Wells D's from 6 to 2080 ug/L;
Copper	4887	668	2967	161	21	48	243) Sitewide D's in "W" and "WB" borings and range from 18 - 1800 ug/L;
Methane	71	1	60	8	0	6	Sitewide Wells 1 D in MW 329 of 100 ug/L. Study Area Wells all ND
Benzene	7584	42	7004	526	0	488	Sitewide D's 0.14 to 520 ug/L
Toluene	7446	35	6844	335	0	312	Sitewide D's range from 2.1 to 4800 ug/L
Phenol	815	10	747				Sitewide D's from 8 to 57 ug/L
Potassium	4499	2375	1674	352	92	209	Sitewide Wells D's from 696 to 823,000 ug/L Study Area Wells D's from 923 to 1040 ug/L
Calcium	4803	3111	2	14004	245	1	Sitewide wells D's' from 1400 to 4,600,000 ug/L; Study Area Well D's from 10,200 to 47,200 ug/L
Sodium	5875	1646	1	228	99	0	itewide Wells D's from ;Study Area Wells D's from 11,000 to 61,000 ug
Magnesium	5314	4077	0	234	140	0	Sitewide Wells D's from 6.5 to 441,000 ug/L; Study Area Wells 6,000 to 15,600 ug/L
Chemical Oxygen Demand	556	201	0	0			Sitewide Wells Detects from 5,000 to 3,170,000 ug/L (limited locations in vicinity of SnT & U Landfills)
Biochemical Oxygen Demand	18	10	0	0			Sitewide Wells Detects from 2,100 to 7,000 ug/L
Chloride	4576	4442	17	144	141	0	Study Area Well D's from 4,300 to 137,000 ug/L Sitewide Wells D's from 8.9 to 979,000 ug/L

The conclusions of current project activities and historical evaluations of TCE degradation mechanisms in the NWP RGA can be summarized relative to the USEPA Technical Protocol lines of evidence:

1) <u>The first line of Technical Protocol evidence</u> is to demonstrate that microbial processes are actively achieving TCE or other contaminant degradation.

   First-order rate constant calculations demonstrate that TCE is preferentially degraded along NWP flowpaths relative to the non-recalcitrant tracers technetium-99 and chloride.

2) <u>The second line of Technical Protocol evidence</u> addressed by this investigation was the identification of the actual processes responsible for TCE degradation and the existence of geochemical conditions capable of supporting the process(es).

   Genetic profiling, Enzyme Activity Probes (EAP) and related control studies indicate that: a) the appropriate genetic material is present in the RGA for the production of enzymes responsible for the destruction of TCE, 2) the enzymes are present and actively being produced in the RGA, 3) the microbial populations evaluated through the EAPs and genetic profiling are representative of the aquifer and not biofouling populations on individual wells.

Study area and site-wide RGA geochemical evaluations indicate that DO and organic carbon sources are present at sufficient concentrations to support populations of aerobic bacteria capable of TCE biodegradation. However, aerobic conditions are not ubiquitous to the RGA and redox conditions and the presence of anaerobic degradation products including cis-1,2-DCE indicate that anaerobic conditions exist locally in on-site and near-site areas of the RGA.

3) <u>The third line of Technical Protocol evidence</u> addressed by this investigation was the utilization of compound specific isotope analyses (CSIA) to provide information supporting the occurrence of aerobic biodegradation processes that is independent of and supplementary to the first-order rate constant calculations, EAP and genetic profiling analyses, and geochemical evaluations.

Based on evaluations of the SCI data through the Decisions Rules developed by the Project Team, aerobic degradation of TCE is occurring and the rate of degradation based on comparison of SCI data to TCE concentration data occurs at significant rates. Formal SCI first-order degradation rate calculations will be addressed by subsequent investigations.

Based on the results of the activities conducted for this Biodegradation Investigation aerobic degradation processes, including aerobic co-metabolic degradation of TCE, are occurring in the RGA within the study area. The Project Team recommendation to DOE is to continue to characterize the occurrence of aerobic co-metabolic TCE degradation in the RGA. A number of general or global recommendations relative to the primary recommendation are appropriate as a result of this investigation:

<u>Recommendation #1</u>. Through a Project Team DQO process, develop a comprehensive sampling and analysis plan (SAP) to expand the characterization of microbial degradation across the extent of the NWP.

The following activities should be considered for the expanded characterization:

1. Collect and evaluate data from distal portions of the NWP from the northern extraction well field to areas immediately south of the TVA and east of Little Bayou Creek. As the concentration of TCE in the RGA decreases, it should be anticipated that the rate of TCE degradation will increase.
2. Revisit wells selected for this investigation and expand the well selection to accommodate spatial characterization of the Upper, Middle, and Lower RGA.
3. Evaluate existing site data to identify the portions of the NWP RGA that are in proximity of sources and secondary source concentrations of TCE related to the NWP.
4. Evaluate the temporal and spatial inputs to and distribution of DO per considerations in Recommendation #5 below.
5. Evaluate the potential impacts of past, ongoing, and planned PGDP remedial activities on existing biogeochemical conditions in the RGA.
6. Identify and document the individual species in RGA groundwater microbial populations responsible for TCE degradation.
7. Consider enhancements to the RGA environment and potential impacts on biogeochemical processes from a range of proposed and potential remedial actions.
    a. Assess the need for bench scale and pilot studies if enhancements are to be pursued as part of a dissolved phase plume remediation option.

Recommendation #2. Through a Project Team DQO process, revisit first-order TCE degradation rate calculations.

The following activities should be considered for the first-order rate constant:

1. Conduct microcosm studies to provide an independent estimation of TCE degradation rates in the RGA. Utilize one or more of the locations identified in Table ES5 (SRNL, 2008).
2. Conduct compound specific isotope analyses for stable carbon and stable hydrogen isotopes and utilize data to independently calculate first-order degradation rate constants.
    a. Collect sufficient temporal data at one or more locations to satisfy statistical requirements of the student t-test (Appendix 3).
3. Develop site-specific carbon and hydrogen isotope enrichment factors.
4. Honor flowpaths in the choice of upgradient/downgradient wells in the URGA, MRGA, and LRGA utilized for first order rate estimations.
5. Address the potential impact of TCE sorption on aquifer media in the RGA and first- order rate constant calculations.
    a. Collect a representative number of cores from the discrete intervals in the URGA, MRGA, and LRGA.
    b. Apply protocols identified in the *Workshop on Biogeochemical Transformation of Chlorinated Solvents* (AFCEE, 2008) to determine the potential biogeochemical impacts on sorption and abiotic degradation of VOCs and metals (AFCEE, 2008).
6. Provide DOE with recommendations for interim and final application of TCE degradation rate constants as TCE half-lives in groundwater modeling for:
    a. Plume scale application.
    b. Discrete plume segment application.
    c. By RGA horizon.

Table ES5 Locations recommended for potential future microcosm studies

Well	TCE (DEC-07)	Number of probes positive	Notes
MW125	700	3	Downgradient of the southern NWP extraction well field along the axis of dissolved phase plume
MW236	21	3	downgradient of MW125, along plume axis
MW 381	50	2	downgradient of MW125, along plume axis

Recommendation #3. Through a Project Team DQO process, conduct a degradation screening process for the UCRS, similar to this investigation, in order to identify the nature and extent of microbial degradation processes in the UCRS.

The following activities should be considered for the characterization of the UCRS:

1. Evaluate historical data to determine if they are of sufficient extent to characterize aerobic, anaerobic, and abiotic degradation processes in the UCRS.
2. Utilize available data to characterize UCRS TCE degradation processes to the extent possible.
3. Provide DOE with recommendations for additional evaluation as necessary.

Recommendation #4. Through a Project Team DQO process, correlate existing NEP and NWP biogeochemical conditions to the biogeochemistry of the NWP in order to document the occurrence of aerobic biodegradation processes.

The goal of this activity would be the development of a Northeast Plume (NEP) and Southwest Plume (SWP) sampling and analysis plan (SAP) to support characterization and monitoring of biodegradation in the NEP and SWP.

Recommendation #5. As part of SAP development in the recommendations above, consider implementation of standard geochemical parameter collection to address existing data gaps related to evaluation of both the existence and sustenance of biological and abiotic degradation processes.

The following parameters should be considered for routine and/or further evaluation:

1. Dissolved organic carbon (DOC) to detection limits less than 1 mg/L as an indicator of readily available carbon necessary to sustain aerobic oxidation and co-metabolism.
2. Carbon dioxide - as an end product of degradation processes.
3. Biochemical Oxygen Demand - as an indicator of carbon available for microbial degradation processes.
4. Oxidation-reduction potential (ORP) as an indicator of redox conditions that support aerobic or anaerobic degradation processes.
5. Specific conductivity to augment characterization of the RGA at sub-plume scales.
6. Ammonium (NH_{4+}) as an indicator of anoxic conditions and as a substrate for organic compound degradation.
7. TCE degradation products cis-1,2 DCE, trans-1,1 DCE, and vinyl chloride as indicators of anoxic conditions in the RGA and UCRS.
8. Copper and copper-based compounds, as well as other substances to be determined from process and industrial operations that may have biocidal effects on microorganisms in the RGA and UCRS.
9. In order to complete characterization of the RGA relative to aerobic biodegradation processes, their occurrence and sustenance, complete spatial characterization of the upper, middle and lower RGA relative to occurrence, nature and/or distribution of the physical and chemical parameters listed below as they relate to sustenance of aerobic degradation:
    a. DO concentrations.
    b. DO cycles
    c. Temperature.
    d. pH

1. Introduction

This document summarizes the activities related to the identification and evaluation of biological degradation processes that may be actively influencing trichloroethene (TCE) fate and transport in the three (3) Regional Gravel Aquifer (RGA) contaminant plumes at the United States Department of Energy (DOE) Paducah Gaseous Diffusion Plant (PGDP) and its environs (Figure 1). The field activities, analytical work, and evaluations conducted for this project focused on the Northwest Plume (NWP) (Figure 2) and on 1) the determination of the presence of microbes capable of aerobic co-metabolic TCE biodegradation using enzyme activity probes and additional lines of evidence related to microbial population diversity; 2) evaluation of historical RGA geochemical data relative to the occurrence and sustenance of microbial activity; 3) evaluation of stable carbon isotope ratio data relative to degradation of TCE along the core of the NWP; and 4) project-specific sampling data collected from upper, middle and lower RGA wells approximating the core of the NWP and two control wells outside of the NWP. A Data Quality Objectives (DQO) process was employed to ensure that project activities identified questions, problems, and relevant information necessary to support project goals related to the identification and occurrence of aerobic co-metabolic biological degradation of TCE.

The evaluation of biological degradation processes addressed by this report are part of a broad PGDP TCE Fate and Transport Investigation that includes four (4) topics of investigation (Table 1) relative to degradation and/or attenuation of TCE in the RGA:

1. Derivation of a TCE first-order rate constant by normalization of TCE values with technetium-99 (^{99}Tc) and chloride levels;
2. Identification, using enzyme activity probes, of the presence of microbes capable of aerobic co-metabolic TCE biodegradation;
3. Stable Carbon Isotope (SCI) ratio analysis to support prevalence of biotic and/or abiotic degradation processes; and
4. Initial evaluation of potential abiotic RGA-TCE attenuation mechanisms including sorption.

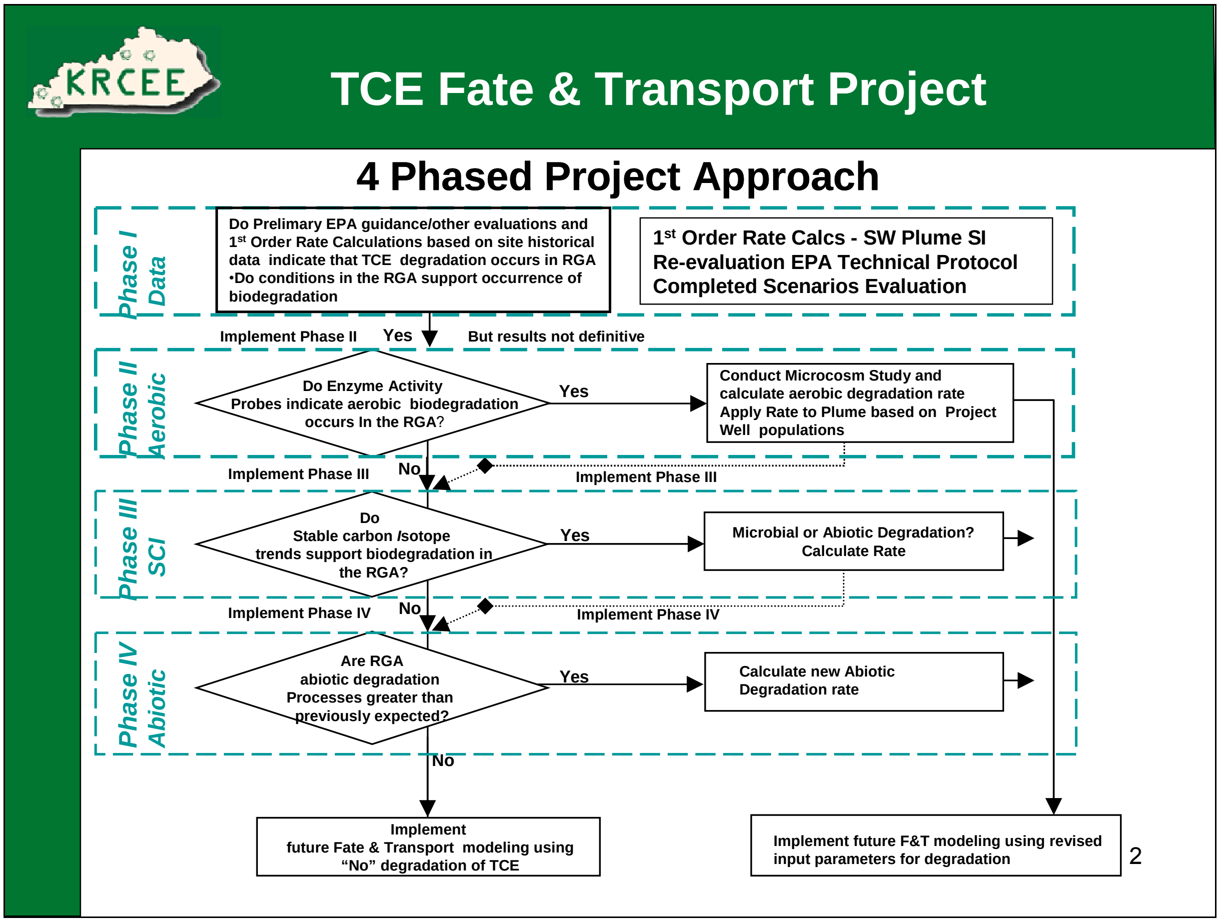
Topics one through three have been through a DQO process. Additional investigation of Topic 3 may be undertaken by the Project Team. Focused investigation of Topic 4 may be undertaken upon completion of reporting investigation results for Topics 1 through 3. The results of investigations for each topic will be employed in the development of TCE degradation rates for the RGA groundwater contaminant plumes at the PGDP.

Evaluations of abiotic degradation processes in the RGA have been conducted as part of historical investigations at the PGDP. Most recently the Southwest Plume (SWP) Investigation re-visited first-order rate-constant calculations for NWP groundwater. USEPA and DOE technical guidance documents were used to guide the evaluation of degradation and attenuation mechanisms and conditions.

1.1. Project Team

A project scoping team was formed to ensure that the appropriate technical, regulatory, and subject-matter expertise was applied to evaluation of TCE-degradation mechanisms and site conditions. The Project Team consists of representatives from the DOE, DOE contractors, Paducah Remediation Services, Portage Environmental, the Commonwealth of Kentucky-Division of Waste Management, EPA Region 4, and the Kentucky Research Consortium for Energy and Environment (KRCEE) (Table 2).

Table 1. Flowchart for phases of PGDP RGA TCE Fate and Transport Project



KRCEE

TCE Fate & Transport Project

4 Phased Project Approach

Phase I
Data

Do Prelimary EPA guidance/other evaluations and 1st Order Rate Calculations based on site historical data indicate that TCE degradation occurs in RGA
•Do conditions in the RGA support occurrence of biodegradation

1st Order Rate Calcs - SW Plume SI
Re-evaluation EPA Technical Protocol
Completed Scenarios Evaluation

Implement Phase II Yes But results not definitive

Phase II
Aerobic

Do Enzyme Activity Probes indicate aerobic biodegradation occurs In the RGA?

Yes

Conduct Microcosm Study and calculate aerobic degradation rate
Apply Rate to Plume based on Project Well populations

Implement Phase III No

Implement Phase III

Phase III
SCI

Do Stable carbon /sotope trends support biodegradation in the RGA?

Yes

Microbial or Abiotic Degradation?
Calculate Rate

Implement Phase IV No

Implement Phase IV

Phase IV
Abiotic

Are RGA abiotic degradation Processes greater than previously expected?

Yes

Calculate new Abiotic Degradation rate

No

Implement future Fate & Transport modeling using "No" degradation of TCE

Implement future F&T modeling using revised input parameters for degradation

2

Table 2. Project Scoping Team Representatives

Organization	Representative
DOE-PPPO	Dr. Rich Bonczek
Paducah Remediation Services	Bryan Clayton, Ken Davis
Portage Environmental	Bruce Phillips
Kentucky Division of Waste Management	Dr. Ed Winner, Todd Mullins, Brian Begley, Dr. Scott Little
USEPA Region IV	David Williams
USEPA Ada Environmental Laboratory	Dr. John Wilson
KRCEE	Dr. John Volpe, Steve Hampson
DOE-EM	Beth Moore
Savannah River Laboratory	Dr. Brian Looney
Idaho National Engineering Laboratory	Dr. Hope Lee
University of Oklahoma	Dr. Paul Philp

2. Site Background

2.1. General Site Information

The PGDP is an active uranium enrichment facility located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in western McCracken County (Figure 1). A U.S. Department of Energy reservation encompasses the uranium enrichment plant. Total reservation acreage is utilized as follows:

- 748 acres-within a restricted area that encompasses plant industrial operations;
- Approximately 822 acres in an uninhabited buffer zone surrounding the restricted area; and
- 1986 acres leased to Commonwealth of Kentucky as part of West Kentucky Wildlife Management Area (WKWMA).

Bordering the PGDP reservation to the northeast, between the plant and the Ohio River, is a Tennessee Valley Authority (TVA) reservation occupied by the Shawnee Steam Plant. Agricultural and other rural properties border the DOE reservation to the east and west (Figure 2).

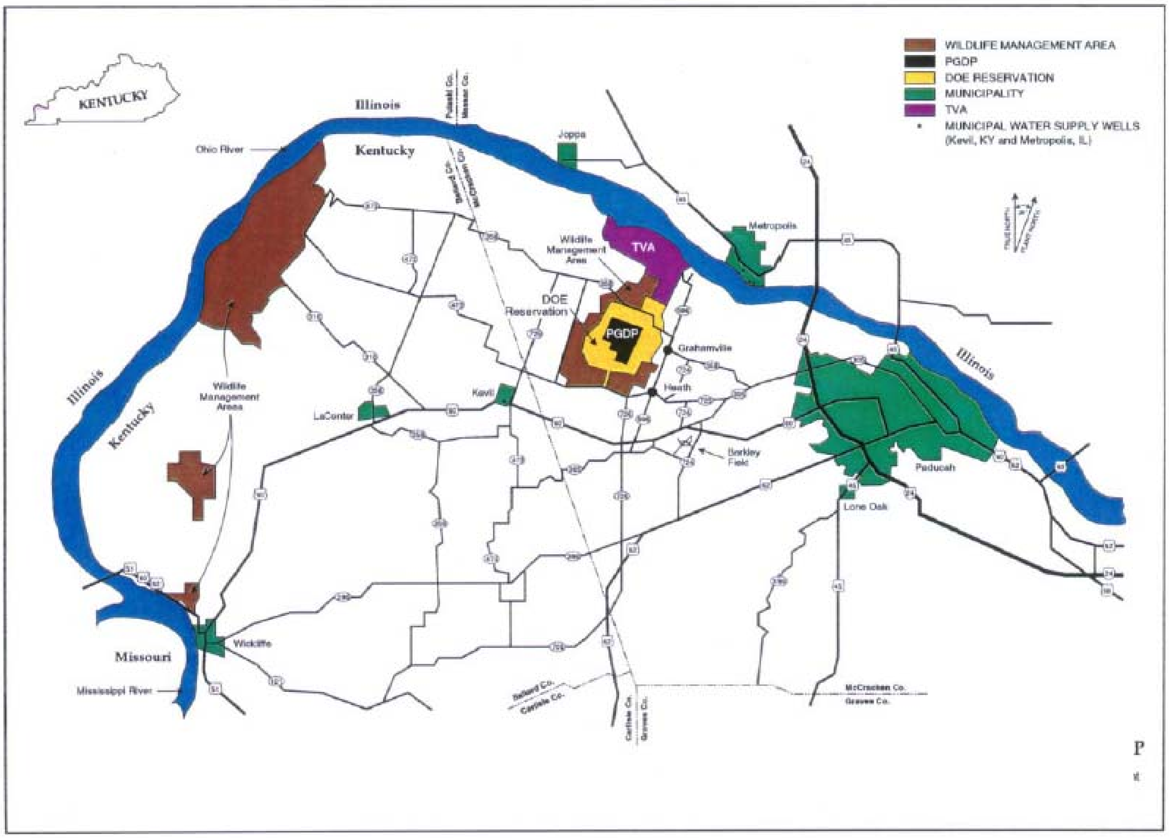


Figure 1. PGDP Location Map (DOE, 2001a)

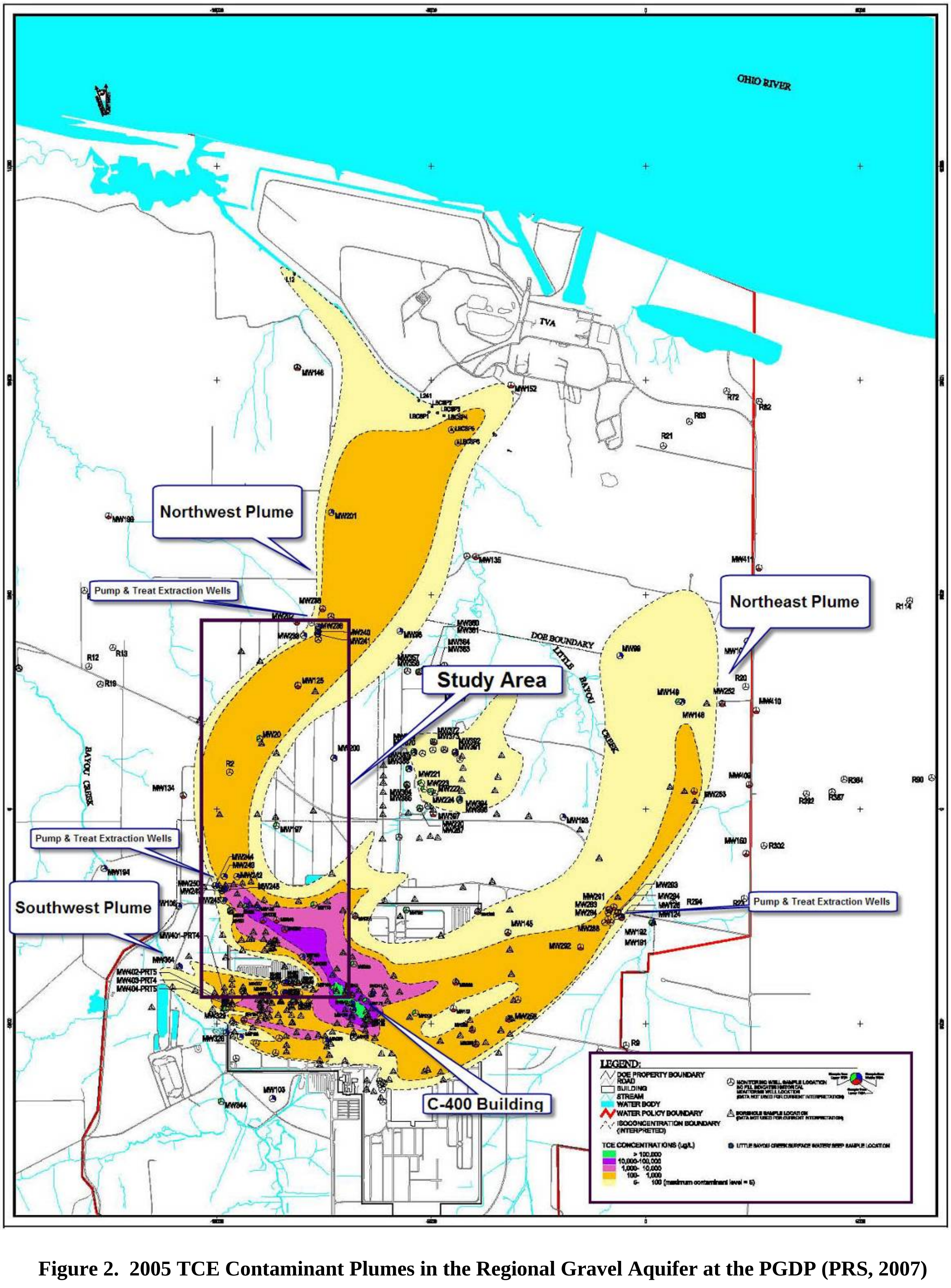


Figure 2. 2005 TCE Contaminant Plumes in the Regional Gravel Aquifer at the PGDP (PRS, 2007)

2.1.1 Geology

Mississippian to Holocene age soil and bedrock underlie the PGDP. The Illinois Basin, the Mississippi Embayment, and ancestral Tennessee River channels are structural/erosional features that controlled the deposition and distribution of sediments in the shallow subsurface underlying the PGDP (DOE, 1997). Mississippian limestone bedrock occurs at approximately 340 feet below ground surface (bgs) and is overlain by Mississippi Embayment sediments of the Cretaceous McNairy Formation (90 – 340 feet bgs), Paleocene Porters Creek Clay, Pleistocene sands and gravels of the Lower Continental Deposits (60 – 100 feet bgs), Pleistocene sands and silts of the Upper Continental Deposits (20 – 60 feet bgs), and Pleistocence-Quaternary loess (0 – 40 feet bgs) ***(Figure 3).***

The Porters Creek Clay and overlying Eocene Sands are absent to the north of a buried terrace of the ancestral Tennessee River ***(Figure 3).*** From the terrace northward, the upward-fining sands and gravels of the Lower Continental Deposits uncomformably overlie the erosional surface of the McNairy Formation. Fine grained sands intermittently occur in the uppermost McNairy Formation and immediately underlie the coarse sands, gravels, and cobbles at the base of the Lower Continental Deposits.

The PGDP occupies an area between the New Madrid Seismic Zone, the Fluorspar Area Fault Complex, and the Wabash Valley Seismic Zone. Several site-specific seismic investigations have identified faulting and vertical displacement of the geologic materials underlying the PGDP ***(Langston & Street, 1996; SAIC, 2001; SAIC, 2003; and KRCEE, 2005).*** Recent seismic investigations in the vicinity of the PGDP indicate the presence of significant vertical displacement of the underlying Mississippian bedrock which correlates upward and into Pleistocene sands/ gravels of the Lower Continental Deposits and possibly silts/sands of the Upper Continental Deposits ***(Personal Communication, Dr. Edward Woolery, 2008)***.

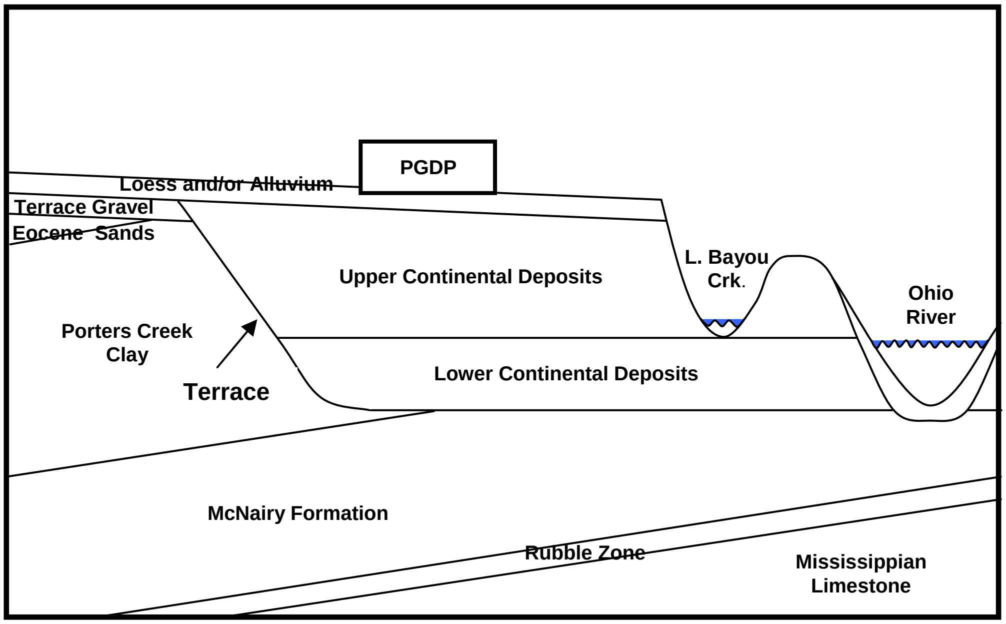


Figure 3. Conceptual Geologic Model for the PGDP and Eenvirons.

2.1.2. Hydrogeology

The PGDP industrial facility and its northern environs are located above the Upper and Lower Continental Deposits and the McNairy Formation. Sand and gravel deposits of the ancestral (Pleistocene-age) Tennessee River occur at a depth of 60 to 90 feet bgs and form the Regional Gravel Aquifer (RGA), which is the primary groundwater pathway for contaminant migration away from the PGDP.

In the southern portion of the industrial area and to the south of the PGDP, the geology is dominated by the Porters Creek Clay Formation, which is underlain by the McNairy Formation. The northern boundary of the Porters Creek Clay is an erosional terrace that underlies the southern extent of the PGDP industrial area and terminates the southern end of the Lower Continental Deposits and serves as a natural barrier to RGA groundwater flow to the south (DOE 1997).

In general, groundwater flows vertically down through the loess and Upper Continental Deposits until it encounters the Lower Continental Deposits/RGA. Because the hydraulic conductivity of the RGA is much greater than the conductivities of the Upper Continental Deposits and underlying McNairy Formation (Table 3), groundwater moves laterally through the RGA toward the Ohio River and the RGA serves as the primary lateral pathway for groundwater flow and contaminant transport beneath the PGDP (Figure 4). The dominant groundwater flow direction in the McNairy Formation is horizontal towards the Ohio River, although vertically upward gradients have been measured in the vicinity of the river (DOE 2005).

Immediately beneath the PGDP industrial area, the predominant axial orientation of RGA sand and gravel deposits is east-west. The orientation of the RGA deposits in combination with leakage from water utilities results in the divergence of groundwater flow under the plant. Groundwater to the east and southeast of the C-400 Building flows to the east-northeast and comprises the Northeast Plume. Groundwater immediately under and to the west-northwest of the C-400 Building migrates to the northwest under the industrial area and then north toward the Ohio River as the Northwest Plume. Groundwater to the west-southwest of the C-400 Building forms the Southwest Plume which flows toward the western perimeter of the industrial area.

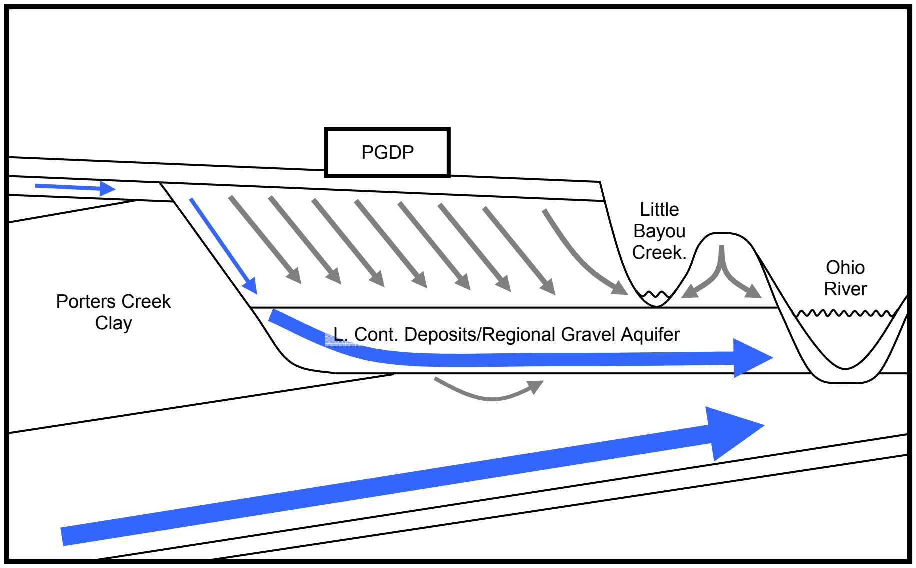


Figure 4. Generalized Groundwater Flow Model for the PGDP and it's environs

2.1.2.1. TCE Sources

The Northwest, Southwest, and Northeast TCE plumes originate in part from the C-400 Building near the center of the PGDP industrial facility but may also receive flow from burial grounds or disposal areas within the PGDP security fence. TCE concentrations indicative of the presence of primary dense non-aqueous phase liquied (DNAPL) sources in the UCRS and secondary DNAPL sources in the RGA generally are limited to areas within the PGDP security fence.

The PGDP Groundwater Operable Unit (GWOU) is comprised of facilities/solid waste management units (SWMUs) that contain impacted groundwater along with facilities and SWMUs that are sources of contamination to groundwater. Table 4 identifies the facilities and SWMUs that are characterized as sources to PGDP's Northwest, Southwest, and Northeast groundwater contaminant plumes:

Table 3. Hydraulic Conductivity Data for the PGDP (DOE, 1999)

HU	Low	Mean	High	Type of test and reference
UCRS (K_h)	**UCRS (K_h)**	**UCRS (K_h)**	**UCRS (K_h)**	**UCRS (K_h)**
(cm/sec)	1.0×10^{-8}		6.9×10^{-4}	Slug tests (CH2M HILL 1992)
(ft/day)	2.9×10^{-5}		1.96	
HU3 (K_v)	**HU3 (K_v)**	**HU3 (K_v)**	**HU3 (K_v)**	**HU3 (K_v)**
(cm/sec)		2.0×10^{-4}		Pumping test at C-404 (Terran 1990)
(ft/day)		5.7×10^{-1}		
(cm/sec)	1.1×10^{-5}		1.1×10^{-4}	Pumping test at C-333 (Terran 1992)
(ft/day)	3.0×10^{-2}		3.0×10^{-1}	
RGA (K_h)	**RGA (K_h)**	**RGA (K_h)**	**RGA (K_h)**	**RGA (K_h)**
(cm/sec)	1.9×10^{-2}		3.8×10^{-2}	Pumping test at C-404 (Terran 1990)
(ft/day)	53		107	
(cm/sec)	3.2×10^{-5}		5.2×10^{-2}	Slug tests (CH2M HILL 1992)
(ft/day)	9.1×10^{-2}		146	
(cm/sec)	3.5×10^{-2}		5.3×10^{-2}	Pumping test at C-537 (CH2M HILL 1992)
(ft/day)	100		150	
(cm/sec)	3.5×10^{-1}		4.2×10^{-1}	Pumping test at C-333 (Terran 1992)
(ft/day)	1,000		1,200	
(cm/sec)	1.9×10^{-1}		4.3×10^{-1}	Pumping test at Northeast Plume containment well field (DOE 1997a)
(ft/day)	529		1,213	
(cm/sec)	9.5×10^{-1}		2	Pumping test at Northwest Plume north containment well field (LMES 1996a)
(ft/day)	2,686		5,700	
McNairy (K_h)	**McNairy (K_h)**	**McNairy (K_h)**	**McNairy (K_h)**	**McNairy (K_h)**
(cm/sec)		6.2×10^{-6}		Analysis of cyclic water level trends in McNairy wells (LMES 1996b)
(ft/day)		1.7×10^{-2}		
(cm/sec)	2.9×10^{-5}		1.8×10^{-4}	Slug tests (CH2M HILL 1992)
(ft/day)	8.2×10^{-2}		5.2×10^{-1}	
McNairy (K_v)	**McNairy (K_v)**	**McNairy (K_v)**	**McNairy (K_v)**	**McNairy (K_v)**
(cm/sec)	1.8×10^{-8}		5.0×10^{-4}	Permeameter tests of C-746-U landfill and Northwest Plume containment well field samples (LMES 1996b)
(ft/day)	5.1×10^{-5}		1	
(cm/sec)		1.6×10^{-7}		Analysis of cyclic water level trends in McNairy wells (LMES 1996b)
(ft/day)		4.5×10^{-4}		

HU = hydrogeologic unit
PGDP = Paducah Gaseous Diffusion Plant
RGA = Regional Gravel Aquifer
UCRS = Upper Continental Recharge System

The C-400 Cleaning Building, located near the center of the industrialized section of PGDP, is the primary source area for TCE in the NWP RGA. Primary industrial activities conducted in the C-400 Building have included maintenance and cleaning of machinery and parts, disassembling and testing cascade components, and laundering plant clothes. Known and suspected sources of leaks and spills at the C-400 Building include degreaser and cleaning tank pits, drains and sewers, the east side plenum/fan room basement, tanks, rail transfer stations/sumps outside the building, and various other processes. The Waste Area Grouping (WAG) 6 Remedial Investigation (DOE, 1998), identified significant TCE leaks and spills that occurred at the southeast corner of the C-400 Building: SWMU 11 is located at the southeast corner of the C-400 Building, where a drain line from a degreaser sump was poorly connected to a storm sewer, and SWMU 533 where transfer pumps and piping moved TCE to and from a storage area associated with the building.

The highest concentrations of TCE in PGDP soil and groundwater are in the UCRS and RGA to the southeast and southwest of the C-400 Building. Elevated concentrations of TCE and its breakdown products in subsurface soils and groundwater suggest the presence of TCE dense non-aqueous phase liquid (DNAPL). In subsurface soil to the southeast of the C-400 Building, TCE has been detected at 11,055 ppm, trans-1,2-dichloroethene (DCE) was detected at 102 ppm; and vinyl chloride (VC) was detected at 29 ppm. Cis-1,2-DCE and 1,1,1-trichloroethane (l,l,l-TCA) have also been detected at 2 ppm. To the southwest of the C-400 building, TCE has been detected in subsurface soil at 168 ppm, trans-1,2-DCE at 15 ppm, and cis-1,2-DCE at 1 ppm. The presence of the TCE degradation products trans-1,2-DCE, Cis-1,2-DCE, and VC indicate that anaerobic degradation processes occur locally within the Upper Continental Deposits/UCRS.

Table 4. GWOU Facilities and Solid Waste Management Units

C-720 Maintenance and Storage Building
C-400 Cleaning Facility
SWMU 1 - C-747-C Oil Land Farm
SWMU 2 - C-749 Uranium Burial Ground
SWMU 4 - C-747 Contaminated Burial Ground
SWMU 201 - Northwest Groundwater Plume
SWMU 202 - Northeast Groundwater Plume
SWMU 210 - Southwest Groundwater Plume
Little Bayou Creek Groundwater Plume Seeps

The maximum historical TCE concentrations detected in the RGA in the vicinity of the C-400 Building are 701 ppm or 64% of the maximum solubility of TCE in water. Several recent concentrations of TCE in MW 408 groundwater , near the southeast corner of the C-400 Building, exceed the TCE solubility limit of $1x10^5$ mg/L and indicate the presence of DNAPL. These high concentration indicate that DNAPL has penetrated the RGA and is acting as a secondary source of groundwater contamination to PGDP contaminant plumes. Site data indicate that the C-400 area sources of TCE and ^{99}Tc to the Northwest Plume are not being rapidly depleted. Concentrations indicating the presence of secondary sources and DNAPL in the RGA have also been identified at SWMU 4 which is associated with the Southwest Plume.

2.1.2.2. Dissolved-Phase TCE Plumes

Dissolved phase TCE contamination is typical of all three (3) PGDP groundwater plumes once away from the immediate vicinity of UCRS primary and RGA secondary TCE sources (Figure 5). Technetium-99 is a dissolved phase co-contaminant to TCE in the NWP, SWP, and on-site portions of the NEP (Figure 6). Redox conditions and the availability of dissolved oxygen in the plumes could support aerobic co-metabolic biodegradation of TCE in PGDP groundwater.

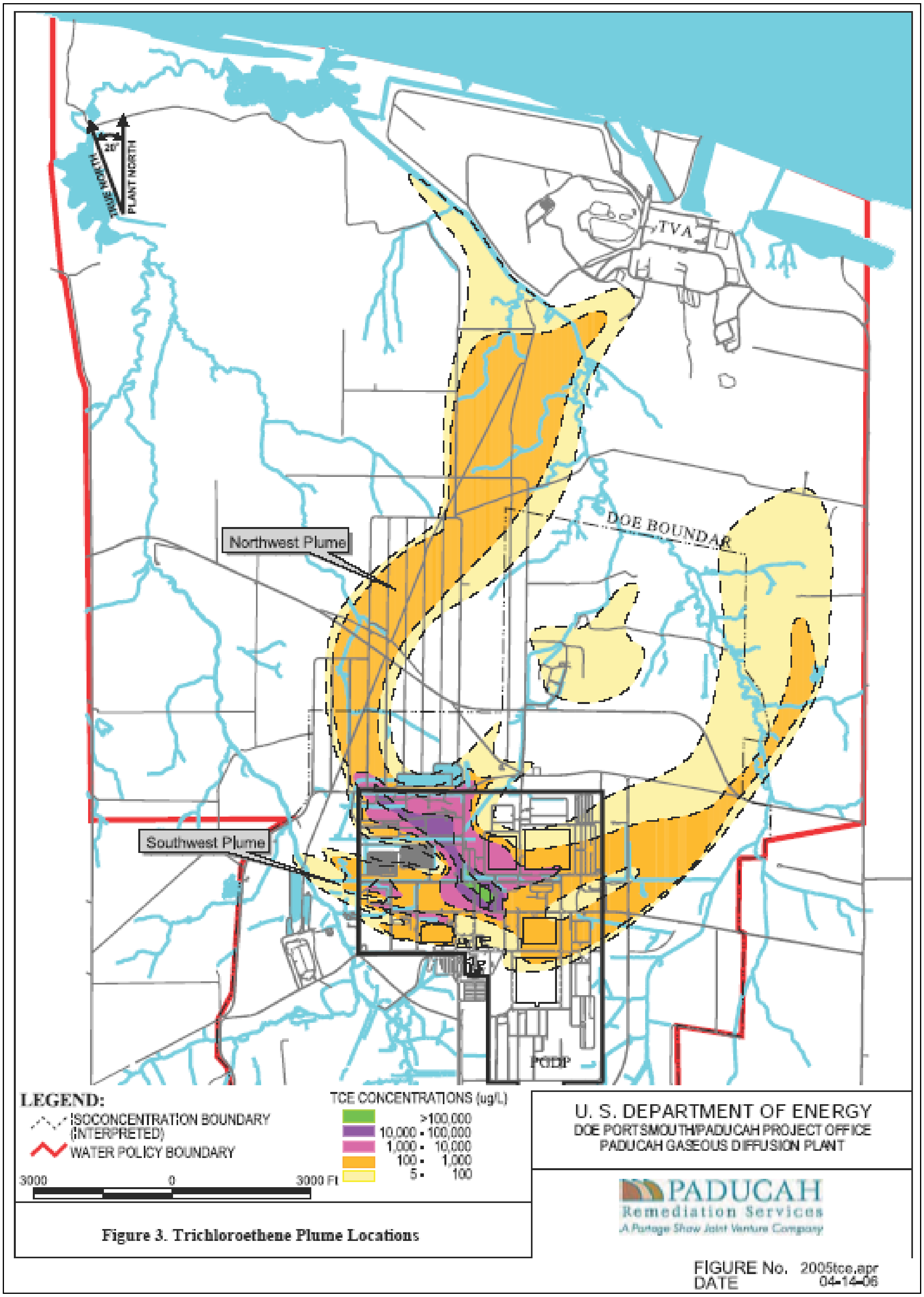


Figure 5. 2005 PGDP TCE plumes (PRS, 2007)

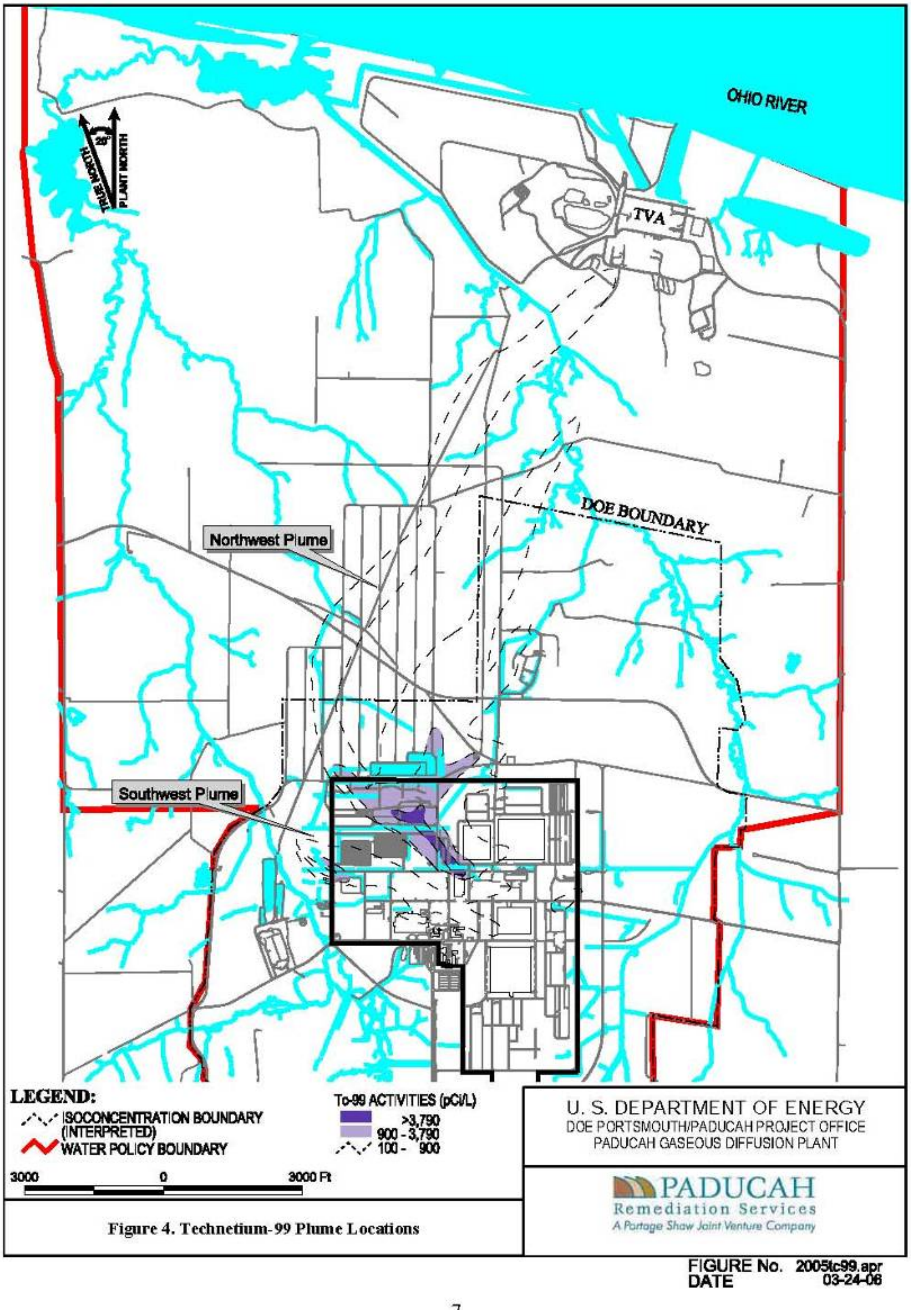


Figure 6. 2005 PGDP technetium-99 plumes (PRS, 2007)

Site data indicate that the Northwest Plume was approximately stable prior to the startup of the NWP pump and treat extraction wells in 1995. More recent evaluations of NWP TCE and ^{99}Tc indicate decreasing trends along the plume core and a possible shift of the plume core to the east (PRS, 2007).

2.1.2.3. Geochemistry

The Phase I and Phase II Site Investigations (DOE, 1989; DOE, 1990) account for the earliest comprehensive geochemical characterizations of groundwater at the PGDP and its environs. Groundwater geochemical characterizations were updated in the Groundwater Conceptual Model for the Paducah Gaseous Diffusion Plant (DOE, 1997) and in the Phase III Groundwater Investigation (DOE, 1992) based on the availability of new geochemical data and later in the *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the* PGDP (Clausen et al., 1997).

The Groundwater Conceptual Model concluded that mineralogy, cation exchange capacity, high dissolved oxygen concentrations, and presence of TCE and ^{99}Tc contaminant plumes are the primary controls on groundwater chemistry at the PGDP Bicarbonate type groundwater generally predominates in the UCRS, the RGA and the McNairy flow systems underlying the PGDP. In the UCRS, the primary anion shifts from sulfate to bicarbonate with depth and calcium remains the dominant ion in RGA groundwater. High dissolved oxygen concentrations, ranging from 1 to 7 mg/L, are prevalent in the RGA. The predominant form of technetium-99 was identified as the negatively charged pertechnetate ion, TcO_4^-. In a preliminary evaluation of TCE fate in the RGA, investigators estimated a 1.3% reduction in TCE concentrations and a 1.0% reduction in ^{99}Tc concentrations for every 30 m (100 feet) of travel between the North and South NWP extraction well fields.

Clausen et al. (1997) summarized RGA geochemical conditions, including contaminant geochemistry, in both the NEP and NWP and noted there is little variability in RGA geochemistry across the site, particularly the major ion chemistry. General RGA geochemical conditions identified for the NE and NW Plumes are summarized in Table 5. The discussion of RGA geochemical conditions notes: 1) that the range of Eh values and dissolved oxygen (DO) concentrations are consistent with an aerobic aquifer system, 2) there is limited evidence of oxygen-limited micro environments within the RGA; and 3) that the concentration trends of contaminants suggest that steady state conditions exist in both plumes.

Table 5. Geochemical conditions in PGDP NE and NW Plume RGA groundwater (Clausen, 1997)

Parameter	Range	Units
pH	5.7 – 6.8	Standard pH
Eh	+120 - +280	mV
Dissolved Oxygen	1.0 – 7.9	mg/L
Bicarbonate	99 – 351	mg/L
Chloride	3 – 120	mg/L
Sulfate	5.5 – 115	mg/L
Nitrate	0.5 – 50	mg/L
Iron (total)	0.3 – 7.0	mg/L
Hydrogen sulfide	<0.1 – 0.04	mg/L
Ammonia	<0.1	mg/L

In addition to summarizing general groundwater geochemical conditions, Clausen et al. (1997) conducted an in-depth investigation and evaluation of PGDP groundwater geochemical conditions relative to physical, chemical and biological attenuation and degradation processes. A summary of the 1997 evaluations related to fate and transport of TCE in the RGA is presented in Section 3.1 of this document.

3.0. Technical Background

3.1. Guidance for Evaluation of Natural Attenuation

A number of guidance documents have been produced by Federal and State agencies, the scientific community, and industry to provide investigators and decision-makers information on appropriate approaches for the evaluation of natural attenuation and protocols for investigation, documentation, evaluation and monitoring of natural attenuation processes. The adequacy of comprehensive natural-attenuation-evaluation protocols, developed prior to 1999 (listed below), was reviewed by the National Academy of Sciences - Committee for Intrinsic Remediation (NAS) in the document Natural Attenuation for Groundwater Remediation (NAP, 2000).

- "Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination in Groundwater," Todd Wiedemeier, John T. Wilson, Donald H. Kampbell, Ross N. Miller, and Jerry E. Hanson, Volume I and Volume II, November 11, 1995, Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB.

- "Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater," Todd H. Wiedemeier, Matthew A. Swanson, David E. Moutoux, E. Kinzie Gordon, John T. Wilson, Barbara H. Wilson, Donald H. Kampbell, Jerry E. Hansen, Patrick Haas, and Francis H. Chapelle, Draft—Revision 2, July 1997, Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks Air Force Base, San Antonio, Tex.

- "Draft Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents," Version 3.0, November 1997, EPA Region 4.

- Department of Energy • "Site Screening and Technical Guidance for Monitored Natural Attenuation at DOE Sites," Patrick V. Brady, Brian P. Spalding, Kenneth M. Krupka, Robert D. Waters, Pengchu Zhang, David J. Borns, and Warren D. Brady, Draft, August 30, 1998, Sandia National Laboratory.

- "Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water," Todd H. Wiedemeier, Matthew A. Swanson, David E. Moutoux, E. Kinzie Gordon, John T. Wilson, Barbara H. Wilson, Donald H. Kampbell, Patrick E. Haas, Ross N. Miller, Jerry E. Hansen, and Francis H. Chapelle, EPA/600/R-98/128, September 1998, EPA Office of Research and Development.

- "Technical Guidelines for Evaluating Monitored Natural Attenuation at Naval and Marine Corps Facilities," Todd H. Wiedemeier and Francis H. Chapelle, Draft—Revision 2, March 1998.

- "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites," Final OSWER Directive (OSWER Directive Number 9200. 4-17P), April 21, 1999, EPA Office of Solid Waste and Emergency Response.

The NAS review noted similarities in the approaches and methods identified in the various protocols. Several of the protocols including the Air Force Center for Environmental Excellence (AFCEE) chlorinated solvents protocol, USEPA Office of Research and Development (ORD) Technical Protocol, and the Region IV Suggested Practices protocol shared authors and general content. The Region IV Suggested Practices document was released in 1997, and information in the Region IV document was expanded in the EPA ORD's 1998 Technical Protocol document. The *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* is the primary document referenced to guide planning and activities for the PGDP TCE Fate and Transport Process Project.

Recent Savannah River National Laboratory technical guidance, *Scenarios Evaluation Tool for Chlorinated Solvent MNA* (SRNL, 2006) provided information and an approach for evaluating existing and historical site conditions that prompted implementation of a formal evaluation of aerobic degradation processes in the RGA. The *Scenarios Evaluation Tool for Chlorinated Solvent MNA* (SRNL, 2006) along with information obtained from the 1998 EPA technical guidance document "*Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water"* (Technical Protocol) provided PGDP investigators with the approaches and tools necessary to evaluate and characterize microbial degradation in an aerobic groundwater setting.

The *Technical Protocol* identifies the need for three lines of evidence to support conclusions that natural attenuation mechanisms are occurring and are sustainable relative to an individual site's contamination.

1. The First Line of Evidence is the evaluation of historical and temporal contaminant concentration trends along the contaminant plume's flow path. Groundwater and soil analytical parameters that provide information about geochemical conditions and the availability of substrates and nutrients in the environment are identified in Tables 6 & 6a. This line of evidence calls for evaluation of the removal of contaminant mass along contaminant flowpaths and includes the calculation of first-order rate constants.

2. The Second Line of Evidence is the identification of the specific attenuation processes, their nature and rate, the resulting destruction of contaminant mass that is occurring, and the hydrogeochemical conditions that exist to support the attenuation processes. There are two components:

    a. Use of mass balance calculations to illustrate that electron donor and receptor concentrations are sufficient to facilitate degradation of dissolved contaminants.

    b. Use of measured contaminant concentrations and/or biologically recalcitrant tracers with hydrogeologic characteristics of the aquifer to illustrate that reduction in contaminant mass is occurring and to calculate biodegradation rate constants.

3. The Third Line of Evidence is the utilization of additional technical information, analytical work, and evaluations related to degradation mechanisms that were not known or recognized at the time of publication of the Technical Protocol. The third line of evidence may include microcosm study data, compound specific isotope analyses (CSIA), numerical modeling, and documentation of the geochemical conditions that support the occurrence and rate of the biodegradation process.

Table 6. Groundwater analytical parameters for characterization of microbial degradation (AFCEE, 1998)

Analysis	Data Use	Field or Fixed-Base Laboratory
Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	Method of analysis for BTEX and chlorinated solvents/daughter products, which are the primary target analytes for monitoring natural attenuation; method can be extended to higher molecular weight alkyl-benzenes; trimethylben-zenes are used to monitor plume dilution if degradation is primarily anaerobic.	Fixed-base
Dissolved Oxygen	Concentrations less than about 0.5 mg/L generally indicate an anaerobic pathway. Measurements made with electrodes; results are displayed on a meter; protect samples from exposure to oxygen during sampling and analysis.	Field
Nitrate	Substrate for microbial respiration in the absence of oxygen	Fixed-base
Mn(II)	Indication of Mn(IV) reduction during microbial degradation of organic compounds in the absence of dissolved oxygen and nitrate.	Field
Fe(II)	Indication of Fe(III) reduction during microbial degradation of organic compounds in the absence of dissolved oxygen, nitrate, and Mn(IV).	Field
Sulfate (SO_4^{2-})	Substrate for anaerobic microbial respiration	Field
Hydrogen Sulfide	Metabolic byproduct of sulfate reduction. The presence of H_2S suggests organic carbon oxidation via sulfate reduction.	Field
Methane, ethane, and ethene	The presence of methane suggests organic carbon degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing biological transformation. Kampbell *et al.*, 1989 or SW3810 Modified	Fixed-base
Carbon Dioxide	Carbon dioxide is produced during the biodegradation of many types of organic carbon	Field
Alkalinity	General water quality parameter used (1) to measure the buffering capacity of groundwater, and (2) as a marker to verify that all site samples are obtained from the same groundwater system;	Field
Oxidation-reduction potential (ORP)	The ORP of groundwater reflects the relative oxidizing or reducing nature of the groundwater system. ORP is influenced by the nature of the biologically mediated degradation of organic carbon; the ORP of groundwater may range from more than 800 mV to less than -400 mV. Measurements made with electrodes; results are displayed on a meter; protect samples from exposure to oxygen. Report results against the hydrogen electrode (Eh) by adding a correction factor specific to the electrode used	Field
pH	Aerobic and anaerobic processes are pH-sensitive	Field
Temperature	Well development	Field
Conductivity	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Field
Major Cations	Can be used to evaluate other remedial actions.	Field
Chloride	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system. Final product of chlorinated solvent reduction.	Fixed-base
Total Organic Carbon	Used to classify plume and to determine if co-metabolism is possible in the absence of anthropogenic carbon	Laboratory
Hydrogen (H_2)	Sampled at well head requires the production of 100mL per minute of water for 30 minutes. Equilibration with gas in the field. Determined with a reducing gas detector.	Field

Table 6a. Groundwater Analytical Data Quality Objectives for characterization of microbial degradation (AFCEE)

Analysis	Minimum Limit of Quantification	Accuracy/Precision	Availability	Data Completeness Objective
Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	MCLs	Definitive Data Quality	Common laboratory analysis	95%
Oxygen	0.2 mg/L	Standard deviation of 0.2 mg/L	Common field instrument	100%
Nitrate	0.1 mg/L	Definitive Data Quality	Common laboratory analysis	100%
Mn(II)	0.5 mg/L	Definitive Data Quality	Common field analysis	100%
Fe(II)	0.5 mg/L	Definitive Data Quality	Common field analysis	100%
Sulfate (SO_4^{2-})	5 mg/L	Definitive Data Quality	Common laboratory or field analysis	100%
Hydrogen Sulfide (H_2S)	5 mg/L	Definitive Data Quality	Common field analysis	100%
Methane, ethane, and ethene	1 μg/L.	Definitive Data Quality	Specialized laboratory analysis.	95%

A great deal of supporting information regarding natural attenuation processes, mechanisms, and technical methods to collect and assess related data is provided in the Technical Protocol. Relative to biological degradation processes, the Technical Protocol focuses on processes that occur in groundwater environments where molecular oxygen is not available, or anaerobic conditions. However, a less focused but substantial amount of information is also available in the document and appendices regarding the biological degradation processes that occur in groundwater environments where aerobic conditions exist and molecular oxygen is available.

3.2. Natural Attenuation Processes

Natural Attenuation refers to naturally-occurring in-situ chemical, physical, and biological processes that attenuate, degrade, and/or destroy a contaminant. According to the USEPA, these mechanisms “act without human intervention to reduce mass, toxicity, mobility, volume or concentration of contaminants in soil or groundwater.” (EPA, 1999b). Natural attenuation mechanisms include: advection, dispersion, diffusion, sorption, chemical degradation processes, and biological degradation processes that are summarized in Table 7.

After several decades of intense study, microorganisms are known to be ubiquitous in the groundwater environment and biodegradation is recognized as the most important process acting to truly reduce contaminant mass in groundwater (EPA, 1998). Since the 1970’s, the scientific community has identified microbes that are indigenous to a variety of physical and geochemical groundwater environments and are capable of degrading organic compounds from jet fuel and gasoline to chlorinated solvents (MLG, 2006).

Microorganisms utilize oxidation (loss of electrons) and reduction (gain of electrons) reactions to harvest chemical energy available in the aquifer for growth and activity. Aerobic conditions exist in groundwater when molecular oxygen is present. Under aerobic conditions, microorganisms couple the oxidation of (electron transfer from) food sources consisting of organic compounds, to the reduction of (addition of electrons to) oxygen. Aerobic microbial metabolic activities utilize organic-compound food sources as electron donors and oxygen as the electron acceptor.

When molecular oxygen is not available in the groundwater environment, anoxic conditions prevail and anaerobic microorganisms utilize compounds other than oxygen as electron acceptors. The compounds used as electron acceptors in the absence of oxygen include, but are not limited to, naturally occurring organic carbon, carbon dioxide, nitrate, sulfate, methane, ammonia, manganese, iron (III), and chlorinated organic compounds. The thermodynamic sequence for microbial redox reactions utilizes electron acceptors as follows: $O_2 > NO_3 >$ Mn (IV) > Fe (II) > $SO_4 > CH_2O$.

Microbial metabolic processes occurring under aerobic or anaerobic conditions change the chemical composition of compounds that serve as the primary electron donors and acceptors and result in the degradation or “biodegradation” of those compounds (Figure 7). Aerobic biodegradation occurs in the presence of oxygen and uses oxygen as the terminal electron acceptor and anaerobic biodegradation occurs in the absence of available oxygen and uses compounds (cited above) as terminal electron acceptors. Terminal electron accepting processes involved in biodegradation are identified in Table 7a.

Microorganisms produce enzymes that catalyze or initiate the chemical oxidation or reduction reactions involved in their aerobic and anaerobic metabolic processes. The compounds that serve as electron donors in both aerobic and anaerobic microbial metabolic reactions (biodegradation)are acted upon by the enzymes and are generally referred to as “substrates” or primary growth substrates.

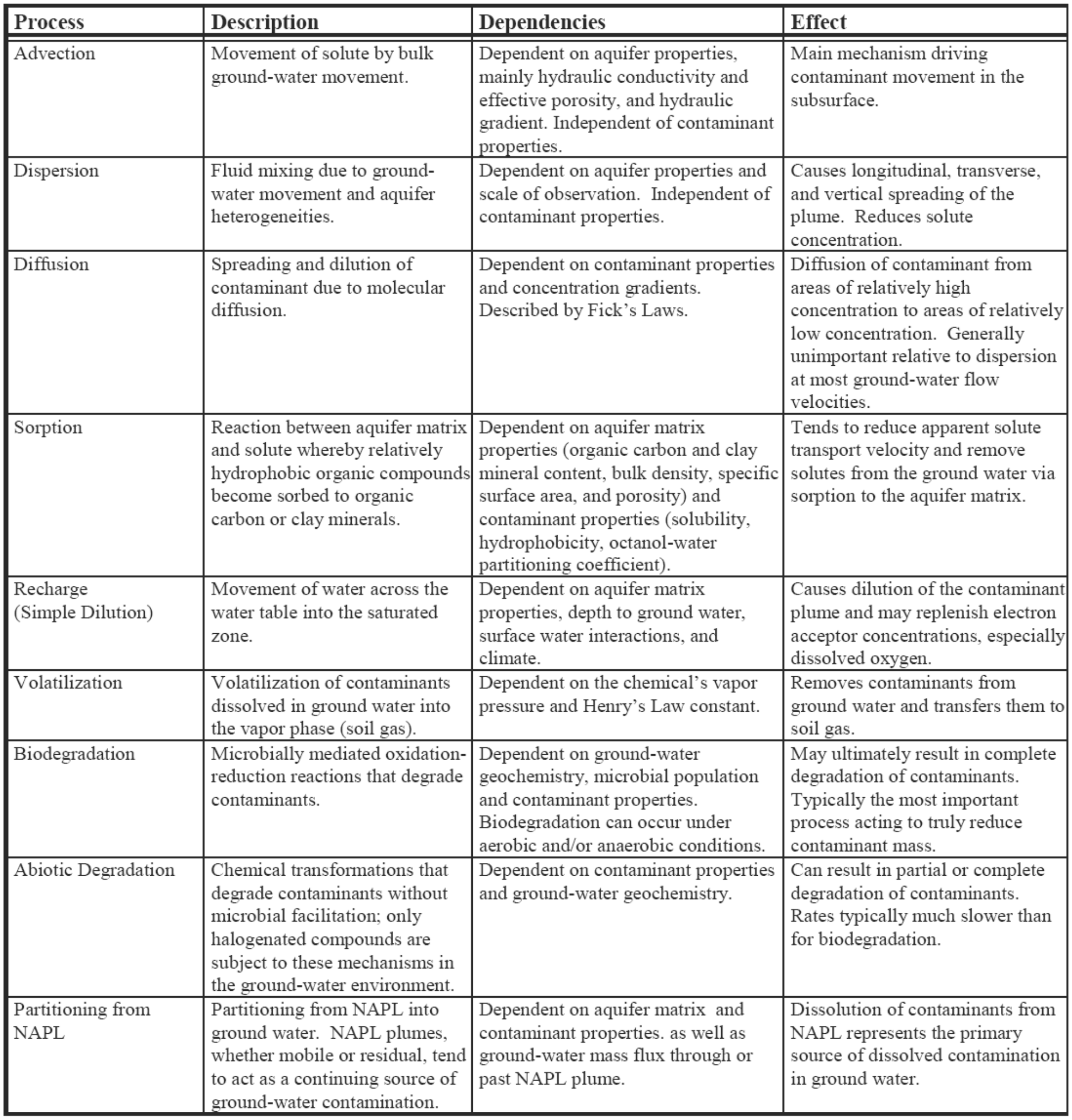
Highly chlorinated ethenes (PCE & TCE) are not known to serve as primary substrates for aerobic microbial metabolic processes and degradation of these substances occurs via a third mechanism of microbially-mediated organic compound degradation, co-metabolism (Vogel, 1994; McCarty and Semprini, 1994). Co-metabolism occurs when the destruction of a chlorinated compound is fortuitously catalyzed by the production of enzymes that are produced by both aerobic and anaerobic microorganisms to react with their primary or growth substrates (EPA, 1998). In co-metabolic degradation the organisms producing the catabolic enzyme (an enzyme that catalyzes a reaction) do not benefit from the fortuitous degradation reaction and the compound being destroyed is neither a substrate nor an electron acceptor.

A number of aerobic bacteria have been identified that produce the catabolic “oxygenase” enzymes capable of initiating co-metabolic degradation of TCE and other chlorinated aromatic compounds. Groups of those aerobic bacteria are identified in Table 8.

Oxygenase enzymes help break down a target molecule by inserting oxygen (Figure 7). Most enzymes catalyze one type of reaction and act on one compound or a group of closely related compounds. Enzymes and substrates are often closely linked so that enzymes are typically named after the substrate and reaction, simply by adding the suffix “*-ase*” (SRNL, 2008). For example, toluene 2-monooxygenase inserts an oxygen atom into toluene at the designated location (Figure 8).

The substrates that are important to aerobic co-metabolism are those that encourage the production of oxygenase enzymes that oxidize a relatively wide range of compounds in addition to the primary substrate. For aerobic co-metabolism, the enzyme must specifically oxidize a target contaminant such as TCE in addition to the primary substrate. Primary substrates that result in TCE co-metabolism include chemicals like toluene that contain "aromatic" carbon rings and short-chain carbon compounds like methane and propane (SRNL, 2008).

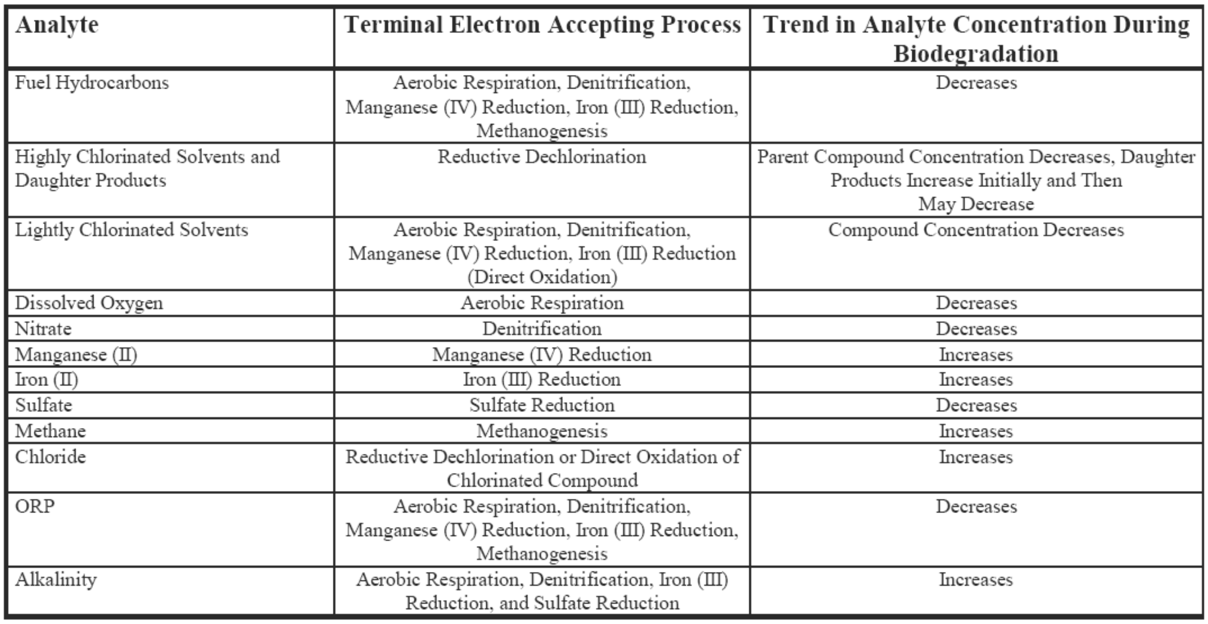
Table 7. Natural Attenuation processes that affect the fate & transport of contaminants in the subsurface **(EPA, 1998)**



Process	Description	Dependencies	Effect
Advection	Movement of solute by bulk ground-water movement.	Dependent on aquifer properties, mainly hydraulic conductivity and effective porosity, and hydraulic gradient. Independent of contaminant properties.	Main mechanism driving contaminant movement in the subsurface.
Dispersion	Fluid mixing due to ground-water movement and aquifer heterogeneities.	Dependent on aquifer properties and scale of observation. Independent of contaminant properties.	Causes longitudinal, transverse, and vertical spreading of the plume. Reduces solute concentration.
Diffusion	Spreading and dilution of contaminant due to molecular diffusion.	Dependent on contaminant properties and concentration gradients. Described by Fick's Laws.	Diffusion of contaminant from areas of relatively high concentration to areas of relatively low concentration. Generally unimportant relative to dispersion at most ground-water flow velocities.
Sorption	Reaction between aquifer matrix and solute whereby relatively hydrophobic organic compounds become sorbed to organic carbon or clay minerals.	Dependent on aquifer matrix properties (organic carbon and clay mineral content, bulk density, specific surface area, and porosity) and contaminant properties (solubility, hydrophobicity, octanol-water partitioning coefficient).	Tends to reduce apparent solute transport velocity and remove solutes from the ground water via sorption to the aquifer matrix.
Recharge (Simple Dilution)	Movement of water across the water table into the saturated zone.	Dependent on aquifer matrix properties, depth to ground water, surface water interactions, and climate.	Causes dilution of the contaminant plume and may replenish electron acceptor concentrations, especially dissolved oxygen.
Volatilization	Volatilization of contaminants dissolved in ground water into the vapor phase (soil gas).	Dependent on the chemical's vapor pressure and Henry's Law constant.	Removes contaminants from ground water and transfers them to soil gas.
Biodegradation	Microbially mediated oxidation-reduction reactions that degrade contaminants.	Dependent on ground-water geochemistry, microbial population and contaminant properties. Biodegradation can occur under aerobic and/or anaerobic conditions.	May ultimately result in complete degradation of contaminants. Typically the most important process acting to truly reduce contaminant mass.
Abiotic Degradation	Chemical transformations that degrade contaminants without microbial facilitation; only halogenated compounds are subject to these mechanisms in the ground-water environment.	Dependent on contaminant properties and ground-water geochemistry.	Can result in partial or complete degradation of contaminants. Rates typically much slower than for biodegradation.
Partitioning from NAPL	Partitioning from NAPL into ground water. NAPL plumes, whether mobile or residual, tend to act as a continuing source of ground-water contamination.	Dependent on aquifer matrix and contaminant properties. as well as ground-water mass flux through or past NAPL plume.	Dissolution of contaminants from NAPL represents the primary source of dissolved contamination in ground water.

The presence of oxidizable organic compounds and the availability of oxygen in an aquifer result in a series of responses by microbial communities. Oxidizable organic compounds may be native carbon sources deposited with the aquifer media, dissolved organic detritus from infiltrating groundwater, organic microbial detritus, and anthropogenic sources of organic carbon. Microbial communities become spatially defined based on the availability of electron donors and acceptors along aquifer flowpaths. Temporally, microbial communities are in flux as oxygen is depleted by the aerobic oxidation of substrates and alternative substrates are then utilized for respiration. When oxygen is sufficiently depleted and aerobic oxidation of substrates no longer occurs, the enzymes responsible for catalyzed aerobic cometabolic degradation are no longer produced and aerobic co-metabolism ceases.

Table 7a. Electron-accepting processes involved in biological metabolic/degradation processes (EPA, 1998)



Analyte	Terminal Electron Accepting Process	Trend in Analyte Concentration During Biodegradation
Fuel Hydrocarbons	Aerobic Respiration, Denitrification, Manganese (IV) Reduction, Iron (III) Reduction, Methanogenesis	Decreases
Highly Chlorinated Solvents and Daughter Products	Reductive Dechlorination	Parent Compound Concentration Decreases, Daughter Products Increase Initially and Then May Decrease
Lightly Chlorinated Solvents	Aerobic Respiration, Denitrification, Manganese (IV) Reduction, Iron (III) Reduction (Direct Oxidation)	Compound Concentration Decreases
Dissolved Oxygen	Aerobic Respiration	Decreases
Nitrate	Denitrification	Decreases
Manganese (II)	Manganese (IV) Reduction	Increases
Iron (II)	Iron (III) Reduction	Increases
Sulfate	Sulfate Reduction	Decreases
Methane	Methanogenesis	Increases
Chloride	Reductive Dechlorination or Direct Oxidation of Chlorinated Compound	Increases
ORP	Aerobic Respiration, Denitrification, Manganese (IV) Reduction, Iron (III) Reduction, Methanogenesis	Decreases
Alkalinity	Aerobic Respiration, Denitrification, Iron (III) Reduction, and Sulfate Reduction	Increases

Table 8. Groups of aerobic bacteria that produce catabolic oxygenase enzymes (EPA, 1998)

Aerobic bacteria categorized by Enzyme Target Compounds
Methane Oxidizers (Methanotrophs)
Propane Oxidizers
Ethene Oxidizers
Toluene, Phenol, Cresol Oxidizers
Ammonia Oxidizers
Isoprene Oxidizers
Vinyl Chloride Oxidizers

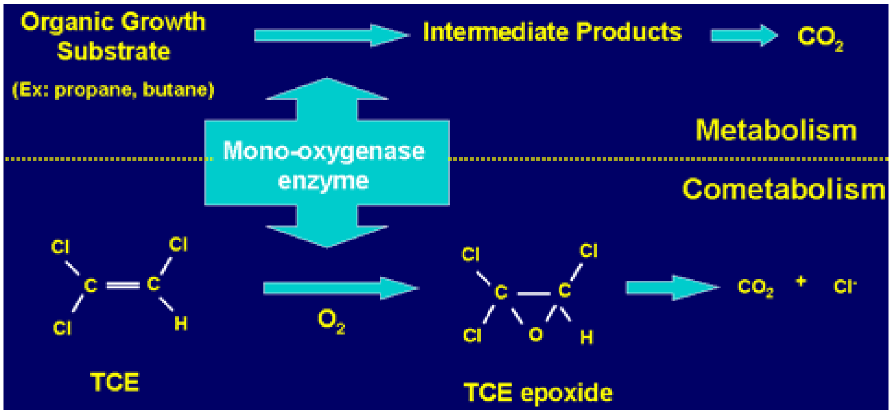


Figure 7. Generalized process diagram of co-metabolism process (WHRSRC, 2007)

Indicators of the occurrence of anaerobic biodegradation of chlorinated compounds, specifically the intermediate daughter products of TCE, are easily recognized, well defined and understood. Aerobic co-metabolism of chlorinated compounds results in different intermediate products (Figure 8) and the end products chloride and carbon dioxide which are common inorganic species in groundwater.

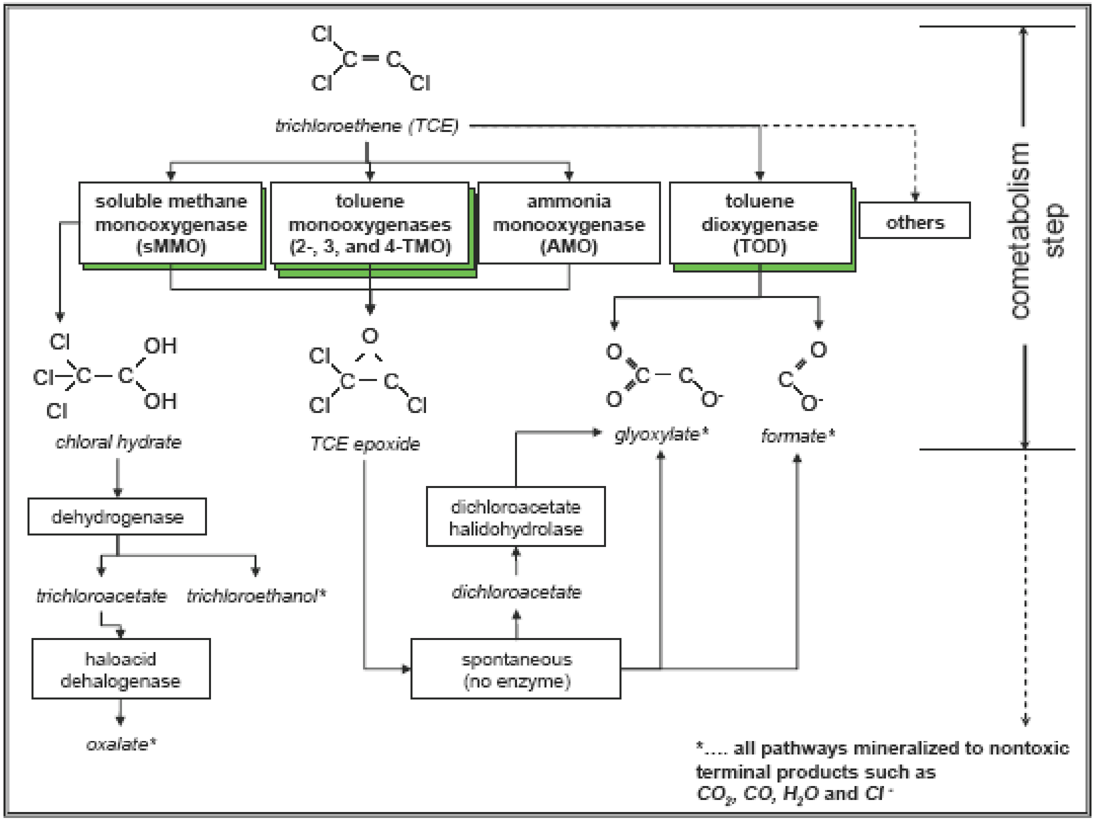


Figure 8. TCE cometabolic degradation pathways (SRNL, 2008)
(Existing EAP assays available for the highlighted items)

The traditional evidence collected to support the occurrence of cometabolic oxidation of TCE includes: 1) identification of appropriate geochemical conditions such as oxygenated groundwater and the presence of a carbon substrate; 2) the disappearance or reduction in concentration of the contaminant; and 3) identification of specific DNA sequences attributable to organisms capable of co-metabolizing a contaminant. These three lines of evidence are capable of identifying the potential for co-metabolism to occur but do not directly measure the active co-metabolic activity. Emerging methods such as enzyme activity probes (EAPs) and compound specific isotope analyses (CSIAs) have been developed and recently applied to the assessment of co-metabolism (SRNL, 2008). EAPs provide for direct measurement of enzyme presence and activity in the environment. CSIAs examine the ratio of stable isotopes in contaminant molecules to determine if isotopic fractionation from abiotic, anaerobic, and aerobic degradation processes are occurring and can provide insight into the specific processes and rates of those processes.

3.3. Technical Methods Background

3.3.1. Enzyme Activity Probe & DNA Control Study Background

Enzyme activity probes are compounds that fluoresce when a co-metabolic enzyme of interest is present and active in a sample. Probes serve as alternate substrates for the enzymes of interest. They include probes for enzymes that target aromatic compounds (toluene, phenol, benzene), and enzymes such as soluble methane monooxygenases (sMMO) that target light hydrocarbons such as methane (SRNL, 2008). Probes undergo transformation to yield a fluorescent product only when the enzyme of interest is actively functioning in a sample. If the appropriate enzyme is not present or is present but not active in a given sample, the probes will not be transformed and no fluorescence will be detected.

The probes used to analyze PGDP study samples include the sMMO probe coumarin and three aromatic enzyme probes: phenylacetylene (PA), 3-hydroxy-phenylacetylene (3HPA) and trans-cinnamonitrile. The probes are nonfluorescent compounds that are transformed by specifically targeted enzymes into fluorescent molecules that are easily quantifiable by microscopy or fluorometry. Positive probe results indicate that enzymes of interest have been induced by environmental conditions. As such, EAPs measure the actual activity of microorganisms and represent in situ conditions (SRNL, 2008).

Microbial DNA can be extracted out of water, soil, or sediment samples. Molecular assay techniques, such as DNA analyses, provide evidence that the blueprint for the enzymes capable of co-metabolic degradation are present. DNA analyses are used as a control to corroborate EAP results. DNA assays are designed to look for the presence of the genes coding for the biological oxygenases. Coupling molecular assessments with EAP analyses provides direct and supporting evidence of cometabolic enzyme activity toward chlorinated solvents (Lee et al., 2005; 2008; Wymore et al., 2007). Natural attenuation of TCE through co-metabolism can be verified using this type of complementary monitoring technique (SRNL, 2008).

3.3.2. Stable Carbon Isotope Background

Compound specific stable isotope analysis (CSIA) is a tool that can supplement traditional techniques for characterizing groundwater flow, identifying potential sources of groundwater contamination, and characterizing the behavior of dissolved organic contaminants in groundwater (MLG, 2006). The ability to determine the isotopic composition of individual compounds in complex mixtures is relatively new and came about with the development and commercial availability of combined gas chromatograph–isotope ratio mass spectrometers (GC-IRMS) in the late 1980s and early 1990s (Philp et al., 2007). Typically, compound specific isotope analyses for environmental forensic purposes rely on stable isotopes of carbon ($^{13}C/^{12}C$), hydrogen ($^{2}H/^{1}H$), oxygen ($^{16}O/^{18}O$), and chlorine ($^{37}Cl/^{35}Cl$).

All compounds are comprised of atoms which are made up of protons, electrons, and neutrons. The protons and the neutrons make up the nucleus of the atom and the electrons orbit the nucleus. Elements are defined by the number of protons in the nucleus. Isotopes of an element are defined by the sum of the protons and neutrons. Because the number of neutrons in an element can vary, most elements have more than one isotope and because stable isotopes are not transformed by radioactive decay, they are inherently stable. Thus, the ratio of two stable isotopes of an element will remain unchanged unless a process occurs that acts preferentially on the lighter or the heavier isotope (MLG, 2006).

The atomic mass difference between isotopes affects each isotope’s chemical kinetic behavior, leading to naturally occurring isotope separation processes (MLG, 2006). Evaporation, volatilization, biodegradation, and chemical transformations are common processes that can result in the isotopic fractionation of chemicals in groundwater. Understanding which processes do or do not cause fractionation and which processes are present in a given environmental system is critical for the application of isotopic analysis. For example, carbon in inorganic carbonates shows little isotopic fractionation, while carbon in materials derived from photosynthesis is depleted of the heavier isotopes. Recent investigations indicate that groundwater/contaminant flow in heterogeneous and slow velocity flow system porous media with mass transfer between relatively fast and slow-flow zones can result in isotopic fractionation of compounds via the molecular diffusion process (LaBolle et al., 2008). Biological degradation processes, through microcosm and field studies, have been recognized as being capable of the depletion of lighter carbon isotopes in compounds because of the preference of microbial degradation processes to target the lighter carbon isotopes (Sherwood-Lollar et al., 2001; Kuder et al., 2005).

Isotopic enrichment of a substance is determined by comparison of a carbon isotope in a sample to a carbon isotope standard, which is the marine carbonate Vienna Pee Dee Belemnite (VPDB). VPDB has been assigned an isotopic carbon-13 ($\sigma^{13}C$) value of “0”. Because other measured materials have $\sigma^{13}C$ values less than that of VPDB, they will have a negative $\sigma^{13}C$ values. With a known standard for comparison, the effects of processes that target the lighter or heavier isotopes in a carbon containing compound (such as TCE) can be evaluated through application of the Rayleigh model. Appendix 3D contains a presentation about utilization of stable isotope analysis to environmental evaluations of MTBE (Philp et al., 2007). The same principles noted in the MTBE example apply to the application of stable isotopes for evaluation of biodegradation of TCE.

3.4. PGDP TCE Groundwater Fate & Transport Investigations

Numerous investigations (Clausen et al., 1997; Stuchio et al., 1998; Starr et al., 2005; DOE, 2003; DOE, 2007; DOE, 1996a; DOE, 2007; MMES, 1994) have assessed the groundwater fate and transport of TCE and ^{99}Tc at the PGDP. The earliest reported characterizations noted the limited presence of reductive dechlorination byproducts of TCE in groundwater at PGDP and attempted to bound the TCE degradation rate by mass balance calculations.

Later contaminant studies applied screening-level fate and transport models to assess downgradient TCE levels associated with specific TCE sources. The results of these screening level models were dependent upon the values applied to variables in the models. Site characterization data, more detailed groundwater flow models of PGDP, and measurements from similar hydrogeologic settings provided reasonable estimates for most of the variables in the screening-level fate and transport models. The common variables that remained poorly documented were the soil-to-water partition coefficient (K_d) and the TCE half-life. However, continued development of the site-wide groundwater flow model led to well-constrained values of K_d for TCE by matching the known extent of the off-site, co-mingled plumes of TCE and ^{99}Tc to fate and transport model simulations (DOE 2002). Subsequent geochemical modeling and measurements based on TCE trends in monitoring wells confirmed the K_d value.

Recently, the SWP Site Investigation (DOE, 2006) compared dissolved TCE and ^{99}Tc trends in PGDP’s Northwest Plume using chloride and ^{99}Tc as conservative groundwater tracers in order to estimate an applicable TCE half-life for the RGA. The first order rate estimation calculations for TCE degradation are presented in Section 3.4.5.3.

3.4.1. Clausen and others, 1997. The *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Clausen et al., 1997) documents an in-depth investigation of TCE attenuation and biodegradation in the RGA. The study reports that although natural attenuation processes are active and plume attenuation is occurring, the rate (of natural attenuation) is insufficient to utilize as a remedial measure (in the absence of a source zone remedial measure). Clausen et al. provide a summary evaluation of the geochemical conditions in the RGA and indicated that RGA geochemical conditions "are consistent with aerobic respiration by microorganisms within the aquifer". However, Clausen et al. note that geochemical conditions within the aquifer do not indicate the presence of an energy source for TCE microbial degradation, whether it be organic carbon, toluene, methane, ammonia or other substrates.

Two scenarios were hypothesized to explain the geochemical data evaluated in the report: 1) The first scenario assumed that current intrinsic biodegradation is negligible and that the evidence for biodegradation is a remnant of past microbiological activity, when co-metabolites, now depleted, were sufficient to support aerobic degradation; 2) The second scenario assumed the presence of organic-rich anaerobic microenvironments within the RGA that supported reductive dechlorination of the TCE. Under the second scenario, any TCE degradation products produced were assumed to remain sorbed to the organic-rich materials of the microenvironments.

In addition to identifying hypothetical conditions that control the fate and transport of TCE at the PGDP, the TCE biodegradation rate was quantified utilizing the geochemical model BIOSCREEN (Newell et al. 1996). The Bioscreen evaluation was based on the downgradient decline in the mass flux of TCE through several transects of the Northwest Plume and yielded an estimated rate for TCE attenuation in the RGA of 0.0206 to 0.074 year^{-1} which is equivalent to a TCE half-life of 9.4 to 26.7 years. The effects of sorption and diffusion were not accounted for in the calculation of the TCE attenuation rate, and the authors estimated a biodegradation half-life greater than 26.6 years for TCE in the RGA if the potential influences of diffusion and sorption were considered.

3.4.2. Sturchio and others. Chloride Isotope Investigation of PGDP Trichloroethene Natural Attenuation

Sturchio et al. (1998) published a peer-reviewed paper, *Chloride Isotope Investigation of Natural Attenuation of Trichloroethene in an Aerobic Aquifer*, which was based in part on results in Clausen et al. (1997). The authors measured carbon, oxygen, and chlorine isotope ratios for groundwater from UCRS, RGA background locations, on-site source areas, and the RGA in the dissolved phases of the Northeast and Northwest Plumes.

Sturchio noted that oxygen levels greater than 1 mg/L in all samples and other indicators of electrochemical state were consistent with an aerobic groundwater environment. Common reductive-dechlorination byproducts were characterized as absent or present at very low levels in the RGA. The highest cis-1,2-dichloroethene concentrations were identified in UCRS wells. The authors concluded that anaerobic conditions were most likely to have existed previously in the UCRS.

Sturchio reported a general downgradient trend of increasing dissolved inorganic carbon along with decreases in the inorganic carbon ^{13}C isotope and decreasing dissolved oxygen. This trend was attributed to oxygen consumption and carbon dioxide production by aerobic microbial respiration.

The study also found that the ^{37}chloride isotopic ratio tended to increase with decreasing TCE concentration in the samples, which was consistent with Rayleigh-type isotopic fractionation of the TCE degradation source. Because the chloride isotope and TCE trends were not compatible with simple closed-system models, the authors concluded the data are consistent with a model of past TCE degradation in the overlying Upper Continental Recharge System (UCRS) and little or no current degradation of TCE in the RGA.

3.4.3. Starr and others. Assessing Aerobic Natural Attenuation of Trichloroethene

Starr, et al. (2005) conducted a nation-wide screening assessment of 24 DOE sites with 127 plumes of contaminated aerobic groundwater in order to identify five (5) sites that warranted further investigation relative to investigating and quantifying rates of aerobic TCE degradation. Screening was based on the following criteria: 1) TCE must be present in an aerobic groundwater; 2) A conservative co-contaminant tracer must be present and have approximately the same source location as the TCE; and 3) The groundwater velocity of the site must be known. Based on screening of site's geochemical and contaminant data, the sites chosen for assessment were: 1) Brookhaven National Laboratory; 2) Paducah Gaseous Diffusion Plant; 3) Rocky Flats Environmental Technology Site; and 4) Savannah River Site, A/M Area Plume. Aerobic co-metabolism of TCE in aerobic groundwater had been previously identified as a significant attenuation process at the Idaho National Engineering and Environmental Laboratory.

Starr applied the approach and methods described in *An Evaluation of Aerobic Trichloroethene Attenuation Using First Order Rate Estimation* (Sorenson et al., 2000) to calculate first-order rate constants for the four retained sites. In the approach, groundwater velocity was a site-specific parameter identified as 1.3 ft/day (Clausen et al., 1997) for the PGDP. Dispersion was accounted for in the calculation of site specific rate constants because of the assumption that it is a physical process affecting groundwater and is not dependent upon contaminants (properties). Thus all contaminants, including the tracer, are subject to the same dispersion along a given flowpath. Because adsorption and volatilization are site specific parameters, they were not independently accounted for, or differentiated in, the attenuation calculated to be occurring at the sites. Based on PGDP data from the lower RGA, a half-life of seven (7) years was calculated for the Northwest Plume at the PGDP.

3.4.4. Screening Level Fate and Transport Modeling.

PGDP's risk assessment guidance (DOE 2000b) outlines a tiered approach to fate and transport modeling based on the intended use of the model results. The most recent fate and transport modeling (DOE 2003 and 2007) employed the SESOIL (GSC 1995, 1996a) and AT123D (GSC 1996b and Yeh 1981) codes in a probabilistic approach as a means of reducing model uncertainty.

Screening-level fate and transport modeling of TCE has been used at PGDP in support of site and remedial investigations, treatability studies, and design investigations. The earliest remedial investigation (DOE 1996a) relied on the Summers Model (EPA 1989) to assess dissolved-phase TCE levels resulting from source units. Subsequent fate and transport models (DOE 1996b, 1998a, 2007) were based on the combination of the SESOIL code (GSC 1995, 1996a) to simulate migration through the UCRS, and the AT123D code (GSC, 1996b and Yeh, 1981) to simulate migration through the RGA. Most subsequent investigations (DOE 1997, 1998b, 1999a, 1999b, 2000a) have used MEPAS (PNL 1989) to derive dissolved-contaminant levels at downgradient points of exposure. TCE degradation has been accounted for in screening level fate and transport modeling efforts through the application of a 26.6 year TCE half-life. The 26.6 year half-life is based on the upper end of the range of potential TCE half-lives identified by Clausen, et al. (1997).

PGDP is currently redeveloping the site-wide groundwater flow model (MODFLOW code, Harbaugh et al. 2000). Results of the redeveloped PGDP MODFLOW model, future site-specific measurements, and data being collected at sites with similar hydrogeology and hydrogeochemistry may impact the estimates for future fate and transport inputs.

3.4.5. Southwest Plume Site Investigation

The SWP Site Investigation (SI) evaluated four potential source areas along the western perimeter of the PGDP Restricted Area and profiled the magnitude and distribution of volatile organic compounds

(VOCs) and ^{99}Tc in the SWP. In addition to SWP-specific aquifer, contaminant, and geochemical information, the SI summarized the current status of site-wide TCE fate and transport parameters used for PGDP modeling and risk assessment. The site-wide parameter assessment was augmented with the derivation of first-order degradation rate constants based on a range of groundwater velocities between 1 and 3 feet/day.

3.4.5.1. PGDP TCE Transport Parameters

Values of TCE transport parameters used as fate and transport modeling inputs have evolved as more and better site-specific measurements become available. The SWP SI (DOE, 2007) documents the current TCE transport parameter estimates applicable to PGDP TCE fate and transport modeling (Table 9).

Measurements of RGA-matrix porosity range from 27 to 54% (DOE, 1999 - Appendix H). The derivation of the dissolved TCE degradation rate coefficient was based on an assumption that the average effective porosity of the RGA matrix is 30%, which is within the 25-to-40% range attributable to gravel, as reported in Freeze and Cherry (1979). Taken together, hydraulic conductivity, hydraulic gradient, and effective porosity determine groundwater flow velocity. PGDP groundwater flow velocity in the RGA has been reported to range from 0.15 to 15.9 ft/day with an average of 1.3 ft/day (Clausen et al. 1997). At PGDP, long-term area-averaged groundwater flow velocity in the Northwest Plume is presently estimated to range between 1 and 3 ft/day.

The RGA matrix consists of chert gravel and quartz sand which are both non-reactive media with respect to metals and volatile organic compounds. Accordingly, the fraction of organic carbon content (f_{oc}) of the RGA has been calculated as 0.02% (DOE 1999) which indicates that the RGA has little sorption potential relative to TCE or inorganic tracers. Based on a TCE organic carbon partition coefficient (K_{oc}) of 94 L/kg (EPA, 1996) and an organic carbon content of 0.02%, the migration of TCE is retarded by a factor of 0.91 relative to the groundwater flow rate

Table 9. Hydrogeologic and geochemical input parameters for PGDP groundwater models

UCRS percolation rate		**11 cm/yr**
UCRS intrinsic permeability		**1.65×10^{-10} cm^2**
UCRS porosity		**0.45**
UCRS organic carbon content (f_{oc})		**0.08 to 0.09**
UCRS soil-to-water partition coefficient (K_d) for TCE*		**0.0752 to 0.0846 L/kg**
UCRS TCE half-life		**26.6 years**
RGA effective porosity		**0.3**
RGA hydraulic conductivity		**19.05 m/hr**
RGA hydraulic gradient		**0.0004**
RGA aquifer thickness		**9.14 m**
RGA longitudinal dispersivity		**15 m**
RGA fraction of organic carbon		**0.02**
***varies with organic carbon content**		

3.4.5.2. Probabilistic Modeling

The SWP Site Investigation Report (DOE 2007) applied a probabilistic approach to the evaluation of potential risks resulting from the transport and fate of TCE. Two scenarios were evaluated for the probabilistic transport modeling: 1) a variable degradation scenario in which the degradation rate for TCE was allowed to vary over the potential range of values calculated using total chloride and ^{99}Tc as tracers to normalize TCE concentrations (Clausen, 1997); and 2) a fixed degradation scenario in which the UCRS TCE degradation half-life was 26.6 yr and no degradation half-life was applied to the RGA. Other parameters in the probabilistic analysis were allowed to vary for both scenarios.

3.4.5.3. Derivation of 1st order rate constant for TCE

Northwest Plume data from pre-pump and treat operations were used to calculate a range of first-order degradation rates utilizing methods in Section 3.3.2 of the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA, 1998). The rate derivation method utilizes downgradient chlorinated solvent concentrations that are predicted or "normalized" based on the concentrations of non-conservative tracers chloride and ^{99}Tc. The difference in the normalized downgradient TCE concentration and the measured downgradient TCE concentration provides the measure of the rate of natural attenuation processes acting upon TCE, exclusive of sorption and volatilization (Figure 9). In transport calculations, sorption is accounted for through the application of a retardation factor for transport velocity. Sorption of TCE and ^{99}Tc are considered similar and minimal.

The data utilized in the calculation of SWP SI first-order degradation rate constants and the assumptions made for their use are discussed in the following bullets:

- Evaluation of analyses from the period preceding implementation of the NWP Pump and Treat System (PTS) indicate that TCE concentration levels in August 1995 are the highest concentrations from the March-through-August 1995 pre-pumping data collection timeframe. These data best approximate a "snapshot" of groundwater quality in the core of the NWP prior to operation of the extraction wells. A good measure of the average contaminant level in the core of the NWP is the contaminant level in the extraction wells and the analyses from nearby wells with highest contaminant levels. The TCE concentrations in extraction well data closely match those in the data set used for calculation of the TCE degradation rate coefficient.

- At sites where chloride concentrations in the chlorinated solvent source zone are significantly elevated above background, as in the case in the Northwest Plume, chloride is a near-ideal tracer. The three requirements of a tracer are: 1) The source of the tracer should either be the source of the dissolved chlorinated solvent plume or must be co-located; 2) The tracer should not degrade within the aquifer; and 3) The relative sorption of the tracer and the chlorinated solvent on the aquifer matrix should be known (Sorenson et al. 2000).

- The elevated chloride levels in the Northwest Plume are directly related to the TCE source zone. In 1995, chloride analyses for the C-400 TCE source zone wells MW155 (lower RGA) and MW156 (upper RGA) were 84 and 68 mg/L, respectively. Background chloride levels for PGDP, as measured in upgradient well MW103, ranged from 3.4 to 7.0 mg/L through 1995. The difference in background and source area concentrations meets the 10% criterion for use of chloride as a tracer per the technical protocol (EPA 1998). Chloride does not degrade, and it does not readily complex with other solutes in the RGA. The matrix of the RGA is composed primarily of chert gravel, coated with an iron-oxide patina, and quartz sand, with little silt and clay content. Chloride is not significantly sorbed to the RGA matrix.

- The total chlorine concentration, consisting of the sum of concentration of ionic chloride and organic chlorine, can be used for normalizing downgradient TCE concentrations (EPA 1998). In the case of the NWP, TCE is essentially the only chlorinated solvent that is present and concentrations of TCE daughter products *cis*-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride in RGA groundwater at the C-400 TCE source zone and in the downgradient plume are typically below laboratory detection limits. Chlorine comprises 80.9% of the mass of the TCE molecule. Thus, the total chlorine concentration to be used in the analysis is the sum of the chloride concentration and 80.9% of the dissolved TCE concentration.

- Technetium-99 also meets the three requirements of a tracer as follows. The ^{99}Tc source is co-located with the TCE source. Technetium-99 does not degrade within the aquifer relative to the potential age of the sources (a maximum of 43 years age for the source, in 1995, relative to a half-life of 212,000 years). The relative sorption of ^{99}Tc and TCE is well understood.

- Technetium-99 degrades to ruthenium-99 by beta and gamma decay, with a half-life of 212,000 years. In aerobic settings such as the RGA, ^{99}Tc is in the form of the pertechnetate (TcO_4^-) anion, which is only weakly reactive with the RGA aquifer matrix and other groundwater solutes.

- Previous studies of ^{99}Tc transport in the RGA have shown that ^{99}Tc likely migrates as a dissolved species and does not form colloids (MMES 1994). More recent sensitivity analysis of the PGDP groundwater fate and transport model (DOE 2002) determined that the distribution coefficient (K_d) of ^{99}Tc ranges from 0.0 to 0.1 L/kg, with a mode of 0.0 L/kg. The distribution coefficient is the measure of sorption in the site's groundwater fate and transport model. A distribution coefficient of 0.0 means that the solute travels at the speed of groundwater and the migration of the solute is not retarded. The same study determined that the distribution coefficient of TCE ranges from 0.01 to 0.1 L/kg, with a mode of 0.01 L/kg. Therefore, the migration of TCE is very slightly retarded relative to groundwater flow and ^{99}Tc migration in the RGA.

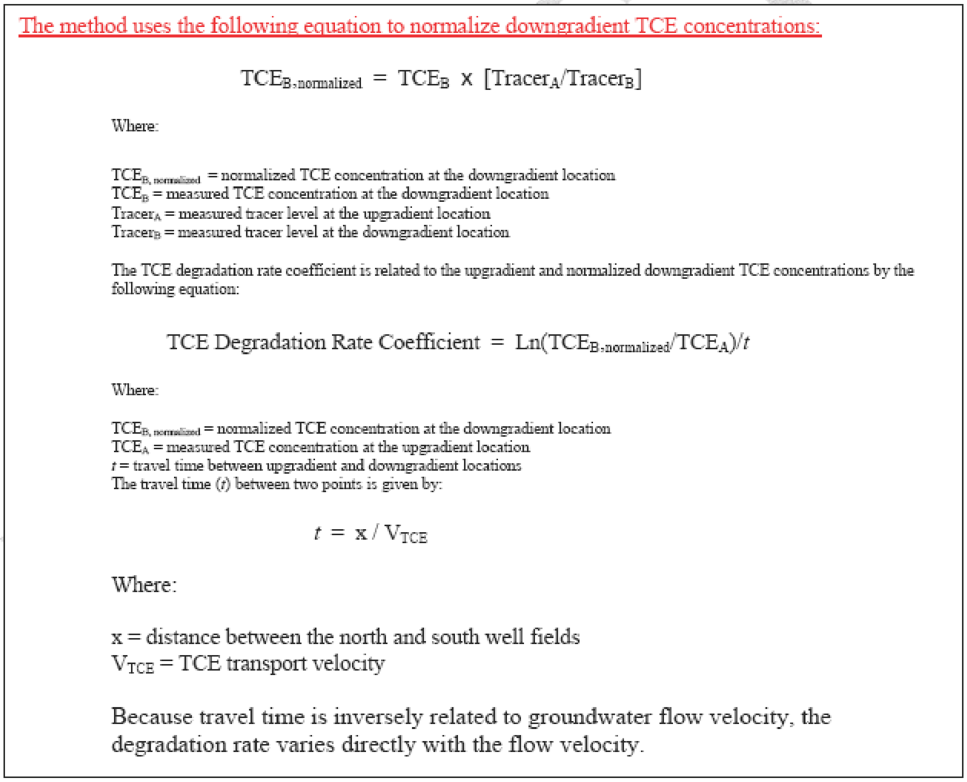
The *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground* Water (EPA, 1998), Section C.3.3.2, documents the method of using inorganic solutes as tracers to derive a first-order rate of degradation of chlorinated solvents by normalizing the downgradient TCE concentration to the non-recalcitrant tracer ^{99}Tc (Figure 9). The six (6) wells located along the approximate axis of the NWP with available data for the first-order rate calculation are identified in Table 10.

When chloride was used as the conservative tracer in the SI rate constant calculations (Figure 10), the range for the TCE degradation rate coefficient was 0.0719 to 0.2149 year^{-1} at groundwater flow rates of 1 and 3 ft/day, respectively. The corresponding TCE half-life ranges from 9.6 to 3.2 years.

Using ^{99}Tc as the conservative tracer (Figure 11), the range for the degradation rate coefficient is 0.0603 to 0.1802 year^{-1} at groundwater flow rates of 1 and 3 ft/day, respectively, which corresponds to a TCE half-life range of 11.5 to 3.8 years. As shown, analyses using these inorganic tracers yield similar results.

Table 10. Well locations utilized for the SWP SI first-order rate constant calculation

MW248
MW250
MW243
MW241
MW238
MW236



The method uses the following equation to normalize downgradient TCE concentrations:

$$TCE_{B\text{-normalized}} = TCE_B \times [Tracer_A/Tracer_B]$$

Where:

$TCE_{B,\text{ normalized}}$ = normalized TCE concentration at the downgradient location
TCE_B = measured TCE concentration at the downgradient location
$Tracer_A$ = measured tracer level at the upgradient location
$Tracer_B$ = measured tracer level at the downgradient location

The TCE degradation rate coefficient is related to the upgradient and normalized downgradient TCE concentrations by the following equation:

$$\text{TCE Degradation Rate Coefficient} = \text{Ln}(TCE_{B\text{-normalized}}/TCE_A)/t$$

Where:

$TCE_{B,\text{ normalized}}$ = normalized TCE concentration at the downgradient location
TCE_A = measured TCE concentration at the upgradient location
t = travel time between upgradient and downgradient locations
The travel time (t) between two points is given by:

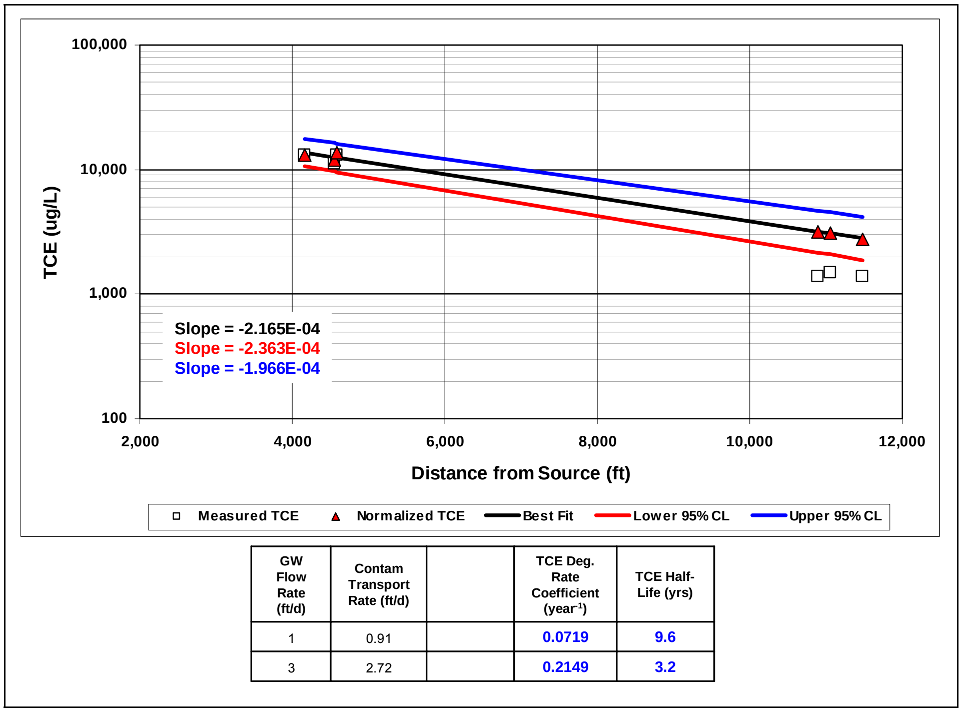
$$t = x / V_{TCE}$$

Where:

x = distance between the north and south well fields
V_{TCE} = TCE transport velocity

Because travel time is inversely related to groundwater flow velocity, the degradation rate varies directly with the flow velocity.

Figure 9. Normalization calculation from the Technical Protocol (EPA, 1998)



GW Flow Rate (ft/d)	Contam Transport Rate (ft/d)		TCE Deg. Rate Coefficient ($year^{-1}$)	TCE Half-Life (yrs)
1	0.91		0.0719	9.6
3	2.72		0.2149	3.2

Figure 10. NWP TCE first order degradation rate constant calculation using chloride as the conservative tracer

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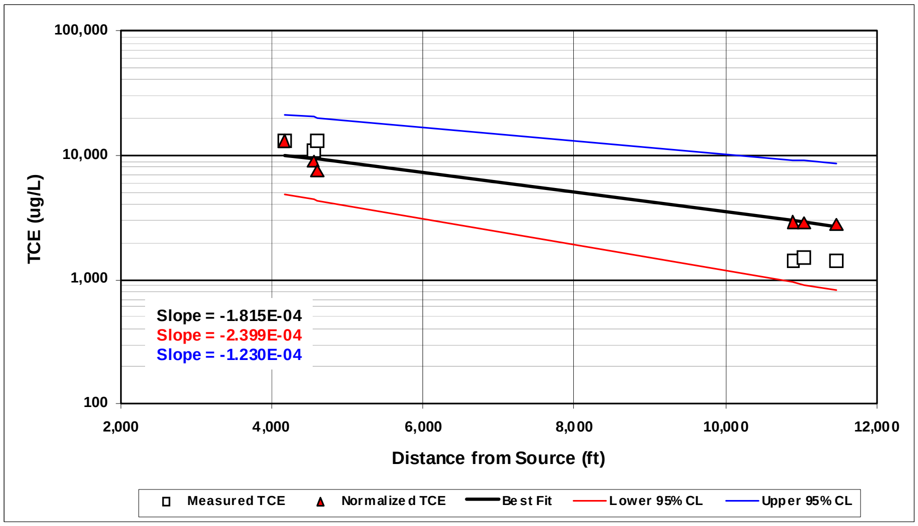


GW Flow Rate (ft/d)	Contam Transport Rate		TCE Deg. Rate Coefficient (year^{-1})	TCE Half-Life (yrs)
1	0.91		0.0603	11.5
3	2.72		0.1802	3.8

Figure 11. NWP TCE first order degradation rate constant calculation using ^{99}Tc as the conservative tracer

3.4.6. Recent NWP First Order Rate Estimations

A procedure for conducting a first-order rate constant estimation for the PGDP NWP was presented as a poster session at the National Ground Water Association, Ground Water Summit in Memphis, TN in March 2008 (Phillips, 2008). The tracer corrected method utilized the site co-contaminant ^{99}Tc to account for dispersion. In order to overcome temporal data set limitations that had challenged previous investigators, a statistical analysis of monitoring well data from an expanded set of wells located along the approximate axis of the plume was conducted to determine if the NWP pump and treat extraction wells had impacted any of the potential data locations. Based on the analysis, four (4) locations in the vicinity of the extraction wells were excluded from the data set. The final data set utilized wells along the entire length of the plume and the TCE half-life was estimated to range from 6.1 to 16.5 years based on a groundwater flow rate range of 1.5 to 2.5 feet per day (Appendix 10).

4.0. Monitored Natural Attenuation/Enhanced Attenuation Technical & Regulatory Considerations

4.1. Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) refers to a remedial alternative which relies upon naturally occurring mechanisms to remediate contaminated media. EPA has expressed a preference for those treatment processes, including natural attenuation processes that can be shown to destroy or degrade contaminants (EPA, 1999a).

Section 300.430(a)(1)(iii)(F) of the National Contingency Plan states that "EPA expects to return usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site." The USEPA considers MNA to be a viable groundwater remediation approach when it can be shown to be capable of remediating a site in a time frame consistent with that required by a more active remedy (EPA, 1999b). Typical prerequisites for the use of MNA as a remedial application include determinations that: 1) risks associated with reliance upon MNA are acceptable, 2) the plume is stable or is growing smaller, 3) the conditions responsible for MNA are sustainable, and 4) MNA is always used in combination with implementation of source control measures (EPA, 1999b). If one or more of these prerequisites are not met, then utilization of more active remedial measures to attain the desired results is necessary (ITRC, 2007).

4.2. Enhanced Attenuation

Enhanced Attenuation (EA) refers to remedies that use additions to in-situ hydro- or bio-geochemical conditions of the groundwater environment in order to enhance the naturally occurring rates of attenuation. EA may be implemented to control source flux or enhance degradation of contaminants. EA remedies include passive permeable treatment zones, source control measures to decrease mass flux into the plume, and/or the injection of amendments and/or nutrients to augment existing biodegradation of contaminants (ITRC, 2007).

Regulatory considerations applicable to both in-situ and ex-situ EA remedial approaches include those that cover injections of materials/liquids into an aquifer as well as those that require the handling and fate of Listed Hazardous Wastes. In-situ amendments would be delivered by injection into groundwater and would be subject to regulation. Ex-situ applications would be subject to regulations because of potential waste generation and possibly re-injection of treated groundwater into the subsurface.

The Federal Underground Injection Control *(UIC)* Program is applicable to the injection of fluids into the subsurface. A prohibition exists against the injection of any fluid into the subsurface unless a permit has been issued to allow such injection or when the injection meets the requirements for a "permit by rule". For example, the injection of toluene as a part of a CERCLA remedial action would be considered a Class V well under the UIC program and should meet the requirements for a "permit by rule". However, any CERCLA action would likely have to comply with all of the substantive requirements governing the use of a Class V injection well (ITRC, 1998).

In addition to UIC regulatory considerations, 401 KAR 30:031, Section 5 would be an applicable relevant and appropriate requirement (ARAR) which states that "No waste site or facility shall contaminate an underground drinking water source beyond the point of compliance in excess of the maximum contaminant levels specified in 401 KAR Chapter 8." If a substrate or nutrient or other amendment were to be injected into an aquifer that could be considered a potential drinking water source (e.g., the RGA), the selected method would have to demonstrate compliance with the allowable levels of toluene in the groundwater as specified in 401 KAR Chapter 8.

Actively managed groundwater contaminated with listed hazardous wastes is considered to contain a hazardous waste per the "Contained-In" rule and is managed as such unless, or until, it is deemed to no longer contain the listed hazardous waste. Since PGDP groundwater is being managed as a hazardous waste, its removal from the aquifer may be considered active management of hazardous waste, and Land Disposal Restrictions (LDRs) may apply. Certain waivers or exclusions may apply such as the Area of Contamination Policy or a Treatability Variance (ITRC, 1998).

Re-injection of TCE contaminated groundwater would be considered a Class IV injection which is prohibited at non-RCRA or non-CERCLA sites. The U.S. EPA has granted an exception to this prohibition when the groundwater is being re-injected as a part of a RCRA or CERCLA cleanup action. However, the exception requires that the groundwater first undergo substantial treatment prior to being re-injected into the aquifer, a requirement that may make the remedy too costly to implement (ITRC, 1998).

A limited number of case studies appear to show that, under certain conditions, the injection of substrates can be used to accelerate aerobic cometabolic degradation of TCE in aquifers. However, studies alone may not be sufficient to persuade regulators or the public to allow the injection of RCRA regulated compounds into an aquifer. At a minimum, it is assumed that bench scale tests (e.g., microcosm studies) that accurately replicate aquifer conditions would be required prior to any attempt being made to introduce RCRA regulated compounds such as phenol or toluene into the environment. These bench scale tests would likely be followed by small-scale pilot studies that could provide evidence that the injected substance would degrade to levels below its MCL or risk-based level within a reasonable amount of time and that hydraulic control could be maintained in the event that the compound did not degrade as planned.

4.2.1. Enhanced Attenuation General Technical Considerations

Concurrent with the implementation of source control measures, supplementing or enhancing the rate of biodegradation may be an option to achieve a reasonable remedial timeframe for contaminated groundwater. At present, the amendments that have generally been utilized to enhance aerobic cometabolic degradation of TCE are phenol, toluene, hydrogen peroxide and oxygen (AFCEE, 1998) as they provide the substrate for aerobic oxidation reactions and hence the production of enzymes that can result in cometabolic TCE degradation. Introduction of additional nutrients, such as ammonium nitrate or disodium phosphate, may be necessary to maintain microbial population health (Cookson, 1995). An EA remedy to address groundwater contamination that is intended to stimulate co-metabolic TCE degradation would require the introduction of amendments into the RGA.

Prior to implementation of full-scale in-situ geochemical or biogeochemical amendments, potential technical considerations would require evaluation in order to ensure the success of the enhancement. In general, those technical considerations can be categorized as follows:

1) Biological competition – a situation that could result from the enhancement of the substrate to stimulate growth of a particular bacterial strain might also serve to enhance the numbers of other bacteria that would compete with the desired strain. The struggle between competing bacterial populations could be detrimental to the desired bacteria that co-metabolize TCE.

2) Competitive Inhibition - a phenomenon that occurs when the introduced substrate *out-competes* the TCE for the enzyme that makes TCE degradation possible (Zubay, 1988).

5.0. Site Specific Applicability

Accurate prediction of and appropriate response to potential future impacts from TCE and organic-solvent contaminated groundwater requires that the key processes that impact a contaminant's fate and transport in the groundwater environment be identified and quantified. Natural attenuation processes, including biodegradation, potentially impact many aspects of the PGDP's environmental management, including: 1) Prediction of temporal and future spatial extents of dissolved phase groundwater contamination; 2) Assessment of future temporal and spatial environmental and health impacts from contaminated groundwater; 3) Regulatory compliance; and 4) Design of remedial measures to address future impacts from PGDP groundwater contamination.

5.1. Operable Units and Contamination

Characterization of aerobic co-metabolic biodegradation of TCE within the RGA has the potential to impact remedial action selection for the Burial Grounds Operable Unit facilities and other sources of PGDP TCE groundwater contamination including locations associated with the C-400 Building. Accurate modeling of aquifer and plume response to contaminant contribution from these areas is necessary in order to identify: 1) The appropriate source area remedial action; 2) The response of the aquifer to existing contaminant contributions from sources; 3) The response of the aquifer to a range of potential source contributions; and 4) Appropriate short and long-term remedial actions necessary to address PGDP's dissolved phase plumes.

5.2. Sites with Similar Groundwater Geochemistry & Contaminants

In the DOE complex alone, 127 plumes of contaminated aerobic groundwater have been evaluated at 24 DOE sites (Starr et al., 2005) relative to the potential for the existence of aerobic co-metabolic biodegradation of TCE. The evaluations identified five (5) plumes that were very similar in terms of; 1) TCE contamination, 2) aerobic groundwater geochemistry, 3) the presence of conservative tracers originating from locations synonymous with TCE source areas, and 4) known groundwater velocities. Those sites include: 1) Brookhaven National Laboratory; 2) Paducah Gaseous Diffusion Plant; 3) Rocky Flats Environmental Technology Site; 4) Savannah River Site, A/M Area Plume, and 5) the Idaho National Engineering and Environmental Laboratory (INL) – Test Area North (TAN) Plume. Also within the DOE complex chlorinated ethane contamination of aerobic groundwater has been identified at the Oak Ridge Reservation in TN, the Hanford Reservation in WA, the Sandia and Los Alamos National Laboratories in NM, and the Lawrence Livermore National Laboratory in CA.

The INL and Savannah River Sites have characterized aerobic biodegradation in their respective aquifers and have implemented pilot or full-scale Monitored Natural Attenuation or EA remedial activities to address chlorinated ethene groundwater contamination. Following comprehensive field and laboratory activities to characterize the nature, extent, and rate of aerobic cometabolic activities at the TAN site, INL implemented a Record of Decision (ROD) based on MNA to remediate the dissolved phase of the TAN plume.

The Savannah River Site in Aiken, South Carolina used methane injected through horizontal wells in conjunction with vapor extraction to reduce the concentration of TCE at a spill site. The methane stimulated the growth of methane-oxidizing bacteria and resulted in an estimated reduction of TCE concentrations to levels 42% lower than levels projected to be attainable by vapor extraction alone (AFCEE, 1998).

Other sites where aerobic co-metabolism has been enhanced include Moffett Naval Air Station and Edwards Air Force Base in California. At Moffett Naval Air Station, TCE was injected into a shallow aquifer contaminated with 1,1,1-TCA. A recirculation system was used to add methane, phenol, and toluene to the aquifer at different times in order to enhance biodegradation. Pure oxygen and hydrogen peroxide were also injected. A 93% TCE removal efficiency was reported following the use of toluene as the primary substrate.

Later EA activities were conducted at Edwards Air Force Base (CA) where TCE was a primary contaminant in aerobic groundwater. A recirculation system was installed perpendicular to the groundwater flow direction in order to treat the TCE as it migrated through the biological treatment zone. Toluene was injected into the aquifer along with oxygen and hydrogen peroxide. A 95 to 97 percent reduction in TCE concentration was observed and destruction of toluene was calculated to be 99.98 percent, which met groundwater MCL requirements for toluene.

Aerobic bio-stimulation has been used to augment microbial degradation in an aerobic groundwater plume in Boston, MA (Cox, 2008). The stratigraphy of the subsurface consisted of characteristic coastal deposits of interbedded sand, silt and clay. Perchloroethene (PCE) levels in soil were up to 18,300 mg/kg and contaminated soils were removed. Monitoring wells were installed in a shallow sand zone (10 feet bgs) and deep zone approximately 30 to 40 feet bgs. Prior to augmentation, dissolved oxygen levels were reported to range from 5 to 7 mg/l.

The 13,000 square foot contaminant plume was actively treated for 15 months utilizing a bio-stimulator consisting of a carbon source and microbes. The bio-stimulator was introduced into the ground water through shallow and deep monitoring wells. In the 15 months of treatment, there were 9 injection events that each used 110 to 165 gallons biostimulator. During treatment PCE concentrations were reduced from 88,000 ppb to 160 ppb, TCE 3,600 ppb to 59 ppb, cis-1,2 DCE- 1,100 ppb to 320 ppb. Vinyl chloride appeared to increase from below elevated detection limits to 120 ppb. Post treatment monitoring showed that the concentrations continued to decrease to the following levels in August 2002 – PCE 68 ppb, TCE 21 ppb, cis -1,2-DCE 21 ppb, and vinyl chloride 60 ppb (Cox, 2008).

6.0. Methods

The Project Team utilized the Data Quality Objectives (DQO) process to identify the specific problems and questions related to understanding the fate of TCE in the NWP. The DQO process also identified the data collection and assessment methods necessary to determine whether microorganisms capable of aerobic co-metabolic degradation are present and active in the aquifer. The PGDP Trichloroethene Biodegradation Investigation scoping process for Enzyme Activity Probe activities are summarized in Section 6.1.1 below.

A DQO process was also conducted for collection and evaluation of SCI data in preparation for data collection and assessment for Phase III of the TCE Fate and Transport Investigation, Stable Carbon Isotope evaluation. However, a single round of SCI samples was collected for the PGDP Trichloroethene Biodegradation Investigation and was evaluated as an additional line of evidence of the occurrence of aerobic cometabolic biodegradation in the NWP. Portions of the SCI DQOs were applied to the SCI data collected for this investigation. The applicable DQOs are identified in Section 6.1.2.

6.1. Data Quality Objectives

6.1.1. Aerobic Biodegradation Data Quality Objectives

6.1.1.1. Description of the Problem

Groundwater underlying and downgradient of the PGDP is contaminated by two (2) primary constituents, TCE and Technetium-99 (^{99}Tc). The need to evaluate the fate of TCE in the RGA can be defined by several observations about the characteristics of the RGA and the behavior of TCE and ^{99}Tc in RGA contaminant plumes:

1. Comparison of TCE concentrations to ^{99}Tc concentrations along NWP flowpaths suggest that TCE concentrations exhibit greater decreases along a given section of the plume than do ^{99}Tc concentrations;
2. Calculation of first-order rate constants indicate that TCE degradation may occur at rates greater than those currently applied to PGDP groundwater fate and transport characterization;
3. The RGA is characterized as an aerobic aquifer based on dissolved oxygen concentrations and the absence of TCE degradation products typically found in anaerobic groundwater environments;
4. Aerobic groundwater conditions preclude the widespread occurrence of anaerobic microbial populations that require anaerobic groundwater conditions for survival and metabolic breakdown of TCE;
5. An evaluation of the PGDP hydrogeological setting, geochemical setting, strength of TCE sources and plume stability was conducted utilizing recently published "Scenarios" guidance for assessing microbial degradation potential in a variety of groundwater and source settings *Analysis for PGDP Groundwater Plumes Utilizing the Scenarios Evaluation Tool for Chlorinated Solvent MNA*" (WSRC-STI-2006-00096, Rev. 1, Savannah River National Laboratory, 2006). The results of the evaluation indicated that groundwater conditions at the PGDP include an aerobic groundwater *environment* and relatively fast groundwater flow rates. The Scenarios evaluation in provided in Appendix 1.

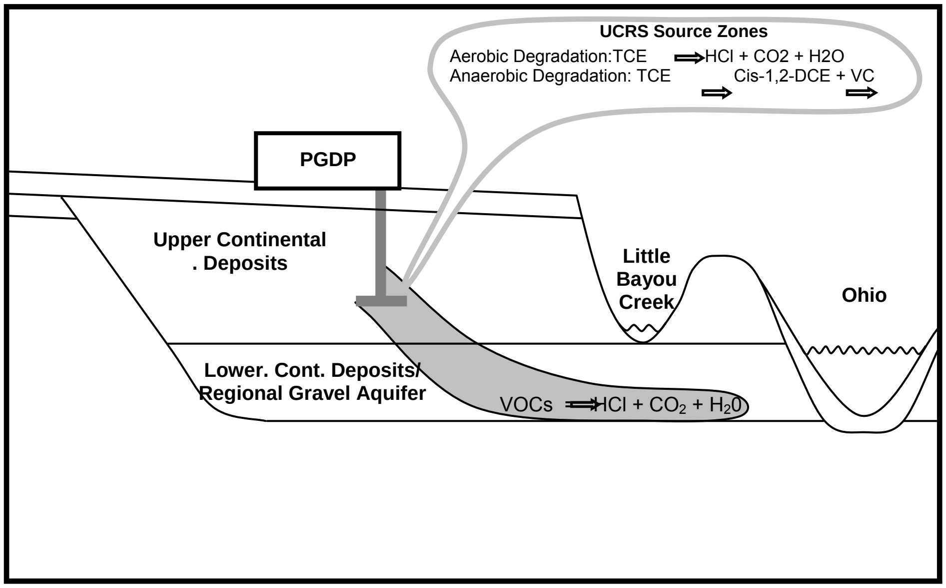


Figure 12. Conceptual TCE Contaminant Transport Model for the PGDP and Environs

6.1.1.2. Purpose and Goals of the Study

The purpose of this project is to demonstrate whether sustainable aerobic biodegradation of TCE is occurring in the RGA and the project specific goals are 1) to evaluate existing data and collect sufficient additional site data to identify mechanisms responsible for the degradation of TCE in RGA groundwater at the PGDP and 2) to provide DOE with recommendations for future investigation of aerobic cometabolic degradation of TCE in the three PGDP contaminant plumes. The activities conducted through this scope of work are expected to provide for improved decision-making related to remedial options and monitoring, shortened time frames for compliance, and the minimization of impacts on public health.

6.1.1.3 Identify the Principal Study Questions

The Principal Study Questions for this investigation were identified by the Project Team as follows:

1. Is aerobic biodegradation, co-metabolism employing an appropriate oxygenase enzyme, occurring in the RGA plumes?
    a. Are the appropriate bacteria present in the aquifer?
    b. Does TCE carbon isotopic fractionation support the biodegradation hypothesis?
2. Are the bacteria present in sufficient numbers to impact the plumes? Are the total cell counts high enough to support biodegradation?
    a. Does the distribution of the biodegradation process in RGA wells support the conclusion that the plume is being temporally and spatially impacted?
3. Are conditions in the RGA conducive for ongoing and sustainable aerobic biodegradation?
    a. Is a primary bioavailable substrate present for co-metabolic reactions?
    b. Does bacterial detritus provide a carbon source for the co-metabolic reaction?
    c. If one or more bioavailable substrates are present, are they available in sufficient quantities to sustain co-metabolic reactions indefinitely?
    d. Are nutrients present for co-metabolic reactions?
4. If aerobic biodegradation is occurring, what is the rate?
    a. What are the probe-specific bacterial cell counts determined for the sampled wells?

    b. What are the physiological parameters of the aquifer that are to be replicated in the microcosm study
    c. What are the rates of biodegradation based on a microcosm study?
    d. Can TCE carbon isotopic fractionation results be used to estimate a rate?
5. Is the calculated biodegradation rate or rates qualitatively supported by literature values?
    a. Are rates generally supported based on similar studies for a variety of bacteria and their co-metabolites?
    b. Are rates generally supported based on the type of "oxygenase" enzyme known to be bound by the probes employed?

6.1.1.4. Decision/Estimation Statements and Supporting Information

Following the development of the Principal Study Questions, the Project Team developed 5 (five) Decision/Estimation Statements (DES) and identified information to address the Principal Study Questions. Data requirements to address each of these are identified by the bullets below:

Decision / Estimation Statement #1. Based on use of specific "oxygenase" probes, determine whether bacteria capable of aerobically biodegrading TCE are present and therefore require an estimation of their impact on the plumes or recommend that other mechanisms of TCE degradation/attenuation be evaluated.

- Representative groundwater samples from the Northwest Plume will be collected and analyzed for "oxygenase" containing bacteria using oxygenase-specific enzyme activity probes.

Decision/Estimation Statement #2. Based on the use of stable carbon isotope (SCI) fractionation tests, determine whether SCI supports the occurrence of aerobic biodegradation processes and/or other biotic or abiotic degradation processes.

- SCI sampling and analysis will be conducted on a path parallel to oxygenase-specific enzyme activity probe sampling and analysis.

Decision/Estimation Statement #3. Estimate whether the distribution and number of bacteria are sufficient to significantly biodegrade TCE in RGA groundwater. If the distribution and number of microorganisms are sufficient to biodegrade TCE in RGA groundwater, determine whether biodegradation is sustainable. If it is determined that biodegradation is not sustainable, recommend that other mechanisms of TCE degradation/attenuation be evaluated.

1. Representative RGA groundwater samples from the Northwest Plume will be collected and analyzed for "oxygenase" containing bacteria using oxygenase-specific enzyme activity probes.
    a. Use on-site enzyme probes to address bacterial quantity (bacteria per liter), or
    b. Containerize, package, and ship samples according to sampling protocols for laboratory enzyme probe evaluation at Idaho National Environmental and Engineering Laboratory (INL-North Wind).
    c. Obtain bacterial information for each well location.
2. Utilize professional judgment and literature values to determine if the cell counts and the distribution of organisms are sufficient to identify the occurrence of aerobic TCE biodegradation.
3. Conduct Microcosm Studies
    a. Collect a representative RGA groundwater sample from one of the NWP enzyme probe analysis wells according to INL-North Wind sampling protocols.
    b. Containerize, package, and ship samples for microcosm studies according to INL-North Wind sampling protocols.

c. Conduct the microcosm study for up to two (2) months to observe changes in TCE concentrations.
d. Establish biodegradation rates from the microcosm study.
e. Representative samples and direct measurements will be required of sufficient quantity and quality to satisfy measurement of rate.

Decision/Estimation Statement #4. Determine whether conditions including, but not limited to, the existence of a bioavailable and sustainable substrate in the RGA and the presence of other geochemical parameters are conducive for ongoing and sustainable aerobic biodegradation of TCE (Table 11). If conditions are determined to be ongoing and sustainable, recommend that an evaluation of the biodegradation rate using a multiple lines of evidence approach be applied at the PGDP. If conditions are not determined to be ongoing and sustainable, recommend that other mechanisms of TCE degradation/attenuation be evaluated immediately.

1. Targeted geochemical parameters (Table 11) will be assessed by evaluation of historical data and from data generated from split samples collected for enzyme probe analysis. Assessment of historical data sets for a number of the targeted geochemical parameters indicate that additional geochemical data to address data gaps may be needed.
2. Geochemical samples will be collected from the wells in Table 12 on a path parallel to the enzyme specific probe sample collections
3. Based on the "*FY07 PGDP Environmental Monitoring Plan*" (PRS, 2007), wells on the proposed sampling list for this project (MW125, etc) may also be sampled for the following parameters on an annual basis: sulfate, nitrate, total organic carbon, chloride, total dissolved solids, silica, fluoride, phosphate, ferrous iron, alkalinity, methane, ethene, ethane, calcium, copper, magnesium, potassium, and sodium. Sampling results from annual and or quarterly PGDP sampling events that include the parameters in Table 11 will be utilized for this study if available.

Decision/Estimation Statement #5. Based upon a comparison of the calculated biodegradation rates to those supported in literature, either accept the calculated rate(s) for use in future fate-and-transport modeling or assess the team's confidence in the unsupported results. If biodegradation is deemed to be sustainable, calculate a degradation rate using the following method(s):

1. First order rate constant calculations (completed)
2. Microcosm studies – (future phase of investigation)
3. Specific carbon isotopic fractionation – Estimate the degradation rate using data obtained during the carbon isotopic fractionation testing (future investigation).
4. Compare the calculated biodegradation rates to values available in literature.

6.1.1.5. Define the Boundaries of the Study

The spatial boundaries of this study include: 1) The areal extent of RGA groundwater; 2) The vertical extents of the RGA groundwater; 3) The screened intervals of monitoring wells in the RGA within and outside of the NWP; 4) Spatial distribution of NWP TCE concentrations less than 1000 μg/L; 5) The location of NWP wells relative to potential source areas; and 6) NWP flowpaths/flowlines relative to on-site NWP primary and secondary sources.

Temporal boundaries of this study include: 1) Dates that annual groundwater sampling is conducted for NWP sampling locations; 2) The availability of INL-North Wind labs to conduct enzyme probe analyses; 3) The number of samples that the INL-North Wind lab can process relative to a designated sampling date; 4) Dates that degradation rates are needed to support ongoing work in PGDP environmental projects; and 5) The availability of organizations and personnel to conduct field sample collection activities.

Table 11. Groundwater geochemical parameters for biodegradation evaluation.

Vinyl Chloride (VC)
Dissolved oxygen (DO)
pH
Eh
Temperature
Specific conductance
Other parameters/analytes:
Total organic carbon
Nitrate
Sulfate
Ferrous iron
Phosphate as Phosphorous
Copper, Dissolved
Copper
Methane
Major cations/anions
K
Ca
Na
Mg
CO3
HCO3
SO4
Cl
CO2

Table 12. Wells Suitable for enzyme probe, stable carbon isotope, and geochemical sampling

Plume	Well	Screen Interval
Available Northwest Plume Wells	***MW65***	***LRGA***
	MW66	***URGA***
	MW125*	LRGA
	MW168	URGA
	MW185	MRGA
	MW194	MRGA
	MW197	URGA
	MW234	LRGA
	MW236	LRGA
	MW238	LRGA
	MW242	LRGA
	MW243	MRGA
	MW262	LRGA
	MW340	LRGA
	MW381/235	LRGA

* = Wells in routine PGDP geochemical sampling schedule.
URGA = upper RGA, MRGA = middle RGA, LRGA = lower RGA
Bold Italics = wells to be sampled as “special cases” because of proximity to source areas.

6.1.1.6. Monitoring Well Selection

The factors considered for identification of monitoring wells suited for this study included: 1) Relative position of monitoring wells to the centerline of the NWP; 2) Relative location of monitoring wells relative to TCE sources and high TCE concentrations that could induce biocide effects on microbial populations; 3) Relative location of suited wells to one another; 4) Screened interval of wells; 5) General geochemical characteristics of each well including alkalinity, pH, dissolved oxygen, TCE concentration. TCE trend analysis, scheduled well sampling dates, and costs for additional analytes or special sampling were also considered in the identification of wells for this project. Geochemical characteristics of the wells were evaluated relative to each parameter's potential to support or inhibit microbial populations capable of TCE degradation.

The NWP was identified as the focus of sampling and characterization activities for this project because NWP wells were used for first-order rate constant tracer normalization analyses and because the greatest number and areal distribution of RGA monitoring wells are available in the NWP. Sampling and analysis of the select NWP-RGA wells was conducted to provide a profile of potential aerobic microbial degradation along the plume axis and to provide an evaluation of geochemical conditions and sustainability of degradation.

Dissolved Oxygen and TCE temporal and spatial data were generated for all of the wells at the PGDP (Appendix 2), including those identified for sampling in this project. Dissolved oxygen and TCE spatial and temporal trends were evaluated relative to potential impacts on field sampling locations prior to final identification of the wells to be sampled.

Table 12 identifies the initial list or "population" of sixteen (16) NWP wells suitable for oxygenase-specific enzyme probe analysis, stable carbon isotope analysis and geochemical sampling based on an evaluation of TCE concentrations, well screen depths, and well locations relative to the centroid of the plume. Figure 13 illustrates the location of the monitoring wells chosen for the study.

6.1.1.7. Decision Rules

- A minimum of 8 NWP wells and 2 control wells outside of the NWP must be sampled and analyzed for the presence of aerobic-oxygenase containing bacteria in RGA groundwater.
- Half (50%) of the minimum number of sampled NWP wells must contain bacteria having an "oxygenase" enzyme capable of aerobically cometabolizing and degrading TCE in order to conclude that aerobic degradation processes are occurring throughout the plume.
  - If greater than 50% of the samples contain bacteria having an oxygenase enzyme capable of degrading TCE, then the spatial relationship between the wells having positive samples will be examined to estimate the areal extents and impact of biodegradation upon the plume.
  - If 50% of the samples do not indicate the presence of oxygenase-containing aerobic microbes, it will be concluded that aerobic bacteria are not present in significantly distributed populations capable of contributing to aerobic degradation across the plume.
  - When 50% or more of the samples do not indicate the presence of oxygenase and aerobic microbes, it is not automatically assumed that biodegradation is not occurring. However, the Project Team will conclude that biodegradation is not significant throughout the dissolved portions of the plume and the project team will evaluate whether areas of the plume are being impacted by aerobic degradation.
- The bacterial cell count per well must be greater than 10^3/mL. If the cell count in any well is less than 10^3/ml the well will be considered to have no activity of aerobic bacteria that degrade

TCE. Any specific well or wells that do not indicate the presence of aerobic bacteria populations greater than 10^3/ml will not be evaluated for the required 50% of the wells.
- If this study shows that aerobic degradation is occurring in the NWP, additional field sampling and analysis may be required to refine the temporal and spatial extents of biodegradation.

6.1.1.8. Limits of the Decision

The failure to meet the criteria set forth in the DQOs will support the conclusion that aerobic biodegradation by means of bacteria expressing oxygenase genes is not occurring at levels sufficient to impact the NWP.

6.1.2. Stable Carbon Isotope DQOs

6.1.2.1. State the Problem

Groundwater underlying and downgradient of the PGDP is contaminated by two (2) primary constituents, TCE and technetium-99 (^{99}Tc). An evaluation of the fate of TCE in the Regional Gravel Aquifer (RGA) is required to support ongoing and future groundwater characterizations and remedial assessments at the Paducah Gaseous Diffusion Plant (PGDP). The evaluation of the fate of TCE in the RGA can be accomplished through several means. This study will utilize compound specific isotope analyses (CSIA), specifically stable carbon isotopes (SCI), to illuminate the potential occurrence of biodegradation of TCE in the NWP.

Calculation of first-order rate constants using PGDP Northwest Plume data obtained prior to initiation of pump and treat actions at the site, indicate that the rate of TCE degradation may be greater than that determined in prior fate and transport studies (e.g. Clausen et al., 1997; C-746-U Landfill Preliminary Assessment) and used in previous groundwater fate and transport modeling efforts. Stable carbon isotope analyses will be used as an additional line of evidence to evaluate the occurrence and rate of TCE degradation in the Northwest Plume. There is also a need to obtain an independent degradation rate estimate using the results of the CSIA.

The RGA is characterized as an aerobic aquifer based on dissolved oxygen concentrations. Therefore, it is assumed that any significant levels of biodegradation that may be occurring within the RGA will potentially be associated with aerobic processes, the most probable of which would be the co-metabolic processes. However, the possible contribution of abiotic processes cannot be discounted due to possible increase of delta ^{13}C caused by abiotic degradation.

6.1.2.2. Identify the Goals of the Study & Principle Study Questions

The goal of stable carbon isotope evaluation is to provide an additional line of evidence that aerobic cometabolic biodegradation is occurring in the NWP. The Project identified the following questions relative to the use and application of stable isotope data collected for project activities.

1. Do CSIAs support the occurrence of biodegradation, specifically aerobic biodegradation?

2. How will CSIAs be utilized to characterize sustainability of biodegradation?

3. Can CSIA-independent calculations of the degradation rate be established?

4. Does CSIA allow for the differentiation of biotic and abiotic degradation processes?

6.1.2.3. Identify Information Inputs (for each decision/estimation statement)

<u>Decision/Estimation Statement #1 Information Inputs</u>. Determine whether CSIA supports the degradation rates from initial first-order rate calculations and EAP analyses and therefore supports the occurrence of aerobic biodegradation. If CSIAs do not support one another and do not support initial first-order rate calculations and enzyme probe analytical results, then CSIA will not permit a conclusion to be drawn. The information inputs for Decision/Estimation Statement #1 are:

1. Representative groundwater samples from the Northwest Plume will be collected and analyzed for CSIA using appropriate sampling and measurement techniques.
2. Representative groundwater sampling should be biased based on the depths of the wells and position within the centroid of the NWP.
3. United States Environmental Protection Agency (USEPA)-Ada CSIA screening criteria (strawman).
4. Other criteria to be established when data and reference information become available (enrichment factors for both stable carbon and stable hydrogen isotopes)
5. Correlations to identify that locations are along a flowpath
6. Literature enrichment values
7. Parameters necessary to calculate site specific enrichment factor.
8. Groundwater flow rates,
    a. utilize a range of 1 to 3 feet per day.

<u>Decision/Estimation Statement #2 Information Inputs.</u> If an independent calculation of the degradation rate range can be established using the existing CSIA data, compare the rate or rate range to any other independent rate calculations and compare to literature based values that exist for co-metabolic degradation rates. The information inputs for Decision/Estimation Statement #2 are:

1. Calculated site-specific enrichment factors for hydrogen and carbon.
    a. If data are not sufficient for this calculation, gather data from microcosm studies and determine the need for additional data collection.
2. Additional parameters necessary to calculate site-specific enrichment factors.
3. Published enrichment factor values
4. Calculated first order rate constants
5. SCI data and SHI data screened with DQO screening criteria
    a. Data sets evaluated with Student T test
6. Other criteria that will be established when data and reference information becomes available, for example enrichment factors for stable carbon and stable hydrogen.
7. Identified groundwater flow rates
    a. Utilize a range of 1 to 3 feet per day.

<u>Decision/Estimation Statement #3 Information Inputs.</u> If results of CSIA, in conjunction with 1st order rate constant estimation calculations indicate that it can be reasonably assumed that both biotic and abiotic processes are contributing to RGA TCE degradation, then attempt to separate the estimated degradation rate into biotic and abiotic components. If this is not possible then the option to conduct additional studies to identify proportional biotic and abiotic degradation components will be considered. The information inputs for Decision/Estimation Statement #3 are:

1. Outputs from Decision Estimation Statements #1 and #2.
2. Time and funding constraints to accomplish Decision Estimation Statements 3.1 and 3.2
3. Estimates of abiotic degradation process rates

Decision/Estimation Statement #4 Information Inputs. If biotic processes are contributing to TCE degradation in the RGA, then establish a preliminary degradation rate or rate range based on existing data. Use information from Decision Estimation Statements 3.1 and 3.2.

6.1.2.4. Boundaries and Conceptual Model for the SCI Study

The spatial boundaries of this study coincide with the boundaries of the aerobic degradation study. Temporal boundaries of the SCI study are: 1) Dates that annual groundwater sampling is conducted for NWP sampling locations; 2) The availability of University of Oklahoma (OU) School of Geology and Geophysics Stable Isotope Laboratory to conduct stable carbon and stable hydrogen analyses; 3) The number of samples that the UO SCI Lab can process relative to a designated sampling date; 4) Dates that degradation rates are needed to support ongoing work in PGDP environmental projects; 5) the availability of organizations and personnel to conduct field sample collection activities, and 6) Technical constraints, decision-making constraints, and funding constraints.

The conceptual model for the Northwest Plume stable carbon isotope evaluation is based on the location of the axis of the NWP relative to contributing TCE source areas (Figure 14). At the upgradient end of the Northwest Plume, in the vicinity of the C-400 building, TCE has been released to the subsurface as DNAPL and dissolved phase TCE, where it presently resides as source material in the immediate vicinity of release and secondary source material in the saturated portions of the UCRS and RGA. The ^{13}C enrichment of the TCE products released in the vicinity of C-400 building and other PGDP source areas is unknown. Downgradient along the axis of the NWP away from C-400 source areas, the ^{13}C signature is likely to increase until TCE sources in the northwest corner of the PGDP industrial area are encountered. Beneath the northwest corner of the PGDP industrial area to the NWP South well field, it is likely that the potentially enriched TCE ^{13}C signature from C-400 area sources will mix with TCE of unknown ^{13}C enrichment from nearby northwest corner source areas.

6.1.2.5. SCI Decision Rules.

The SCI decision rules are identified by bold text in boxesand the stepwise reduction and evaluation of SCI data from the "Strawman Approach" (Appendix 3D) are identified as "SCI Step xx, etc". Although reference is made to hydrogen isotope evaluations, those evaluations will not be conducted as part of the activities related to this report.

Decision Rule 1. If sample volumes of appropriate quantity and method–limit TCE concentrations are obtained through the implementation of laboratory & site specific sampling protocols from the EAP wells, then conduct TCE, VOC, geochemical, stable carbon and stable hydrogen isotope analyses on the samples from those wells.

If appropriate sample volumes or methods cannot be obtained from a specific EAP sample location, then do not consider the location relative to the evaluation of SCI and SHI data.

SCI Step 1. Calculate apparent removal of TCE:

a. Based on concentration of TCE normalized to concentration of ^{99}Tc from population of sample well data for this investigation.

b. Calculate C/C_0 for TCE concentration

$$C/C_0 = \text{TCE}_{\text{down gradient}} / (\text{TCE}_{\text{up gradient}} * [\,^{99}\text{Tc}_{\text{down gradient}} / ^{99}\text{Tc}_{\text{upgradient}}\,])$$

c. Up gradient well = Well with the highest concentration of TCE that is in a plausible flow path; Down gradient well = Well in the down gradient plausible flow path.

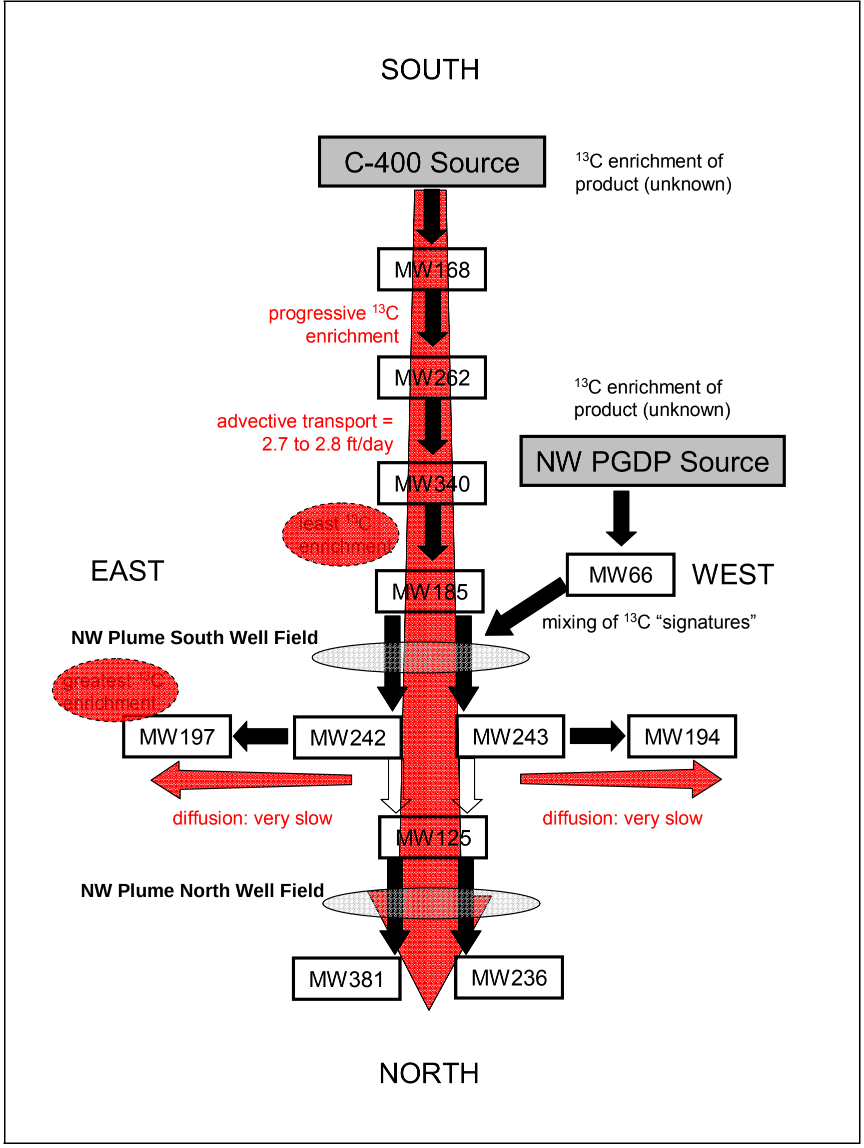


Figure 13. Conceptual model for distribution of stable carbon isotopes along NWP flowpaths from upgradient to downgradient

__SCI Step 2.__ Conduct SCI, SHI* and geochemical analyses

*The laboratory analyses of samples for stable hydrogen isotopes will be conducted on the same samples collected for stable carbon isotope analysis. The data set for the stable hydrogen isotope analyses will be appended to this report when available.

Decision Rule 2. If Measurement Quality Objectives (MQOs) have been met, then utilize data for CSIA evaluation. If MQOs have not been met do not use the data for CSIA evaluation

__SCI Step 3.__ Based on analysis of stable carbon isotopes, independently calculate ^{13}C C/ C_0 using the following:

a. $C/\ C_0 = e^{((\delta 13Cdowngradient - \delta 13Cupgradient)/\varepsilon)}$

b. $\ln(C/C_0) = (\delta^{13}C_{down\ gradient} - \delta^{13}C_{upgradient})/\varepsilon$

c. Where $\delta^{13}C_{upgradient}$ is the carbon isotopic ratio in TCE in the upgradient well and $\delta^{13}C_{downgradient}$ is the carbon isotopic ratio in TCE in the downgradient well

d. Epsilon (ε), the isotopic fractionation factor for aerobic biodegradation of TCE, = -1.1%

e. Based on analysis of stable hydrogen isotopes, calculate ^2H C/Co based on SHI measurements

$C/Co = e^{((\delta^2 H_{downgradient} - \delta^2 H_{upgradient})/\varepsilon)}$ or $\ln(C/Co) = (\delta^2 H_{downgradient} - \delta^2 H_{upgradient})/\varepsilon$

f. Where $\delta^2H_{upgradient}$ is the hydrogen isotopic ratio in TCE in the up gradient well and $\delta^2H_{downgradient}$ is the hydrogen isotopic ratio in TCE in the down gradient well

g. ε, the isotopic fractionation factor for aerobic biodegradation of TCE, = -1.4. Calculations 4a & 4b for stable hydrogen isotopes will be conducted when additional isotopic fractionation factors are published and/or are developed specifically for the PGDP.

Decision Rule 3. A range of values for the isotopic fractionation factor epsilon (ε) will be used based on a published value of -1.1 (Chu, et.al, 2004), -1.39692851 from a statistical workup of the published data set, -1.61385311 which is the value of the 90% one tailed confidence interval on epsilon, and 90% 1-Tailed CI (ε) value ofn epsilon and 95% 1-Tailed CI ε on epsilon value of -1.682657524 will be utilized in calculations.

SCI Step 4. Compare the TCE data C/Co to SCI and SHI C/Co

SCI Step 5. Calculate 1st order rate constant:

Assuming pseudo first order kinetics for transformation along the flow path in the aquifer.

$$C/Co = e^{-kt}$$

Where k is the first order rate constant for attenuation and t is time of travel from the up gradient to the down gradient well. Taking the natural logarithm of both sides:

$$\ln(C/Co) = -kt$$

Because *t* is the same for the estimate based on TCE concentrations or the estimate based on stable isotope ratios, it can be scaled as "one travel time." The value of *t* in both cases is one.

SCI Step 6. Apply Decision Rule 4:

Decision Rule 4: If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more negative than natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, or if the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is no more than a factor of 0.33 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide a third line of evidence for MNA processes.

SCI Step 7. Apply Decision Rule 5.

Decision Rule 5. If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more than a factor of 0.33 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide no interpretable information, and will not be used to support a decision.

SCI Step 8. Apply Decision Rule 6.

Decision Rule 6.

a. To allow for statistical uncertainty in the determination of δ^{13}C analyses, the value of $\delta^{13}C_{upgradient}$ will be replaced with $\delta^{13}C_{upgradient}$ plus the sample standard deviation of the analysis, and $\delta^{13}C_{downgradient}$ will be replaced with $\delta^{13}C_{downgradient}$ minus the sample standard deviation of the analysis.

b. If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is not more than a factor of 0.10 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide a third line of evidence for MNA processes.

c. If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more than a factor of 0.1 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide no interpretable information, and will not be used to support a decision.

6.1.2.6. Limits of the Decision

The failure for the results of the CSIA data reductions and evaluations to meet the criteria set forth in the Decision Rules will be considered to provide no interpretable information to support the conclusion that cometabolic aerobic biodegradation by means of bacteria containing the oxygenase genes considered is occurring.

6.2. Monitoring Well Selection for Enzyme Activity Probe, Geochemical, and SCI Analyses

The most important factors in the selection of sampling wells for this project included: (1) the location of wells relative to the plume core and plume flowpaths; (2) the location of wells relative to TCE sources; (3) TCE concentrations in the well; (4) the date when the well could be sampled. The wells suitable for sampling were identified through the evaluation of each well relative to the parameters cited above and the parameters cited in the preceding text for “Step 4. Define the Boundaries of the Study - Monitoring Well Selection.” Sample collection for this investigation focused on twelve (12) of the sixteen (16) NWP wells identified in Table 4 as suitable for sampling.

- Monitoring wells MW194 and MW197 will be sampled and evaluated as control wells to identify the presence of aerobic microbial populations outside of the PGDP contaminant plumes.

- MW66 is being evaluated in this project as a “special case”. MW 66 will be sampled in order to evaluate the presence and level of activity of aerobic biodegradation relative to high dissolved concentrations of TCE in the vicinity of suspected DNAPL sources.

Based on evaluation of the original sixteen (16) wells in Table 7, the twelve wells retained for sampling are identified in Table 13 and Figure 14. The relative RGA intervals of the study-area well screens are identified in Table 14 and the lateral/vertical relationships of the wells and screened intervals are provided in a cross-section of the NWP core Figures 15 & 16. Particle tracks from the most recent PGDP flow and transport model are provided as verification that the study area reflects the flowpaths associated with the core of the NWP (Figure 17).

Table 13. Final wells selected for enzyme probe, stable carbon isotope, and geochemical sampling

Well ID	Screen Interval	Approx. Screen Depth (ft bgs)	Priority	Comments
MW66	URGA	55 - 60	2	Near SWMU 7/30 Source
MW125	LRGA	78 - 88	1	
MW168	URGA	63 - 68	1	
MW185	MRGA	68 - 73	1	
MW194	URGA	47 - 52	2	Control Well - outside of Plume
MW197	URGA	58 - 63	3	Control Well - outside of Plume
MW236	LRGA	69.5 - 79.5	2	
MW381	MRGA	66 - 76	3	
MW242	MRGA	65 - 75	3	
MW243	MRGA	65 - 75	3	Downgradient of South Well Field; initially >10 mg/L, been at 1 mg/L for last 10 years
MW262	LRGA	90 - 95	1	
MW340	LRGA	85.5 - 95.3	2	

Table 14. Study area sample location information

Well Number	**Year Completed**	**Well Location, Plant Coordinates**		**Within NW Plume**	**RGA Horizon**	**Approximate Screen Interval, (ft bgs)**
		X	Y			
66	1986	-6872.62	978.57	Yes	URGA	55.2-60.2
125	1990	-5662.81	6139.28	Yes	LRGA	78-88
168	1991	-4822.5	-924.8	Yes	URGA	63-68
185	1991	-6601.9	952.9	Yes	MRGA	68-73
194	1991	-10177.5	1865.6	No	URGA	46.9-41.9
197	1991	-6162.5	2863.1	No	URGA	58-63
236	1995	-5087.79	7919.99	Yes	LRGA	69.5-79.5
242	1995	-7083.28	1678.98	Yes	MRGA	65.1-75.1
243	1995	-7382.0	1681.40	Yes	MRGA	65.1-75.1
262	1995	-5378.46	86.98	Yes	LRGA	90.2-94.9
340	1996	-6165.4	665.5	Yes	LRGA	85.6-95.3
381	2002	-4890.7	7746.4	Yes	MRGA	65.8-75.8

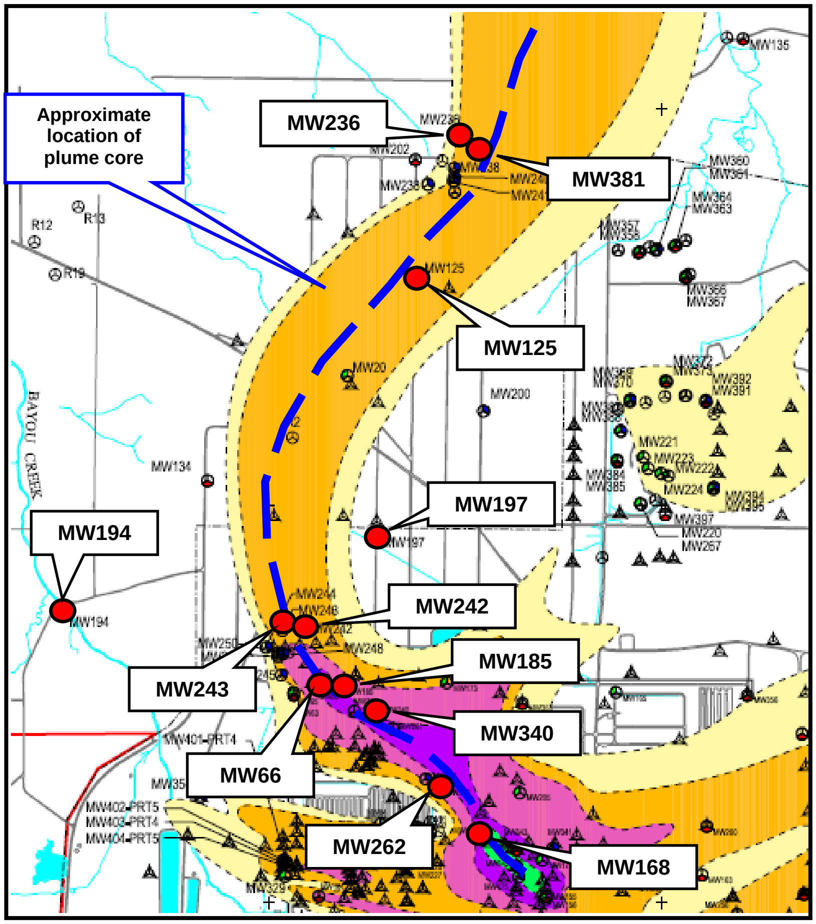


Figure 14. Locations in NWP for EAP, T-RFLP, SCI, SHI & geochemical sampling

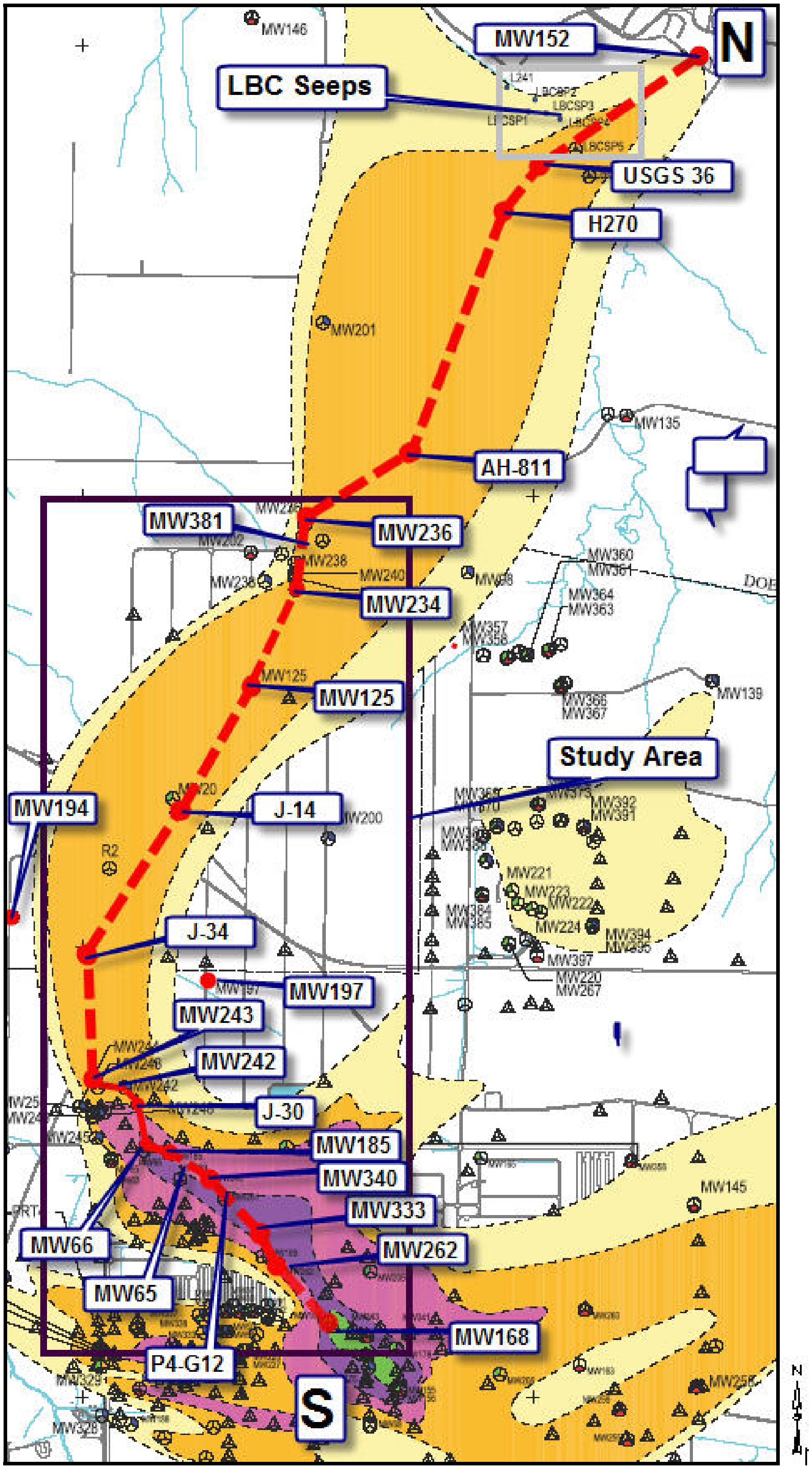


Figure 15. NWP cross-section location.

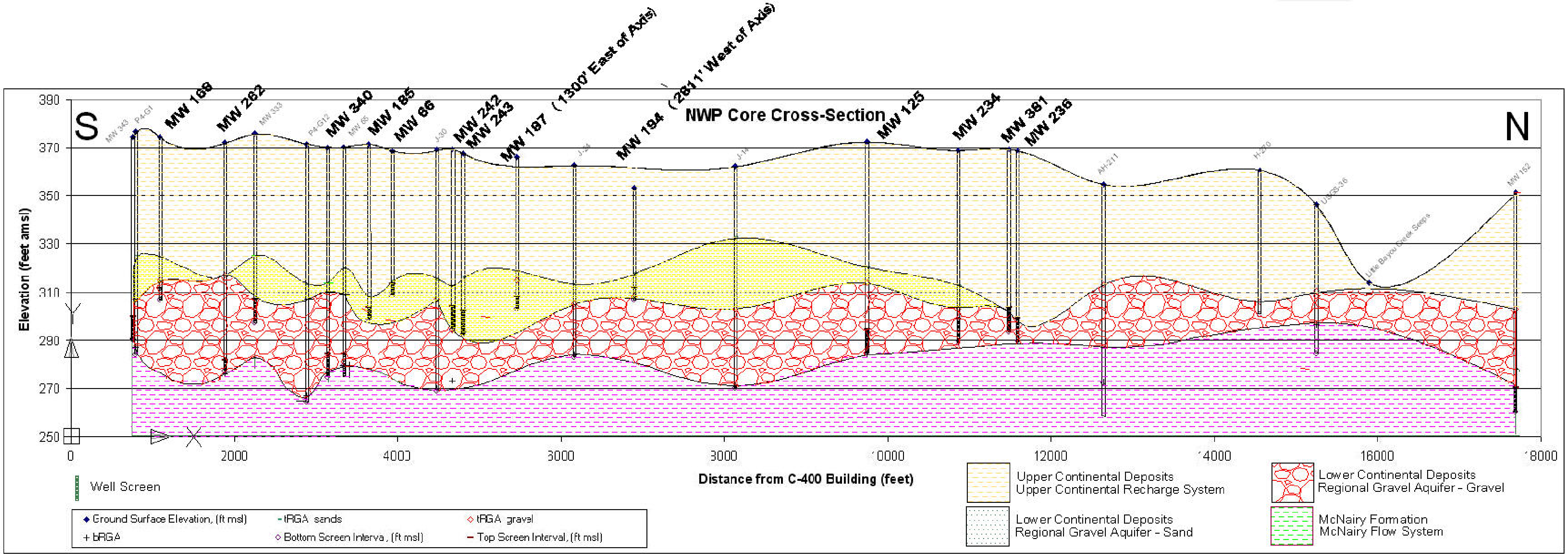


Figure 16. NWP cross-section identifying well locations along plume core and screened intervals relative to RGA materials

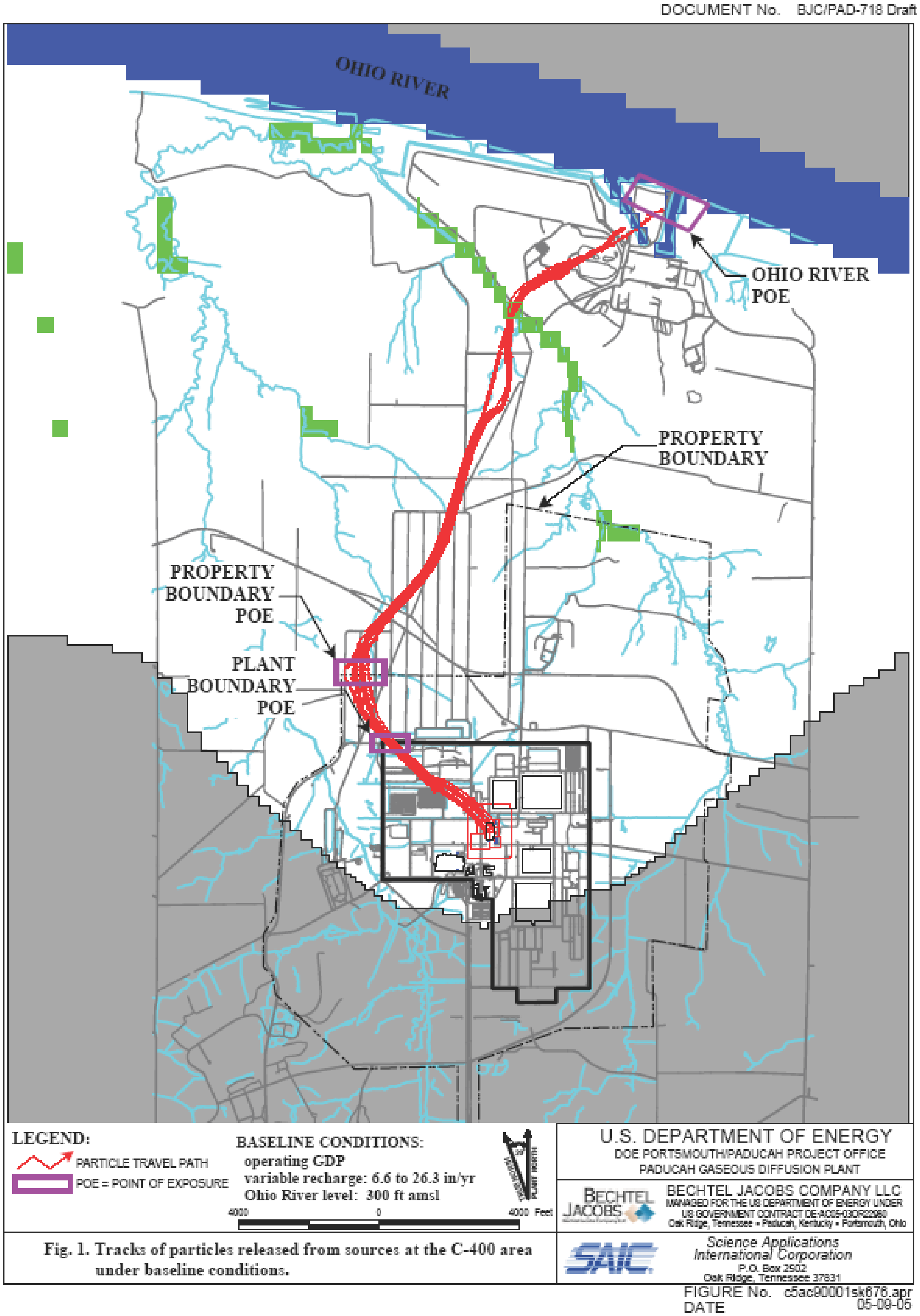


Figure 17. Simulated particle tracks for the Regional Gravel Aquifer (Bechtel Jacobs, 2005)

6.3. Field Sample Collection

6.3.1. Geochemical Sample Collection and Analysis

Fieldwork efforts required to support the PGDP TCE Fate and Transport Project – Aerobic Biodegradation Investigation consisted of obtaining groundwater samples from specific NWP monitoring wells and shipping those samples to laboratories for geochemical, EAP and SCI analyses.

Specific monitoring wells sampled in support of project activities were determined by the project team during project scoping and development of project Data Quality Objectives and decision rules (Appendix 1). The well numbers and specific completion information are listed in Table 14.

Groundwater samples were obtained by the Paducah Remediation Services, LLC, Field Services Organization on three different occasions. The collection dates and the family of compounds or measurements tested for by date are shown below in Table 15.

The sampling of the wells was performed by the Paducah Remediation Services Field Services Team using the following procedures:

- PRS-ENM-2100, Groundwater Level Measurement
- PRS-ENM-2101, Groundwater Sampling
- PRS-ENM-2700, Logbooks and Data Forms
- PRS-ENM-2704, Trip, Equipment and Field Blank Preparation
- PRS-ENM-2708, Sample Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals

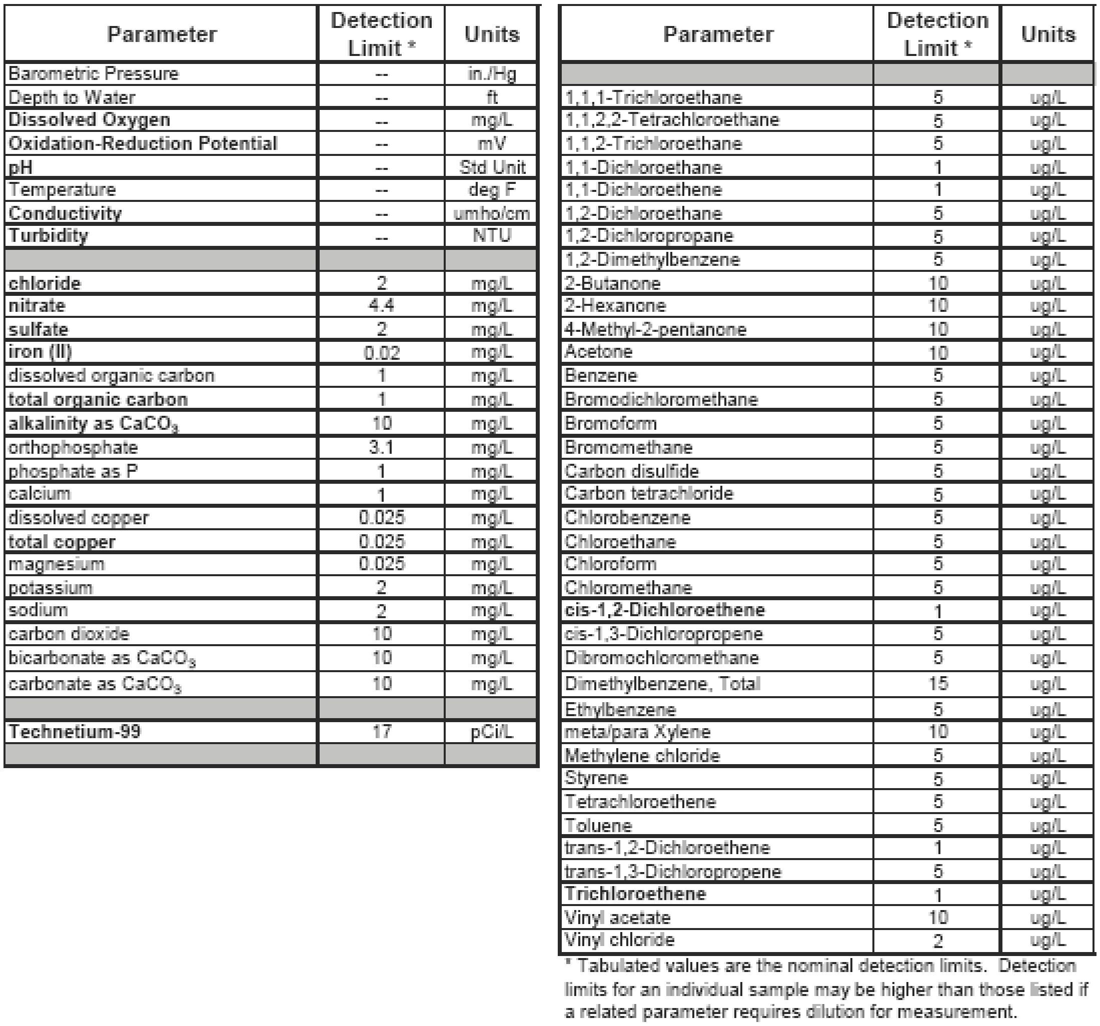
Handling for the Enzyme Activity Probe samples was consistent with the requirements provided in the INL EAP sampling method. All samples were shipped to the analytical laboratories via overnight delivery.

Table 15. Data collection parameters for field sampling by date

Collection Date	Compound/Measurement
May 15 to May 23, 2007	Anions Field Measurements Metals Dissolved Metals Volatile Organic Compounds Wet Chemistry Enzyme Activity Probe
December 17, 2007	Field Measurements Volatile Organic Compounds Technetium 99 Stable Carbon Isotopes
January 17, 2008*	Anions Field Measurements Metals Dissolved Metals Volatile Organic Compounds Wet Chemistry Enzyme Activity Probe
* MW197 and MW262 Resampled	

Several laboratories were responsible for performing analytical testing on the samples: 1) EAP analyses were performed by North Wind Environmental, Inc., at the INL; 2) SCI analyses were performed by the University of Oklahoma, School of Geology and Geophysics Stable Isotope Laboratory; and 3) geochemical and organic compound analyses were conducted by the DOE Sample Management Office (SMO) Laboratories. The SMO laboratories utilized were Southwest Research Institute, San Antonio, Texas, and the United States Enrichment Corporation, Paducah, Kentucky. The parameters in Table 15a were identified for analysis on project samples by the Project Team along with the required method detection limits for each analyte.

Table 15a. Geochemical Parameters and Detection Limits for Project Samples (SRNL, 2008).



Parameter	Detection Limit *	Units
Barometric Pressure	--	in./Hg
Depth to Water	--	ft
Dissolved Oxygen	--	mg/L
Oxidation-Reduction Potential	--	mV
pH	--	Std Unit
Temperature	--	deg F
Conductivity	--	umho/cm
Turbidity	--	NTU
chloride	2	mg/L
nitrate	4.4	mg/L
sulfate	2	mg/L
iron (II)	0.02	mg/L
dissolved organic carbon	1	mg/L
total organic carbon	1	mg/L
alkalinity as $CaCO_3$	10	mg/L
orthophosphate	3.1	mg/L
phosphate as P	1	mg/L
calcium	1	mg/L
dissolved copper	0.025	mg/L
total copper	0.025	mg/L
magnesium	0.025	mg/L
potassium	2	mg/L
sodium	2	mg/L
carbon dioxide	10	mg/L
bicarbonate as $CaCO_3$	10	mg/L
carbonate as $CaCO_3$	10	mg/L
Technetium-99	17	pCi/L

Parameter	Detection Limit *	Units
1,1,1-Trichloroethane	5	ug/L
1,1,2,2-Tetrachloroethane	5	ug/L
1,1,2-Trichloroethane	5	ug/L
1,1-Dichloroethane	1	ug/L
1,1-Dichloroethene	1	ug/L
1,2-Dichloroethane	5	ug/L
1,2-Dichloropropane	5	ug/L
1,2-Dimethylbenzene	5	ug/L
2-Butanone	10	ug/L
2-Hexanone	10	ug/L
4-Methyl-2-pentanone	10	ug/L
Acetone	10	ug/L
Benzene	5	ug/L
Bromodichloromethane	5	ug/L
Bromoform	5	ug/L
Bromomethane	5	ug/L
Carbon disulfide	5	ug/L
Carbon tetrachloride	5	ug/L
Chlorobenzene	5	ug/L
Chloroethane	5	ug/L
Chloroform	5	ug/L
Chloromethane	5	ug/L
cis-1,2-Dichloroethene	1	ug/L
cis-1,3-Dichloropropene	5	ug/L
Dibromochloromethane	5	ug/L
Dimethylbenzene, Total	15	ug/L
Ethylbenzene	5	ug/L
meta/para Xylene	10	ug/L
Methylene chloride	5	ug/L
Styrene	5	ug/L
Tetrachloroethene	5	ug/L
Toluene	5	ug/L
trans-1,2-Dichloroethene	1	ug/L
trans-1,3-Dichloropropene	5	ug/L
Trichloroethene	1	ug/L
Vinyl acetate	10	ug/L
Vinyl chloride	2	ug/L

* Tabulated values are the nominal detection limits. Detection limits for an individual sample may be higher than those listed if a related parameter requires dilution for measurement.

Sample analysis turnaround times were 30 days. Following completion of the laboratory analyses, analytical data were assessed by the PRS Environmental Monitoring Group utilizing procedure PRS-ENM-5003, Quality Assured Data. Geochemical data sets were uploaded to the Oak Ridge Environmental Information System (OREIS) and also released to the TCE Fate and Transport Project Team. EAP, T-RFLP, and SCI data were distributed to KRCEE and the project team upon completion of analyses. Analytical procedures for EAP and T-RFLP are provided in Appendix 11 of this report and SCI analytical procedures are contained in Appendix 1B.

6.4. Analytical Methods

6.4.1. Enzyme Activity Probes & Related Laboratory Analyses

A Complete discussion of methods utilizedfor EAP and genetic profiling laboratory analyses and control studies can be found in *Enzyme Activity Probe and Geochemical Assessment for Potential Aerobic Cometabolism of Trichloroethene in Groundwater of the Northwest Plume, Paducah Gaseous Diffusion Plant, Kentucky* (SRNL, 2008). In summary the EAP and genetic profiling consisted of the following activities:

1. Each sample was qualitatively screened for response to three (3) toluene enzymes and soluble methane monooxygenase.
2. Samples were then quantitatively screened (cells/mL) for the three toluene monooxygenase enzymes.
3. Samples were quantitatively screened for sMMO enzyme activity
4. Inhibition assays that suppress enzymes other than those being evaluated were conducted on all samples to ensure that probe response was to the toluene enzymes and sMMO.
5. DNA control studies were conducted to determine if the appropriate genetic material to produce the toluene and sMMO enzymes was present in the samples.

Based on comparison to the qualitative measurements, the initial project DQO-determined quantitative criteria of 1 x 10^3 cells per mL was determined to be too low and resulted in identifying all the samples as positive including the samples that were determined to be negative in the qualitative examination. As a result, the following criteria were used; < 3x10^3 cells/mL = low activity, 3 x10^3 to 8 x10^3 cells/mL = moderate activity, and > 8 x10^3 cells/mL = high activity. Further discussion of the probe procedure is provided in (SRNL, 2008).

6.4.2. Stable Carbon Isotope Analysis Operating Procedures

6.4.2.1. Purge-and-trap extraction and compound-specific isotope ratio analysis

A purge and trap (P & T) method of extraction for VOC-class compounds was coupled with GC-IRMS for the SCI analyses. A complete discussion of the methods used for stable carbon isotope extraction and stable carbon isotope ratio analysis is provided in Appendix 1.

6.4.2.2. Quantification of isotope ratios in individual compounds by GC-IRMS

Raw output of GC-IRMS consists of three (carbon mode) or two (hydrogen mode) simultaneously acquired signal channels, corresponding to target analyte (CO_2 or H_2, respectively) with variable C-H-O isotope substitution. Rather than measuring the absolute ratios of isotope species, the IRMS technique relies on data normalization relative to internal standard of known isotopic composition. A number of pulses of standard gas (CO_2 or hydrogen, respectively) and/or co-injected standard are introduced into the IRMS source during each run to provide a reference for sample-derived signal. GC separation of the analyte permits integration of individual chromatographic peaks, positioned over uniform background noise. An automatic software routine detects peaks and assigns their background value. Integration of the individual channel outputs over the peak's retention time window provides a ratio of isotope species (Deuterium/H or $^{13}C/^{12}C$), which in turn is automatically normalized relative to the standard of known isotopic composition. The final output of the automatic integrator has to be reviewed manually, in particular to eliminate errors upon the background determination. The data are reported in delta notation.

$\delta^{13}C = (R_{sample}/R_{standard} - 1) * 1000$

R_{sample} and $R_{standard}$ represent $^{13}C/^{12}C$ ratios of the sample and the international standard (VPDB), respectively.

6.4.3. Geochemical Evaluations

Geochemical evaluations were conducted to identify the presence and distribution of groundwater and soil geochemical parameters related to microbial activity and RGA geochemical environments. Data sets generated for evaluation in this project included: 1) project-specific geochemical data; 2) annual groundwater surveillance and quarterly-monitoring geochemical data from upper, middle, and lower RGA horizons; and 3) historical geochemical data from all groundwater monitoring locations sampled for TCE. Data files were generated from the PGDP Data Warehouse and Geographical Information System (DWGIS) and downloaded to spreadsheets where the data were parsed for temporal and spatial plots. UCRS and RGA data files were generated based upon well-screen horizons from boring logs developed for United States Army Corp of Engineers Groundwater Modeling System (GMS) software cross-sectional solid models of the RGA. Temporal trend data plots were generated in MS Excel for DO and TCE. Converted data files were imported into Spatial Analysis and Decision Assistance (SADA) version 4.1.5 software (University of Tennessee Institute for Environmental Modeling; http://www.tiem.utk.edu/~sada/index.shtml) and spatial plots by analyte and RGA interval were generated (Appendix 2).

7.0. Results and Discussion for TCE Degradation Analytical & Evaluation Activities

7.1. Enzyme Activity Probe, DNA, and T-RFLP Analytical and Evaluation Results.

The EAP analytical work was conducted in two steps: 1) initial qualitative EAP analyses utilizing the sMMO and toluene probes; and 2) quantitative analyses utilizing the toluene probes. Qualitative results provided evidence for the presence of sMMO and toluene activity in NWP. The quantitative toluene EAPs were used to quantify toluene enzyme activity which was evaluated relative to project DQOs. A DNA control study was conducted concurrently with the qualitative and quantitative analyses. The DNA control study was used to identify the presence or absence of organisms that contain the genes of interest related to enzymes capable of co-metabolic degradation of TCE. Finally, the T-RFLP evaluation was performed to develop some general conclusions about the community structure in the samples and to assess the "representativeness" of the samples relative to the aquifer and local biofouling concerns at each well. Additional discussions of the EAP, DNA, and T-RFLP results are provided in (SRNL, 2008).

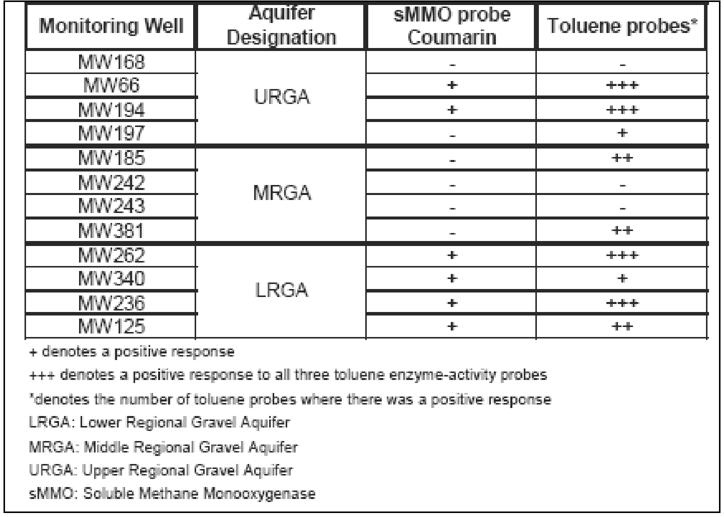
7.1.1. Enzyme Activity Probes

7.1.1.1. Qualitative Toluene and sMMO Enzyme-Activity Probe Results (SRNL, 2008)

Qualitative toluene EAP data is presented in Table 16. A positive result (+) indicates that the probe was determined to be significant based on its fluorescent signal and indicates the fluorescence of one or more cells in the sample as illustrated by the phenylacetylene (PA) micrograph in Figure 18. Each probe responds to a primary oxidation pathway and each sample can be positive for one, two, or three probes. No single probe provides more or less information regarding the activity or potential activity in a groundwater consortia of bacteria, rather, pathways are stimulated or induced under different conditions. Variable activity, or a positive response in one or more groundwater samples with all of the probes, may be indicative of a diverse metabolic community throughout the study area (Figures 19 and 20a). The sMMO results were determined based on solution fluorescence and indicated a fluorescence that was statistically greater than background and control samples.

Table 16. Results for Qualitative EAP Analyses

A positive mark means activity was determined in the sample (SRNL, 2008).



Monitoring Well	Aquifer Designation	sMMO probe Coumarin	Toluene probes*
MW168	URGA	-	-
MW66		+	+++
MW194		+	+++
MW197		-	+
MW185	MRGA	-	++
MW242		-	-
MW243		-	-
MW381		-	++
MW262	LRGA	+	+++
MW340		+	+
MW236		+	+++
MW125		+	++

+ denotes a positive response
+++ denotes a positive response to all three toluene enzyme-activity probes
*denotes the number of toluene probes where there was a positive response
LRGA: Lower Regional Gravel Aquifer
MRGA: Middle Regional Gravel Aquifer
URGA: Upper Regional Gravel Aquifer
sMMO: Soluble Methane Monooxygenase

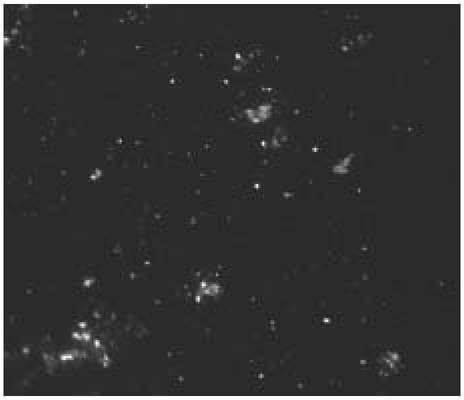


Figure 18. Microphotograph of Groundwater from MW66 Exposed to Phenylacetylene (SRNL, 2008)

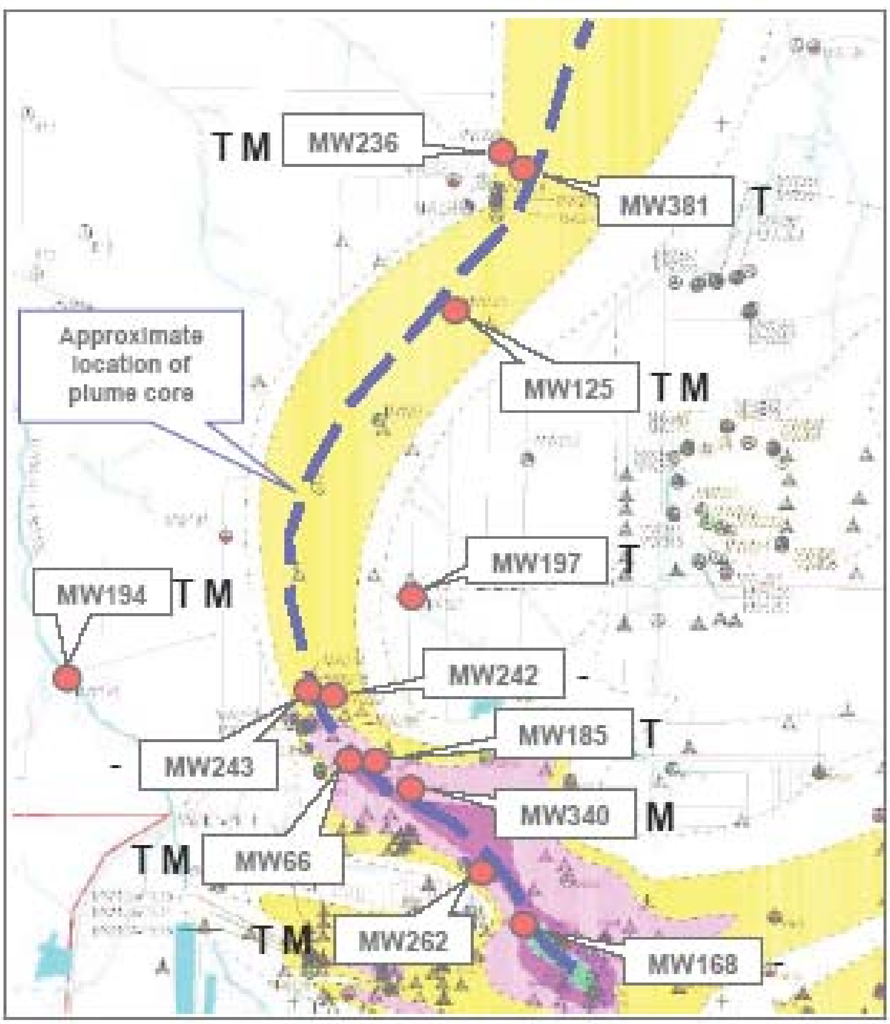


Figure 19. Response to Enzyme Activity Probes (SRNL, 2008)
(sMMO denoted with an "M", and/or one or more toluene probes, denoted with a "T")

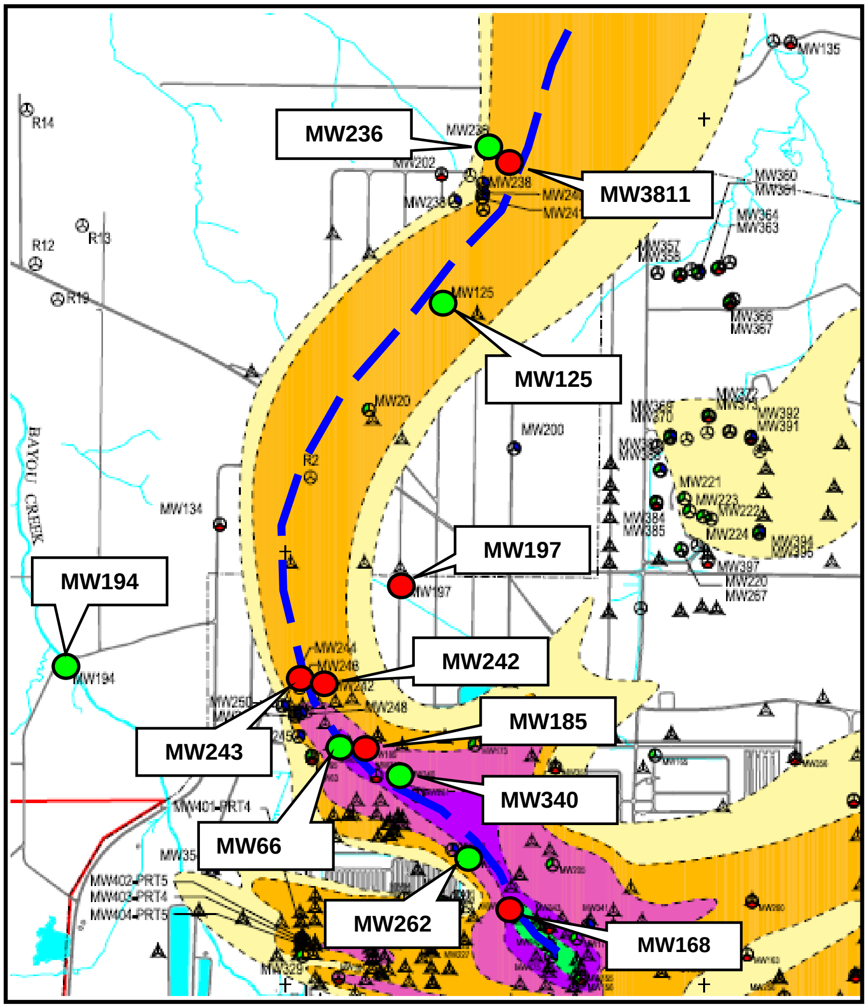


Figure 20a. Qualitative sMMO Response along NWP Core . (Red = no response, Green = positive response)

7.1.1.2. Quantitative Toluene Enzyme-Activity Probe Results (SRNL, 2008)

Toluene EAP data were quantified to determine where significant toluene activity was present in the study area (Table 17; Figures 19 & 20b). Highlighted values indicate moderate and high activity as identified by Project Team scoping criteria and later by more refined standards developed by investigators. The refined binning criteria resulted in a good concordance between the qualitative and the quantitative results. Total microorganism counts (DAPI results, Table 17) showed that the NWP groundwater has total microbial population levels typical of large aerobic groundwater systems with cell counts ranging from 10^5 to 10^6 cells per mL of sample (SRNL, 2008).

The two control wells outside the NWP (MW194 and MW197) showed high (significant) presence of toluene degraders and one of these wells showed sMMO activity. Among the 10 wells in the plume, 80% showed significant presence of toluene oxidizers, 50% showed sMMO activity, and 80% showed at least one type of oxidizing capability. The expression and activity are lower in the middle portion of the aquifer (MRGA) for both methane and aromatic (toluene) oxidation. Both the URGA and LRGA showed diverse and robust oxidation potential. Using the original DQO criteria (quantitative results above 10^3 cells/mL), 100% of the control and plume wells showed at least one type of oxidizing activity. Notably, the activity appears to vary vertically within the RGA. Spatially, the presence and activity of methane and aromatic oxidizers was measured throughout the plume. The location of wells with positive enzyme activity response is shown in relation to TCE footprint for the Northwest Plume at the PGDP (Figure 19). Wells with positive EAP response to the sMMO probe are denoted with an "M" and wells with significant positive response to the toluene EAPs are denoted with a "T".

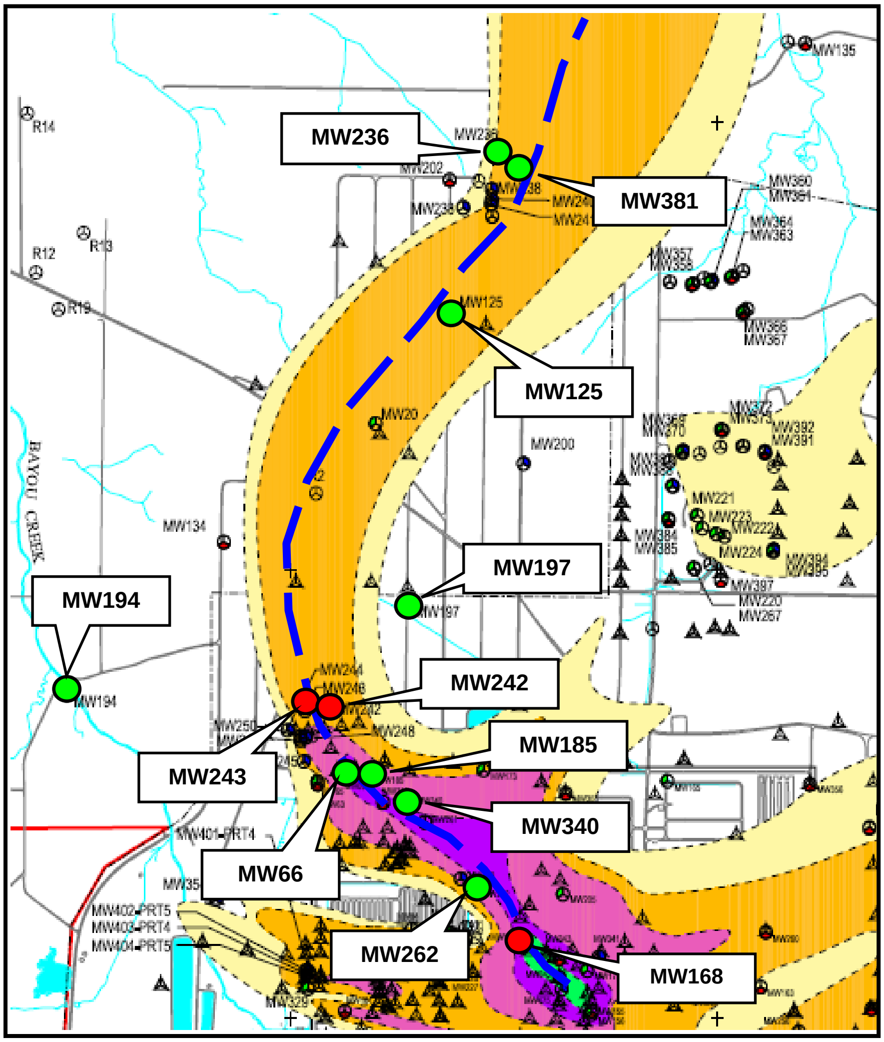
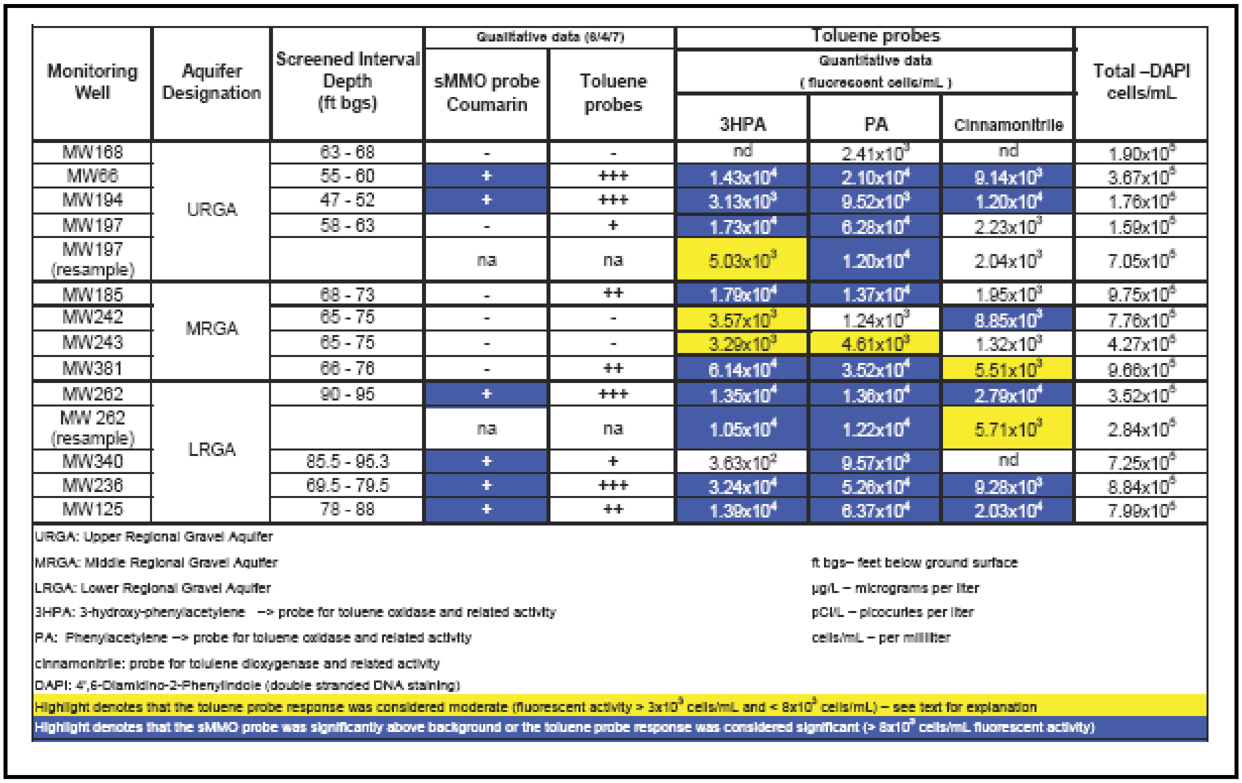


Figure 20b. Qualitative Toluene Probe Response
(Red = no response, Green = positive response to one or more of the three toluene probes)

7.1.1.3. DNA Control Study Results (SRNL, 2008)

The DNA amplification control study was performed to determine if genetic material related to the sMMO and toluene monooxygenase enzymes were present in the microbial community. DNA control study data are shown in Table 18. A positive result (+) indicates the gene of interest was amplified from the groundwater sample and a negative (-) indicates that amplification was not successful. Positive response with the primers (Table 18) provides significant evidence that the oxygenase genes of interest, sMMO and toluene monooxygenases, are present in groundwater from each particular monitoring well.

Table 17. Enzyme Activity Probe Assay Results **(SRNL, 2008).**



Monitoring Well	Aquifer Designation	Screened Interval Depth (ft bgs)	Qualitative data (8/4/7)		Toluene probes			Total –DAPI cells/mL
					Quantitative data (fluorescent cells/mL)			
			sMMO probe Coumarin	Toluene probes	3HPA	PA	Cinnamonitrile	
MW168	URGA	63 - 68	-	-	nd	2.41×10^3	nd	1.90×10^5
MW66		55 - 60	+	+++	1.43×10^4	2.10×10^4	9.14×10^3	3.67×10^5
MW194		47 - 52	+	+++	3.13×10^3	9.52×10^3	1.20×10^4	1.76×10^5
MW197		58 - 63	-	+	1.73×10^4	6.28×10^4	2.23×10^3	1.59×10^5
MW197 (resample)			na	na	5.03×10^3	1.20×10^4	2.04×10^3	7.05×10^5
MW185	MRGA	68 - 73	-	++	1.79×10^4	1.37×10^4	1.95×10^3	9.75×10^5
MW242		65 - 75	-	-	3.57×10^3	1.24×10^3	8.85×10^3	7.76×10^5
MW243		65 - 75	-	-	3.29×10^3	4.61×10^3	1.32×10^3	4.27×10^5
MW381		66 - 76	-	++	6.14×10^4	3.52×10^4	5.51×10^3	9.66×10^5
MW262	LRGA	90 - 95	+	+++	1.35×10^4	1.36×10^4	2.79×10^4	3.52×10^5
MW 262 (resample)			na	na	1.05×10^4	1.22×10^4	5.71×10^3	2.84×10^5
MW340		85.5 - 95.3	+	+	3.63×10^2	9.57×10^3	nd	7.25×10^5
MW236		69.5 - 79.5	+	+++	3.24×10^4	5.26×10^4	9.28×10^3	8.84×10^5
MW125		78 - 88	+	++	1.39×10^4	6.37×10^4	2.03×10^4	7.99×10^5

URGA: Upper Regional Gravel Aquifer
MRGA: Middle Regional Gravel Aquifer
LRGA: Lower Regional Gravel Aquifer
3HPA: 3-hydroxy-phenylacetylene –> probe for toluene oxidase and related activity
PA: Phenylacetylene –> probe for toluene oxidase and related activity
cinnamonitrile: probe for toluene dioxygenase and related activity
DAPI: 4',6-Diamidino-2-Phenylindole (double stranded DNA staining)

ft bgs– feet below ground surface
µg/L – micrograms per liter
pCi/L – picocuries per liter
cells/mL – per milliliter

Highlight denotes that the toluene probe response was considered moderate (fluorescent activity > 3×10^3 cells/mL and < 8×10^3 cells/mL) – see text for explanation
Highlight denotes that the sMMO probe was significantly above background or the toluene probe response was considered significant (> 8×10^3 cells/mL fluorescent activity)

These DNA data provides (1) evidence of the potential for activity in any groundwater sample and (2) support for the enzyme activity assessment. Although amplification identifies which monitoring wells demonstrate a positive response to the genes of interest, it does not necessarily identify expression of the pathway and a positive response to the EAP.

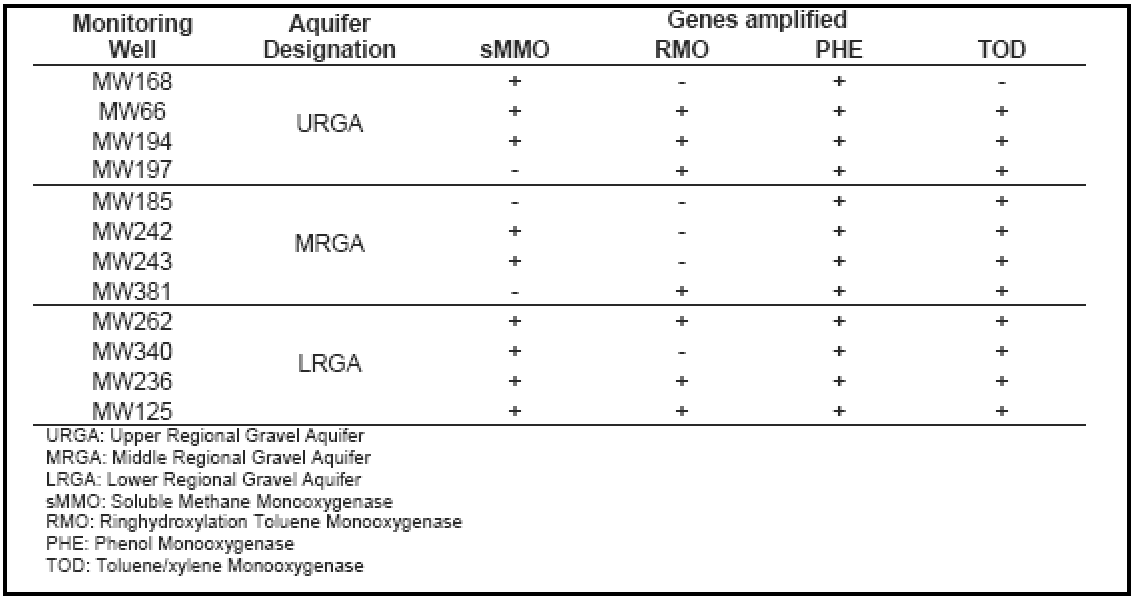
The sMMO results (Table 17) were compared to the sMMO DNA control study (Table 18) to determine the degree of concordance between the EAP and the associated DNA targeted genes. Several wells (MW168, MW242, and MW243) showed a positive response to the genes of interest but did not display a positive response to the EAP. This indicates that enzyme activity was not observed even though the genes necessary to produce the enzyme were present in the microbial population.

For aromatic oxidation, two of the EAP compounds, PA (phenylacetylene) and 3HPA (3-hydroxyphenylacetylene), do not strictly correlate with a single enzymatic pathway. Each of the EAP probes reliably works with a preferred pathway but may also function with other pathways. For example, the 2 and 3 monooxygenase are both targeted with 3HPA; therefore, the two pathways cannot be distinguished using EAP alone. However, since the two PCR primer sets, RMO and PHE discriminate between the 2- and 3-monooxygenase pathways, some assessment of which pathway predominates is possible when the EAP data and PCR data are combined in a complementary fashion (Table 17).

Since the PGDP wells showed a general positive response with PA and HPA probes, the only way to determine the significance of the 2- versus the 3-monoxygenase is to examine the PCR results. MW168, MW185, MW242, MW243, and MW340 all had a negative PCR response with the RMO primer sets but a positive response with the PHE. This suggests that in these groundwater samples, 2-monooxygenase is a contributing pathway to cometabolic attenuation of TCE. Basic science efforts are underway to improve the understanding of the various potential combined response profiles for the EAPs and the PCR primers.

The only aromatic oxidation probe response that can be directly compared with the DNA results is cinnamontrile, which preferentially targets the dioxygenase (TOD) gene. MW 197, MW185, MW243 and MW340 assayed positive for the gene sequence for TOD when amplified using DNA primers. However, these wells showed low activity with the EAP cinnamonitrile. Wells 242, 381 and 236 assayed positive for the gene sequence for TOD and showed moderate activity with the EAP cinnamonitrile. This indicates that significant (high) enzyme activity was not observed in the EAP results for these seven wells even though the genes necessary to produce the enzyme were present in the microbial population.

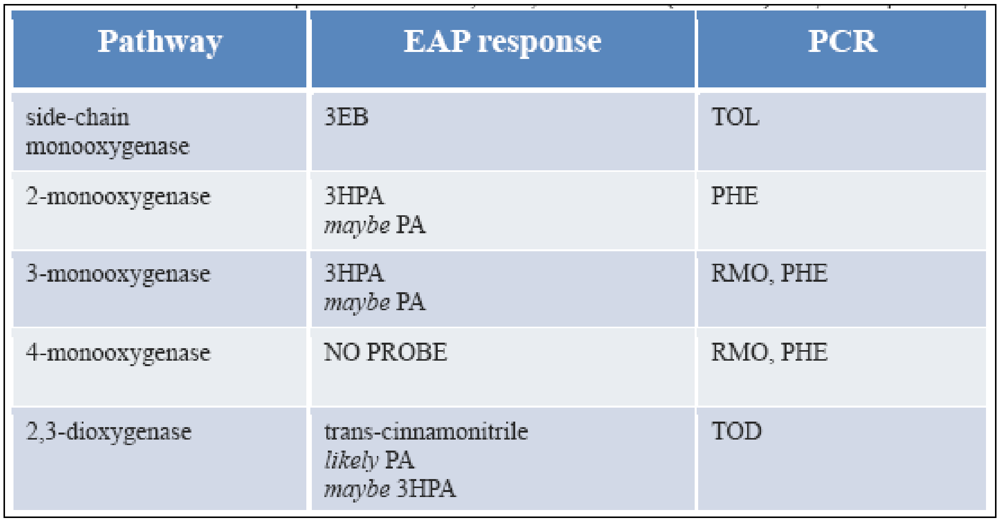
Table 18. Results of DNA Control Studies. **(A positive mark indicates the gene of interest was amplified from the groundwater sample)**



Monitoring Well	Aquifer Designation	Genes amplified sMMO	 RMO	 PHE	 TOD
MW168	URGA	+	-	+	-
MW66		+	+	+	+
MW194		+	+	+	+
MW197		-	+	+	+
MW185	MRGA	-	-	+	+
MW242		+	-	+	+
MW243		+	-	+	+
MW381		-	+	+	+
MW262	LRGA	+	+	+	+
MW340		+	-	+	+
MW236		+	+	+	+
MW125		+	+	+	+

URGA: Upper Regional Gravel Aquifer
MRGA: Middle Regional Gravel Aquifer
LRGA: Lower Regional Gravel Aquifer
sMMO: Soluble Methane Monooxygenase
RMO: Ringhydroxylation Toluene Monooxygenase
PHE: Phenol Monooxygenase
TOD: Toluene/xylene Monooxygenase

Table 19. Relationships between EAPs, PCR, and toluene (aromatic) enzymatic pathways



Pathway	EAP response	PCR
side-chain monooxygenase	3EB	TOL
2-monooxygenase	3HPA *maybe* PA	PHE
3-monooxygenase	3HPA *maybe* PA	RMO, PHE
4-monooxygenase	NO PROBE	RMO, PHE
2,3-dioxygenase	trans-cinnamonitrile *likely* PA *maybe* 3HPA	TOD

7.1.1. T-RFLP Analysis (from SRNL, 2008)

The T-RFLP evaluation was performed to provide information to assess the community structure at each sample location and across the plume study area (SRNL, 2008). Because of concerns about biofouling, which is routinely observed in PGDP well screens, the T-RFLP was conducted to profile the community via the following assumptions:

1. Community profiles will differ based on TCE concentrations,
2. Community profiles will differ based on geochemical or biogeochemical parameters,
3. Community profiles of the wells that were cleaned in the same time frame should look more similar to one another than those that were cleaned more recently or never,
4. If a biofilm is present, all of the profiles should have similarities that "outweigh" the differences.

Each well produced a distinct profile, detailing the micro-niches and diversity of genetic and physiological activities of in-situu microbial populations. Profiles of microbial populations at each location were more diverse than expected (SRNL, 2008). Based on this overall diversity and the distinct differences of each of the fingerprints, it is clear that:

- There is no dominance of any one organism or even group of organisms in the groundwater plume based on DNA amplification.
- Dominant organisms from any given monitoring well are different than those from other monitoring wells, even when the wells exhibit similar geochemical or contaminant concentrations.
- The groundwater evaluated using EAPs does not appear biased by biofouling in the well casings.
- The groundwater sampled appears to represent distinct micro-communities present within the Northwest Plume as would be expected if the plume, rather than the well casings and associated biofilms, was being sampled and analyzed.

These data provide scientifically and statistically defensible results that the groundwater sampled and analyzed for enzyme activity primarily represents sampling of the groundwater plume (i.e. formation water), rather than sampling the micro-communities present as biofilms in individual well casings.

7.2. SCI Analytical & Evaluation Results.

7.2.1. SCI Analytical Results.

Stable carbon isotope analyses were conducted by the University of Oklahoma School of Geology and Geophysics Stable Isotope Laboratory on the twelve samples from the December 2007 PGDP NWP groundwater sampling event. Laboratory results for eleven of the twelve sample locations are provided in Table 20. The sample from MW 194 did not yield SCI analytical results because TCE was not present in the sample. SCI Quality Assurance results are provided in Appendix 3.

7.2.2. SCI Evaluations.

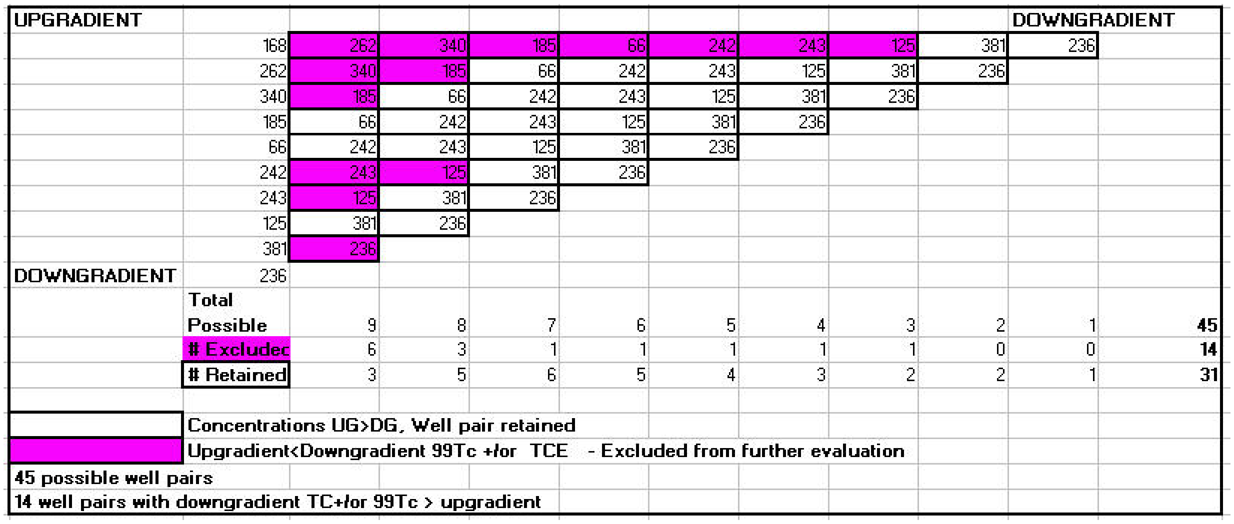
The SCI data evaluation was accomplished through application of the stepwise data reduction and assessment process developed during the SCI DQO process. Concentration data, screened interval data, SCI concentration data, and normalized concentration data were screened to ensure suitability for evaluation prior to application of the SCI decision rules to upgradient-downgradient SCIR well-pair data. Well-pair screenings for all of the 45 well pairs in the study area were accomplished in four (4) steps:

Table 20. Stable carbon isotope data for NWP study wells .

	Averages
Sample ID	TCE d13C (permil)
MW-66	-25.3
MW-125	-25.6
MW-168	-24.8
MW-185	-25.9
MW-194	na
MW-197	-23.1
MW-236	-25.3
MW-242	-24.6
MW-243	-25.3
MW-262	-25.8
MW-340	-25.9
MW-381	-25.4

1) Downgradient TCE and ^{99}Tc concentration data from the December 2007 SCI sampling event were compared to upgradient concentration data for each well pair and well pairs were excluded from further evaluation if either the downgradient TCE or ^{99}Tc concentrations were higher than upgradient concentrations. This screening ruled out evaluation of well pairs where the downgradient concentration data indicated that the downgradient well could have been impacted by sources along the well-pair flowpaths. Fourteen (14) of the 45 study area well pairs were screened from further evaluation and 31 well-pairs were carried forward to screening step 2 (Table 21).

Table 21. Well TCE/^{99}Tc upgradient – downgradient concentration comparison matrix



UPGRADIENT										DOWNGRADIENT	
	168	262	340	185	66	242	243	125	381	236	
	262	340	185	66	242	243	125	381	236		
	340	185	66	242	243	125	381	236			
	185	66	242	243	125	381	236				
	66	242	243	125	381	236					
	242	243	125	381	236						
	243	125	381	236							
	125	381	236								
	381	236									
DOWNGRADIENT	236										
	Total Possible	9	8	7	6	5	4	3	2	1	**45**
	# Excludec	6	3	1	1	1	1	1	0	0	**14**
	# Retained	3	5	6	5	4	3	2	2	1	**31**

☐ Concentrations UG>DG, Well pair retained

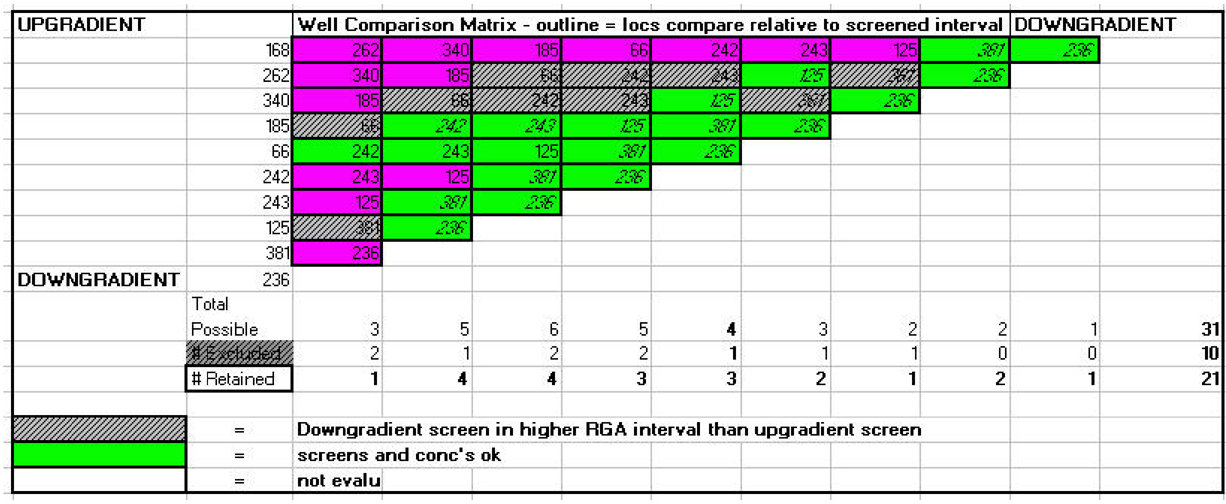
🟪 Upgradient<Downgradient 99Tc +/or TCE - Excluded from further evaluation

45 possible well pairs

14 well pairs with downgradient TC+/or 99Tc > upgradient

2) The screened intervals of paired wells were compared and well pairs with downgradient screened intervals higher in the RGA than upgradient screened intervals were excluded from further evaluation. This screening ruled out evaluation of well pairs that were not monitoring possible RGA flowpaths. Ten (10) of the remaining 31 study area well pairs were screened from further evaluation and 21 well-pairs were carried forward to screening step 3 ***(Table 22)***.

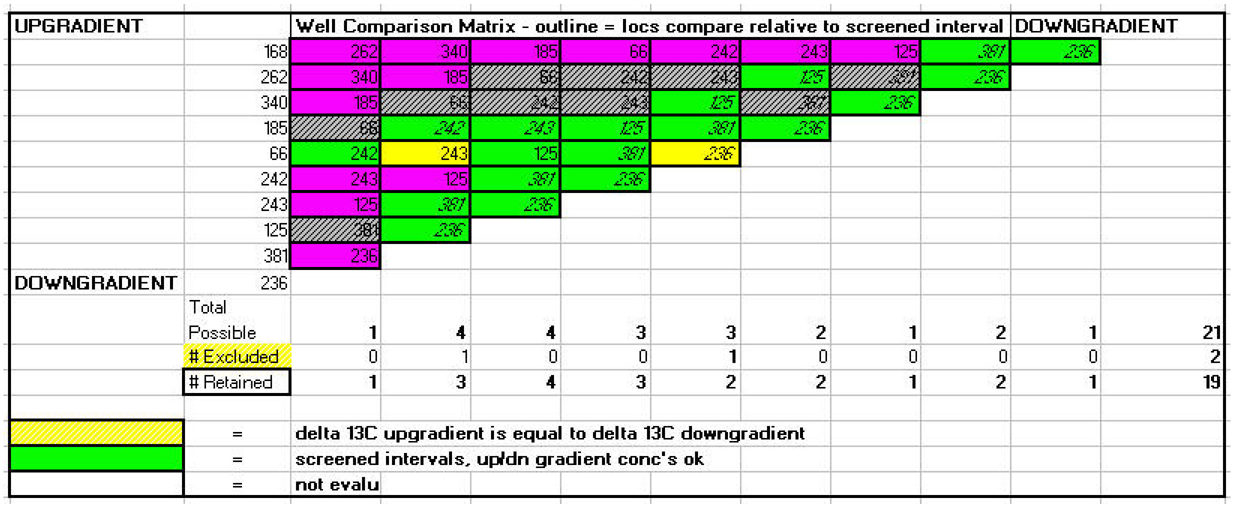
Table 22. Well-pair screened interval matrix



UPGRADIENT		Well Comparison Matrix - outline = locs compare relative to screened interval								DOWNGRADIENT	
	168	🟪 262	🟪 340	🟪 185	🟪 66	🟪 242	🟪 243	🟪 125	🟩 381	🟩 236	
	262	🟪 340	🟪 185	▨ 66	▨ 242	▨ 243	🟩 125	▨ 381	🟩 236		
	340	🟪 185	▨ 66	▨ 242	▨ 243	🟩 125	▨ 381	🟩 236			
	185	▨ 66	🟩 242	🟩 243	🟩 125	🟩 381	🟩 236				
	66	🟩 242	🟩 243	🟩 125	🟩 381	🟩 236					
	242	🟪 243	🟪 125	🟩 381	🟩 236						
	243	🟪 125	🟩 381	🟩 236							
	125	▨ 381	🟩 236								
	381	🟪 236									
DOWNGRADIENT	236										
	Total Possible	3	5	6	5	4	3	2	2	1	31
	# Excluded	2	1	2	2	1	1	1	0	0	10
	# Retained	1	4	4	3	3	2	1	2	1	21
▨	=	Downgradient screen in higher RGA interval than upgradient screen									
🟩	=	screens and conc's ok									
	=	not evalu									

3) TCE (permil) values from remaining upgradient/downgradient well pairs were compared. If the upgradient δ^{13}C and downgradient δ^{13}C concentrations were equal, the well pair was excluded from further evaluation because no enrichment had occurred along the well-pair flowpath ***(Table 23).*** Two (2) well pairs were excluded from further evaluation in this screening step and nineteen (19) well pairs were carried forward to the fourth and final screening step.

Table 23. Well-pair normalized concentration data screening matrix

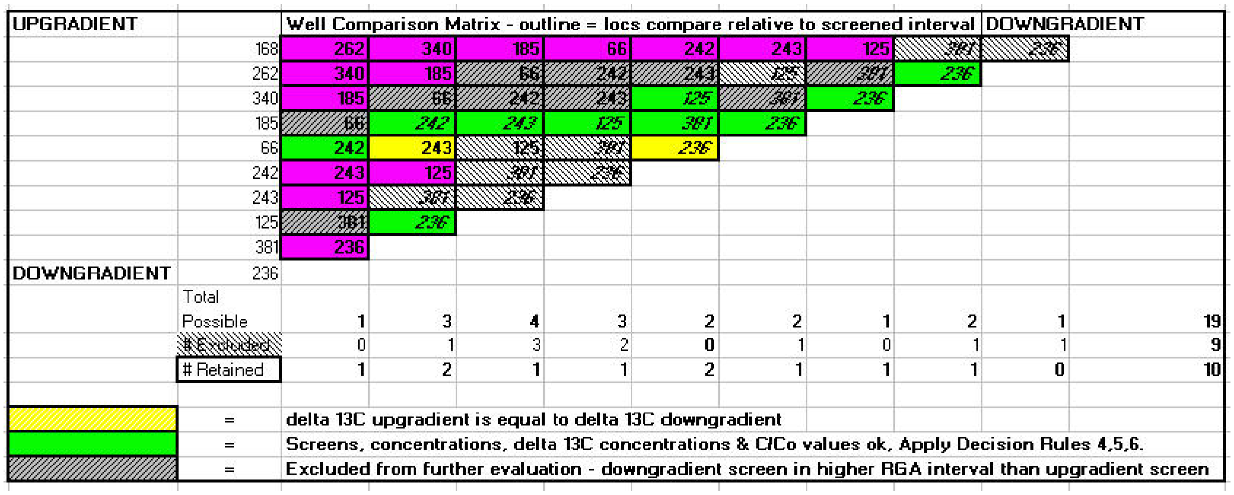


UPGRADIENT		Well Comparison Matrix - outline = locs compare relative to screened interval								DOWNGRADIENT	
	168	🟪 262	🟪 340	🟪 185	🟪 66	🟪 242	🟪 243	🟪 125	🟩 381	🟩 236	
	262	🟪 340	🟪 185	▨ 66	▨ 242	▨ 243	🟩 125	▨ 381	🟩 236		
	340	🟪 185	▨ 66	▨ 242	▨ 243	🟩 125	▨ 381	🟩 236			
	185	▨ 66	🟩 242	🟩 243	🟩 125	🟩 381	🟩 236				
	66	🟩 242	🟨 243	🟩 125	🟩 381	🟨 236					
	242	🟪 243	🟪 125	🟩 381	🟩 236						
	243	🟪 125	🟩 381	🟩 236							
	125	▨ 381	🟩 236								
	381	🟪 236									
DOWNGRADIENT	236										
	Total Possible	1	4	4	3	3	2	1	2	1	21
	# Excluded	0	1	0	0	1	0	0	0	0	2
	# Retained	1	3	4	3	2	2	1	2	1	19
🟨	=	delta 13C upgradient is equal to delta 13C downgradient									
🟩	=	screened intervals, up/dn gradient conc's ok									
	=	not evalu									

4) For the 19 well pairs retained in the third screening step, TCE concentration data was normalized to ^{99}Tc concentration data for each well pair. If the value of the normalized concentration exceeded or equaled unity, the well pair was excluded from further evaluation ***(Table 24 & 25)***. This screening ruled out evaluation of well pairs where the normalized downgradient concentration data indicated that the downgradient well could be impacted by sources along the well-pair flowpath. Finally, the normalized concentration data from the 19 well pairs retained from step 3 were evaluated relative to the value of the normalized concentration ***(Table 25)***. If the normalized well-pair concentrations exceeded unity, the well pairs were excluded from further

evaluation. The ten (10) well pairs retained for evaluation through application of SCI Decision Rules 4, 5. and 6 are identified in ***Table 26.***

Table 24. Well-pair normalized concentration data screening matrix



UPGRADIENT		Well Comparison Matrix - outline = locs compare relative to screened interval							DOWNGRADIENT		
	168	262	340	185	66	242	243	125	381	236	
	262	340	185	66	242	243	125	381	236		
	340	185	66	242	243	125	381	236			
	185	66	242	243	125	381	236				
	66	242	243	125	381	236					
	242	243	125	381	236						
	243	125	381	236							
	125	381	236								
	381	236									
DOWNGRADIENT	236										
	Total Possible	1	3	4	3	2	2	1	2	1	19
	# Excluded	0	1	3	2	0	1	0	1	1	9
	# Retained	1	2	1	1	2	1	1	1	0	10
🟨	=	delta 13C upgradient is equal to delta 13C downgradient									
🟩	=	Screens, concentrations, delta 13C concentrations & C/Co values ok, Apply Decision Rules 4,5,6.									
▨	=	Excluded from further evaluation - downgradient screen in higher RGA interval than upgradient screen									

Isotopic enrichment factor (epsilon; ε) data for aerobic biodegradation of TCE (Appendix 3B) were obtained from published data in "*Stable Carbon Isotope Fractionation during Aerobic Biodegradation of Chlorinated Ethenes*" (Chu et al., 2005). The published data were statistically evaluated to provide the 90% one-tailed confidence interval value on epsilon and the 95% one-tailed confidence interval value on epsilon which were calculated to be -1.4 and -1.68, respectively.

Stable-carbon isotope ratios were evaluated by application of Decision Rule 4, Decision Rule 5, and Decision Rule 6. Decision Rule 4 evaluates whether removal expected from SCIRs is greater than the removal calculated from TCE/^{99}Tc concentration data and whether removal based on SCIR is plausible based on the variation in field-scale removal rates when the SCIR removal is less than that predicted by TCE/^{99}Tc concentration data. Decision Rule 5 evaluates whether the removal expected from the SCIR is too little to make aerobic biodegradation a plausible explanation for the change in TCE concentrations based on variation in removal rates at field scale. Decision Rule 6 evaluates whether the removal based on SCIR is significant, greater than 10 per cent, of the removal predicted from the TCE/^{99}Tc concentration data

Excel spreadsheets were developed to accomplish the data reduction and evaluations identified in SCI Steps 1-8 above. For each well pair retained for evaluation, three (3) calculations were made utilizing TCE stable-carbon enrichment factors (ϵ) of: 1) -1.1 from published data (Chu et al., 2005); 2) -1.4, the 90% one-tailed confidence interval on ϵ value from the reworked data set, and 3) -1.68, the 95% one-tailed confidence interval on ϵ value from the statistical evaluation of the published data set.

Data and calculations for each retained well pair are provided in Tables 27a, 27b and 27c. Table 27a contains the data, ϵ statistics, and concentration data statistics for the published data set (Chu et al., 2005) which utilized an ϵ value of -1.1.

Table 25. Well-pair Normalized Concentration Data Screening

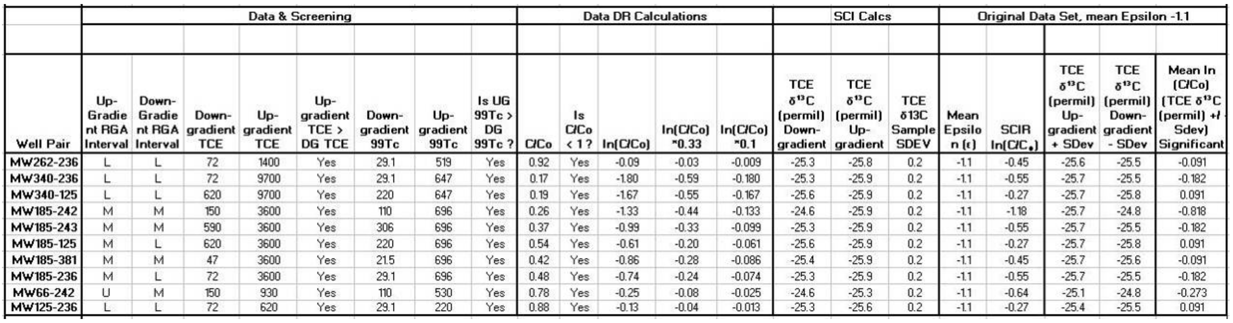
	Well Pair	C/Co
1	***MW168-381***	***47.70***
2	***MW168-236***	***59.23***
3	***MW262-125***	***1.04***
4	MW262-236	0.92
5	MW340-236	0.17
6	MW340-125	0.19
7	MW185-242	0.26
8	MW185-243	0.37
9	MW185-125	0.54
10	MW185-381	0.42
11	MW185-236	0.48
12	MW66-242	0.78
13	***MW66-125***	***1.61***
14	***MW66-381***	***1.25***
15	***MW242-236***	***11.48***
16	***MW242-381***	***10.14***
17	***MW243-236***	***1.28***
18	***MW243-381***	***1.13***
19	MW125-236	0.88

(Italicized = well pairs and data with C/C0 > 0)

Table 26. Well-pairs Retained for Evaluation through SCI Decision Rules.

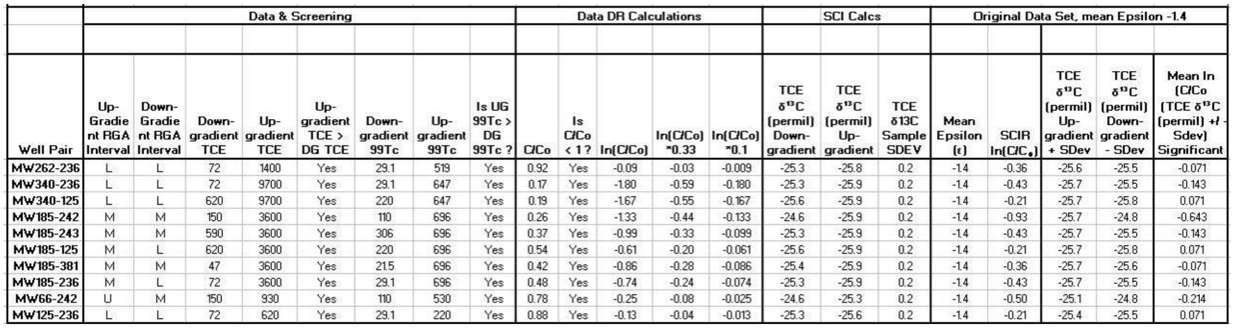
	Well Pair	C/Co
1	MW262-236	0.92
2	MW340-236	0.17
3	MW340-125	0.19
4	MW185-242	0.26
5	MW185-243	0.37
6	MW185-125	0.54
7	MW185-381	0.42
8	MW185-236	0.48
9	MW66-242	0.78
10	MW125-236	0.88
11	MW381-340	0.15
12	MW381-262	0.81

Table 27a. SCI Data, Data Reduction, and Evaluation for Well Pair Data with Published ϵ Value of -1.1.



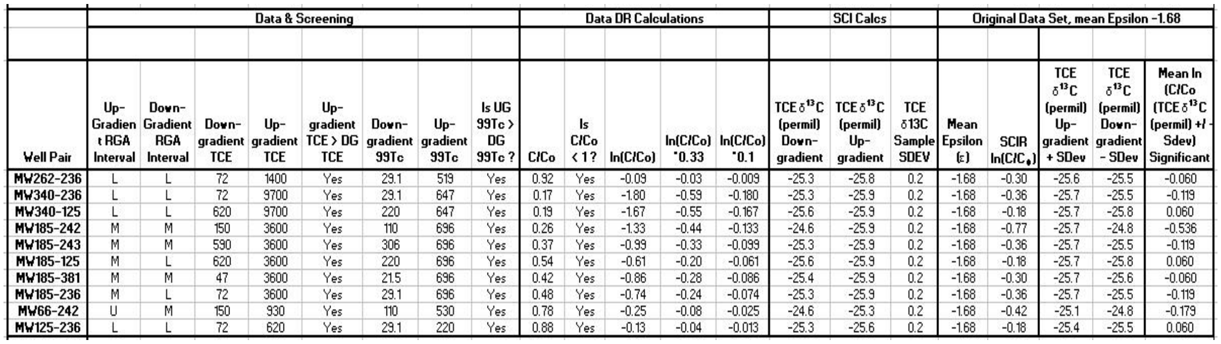
	Data & Screening								Data DR Calculations					SCI Calcs			Original Data Set, mean Epsilon -1.1				
Well Pair	Up-Gradient RGA Interval	Down-Gradient RGA Interval	Down-gradient TCE	Up-gradient TCE	Up-gradient TCE > DG TCE	Down-gradient 99Tc	Up-gradient 99Tc	Is UG 99Tc > DG 99Tc ?	C/Co	Is C/Co < 1 ?	ln(C/Co)	ln(C/Co) *0.33	ln(C/Co) *0.1	TCE $\delta^{13}C$ (permil) Down-gradient	TCE $\delta^{13}C$ (permil) Up-gradient	TCE δ13C Sample SDEV	Mean Epsilon (ε)	SCIR $\ln(C/C_0)$	TCE $\delta^{13}C$ (permil) Up-gradient + SDev	TCE $\delta^{13}C$ (permil) Down-gradient - SDev	Mean ln (C/Co) (TCE $\delta^{13}C$ (permil) +/- Sdev) Significant
MW262-236	L	L	72	1400	Yes	29.1	519	Yes	0.92	Yes	-0.09	-0.03	-0.009	-25.3	-25.8	0.2	-1.1	-0.45	-25.6	-25.5	-0.091
MW340-236	L	L	72	9700	Yes	29.1	647	Yes	0.17	Yes	-1.80	-0.59	-0.180	-25.3	-25.9	0.2	-1.1	-0.55	-25.7	-25.5	-0.182
MW340-125	L	L	620	9700	Yes	220	647	Yes	0.19	Yes	-1.67	-0.55	-0.167	-25.6	-25.9	0.2	-1.1	-0.27	-25.7	-25.8	0.091
MW185-242	M	M	150	3600	Yes	110	696	Yes	0.26	Yes	-1.33	-0.44	-0.133	-24.6	-25.9	0.2	-1.1	-1.18	-25.7	-24.8	-0.818
MW185-243	M	M	590	3600	Yes	306	696	Yes	0.37	Yes	-0.99	-0.33	-0.099	-25.3	-25.9	0.2	-1.1	-0.55	-25.7	-25.5	-0.182
MW185-125	M	L	620	3600	Yes	220	696	Yes	0.54	Yes	-0.61	-0.20	-0.061	-25.6	-25.9	0.2	-1.1	-0.27	-25.7	-25.8	0.091
MW185-381	M	M	47	3600	Yes	21.5	696	Yes	0.42	Yes	-0.86	-0.28	-0.086	-25.4	-25.9	0.2	-1.1	-0.45	-25.7	-25.6	-0.091
MW185-236	M	L	72	3600	Yes	29.1	696	Yes	0.48	Yes	-0.74	-0.24	-0.074	-25.3	-25.9	0.2	-1.1	-0.55	-25.7	-25.5	-0.182
MW66-242	U	M	150	930	Yes	110	530	Yes	0.78	Yes	-0.25	-0.08	-0.025	-24.6	-25.3	0.2	-1.1	-0.64	-25.1	-24.8	-0.273
MW125-236	L	L	72	620	Yes	29.1	220	Yes	0.88	Yes	-0.13	-0.04	-0.013	-25.3	-25.6	0.2	-1.1	-0.27	-25.4	-25.5	0.091

Table 27b. SCI Data, Data Reduction, and Evaluation for Well pair Data with Mean ϵ 90% Upper Confidence Interval Value of -1.4.



	Data & Screening								Data DR Calculations					SCI Calcs			Original Data Set, mean Epsilon -1.4				
Well Pair	Up-Gradient RGA Interval	Down-Gradient RGA Interval	Down-gradient TCE	Up-gradient TCE	Up-gradient TCE > DG TCE	Down-gradient 99Tc	Up-gradient 99Tc	Is UG 99Tc > DG 99Tc ?	C/Co	Is C/Co < 1 ?	ln(C/Co)	ln(C/Co) *0.33	ln(C/Co) *0.1	TCE $\delta^{13}C$ (permil) Down-gradient	TCE $\delta^{13}C$ (permil) Up-gradient	TCE δ13C Sample SDEV	Mean Epsilon (ε)	SCIR $\ln(C/C_0)$	TCE $\delta^{13}C$ (permil) Up-gradient + SDev	TCE $\delta^{13}C$ (permil) Down-gradient - SDev	Mean ln (C/Co (TCE $\delta^{13}C$ (permil) +/- Sdev) Significant
MW262-236	L	L	72	1400	Yes	29.1	519	Yes	0.92	Yes	-0.09	-0.03	-0.009	-25.3	-25.8	0.2	-1.4	-0.36	-25.6	-25.5	-0.071
MW340-236	L	L	72	9700	Yes	29.1	647	Yes	0.17	Yes	-1.80	-0.59	-0.180	-25.3	-25.9	0.2	-1.4	-0.43	-25.7	-25.5	-0.143
MW340-125	L	L	620	9700	Yes	220	647	Yes	0.19	Yes	-1.67	-0.55	-0.167	-25.6	-25.9	0.2	-1.4	-0.21	-25.7	-25.8	0.071
MW185-242	M	M	150	3600	Yes	110	696	Yes	0.26	Yes	-1.33	-0.44	-0.133	-24.6	-25.9	0.2	-1.4	-0.93	-25.7	-24.8	-0.643
MW185-243	M	M	590	3600	Yes	306	696	Yes	0.37	Yes	-0.99	-0.33	-0.099	-25.3	-25.9	0.2	-1.4	-0.43	-25.7	-25.5	-0.143
MW185-125	M	L	620	3600	Yes	220	696	Yes	0.54	Yes	-0.61	-0.20	-0.061	-25.6	-25.9	0.2	-1.4	-0.21	-25.7	-25.8	0.071
MW185-381	M	M	47	3600	Yes	21.5	696	Yes	0.42	Yes	-0.86	-0.28	-0.086	-25.4	-25.9	0.2	-1.4	-0.36	-25.7	-25.6	-0.071
MW185-236	M	L	72	3600	Yes	29.1	696	Yes	0.48	Yes	-0.74	-0.24	-0.074	-25.3	-25.9	0.2	-1.4	-0.43	-25.7	-25.5	-0.143
MW66-242	U	M	150	930	Yes	110	530	Yes	0.78	Yes	-0.25	-0.08	-0.025	-24.6	-25.3	0.2	-1.4	-0.50	-25.1	-24.8	-0.214
MW125-236	L	L	72	620	Yes	29.1	220	Yes	0.88	Yes	-0.13	-0.04	-0.013	-25.3	-25.6	0.2	-1.4	-0.21	-25.4	-25.5	0.071

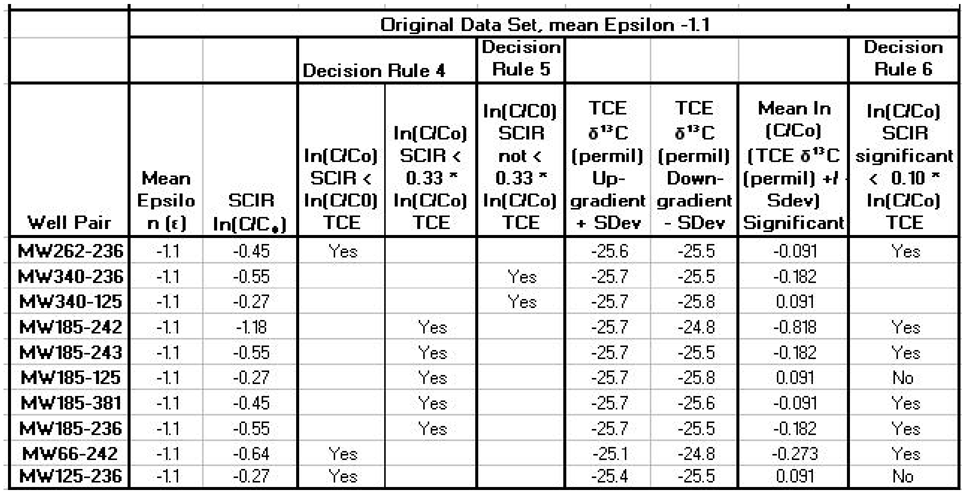
Table 27c. SCI Data, Data Reduction, and Evaluation for Well pair **Data with Mean ϵ 95% Upper** Confidence Interval Value of -1.68.



	Data & Screening								Data DR Calculations					SCI Calcs			Original Data Set, mean Epsilon -1.68				
Well Pair	Up-Gradient RGA Interval	Down-Gradient RGA Interval	Down-gradient TCE	Up-gradient TCE	Up-gradient TCE > DG TCE	Down-gradient 99Tc	Up-gradient 99Tc	Is UG 99Tc > DG 99Tc ?	C/Co	Is C/Co < 1 ?	ln(C/Co)	ln(C/Co) *0.33	ln(C/Co) *0.1	TCE $\delta^{13}C$ (permil) Down-gradient	TCE $\delta^{13}C$ (permil) Up-gradient	TCE δ13C Sample SDEV	Mean Epsilon (ε)	SCIR $\ln(C/C_0)$	TCE $\delta^{13}C$ (permil) Up-gradient + SDev	TCE $\delta^{13}C$ (permil) Down-gradient - SDev	Mean ln (C/Co (TCE $\delta^{13}C$ (permil) +/- Sdev) Significant
MW262-236	L	L	72	1400	Yes	29.1	519	Yes	0.92	Yes	-0.09	-0.03	-0.009	-25.3	-25.8	0.2	-1.68	-0.30	-25.6	-25.5	-0.060
MW340-236	L	L	72	9700	Yes	29.1	647	Yes	0.17	Yes	-1.80	-0.59	-0.180	-25.3	-25.9	0.2	-1.68	-0.36	-25.7	-25.5	-0.119
MW340-125	L	L	620	9700	Yes	220	647	Yes	0.19	Yes	-1.67	-0.55	-0.167	-25.6	-25.9	0.2	-1.68	-0.18	-25.7	-25.8	0.060
MW185-242	M	M	150	3600	Yes	110	696	Yes	0.26	Yes	-1.33	-0.44	-0.133	-24.6	-25.9	0.2	-1.68	-0.77	-25.7	-24.8	-0.536
MW185-243	M	M	590	3600	Yes	306	696	Yes	0.37	Yes	-0.99	-0.33	-0.099	-25.3	-25.9	0.2	-1.68	-0.36	-25.7	-25.5	-0.119
MW185-125	M	L	620	3600	Yes	220	696	Yes	0.54	Yes	-0.61	-0.20	-0.061	-25.6	-25.9	0.2	-1.68	-0.18	-25.7	-25.8	0.060
MW185-381	M	M	47	3600	Yes	21.5	696	Yes	0.42	Yes	-0.86	-0.28	-0.086	-25.4	-25.9	0.2	-1.68	-0.30	-25.7	-25.6	-0.060
MW185-236	M	L	72	3600	Yes	29.1	696	Yes	0.48	Yes	-0.74	-0.24	-0.074	-25.3	-25.9	0.2	-1.68	-0.36	-25.7	-25.5	-0.119
MW66-242	U	M	150	930	Yes	110	530	Yes	0.78	Yes	-0.25	-0.08	-0.025	-24.6	-25.3	0.2	-1.68	-0.42	-25.1	-24.8	-0.179
MW125-236	L	L	72	620	Yes	29.1	220	Yes	0.88	Yes	-0.13	-0.04	-0.013	-25.3	-25.6	0.2	-1.68	-0.18	-25.4	-25.5	0.060

Table 28 identifies the well-pair data comparisons that support the occurrence of aerobic biodegradation based on the published data set with a mean epsilon value of -1.1. Eight of the ten well pairs satisfy the criteria in Decision Rules 4 and indicate that TCE concentrations are being impacted by microbial degradation processes. Based on Decision Rule 6, the rate of removal was determined to be significant in six (6) of the eight (8) locations.

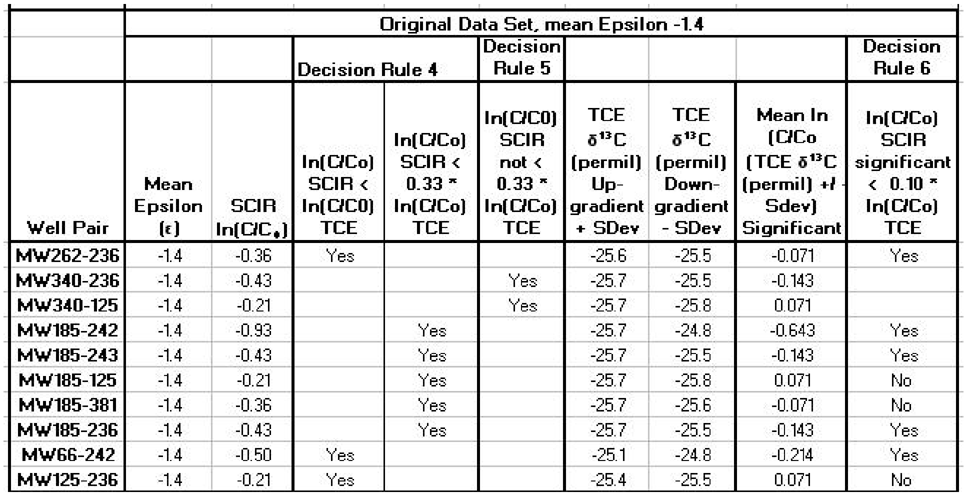
Table 28. Summary of SCI Published Data Set Decision Rule Evaluation (epsilon = -1.1)



	Original Data Set, mean Epsilon -1.1								
			Decision Rule 4		Decision Rule 5				Decision Rule 6
Well Pair	Mean Epsilon (ε)	SCIR ln(C/C$_0$)	ln(C/Co) SCIR < ln(C/C0) TCE	ln(C/Co) SCIR < 0.33 * ln(C/Co) TCE	ln(C/C0) SCIR not < 0.33 * ln(C/Co) TCE	TCE δ^{13}C (permil) Up-gradient + SDev	TCE δ^{13}C (permil) Down-gradient - SDev	Mean ln (C/Co) (TCE δ^{13}C (permil) +/- Sdev) Significant	ln(C/Co) SCIR significant < 0.10 * ln(C/Co) TCE
MW262-236	-1.1	-0.45	Yes			-25.6	-25.5	-0.091	Yes
MW340-236	-1.1	-0.55			Yes	-25.7	-25.5	-0.182	
MW340-125	-1.1	-0.27			Yes	-25.7	-25.8	0.091	
MW185-242	-1.1	-1.18		Yes		-25.7	-24.8	-0.818	Yes
MW185-243	-1.1	-0.55		Yes		-25.7	-25.5	-0.182	Yes
MW185-125	-1.1	-0.27		Yes		-25.7	-25.8	0.091	No
MW185-381	-1.1	-0.45		Yes		-25.7	-25.6	-0.091	Yes
MW185-236	-1.1	-0.55		Yes		-25.7	-25.5	-0.182	Yes
MW66-242	-1.1	-0.64	Yes			-25.1	-24.8	-0.273	Yes
MW125-236	-1.1	-0.27	Yes			-25.4	-25.5	0.091	No

Table 29 identifies the well-pair data comparisons that support the occurrence of aerobic biodegradation based on the statistical evaluation of the published data set and a calculated mean epsilon value of -1.4. Eight of the ten well pairs satisfy the criteria in Decision Rules 4 and indicate that TCE concentrations are being impacted by microbial degradation processes. Based on Decision Rule 6, the rate of removal was determined to be significant in five (5) of the eight (8) locations.

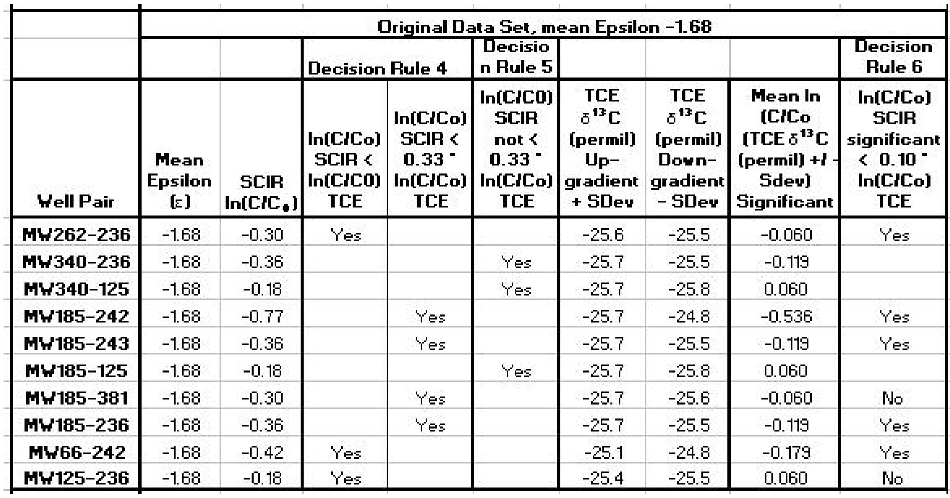
Table 29. Summary of Calculations Supporting SCI Decision Rules (90% One-tailed Confidence Interval on Epsilon Value of -1.4 from Statistical Evaluation of Published Data Set).



	Original Data Set, mean Epsilon -1.4								
			Decision Rule 4		Decision Rule 5				Decision Rule 6
Well Pair	Mean Epsilon (ε)	SCIR ln(C/C$_0$)	ln(C/Co) SCIR < ln(C/C0) TCE	ln(C/Co) SCIR < 0.33 * ln(C/Co) TCE	ln(C/C0) SCIR not < 0.33 * ln(C/Co) TCE	TCE δ^{13}C (permil) Up-gradient + SDev	TCE δ^{13}C (permil) Down-gradient - SDev	Mean ln (C/Co (TCE δ^{13}C (permil) +/- Sdev) Significant	ln(C/Co) SCIR significant < 0.10 * ln(C/Co) TCE
MW262-236	-1.4	-0.36	Yes			-25.6	-25.5	-0.071	Yes
MW340-236	-1.4	-0.43			Yes	-25.7	-25.5	-0.143	
MW340-125	-1.4	-0.21			Yes	-25.7	-25.8	0.071	
MW185-242	-1.4	-0.93		Yes		-25.7	-24.8	-0.643	Yes
MW185-243	-1.4	-0.43		Yes		-25.7	-25.5	-0.143	Yes
MW185-125	-1.4	-0.21		Yes		-25.7	-25.8	0.071	No
MW185-381	-1.4	-0.36		Yes		-25.7	-25.6	-0.071	No
MW185-236	-1.4	-0.43		Yes		-25.7	-25.5	-0.143	Yes
MW66-242	-1.4	-0.50	Yes			-25.1	-24.8	-0.214	Yes
MW125-236	-1.4	-0.21	Yes			-25.4	-25.5	0.071	No

Table 30 identifies the well-pair data comparisons that support the occurrence of aerobic biodegradation based on the rework of published data using the 95% one-tailed confidence interval value of epsilon, -1.68. Seven (7) of the ten well pairs satisfy the criteria in Decision Rules 4 and indicate that TCE concentrations are being impacted by microbial degradation processes. Based on Decision Rule 6, the rate of removal was determined to be significant in five (5) of the seven (7) locations.

Table 30. of Calculations Supporting SCI Decision Rules (95% One-tailed Confidence Interval on Epsilon Value of -1.68 from Statistical Evaluation of Published Data Set).



	Original Data Set, mean Epsilon -1.68								
			Decision Rule 4		Decision Rule 5				Decision Rule 6
Well Pair	Mean Epsilon (ε)	SCIR $\ln(C/C_0)$	ln(C/Co) SCIR < ln(C/C0) TCE	ln(C/Co) SCIR < 0.33 ˉ ln(C/Co) TCE	ln(C/C0) SCIR not < 0.33 ˉ ln(C/Co) TCE	TCE $\delta^{13}C$ (permil) Up-gradient + SDev	TCE $\delta^{13}C$ (permil) Down-gradient - SDev	Mean ln (C/Co (TCE $\delta^{13}C$ (permil) +/ - Sdev) Significant	ln(C/Co) SCIR significant < 0.10 ˉ ln(C/Co) TCE
MW262-236	-1.68	-0.30	Yes			-25.6	-25.5	-0.060	Yes
MW340-236	-1.68	-0.36			Yes	-25.7	-25.5	-0.119	
MW340-125	-1.68	-0.18			Yes	-25.7	-25.8	0.060	
MW185-242	-1.68	-0.77		Yes		-25.7	-24.8	-0.536	Yes
MW185-243	-1.68	-0.36		Yes		-25.7	-25.5	-0.119	Yes
MW185-125	-1.68	-0.18			Yes	-25.7	-25.8	0.060	
MW185-381	-1.68	-0.30		Yes		-25.7	-25.6	-0.060	No
MW185-236	-1.68	-0.36		Yes		-25.7	-25.5	-0.119	Yes
MW66-242	-1.68	-0.42	Yes			-25.1	-24.8	-0.179	Yes
MW125-236	-1.68	-0.18	Yes			-25.4	-25.5	0.060	No

7.3. Geochemical Testing and Data Evaluations Results

A summary of key project-specific geochemical results is presented in Tables 31 & 32. Complete datasets for the two project-specific sampling events are provided in Appendix 2A. Spatial plots of key geochemical parameters for study area wells from the May, 2007 EAP sampling event and December 2007 SCI sampling event are provided in Appendix 2B. Temporal graphs of TCE, ^{99}Tc, dissolved oxygen, conductivity, and pH for the study wells are provided in Appendix 2C.

In addition to project-specific geochemical results evaluation, several other data sets were evaluated relative to the presence/absence and spatial/temporal trends of analytes that could impact or that indicate the presence of degradation processes in the RGA: 1) A master summary dataset of historical site-wide groundwater analytical results was extracted from the PGDP Data Warehouse to evaluate the presence and/or absence of geochemical conditions related to biotic and abiotic degradation processes (Table 33). The dataset was extracted as “all groundwater locations sampled for TCE”. All wells that could be identified in the RGA were extracted for use; 2) URGA, MRGA, and LRGA specific monitoring well data was extracted from the “all groundwater locations sampled for TCE” data set based on the wells utilized in the most recent PGDP annual-groundwater-mapping document “*Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2005*” (PRS, 2007).

UCRS, Eocene Sand and Terrace Gravel groundwater data were extracted from the master summary dataset and temporal and spatial evaluations were conducted as necessary for discussion of RGA groundwater conditions. UCRS, RGA, and McNairy soil boring data were also extracted as necessary for discussion of RGA groundwater conditions related to degradation processes. Reference is provided to specific data sets and relevant spatial and temporal plots throughout the text.

7.3.1. Geochemical Results

The project-specific data set consists of field measurements and analytical results from samples collected during the EAP and SCI field-sampling activities. Observations from evaluation of project-specific analytical data, temporal trends of select analytes at each sampling location and spatial plots of project-specific data are noted by analyte in the text below.

Results related to historical site-wide geochemical data, the RGA-TCE sampling locations and the URGA, MRGA, and LRGA annual groundwater mapping locations follow the project-specific text. RGA-TCE sample locations are identified in Appendix 2E, Figure 2E.1. The annual monitoring locations in the upper, middle, and lower RGA utilized for the most recent interpretations of TCE plume extents are identified in Appendix 2E; Figures 2D.1-2D.3. Specific URGA, MRGA, and LRGA sampling and data locations are provided with spatial and temporal plots for select analytes (Appendix 2F).

TCE was evaluated because it is the primary groundwater contaminant from historical PGDP industrial operations.

Concentrations in study area monitoring wells within the NWP ranged from method detection limits of 1 μg/L to 9700 μg/L. Concentrations in the control wells outside of the plume, monitoring wells 194 and 197, ranged from 1 to 3 μg/L indicating that a larger footprint of TCE contamination may exist in the NWP RGA than the footprint depicted by the regulatory threshold, 5 μg/L. The highest project-specific TCE concentrations were in MW's 185 (MRGA), 262 (LRGA) and 340 (LRGA), all located in close proximity to one another along the core of the NWP within the PGDP security fence.

Technetium-99 was evaluated because it is a TCE co-contaminant in the NWP, SWP, and on-site portions of the NEP at the PGDP.

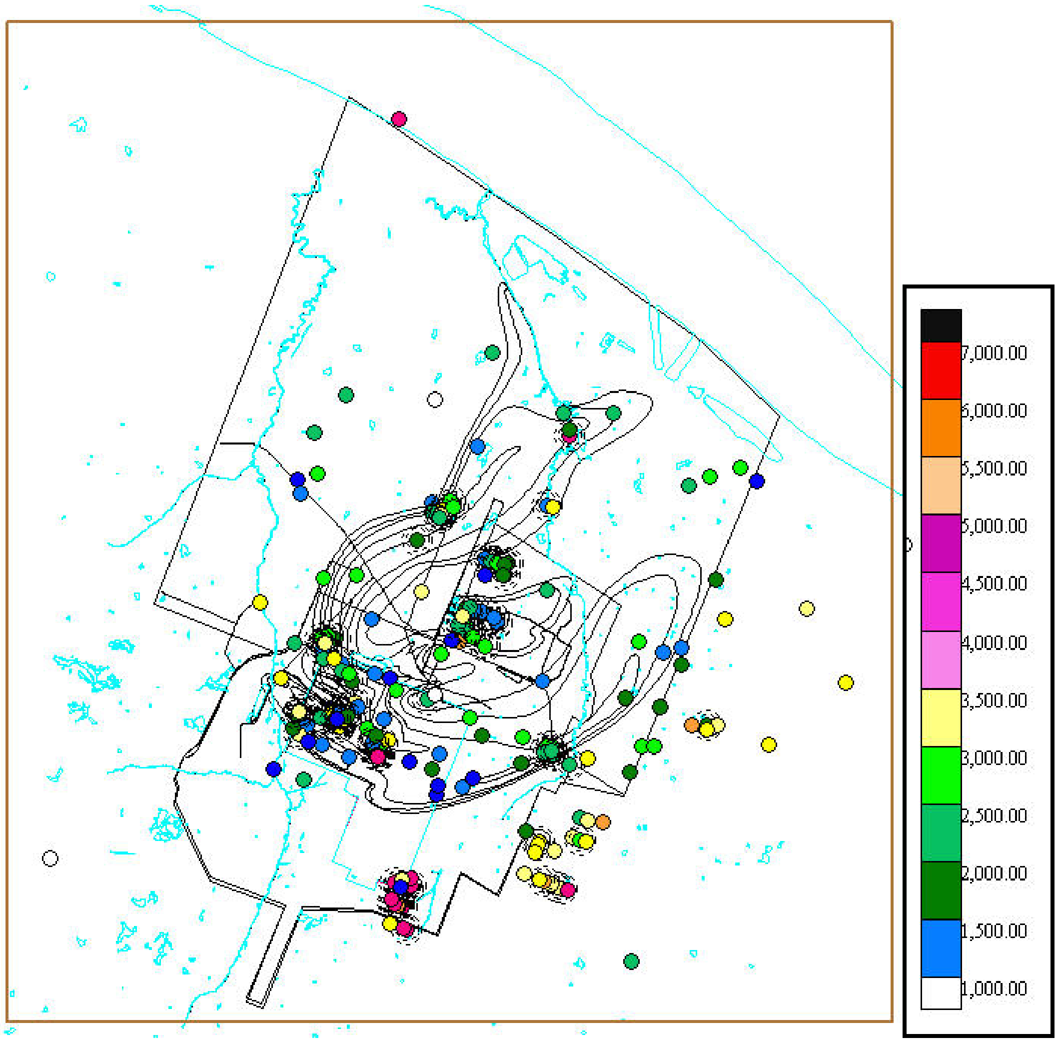
Technetium-99 was detected in all of the study area wells within the NWP at concentrations ranging from 21 to 2400 pCi/L. Technetium-99 was not detected in control wells MW 194 and MW 197 outside of the plume. Historical ^{99}Tc data were not evaluated for this study.

Dissolved Oxygen (DO) was evaluated because it is the primary substrate that allows aerobic biodegradation to occur when it is present in concentrations greater than 0.5 mg/L and appropriate redox conditions. Decreasing dissolved oxygen concentration trends in groundwater may be indicative of the occurrence of aerobic biodegradation.

DO concentrations in project wells ranged from 0.6 to 6.1 mg/L (Tables 27 and 28). Dissolved oxygen concentrations in MW 197 (URGA outside of the plume) were less than 1.0 mg/L. Dissolved oxygen concentrations less than 1.0 mg/L were also identified in project sampling locations MW 262 (LRGA downgradient of C-400 source area) and MW's 242 and 243 (MRGA wells in the NWP south well field). The low DO concentrations noted in the EAP and SCI samples indicate that aerobic groundwater conditions do not exist at MW 197.

Dissolved oxygen concentration trends in project wells are provided graphically in Appendix 2C. In general, DO concentrations exhibit slightly increasing trends in MW's with decreasing TCE concentration trends (MW's 236, 243, 381, 242, 262). MW 125 exhibits decreasing DO concentrations in conjunction with increasing TCE concentrations. Dissolved oxygen concentrations generally decrease temporarily following well maintenance activities with the exception of MW 262 as illustrated in the temporal trend graphs in Appendix 2C.

Spatial DO plots were produced for all RGA-TCE wells sampled from 1988 through 2006 and the data set used for this exercise includes residential monitoring wells (Appendix E, Figure 2E.1). The all RGA-TCE sampling location data set (Figure 21) does not discriminate between URGA, MRGA, and LRGA horizons. RGA-TCE sample location DO spatial plots are provided in Appendix E, Figures 2E.8 through 2E.13. As the plots indicate, DO is present throughout the RGA at on-site and off-site monitoring locations (1988 through 2006). Plots of average, minimum and maximum detects at each location provide an indication of the variability in DO concentrations.



(Outside contour = 5 ppb TCE)

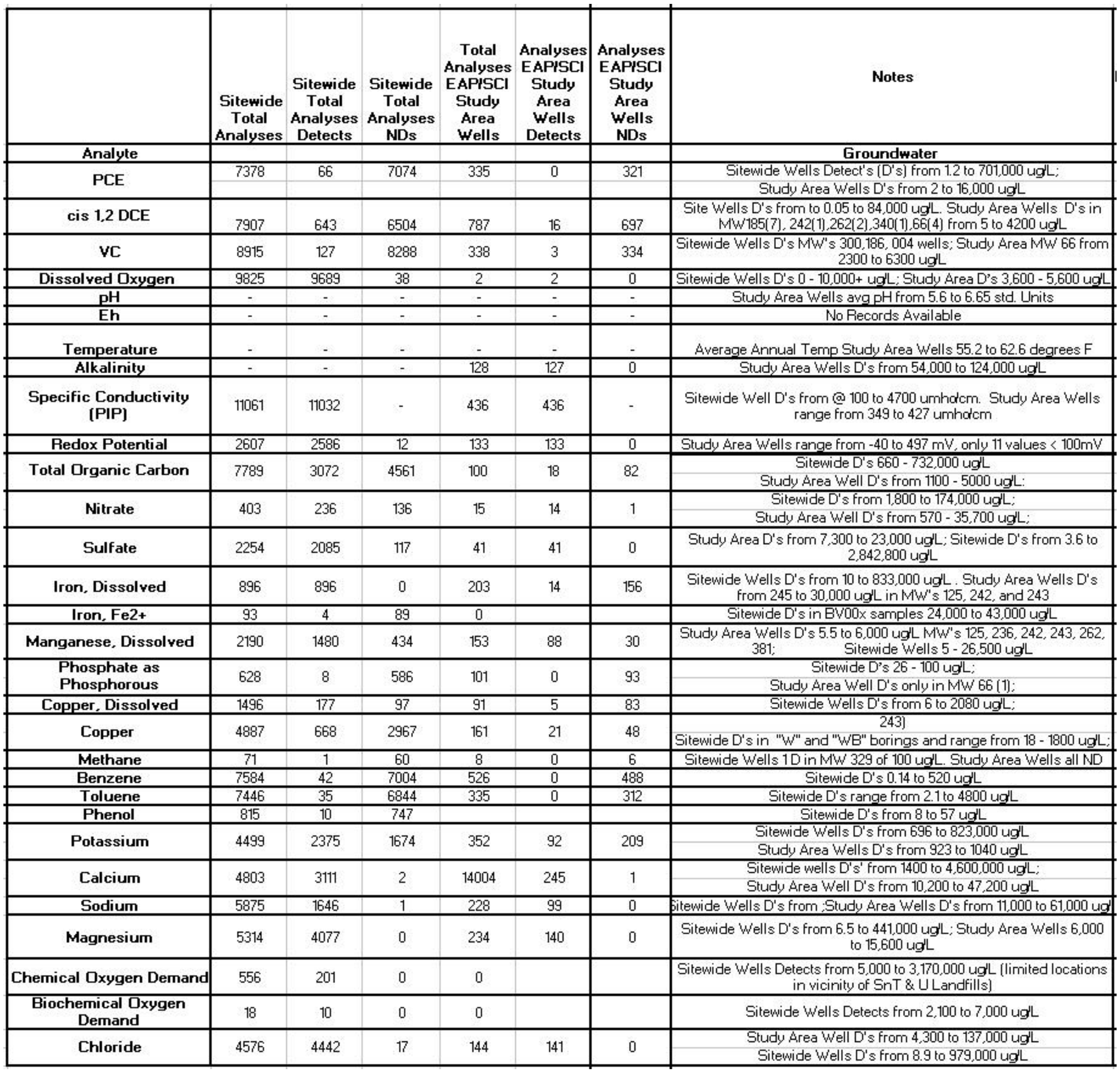
Figure 21. Distribution of average dissolved oxygen in RGA sampling locations 1996 – 2006 (ug/L).

Evaluation of dissolved oxygen data (Table 34) from annual-groundwater-mapping locations indicates that the MRGA has the highest mean DO concentration (3598 μg/L) over the vertical profile of the RGA, followed by the URGA (3105 μg/L). The lowest average DO concentration is in the LRGA, 2754 μg/L. The LRGA's average DO concentration being less than the MRGA and URGA average DO concentrations is expected. However, the fact that MRGA average DO concentration exceeds the average URGA DO concentration would not be expected based on the assumption of relatively uniform groundwater recharge and similar biogeochemical vadose zone processes across the PGDP.

Mean DO concentrations calculated from 1996 through 2006 data were evaluated for each annual-groundwater-mapping well. Tabulation of the DO concentrations for each monitoring location indicates significant spatial variability of DO concentrations throughout the URGA (Table 35), MRGA *(Table 36)*, and LRGA *(Table 37)*. Six monitoring locations in the URGA have average DO concentrations less than 1 mg/L (1000 μg/L), MW 20, MW 366, MW 344, MW 384, MW 256 and MW 363. No locations in the MRGA have average DO concentrations less than 1 mg/L. LRGA locations MW 226, MW 255, MW 364, and MW 256 each have average DO concentrations less than 1 mg/L.

The highest average DO concentration at any given RGA monitoring location, 6385 μg/L, is in URGA MW 66 located in the northwest corner of the industrial area and in the NWP. The lowest average DO concentration, 770 μg/L are found in URGA MW 20 and LRGA MW 226. MW DO concentrations in UCRS wells overlying the RGA range from 30 to 9,270 μg/L and a similar range of DO values exists in groundwater samples from the Eocene Sands and Terrace Gravel that occur south and upgradient of the southern extent of the RGA.

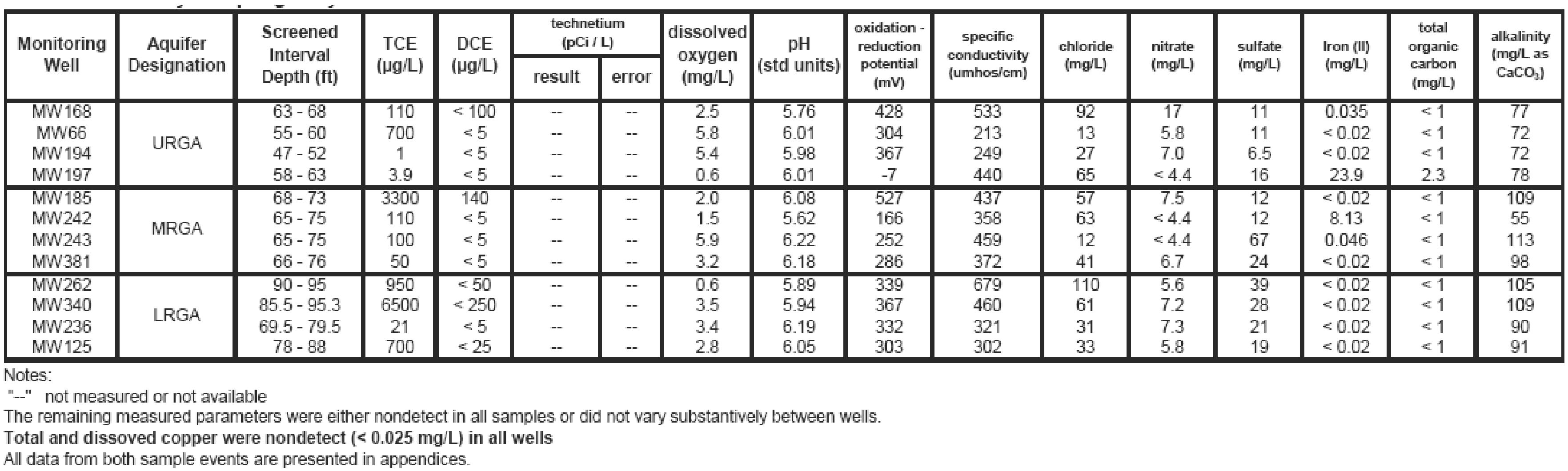
Table 33. Summary of historical PGDP monitoring well and study area monitoring well geochemical data.



	Sitewide Total Analyses	Sitewide Total Analyses Detects	Sitewide Total Analyses NDs	Total Analyses EAP/SCI Study Area Wells	Analyses EAP/SCI Study Area Wells Detects	Analyses EAP/SCI Study Area Wells NDs	Notes
Analyte							**Groundwater**
PCE	7378	66	7074	335	0	321	Sitewide Wells Detect's (D's) from 1.2 to 701,000 ug/L; Study Area Wells D's from 2 to 16,000 ug/L
cis 1,2 DCE	7907	643	6504	787	16	697	Site Wells D's from to 0.05 to 84,000 ug/L. Study Area Wells D's in MW185(7), 242(1),262(2),340(1),66(4) from 5 to 4200 ug/L
VC	8915	127	8288	338	3	334	Sitewide Wells D's MW's 300,186, 004 wells; Study Area MW 66 from 2300 to 6300 ug/L
Dissolved Oxygen	9825	9689	38	2	2	0	Sitewide Wells D's 0 - 10,000+ ug/L; Study Area D's 3,600 - 5,600 ug/L
pH	-	-	-	-	-	-	Study Area Wells avg pH from 5.6 to 6.65 std. Units
Eh	-	-	-	-	-	-	No Records Available
Temperature	-	-	-	-	-	-	Average Annual Temp Study Area Wells 55.2 to 62.6 degrees F
Alkalinity	-	-	-	128	127	0	Study Area Wells D's from 54,000 to 124,000 ug/L
Specific Conductivity (PIP)	11061	11032	-	436	436	-	Sitewide Well D's from @ 100 to 4700 umho/cm. Study Area Wells range from 349 to 427 umho/cm
Redox Potential	2607	2586	12	133	133	0	Study Area Wells range from -40 to 497 mV, only 11 values < 100mV
Total Organic Carbon	7789	3072	4561	100	18	82	Sitewide D's 660 - 732,000 ug/L Study Area Well D's from 1100 - 5000 ug/L:
Nitrate	403	236	136	15	14	1	Sitewide D's from 1,800 to 174,000 ug/L; Study Area Well D's from 570 - 35,700 ug/L;
Sulfate	2254	2085	117	41	41	0	Study Area D's from 7,300 to 23,000 ug/L; Sitewide D's from 3.6 to 2,842,800 ug/L
Iron, Dissolved	896	896	0	203	14	156	Sitewide Wells D's from 10 to 833,000 ug/L . Study Area Wells D's from 245 to 30,000 ug/L in MW's 125, 242, and 243
Iron, Fe2+	93	4	89	0			Sitewide D's in BV00x samples 24,000 to 43,000 ug/L
Manganese, Dissolved	2190	1480	434	153	88	30	Study Area Wells D's 5.5 to 6,000 ug/L MW's 125, 236, 242, 243, 262, 381; Sitewide Wells 5 - 26,500 ug/L
Phosphate as Phosphorous	628	8	586	101	0	93	Sitewide D's 26 - 100 ug/L; Study Area Well D's only in MW 66 (1);
Copper, Dissolved	1496	177	97	91	5	83	Sitewide Wells D's from 6 to 2080 ug/L;
Copper	4887	668	2967	161	21	48	243) Sitewide D's in "W" and "WB" borings and range from 18 - 1800 ug/L;
Methane	71	1	60	8	0	6	Sitewide Wells 1 D in MW 329 of 100 ug/L. Study Area Wells all ND
Benzene	7584	42	7004	526	0	488	Sitewide D's 0.14 to 520 ug/L
Toluene	7446	35	6844	335	0	312	Sitewide D's range from 2.1 to 4800 ug/L
Phenol	815	10	747				Sitewide D's from 8 to 57 ug/L
Potassium	4499	2375	1674	352	92	209	Sitewide Wells D's from 696 to 823,000 ug/L Study Area Wells D's from 923 to 1040 ug/L
Calcium	4803	3111	2	14004	245	1	Sitewide wells D's' from 1400 to 4,600,000 ug/L; Study Area Well D's from 10,200 to 47,200 ug/L
Sodium	5875	1646	1	228	99	0	Sitewide Wells D's from ;Study Area Wells D's from 11,000 to 61,000 ug/
Magnesium	5314	4077	0	234	140	0	Sitewide Wells D's from 6.5 to 441,000 ug/L; Study Area Wells 6,000 to 15,600 ug/L
Chemical Oxygen Demand	556	201	0	0			Sitewide Wells Detects from 5,000 to 3,170,000 ug/L (limited locations in vicinity of SnT & U Landfills)
Biochemical Oxygen Demand	18	10	0	0			Sitewide Wells Detects from 2,100 to 7,000 ug/L
Chloride	4576	4442	17	144	141	0	Study Area Well D's from 4,300 to 137,000 ug/L Sitewide Wells D's from 8.9 to 979,000 ug/L

* Data from "all wells sampled for TCE" data set (1996 – 2006).

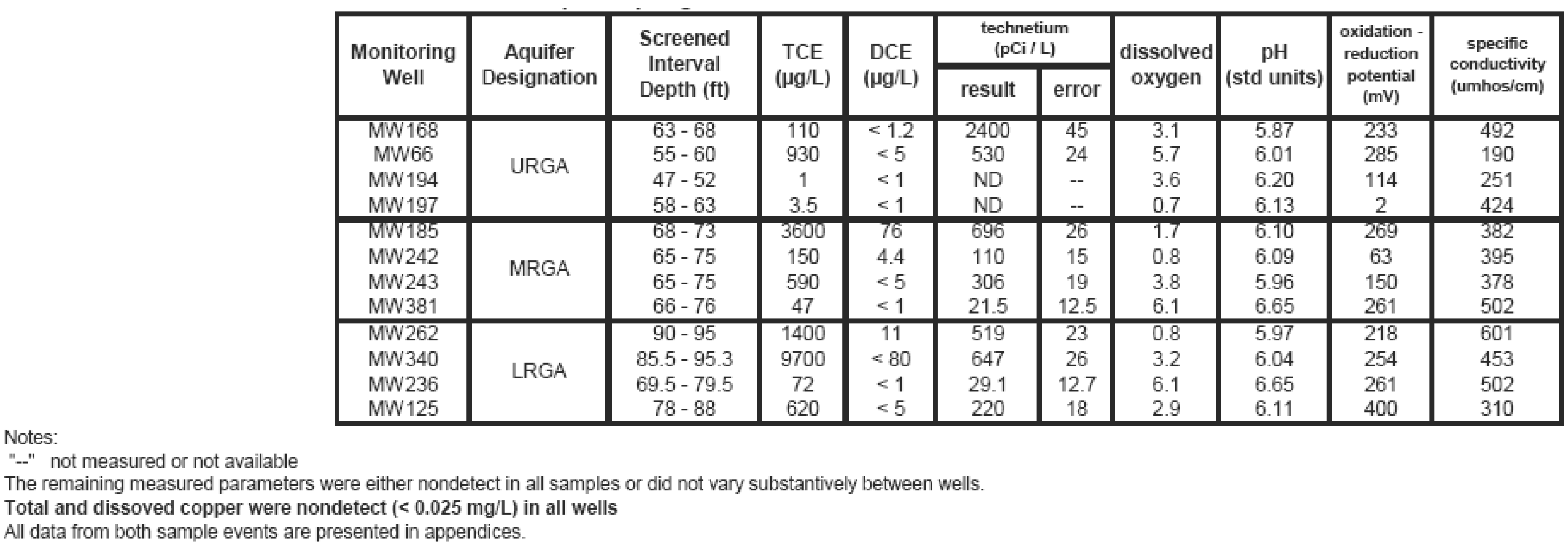
Table 31. Key geochemical results from the May 2007 EAP sampling event (SRNL, 2008).



Monitoring Well	Aquifer Designation	Screened Interval Depth (ft)	TCE (µg/L)	DCE (µg/L)	technetium (pCi / L)		dissolved oxygen (mg/L)	pH (std units)	oxidation - reduction potential (mV)	specific conductivity (umhos/cm)	chloride (mg/L)	nitrate (mg/L)	sulfate (mg/L)	Iron (II) (mg/L)	total organic carbon (mg/L)	alkalinity (mg/L as $CaCO_3$)
					result	error										
MW168	URGA	63 - 68	110	< 100	--	--	2.5	5.76	428	533	92	17	11	0.035	< 1	77
MW66		55 - 60	700	< 5	--	--	5.8	6.01	304	213	13	5.8	11	< 0.02	< 1	72
MW194		47 - 52	1	< 5	--	--	5.4	5.98	367	249	27	7.0	6.5	< 0.02	< 1	72
MW197		58 - 63	3.9	< 5	--	--	0.6	6.01	-7	440	65	< 4.4	16	23.9	2.3	78
MW185	MRGA	68 - 73	3300	140	--	--	2.0	6.08	527	437	57	7.5	12	< 0.02	< 1	109
MW242		65 - 75	110	< 5	--	--	1.5	5.62	166	358	63	< 4.4	12	8.13	< 1	55
MW243		65 - 75	100	< 5	--	--	5.9	6.22	252	459	12	< 4.4	67	0.046	< 1	113
MW381		66 - 76	50	< 5	--	--	3.2	6.18	286	372	41	6.7	24	< 0.02	< 1	98
MW262	LRGA	90 - 95	950	< 50	--	--	0.6	5.89	339	679	110	5.6	39	< 0.02	< 1	105
MW340		85.5 - 95.3	6500	< 250	--	--	3.5	5.94	367	460	61	7.2	28	< 0.02	< 1	109
MW236		69.5 - 79.5	21	< 5	--	--	3.4	6.19	332	321	31	7.3	21	< 0.02	< 1	90
MW125		78 - 88	700	< 25	--	--	2.8	6.05	303	302	33	5.8	19	< 0.02	< 1	91

Notes:
"--" not measured or not available
The remaining measured parameters were either nondetect in all samples or did not vary substantively between wells.
Total and dissoved copper were nondetect (< 0.025 mg/L) in all wells
All data from both sample events are presented in appendices.

Table 32. Key geochemical results from December 2007 SCI sampling event (SRNL, 2008).



Monitoring Well	Aquifer Designation	Screened Interval Depth (ft)	TCE (µg/L)	DCE (µg/L)	technetium (pCi / L)		dissolved oxygen	pH (std units)	oxidation - reduction potential (mV)	specific conductivity (umhos/cm)
					result	error				
MW168	URGA	63 - 68	110	< 1.2	2400	45	3.1	5.87	233	492
MW66		55 - 60	930	< 5	530	24	5.7	6.01	285	190
MW194		47 - 52	1	< 1	ND	--	3.6	6.20	114	251
MW197		58 - 63	3.5	< 1	ND	--	0.7	6.13	2	424
MW185	MRGA	68 - 73	3600	76	696	26	1.7	6.10	269	382
MW242		65 - 75	150	4.4	110	15	0.8	6.09	63	395
MW243		65 - 75	590	< 5	306	19	3.8	5.96	150	378
MW381		66 - 76	47	< 1	21.5	12.5	6.1	6.65	261	502
MW262	LRGA	90 - 95	1400	11	519	23	0.8	5.97	218	601
MW340		85.5 - 95.3	9700	< 80	647	26	3.2	6.04	254	453
MW236		69.5 - 79.5	72	< 1	29.1	12.7	6.1	6.65	261	502
MW125		78 - 88	620	< 5	220	18	2.9	6.11	400	310

Notes:
"--" not measured or not available
The remaining measured parameters were either nondetect in all samples or did not vary substantively between wells.
Total and dissoved copper were nondetect (< 0.025 mg/L) in all wells
All data from both sample events are presented in appendices.

Table 34. Groundwater Dissolved Oxygen distribution data summary from well monitored from annual groundwater mapping from 1996 – 2006 (μg/L).

* Data for URGA, MRGA, LR

Horizon	# Locat-ions	# Records	Maximum Record	Minimum Record	Unit Average	Average Maximum Location	Maximum Location	Average Minimum Location	Minimum Location
UCRS**	50	930	9270	30	3217	6433	MW166	331	MW138
ES & TG**	9	235	8450	40	1639	2132	MW196	987	MW301
URGA	29	1040	9450	50	3105	6385	MW66	772	MW20
MRGA	45	1476	9590	270	3598	5354	MW194	1451	MW93
LRGA	55	1621	9350	30	2816	5161	MW397	770	MW226

GA quarterly and mapping locations extracted from "all wells sampled for TCE" data set (1996 – 2006).

** Based on locations with greater than 2 measurements

Table 35. Average DO concentrations (μg/L) in URGA annual groundwater mapping wells (1996 – 2006)*.

Location	NEWCHEMICAL	Location Average	Location Minimum	Location Maximum	UNITS
MW20	Dissolved Oxygen	772	180	1790	ug/L
MW366	Dissolved Oxygen	788	60	2740	ug/L
MW344	Dissolved Oxygen	813	820	3450	ug/L
MW384	Dissolved Oxygen	921	290	1610	ug/L
MW156	Dissolved Oxygen	957	400	1730	ug/L
MW363	Dissolved Oxygen	999	140	1650	ug/L
MW173	Dissolved Oxygen	1141	240	2500	ug/L
MW206	Dissolved Oxygen	1186	500	3160	ug/L
MW360	Dissolved Oxygen	1353	200	4520	ug/L
MW197	Dissolved Oxygen	1532	510	4340	ug/L
MW372	Dissolved Oxygen	1566	50	3890	ug/L
MW369	Dissolved Oxygen	1808	680	5410	ug/L
MW329	Dissolved Oxygen	2111	880	4160	ug/L
MW205	Dissolved Oxygen	2134	990	4870	ug/L
MW223	Dissolved Oxygen	2194	1420	6050	ug/L
MW224	Dissolved Oxygen	2792	860	6260	ug/L
MW357	Dissolved Oxygen	2833	1120	5120	ug/L
MW222	Dissolved Oxygen	3068	470	8330	ug/L
MW165	Dissolved Oxygen	3323	2200	5230	ug/L
MW192	Dissolved Oxygen	3487	2060	7540	ug/L
MW227	Dissolved Oxygen	3627	1060	7770	ug/L
MW168	Dissolved Oxygen	3810	850	6960	ug/L
MW178	Dissolved Oxygen	3897	1540	5290	ug/L
MW387	Dissolved Oxygen	4066	1220	5300	ug/L
MW221	Dissolved Oxygen	4545	1310	8440	ug/L
MW220	Dissolved Oxygen	4772	940	8890	ug/L
MW63	Dissolved Oxygen	4835	2150	9450	ug/L
MW338	Dissolved Oxygen	5216	2360	6250	ug/L
MW149	Dissolved Oxygen	6284	5650	7180	ug/L
MW66	Dissolved Oxygen	6385	2150	9200	ug/L

*Data for quarterly/annual mapping locations only extracted from all wells sampled for TCE data set (1996 – 2006)

Table 36. Average DO concentrations (μg/L) for MRGA annual groundwater mapping wells (1996 – 2006) *

Location	NEWCHEMICAL	Location Average	Location Minimum	Location Maximum	UNITS
MW93	Dissolved Oxygen	1451	600	2260	ug/L
MW84	Dissolved Oxygen	1480	860	2070	ug/L
MW193	Dissolved Oxygen	1550	650	2590	ug/L
MW242	Dissolved Oxygen	1630	690	4480	ug/L
MW330	Dissolved Oxygen	1653	870	3720	ug/L
MW245	Dissolved Oxygen	1664	670	4310	ug/L
MW90A	Dissolved Oxygen	1702	1000	3010	ug/L
MW370	Dissolved Oxygen	1778	750	4320	ug/L
MW333	Dissolved Oxygen	1844	570	4750	ug/L
MW342	Dissolved Oxygen	2026	820	3620	ug/L
MW185	Dissolved Oxygen	2124	1080	5180	ug/L
MW203	Dissolved Oxygen	2156	900	3220	ug/L
MW87	Dissolved Oxygen	2165	1420	3010	ug/L
MW201	Dissolved Oxygen	2244	1050	3410	ug/L
MW191	Dissolved Oxygen	2631	1080	4900	ug/L
MW402-PRT5	Dissolved Oxygen	2987	270	8120	ug/L
MW103	Dissolved Oxygen	3259	860	5060	ug/L
MW169	Dissolved Oxygen	3494	870	7630	ug/L
MW249	Dissolved Oxygen	3558	700	5880	ug/L
MW404-PRT5	Dissolved Oxygen	3561	280	8500	ug/L
MW354	Dissolved Oxygen	3593	550	7560	ug/L
MW341	Dissolved Oxygen	3631	1970	7210	ug/L
MW99	Dissolved Oxygen	3704	1390	5630	ug/L
MW126	Dissolved Oxygen	3748	2370	5770	ug/L
MW98	Dissolved Oxygen	3897	2430	5050	ug/L
MW391	Dissolved Oxygen	3915	3590	4470	ug/L
MW235	Dissolved Oxygen	3940	2390	6140	ug/L
MW248	Dissolved Oxygen	4033	2330	5550	ug/L
MW90	Dissolved Oxygen	4072	1510	8870	ug/L
MW188	Dissolved Oxygen	4084	2110	6870	ug/L
MW395	Dissolved Oxygen	4291	1140	7650	ug/L
MW175	Dissolved Oxygen	4312	3120	5530	ug/L
MW243	Dissolved Oxygen	4366	930	6030	ug/L
MW106	Dissolved Oxygen	4424	3240	6370	ug/L
MW139	Dissolved Oxygen	4428	3220	5380	ug/L
MW337	Dissolved Oxygen	4434	2600	5900	ug/L
MW240	Dissolved Oxygen	4461	3160	7310	ug/L
MW233	Dissolved Oxygen	4656	2660	6850	ug/L
MW241	Dissolved Oxygen	4694	3080	8290	ug/L
MW200	Dissolved Oxygen	4787	2370	6490	ug/L
MW250	Dissolved Oxygen	5014	1710	6410	ug/L
MW388	Dissolved Oxygen	5018	3740	6590	ug/L
MW238	Dissolved Oxygen	5028	3300	7650	ug/L
MW244	Dissolved Oxygen	5105	2970	9590	ug/L
MW194	Dissolved Oxygen	5354	3330	7180	ug/L

*Data for quarterly/annual mapping locations only extracted from all wells sampled for TCE data set (1996 – 2006)

Table 37. Average DO concentrations* in LRGA wells utilized for annual groundwater mapping (μg/L).
*Data for quarterly/annual mapping locations only extracted from all wells sampled for TCE data set (1996 – 2006)

Location	NEWCHEMICAL	Location Average	Location Minimum	Location Maximum	UNITS
MW226	Dissolved Oxygen	770	170	1800	ug/L
MW255	Dissolved Oxygen	808	260	2310	ug/L
MW364	Dissolved Oxygen	900	190	2360	ug/L
W256	Dissolved Oxygen	984	410	3010	ug/L
MW392	Dissolved Oxygen	1074	140	2840	ug/L
MW367	Dissolved Oxygen	1151	90	3290	ug/L
MW373	Dissolved Oxygen	1219	30	3040	ug/L
MW95A	Dissolved Oxygen	1326	320	2680	ug/L
MW258	Dissolved Oxygen	1381	670	3210	ug/L
MW86	Dissolved Oxygen	1398	530	2980	ug/L
MW385	Dissolved Oxygen	1498	690	4670	ug/L
MW95	Dissolved Oxygen	1567	690	4070	ug/L
MW89	Dissolved Oxygen	1578	390	2400	ug/L
MW358	Dissolved Oxygen	1609	430	4310	ug/L
MW92	Dissolved Oxygen	1631	790	4200	ug/L
MW260	Dissolved Oxygen	1634	650	2290	ug/L
MW262	Dissolved Oxygen	1774	610	3810	ug/L
MW150	Dissolved Oxygen	1829	960	5490	ug/L
MW293A	Dissolved Oxygen	2060	1200	2610	ug/L
MW261	Dissolved Oxygen	2081	820	3960	ug/L
MW161	Dissolved Oxygen	2175	680	6280	ug/L
MW202	Dissolved Oxygen	2369	1010	4740	ug/L
MW145	Dissolved Oxygen	2372	1400	3750	ug/L
MW343	Dissolved Oxygen	2487	650	4000	ug/L
MW155	Dissolved Oxygen	2499	780	4820	ug/L
MW410	Dissolved Oxygen	2508	2190	3070	ug/L
MW252	Dissolved Oxygen	2594	1700	3210	ug/L
MW339	Dissolved Oxygen	2732	700	4580	ug/L
MW401-PRT4	Dissolved Oxygen	2760	370	7880	ug/L
MW292	Dissolved Oxygen	2833	2000	4270	ug/L
MW124	Dissolved Oxygen	2899	1040	7940	ug/L
MW409	Dissolved Oxygen	3081	2360	3540	ug/L
MW403-PRT4	Dissolved Oxygen	3102	590	6330	ug/L
MW125	Dissolved Oxygen	3156	1020	4660	ug/L
MW236	Dissolved Oxygen	3260	1430	5260	ug/L
MW411	Dissolved Oxygen	3270	2790	3840	ug/L
MW288	Dissolved Oxygen	3412	2000	5270	ug/L
MW340	Dissolved Oxygen	3415	1420	5400	ug/L
MW135	Dissolved Oxygen	3539	1150	7750	ug/L
MW294A	Dissolved Oxygen	3541	2790	3960	ug/L
MW356	Dissolved Oxygen	3625	1940	5960	ug/L
MW199	Dissolved Oxygen	3868	3320	4370	ug/L
MW65	Dissolved Oxygen	3886	3020	4950	ug/L
MW134	Dissolved Oxygen	4015	2680	5390	ug/L
MW355	Dissolved Oxygen	4096	3420	5040	ug/L
MW293A	Dissolved Oxygen	4214	2770	7160	ug/L
MW146	Dissolved Oxygen	4229	2720	5540	ug/L
MW284	Dissolved Oxygen	4371	3340	5640	ug/L
MW100	Dissolved Oxygen	4413	260	8700	ug/L
MW234	Dissolved Oxygen	4426	2470	6700	ug/L
MW152	Dissolved Oxygen	4587	3630	5350	ug/L
MW293	Dissolved Oxygen	4611	2910	6740	ug/L
MW291	Dissolved Oxygen	4709	700	6590	ug/L
MW283	Dissolved Oxygen	4980	3350	9350	ug/L
MW397	Dissolved Oxygen	5161	3470	5940	ug/L

The ranges of DO concentrations at nearly all locations vary temporally. Annual DO concentration cycles ranges from +/- 0.5 mg/L to over 2.0 mg/L (Appendices 2H.1, 2H.2, and 2H.3, respectively). The minimum and maximum DO concentrations for URGA, MRGA, and LRGA wells (1996 to 2006) are provided for each well in Tables 31 – 33. Dissolved-oxygen-trend plots from RGA locations are presented in Appendix 2D; Figures 2D.4 through 2D.7. Average DO concentration plots for the URGA, MRGA and LRGA annual groundwater mapping locations are provided in Appendix 2D, Figures 2D.8 through 2D.10. UCRS and Eocene Sand/Terrace Gravel sampling location DO plots are provided in Appendix 2F.

Initially, long-term DO trends encompassing all data collected between 1988 and 2006 were developed. However, concern about the accuracy of field DO analytical methods utilized between 1988 and 1995 prompted changing the duration of the trend graphs to 1996 through 2006. A number of 1988 – 2006 DO trends are provided in Appendix 2H and generally show clusters of higher concentration DO data from 1988 to 1995 relative to data collected from 1996 through 2006. Evaluation of the 1996 – 2006 URGA, MRGA, and LRGA DO concentration trends (Appendices 2H.1, 2H.2, and 2H.3, respectively) indicate that decreasing DO trends predominate the upper, middle, and lower horizons of the aquifer.
The presence of dissolved oxygen is not in itself a sufficient condition to support microbial populations capable of aerobic biodegradation. When levels of dissolved oxygen are greater than 1.0 mg/l, reductive dechlorination cannot occur because the microorganisms required do not grow in the presence of oxygen (Cox, 2008). Chapelle, and Bradley (2003) identify DO concentrations of 0.5 mg/ as a general lower DO-concentration threshold to the support oxidative processes as the chlorinated ethene degradation primary terminal electron accepting process (Figure 22). Oxidation-reduction potential also determines whether oxidative processes will occur in a given geochemical environment.

Oxidation-reduction potential (ORP) was evaluated because it identifies the oxidizing or reducing properties of the groundwater system. Relative to biodegradation, redox values define the oxidizing or reducing properties of groundwater at a sampling location. Figures 23a and b (EPA, 1999; Mukherjee et al., 2008) provide the general relationships between DO and redox conditions and the associated biotic and abiotic degradation processes in groundwater.

ORP in study area wells ranged between -7.0 and 500 mV. MW 197 (URGA north of C-616 lagoons) exhibited the lowest oxidation-reduction potentials amongst the study area wells, -7.0 and 2.0 mV, which suggests the depletion of DO and the presence of conditions that favor anaerobic degradation. Distributions of minimum ORP measurements at locations sampled for TCE from 1988 to mid 2006 are illustrated in Figure 24 at the plume scale and Figure 25 focused on the on-site and northwest corner of the industrial area.

Chloride was evaluated as an end-product of microbial degradation of organic compounds. Increasing chloride concentrations at a location or along flowpaths were evaluated as an indicators of the occurrence of degradation of TCE.

Chloride was detected in all of the project study area samples. Concentrations ranged from 3 to > 100 mg/L (Appendix 2B; Figure 2B.1). Historically, concentrations in study area wells have ranged from 4.3 to 137 mg/L (Table 29). The presence of chloride in study area and site wide samples has been characterized to be above background and indicates that TCE degradation processes are occurring in RGA groundwater.

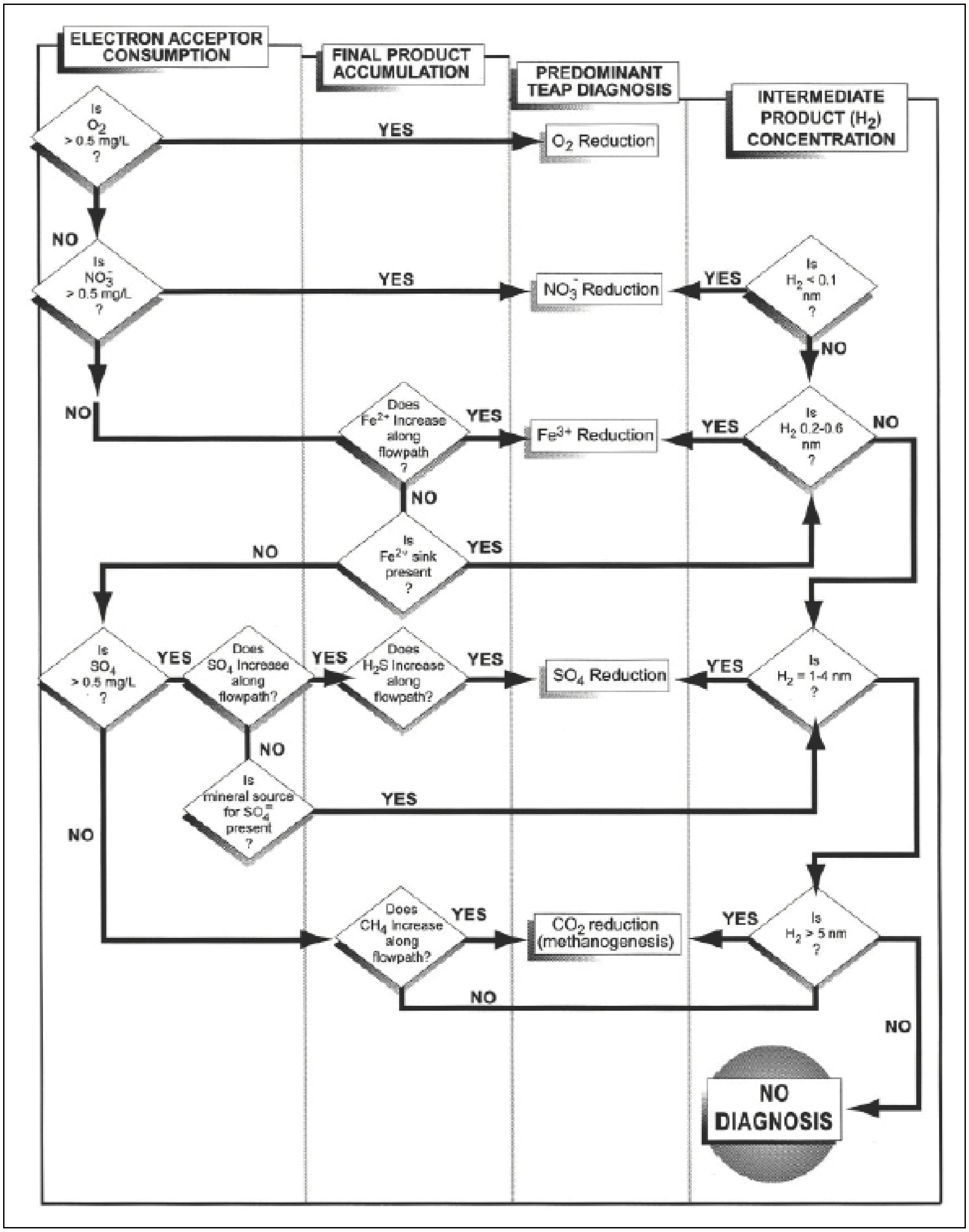


Figure 22. Characterization of terminal electron accepting processes based on DO concentration (Chapelle and Bradley, 2003)

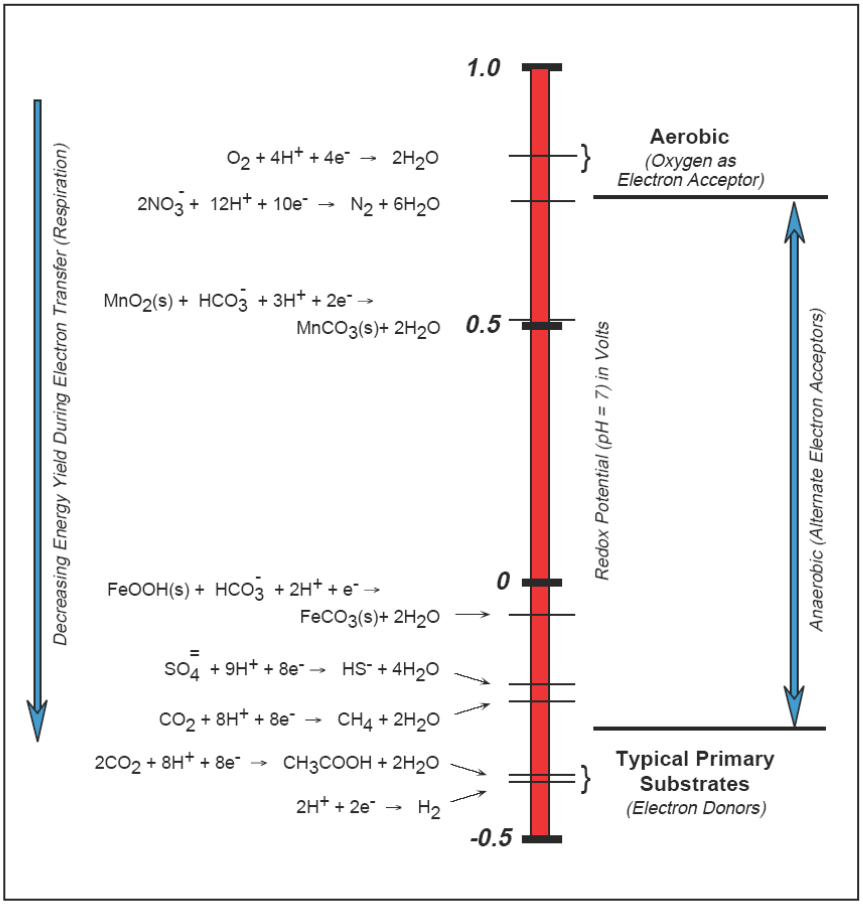


Figure 23a. Relationship of Aerobic and Anaerobic Degradation Processes to Redox Potential (EPA, 1999)

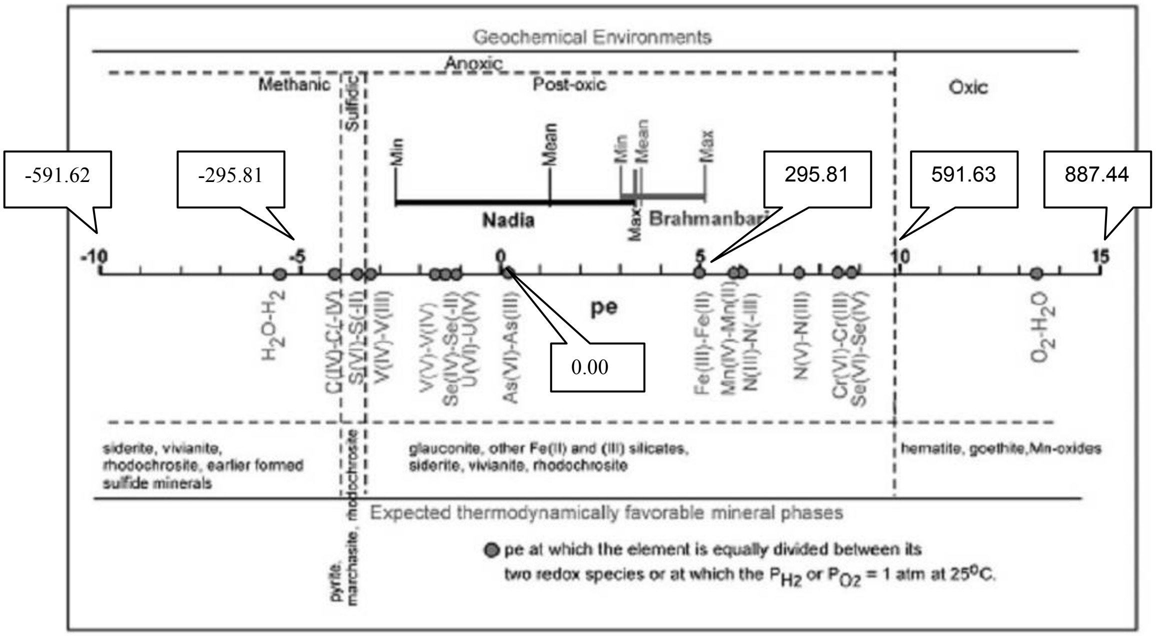
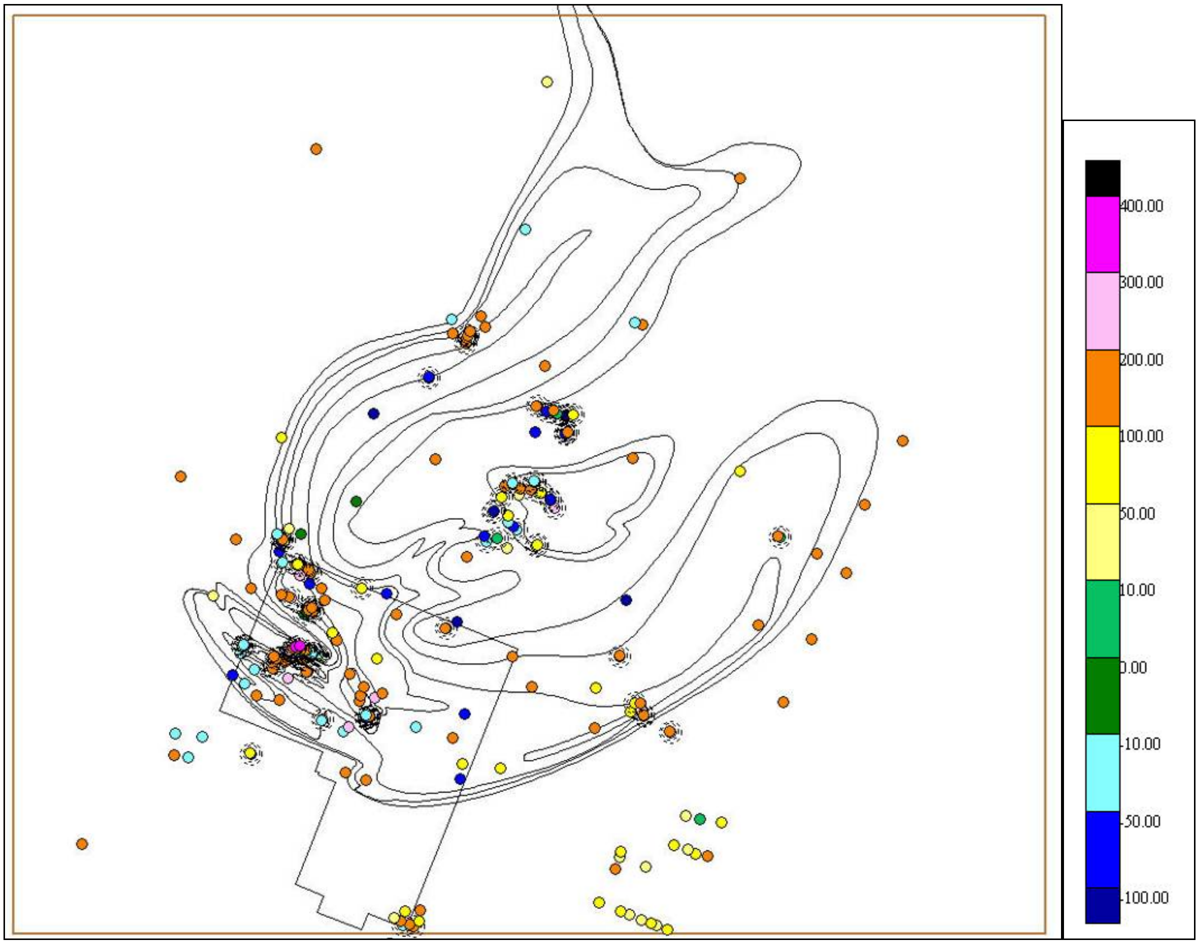


Figure 23b. Relationship of Aerobic and Anaerobic Degradation Processes to Redox Potential
(Mukherjee et al., 2008). (Boxes indicate mV equivalent Eh at 25°C, pH = 7.)



(Outside contour = 5 ppb TCE)

Figure 24. Minimum redox values at all groundwater locations sampled for TCE 1988 to 2006 (mV)

pH was evaluated because microbial degradation processes are pH sensitive.

The pH of project study area wells ranged from 5.63 to 6.22 standard units in the EAP (May 2007) samples and 5.87 to 6.65 standard units in the December 2007 SCI samples. Average pH of study area groundwater at (1988 to 2006) ranges from 5.76 to 6.17 standard units. Site-wide, the pH in wells sampled for TCE from 1988 to 2006 ranges from 2.5 to 11.3 standard units.

TCE degradation products cis-1,2-dichloroethene, 1,1-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride were evaluated relative to the potential presence of anaerobic microbial or abiotic degradation processes along the core of the plume. Cis-1,2-dichloroethene was detected in MW 185 (MRGA on-site) in samples from the May EAP and December SCI sampling events. 1,1-dichloroethene was detected in MW 168.

Cis-1,2-dichloroethene (DCE) was detected in MW 185 samples (MRGA – on-site) from both EAP and SCI sampling events at concentrations of 76 μg/L and 140 μg/L, respectively. DCE was also detected in MW242 (MRGA – NWP south well field) and MW262 (LRGA downgradient of C-400 source area). DCE detections in these NWP wells likely indicate the presence of nearby or upgradient conditions that support anaerobic/abiotic TCE degradation. These conditions could be related to source areas or may be related to micro-environments within the RGA where dissolved oxygen has been depleted and anaerobic degradation processes are occurring.

Cis-1,2-dichloroethene has been detected in historical samples (1988 – 2006) from study area wells MW 66, MW 185, MW 242, MW 262, and MW 340 (Table 30). The historical detections in study area sample locations are: MW 66 22.6 – 4200 μg/L; MW 185 65 – 250 μg/L; MW 242 6 – 7 μg/L; MW 262, 29 – 48 μg/L; MW 340 13 μg/L. Upper, middle, and lower RGA cis-1,2 dichloroethene maximum detection plots from 1988 through 2006 are provided in Appendix 2D, Figures 2D.9 - 2D.11.

Trans-1,2-dCE was not detected in study area monitoring wells. There have been 62 detections of trans-1,2-DCE in PGDP-RGA groundwater from 1988 – 2006 from 8,556 sample analyses. Detections range from <1 to 300 μg/L and were primarily in samples collected from C-400 Building and vicinity monitoring locations.

Vinyl chloride was not detected in project samples. Historically, 8915 samples have been analyzed for vinyl chloride. The only study area well with historical detections of vinyl chloride is MW 66. VC was detected at MW66 on three occasions with concentrations ranging from 2.3 – 63 μg/L.

The oxidation reduction potentials (ORP) and DO trends at MW's 185 and 168 suggest the presence of aerobic groundwater conditions. Given the DO trends at these locations, the cis-1,2 dichloroethene and 1,1 dichloroethene detections may indicate an upgradient and nearby area of anaerobic degradation activity. Alternatively, detections of TCE degradation products in some oxygenated Dover Air Force Base groundwater samples was determined to be indicative of discrete zones of anaerobic groundwater that were intercepted by within the interval of an individual well screen.

DO trends and EAP responses in MW 185 indicate the presence of aerobic microbial processes, however, there were no significant responses to the EAPs in MW 168.

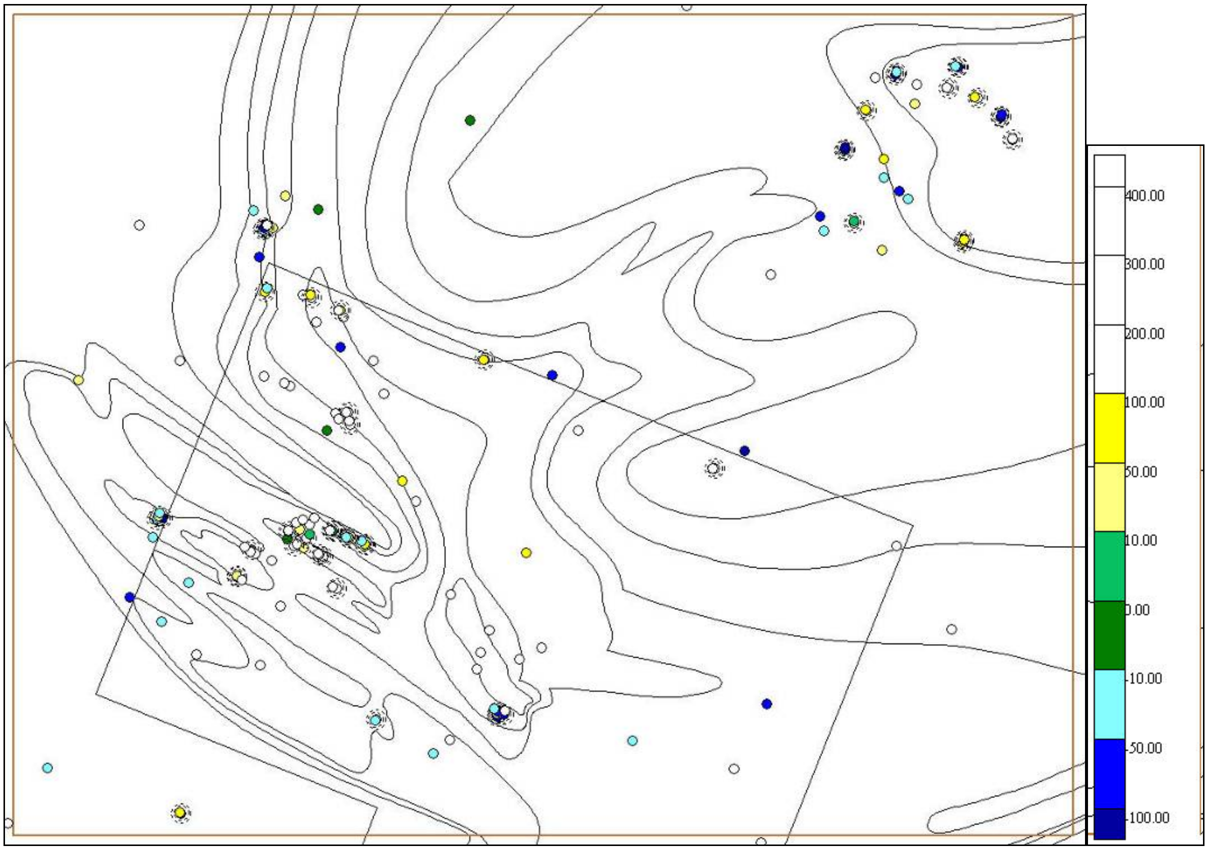
Ethylene (Ethene) was evaluated as an end-product of anaerobic biodegradation.

Ethylene was not analyzed in project-specific samples. Historical groundwater data identifies ethylene in study area location MW 66 ranging from 1 μg/L to 4166 μg/L and MW 186 (Northwest Corner of PGDP industrial area at SWMUs 7 & 30). Concentrations ranged from 168 μg/L to 3964 μg/L.

Total Organic Carbon (TOC) was evaluated to identify potential carbon sources necessary for microbial respiration. TOC includes organic compounds such as TCE, but does not include inorganic carbon compounds, primarily carbon dioxide, carbonic acid and bicarbonate. TOC differs from DOC in that DOC is filtered through a 0.45 μm filter to remove particulate and large carbon compound colloids.

TOC was detected in the December SCI sample from one project study-area well, MW 197, at a concentration of 2.3 mg/L. Historically, TOC has been detected in 18 samples from study area wells at concentrations ranging from 1.10 to 5.0 mg/L. Historical detections of TOC in all URGA, MRGA, and LRGA sample locations range from 0.97 to 324.0 mg/L.

TOC analyses from surface, UCRS, RGA, and McNairy soil horizons were evaluated relative to general availability of carbon in the PGDP subsurface (Appendix 2E; Figures 2E.1 through 2E.5). Shallow subsurface soil (0 to 6 feet bgs) in the NW corner of the PGDP contained TOC in excess of 5,000 mg/kg. On-site UCRS soils (6 – 60 feet bgs) and RGA soils (60 – 120 feet bgs) contained TOC ranging from 50 mg/kg to 5,000 mg/kg. McNairy soils (120+ feet bgs) contained TOC ranging from 500 mg/kg to 10,000 mg/kg. TOC analyses of soils from UCRS, RGA, and McNairy flow system matrices indicate that substantial amounts of organic carbon are present throughout the vertical profile of the PGDP flow system.



(Outside contour = 5 ppb TCE)

Figure 25. Minimum redox values (mV) at all groundwater locations sampled for TCE from 1988 to 2006

Dissolved Organic Carbon (DOC) was evaluated as a readily available carbon source for microbial respiration. A significant difference between TOC and DOC is that the DOC sample is filtered through a 0.45 um filter and does not reflect the presence of colloidal and particulate organic carbon compounds in groundwater.

DOC was detected in project samples from MWs 168 and 194 at concentrations of 8.2 and 2.0 mg/L, respectively. Only 16 historical DOC samples were available for RGA groundwater locations and there were ten (10) detections at low concentrations ranging from 1.0 mg/L to 6.0 mg/L. The DOC content of RGA groundwater is generally below the PGDP's detection limit of 1.0 mg/L noted in project samples and the limited number of historical DOC analyses.

The carbon cycle (Drever, 1982) indicates that most of the carbon in groundwater systems is contained in humic and fulvic acids that contain 40 to 60 % aromatic carbon compounds such as phenol, benzene and toluene. Because of chemical and biological influences encountered in the shallow subsurface, the DOC content of most groundwater decreases substantially with depth to approximately 0.7 mg/L (Drever, 1982). This indicates that present DOC detection limits for PGDP samples may preclude the routine quantification of DOC at concentrations likely to be encountered in the RGA.

Nitrate (NO_3-) was evaluated because it is a substrate for anaerobic microbial degradation in the absence of oxygen.

Nitrate was detected in project samples from eight (8) of the 12 study area wells. The exceptions were MW's 242, 243, 168 and 197, where concentrations were below the detection limit of 4.4 mg/L. Historical detections of NO_3^- in study area wells include; ND to 2.9 mg/L in MW 197; 8.0 mg/L in MW 194; 10.0 mg/L in MW 168; 570 mg/L in MW 125 and; ND to 32.3 mg/L in MW 66. Nitrate detections in all RGA locations sampled for TCE are spatially illustrated in Appendix D, Figures 2D.30 and 2D.31.

Nitrite was evaluated because it is the product of the reduction of NO_3- and its presence is indicative of anaerobic degradation activity.

Seventy-three nitrite samples have been collected and analyzed from PGDP groundwater including more than 50 samples collected in the vicinity of the C-400 Building. Nitrite was detected in only nine (9) samples from an Innovative Technology Demonstration in the vicinity of the NWP Pump and Treat facility.

Sulfate (SO_4^{2-}) was evaluated as a substrate for anaerobic microbial degradation.

SO_4^{2-} was present at detectable concentrations in all of the project study-area monitoring well samples within and outside of the NWP. Concentrations ranged from 6.0 to 65 mg/L. Historical study area detections range from 7.3 to 27.3 mg/L. Sitewide, there have been 2095 historical detections of sulfate in 2254 samples with concentrations that range from 0.036 to 2,842 mg/L.

Sulfide was evaluated because it is a product of the reduction of sulfate (SO_4^{2+}) and its presence is indicates the occurrence of sulfate reduction in anaerobic conditions.

Historically, sulfide was detected in calendar year 1991 study area location MW 185 at concentrations of 200 μg/L and 210 μg/L. Detections of sulfide have been very localized in the URGA, MRGA, and LRGA (Appendix 2D; Figures 2D.27, 2D.28, and 2D.29). Primary areas occur to the NE of the C-400 Building, in the NW corner of the industrial area in the vicinity of SWMUs 7 and 30, and in the vicinity of the S and T Landfills. The detection of sulfide indicates the local existence of sulfate reducing degradation under anaerobic conditions.

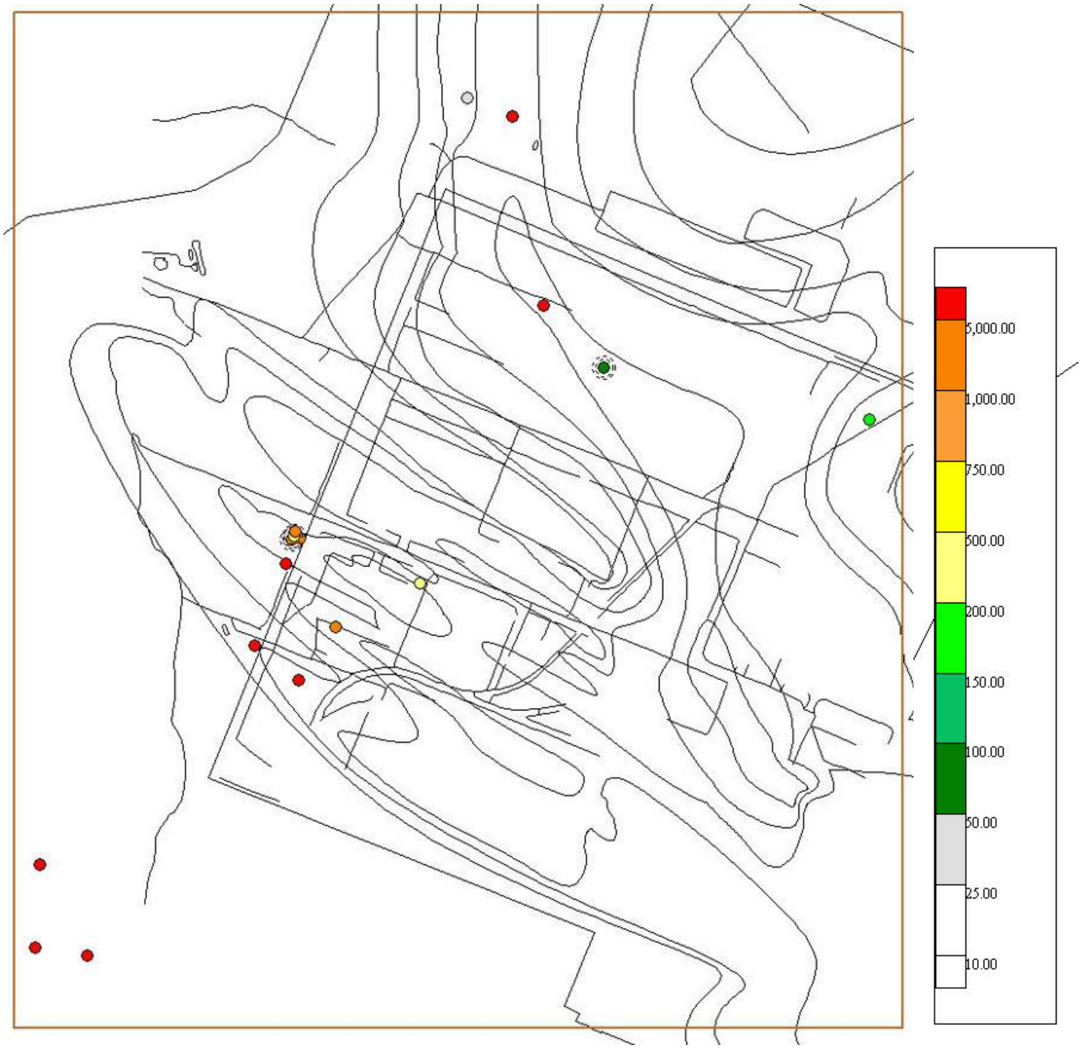
Ferric Iron (Fe^{2+}) was evaluated because it is an indicator that anaerobic biodegradation processes are occurring that result in the reduction of Fe^{3+} to Fe^{2+} in the absence of DO as well as the absence of nitrate, and sulfate.

Fe^{2+} was detected in study area MW 197 at 23 mg/L. MW 242 in the study area contained Fe^{2+} at 8.3 mg/L. Trace concentrations of Fe^{2+} were detected in MW's 243, and 168. Presence of Fe^{2+} may be indicative of the presence of discrete zones of DO depletion where Fe^{3+} is being reduced under anaerobic conditions or nearby/upgradient zones where Fe^{3+} is being reduced under anaerobic conditions (Figure 26).

Copper (Figure 25) was evaluated because as a known biocide. Copper has been detected in sitewide samples at concentrations ranging from 6 to 2080 ug/L and has been detected in 21 of 161 samples collected from study area wells (Figure 27).

Alkalinity was evaluated as an indicator of microbial respiration which will result in an increase in alkalinity.

Alkalinity in study area wells ranged from 55 to 113 mg/L ($CaCO_3$). Alkalinity average detects in URGA, MRGA and LRGA annual mapping location are illustrated in Appendix D; Figures 2D.23 through 2D.25. Figure 2D.26 illustrates maximum alkalinity detects in LRGA sample locations and may indicate increasing concentration trends in the NWP and SWP relative to plume origins at the C-400 building.



(Outside contour = 5 ppb TCE)

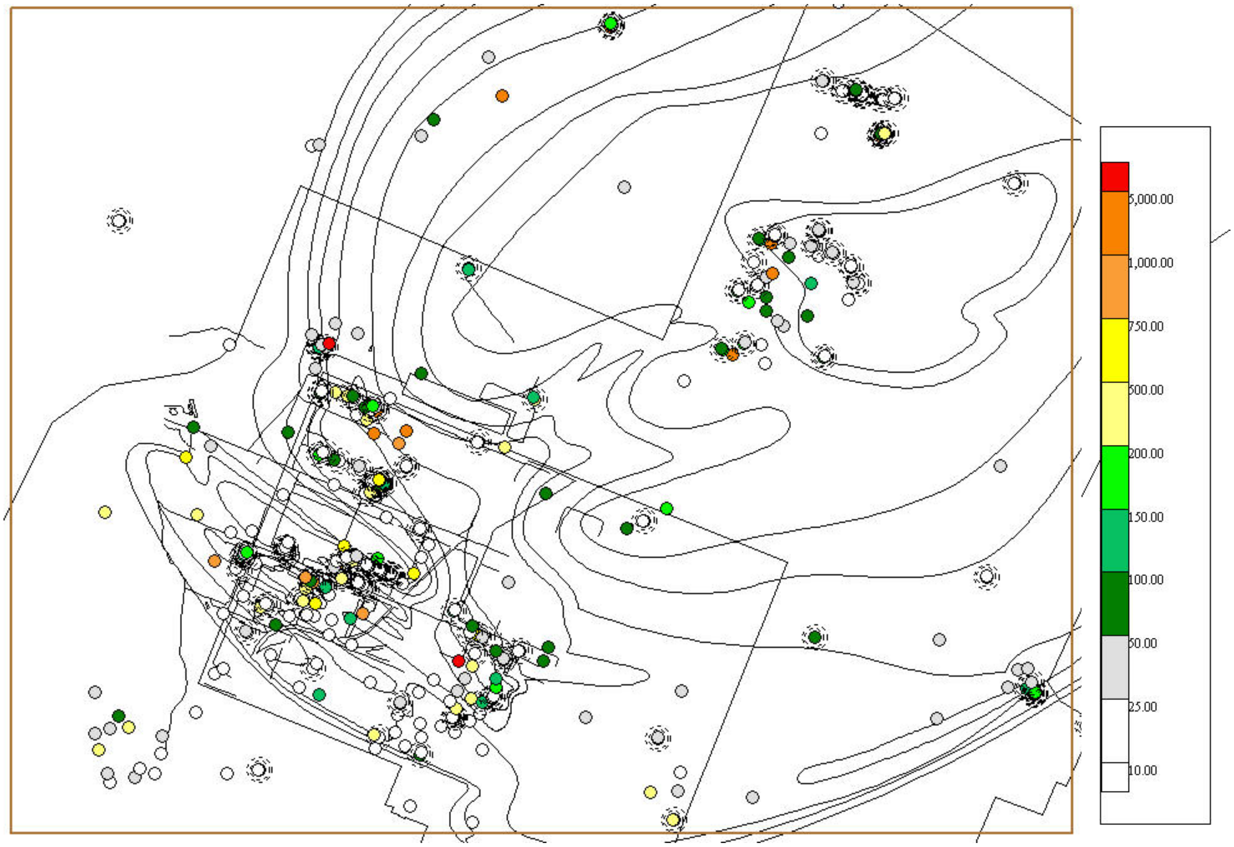
Figure 26. Maximum Fe^{2+} detections in groundwater 1988 – 2006 (ug/L)

<u>Carbon Dioxide</u> (CO_2) was evaluated because it is an end product of microbial respiration processes. CO_2 was detected in all of the project study wells and ranged from concentrations of 52,000 μg/L in off-site samples collected from control location MW 194 to 204,000 μg/L in MW 340 (LRGA on-site). Sufficient records could not be produced to evaluate CO_2 on a site-wide basis.

<u>Toluene</u> was evaluated as an aromatic hydrocarbon of anthropogenic and/or natural origin that is a carbon source for aerobic respiration.

Toluene was not detected in May 2007 EAP or December 2007 SCI samples. However toluene has been detected historically in study area location MW 66, 2.1 μg/L. Historically, toluene ranging from

2.1 to 4800 μg/L has been detected in 35 PGDP groundwater samples (Appendix D; Figure 2D.20 to 2D.22).



(Outside contour = 5 ppb TCE)

Figure 27. Maximum copper detections at groundwater locations sampled for TCE 1988 – 2006 (ug/L)

8.0. Discussion of Results and Degradation Technical Issues

The major tasks undertaken for this investigation were

1) The collection of sampling data from URGA, MRGA and LRGA wells approximating the core of the NWP and two control wells outside of the NWP.

2) Identification of the presence of microbes capable of aerobic co-metabolic TCE biodegradation using enzyme activity probes and additional lines of evidence related to microbial population diversity.

3) Evaluation of stable carbon isotope sampling data relative to degradation of TCE along the core of the NWP; and

4) Evaluation of historical and current RGA geochemical data relative to the occurrence and sustenance of microbial activity.

Samples were collected from the approximate core of the NWP at locations identified by the Project Team during the scoping process. Samples for EAP and laboratory geochemical analyses were collected in May 2007. SCI samples were collected in December 2007. Field parameters including DO, conductivity, pH, and temperature were collected as samples for EAP, geochemical and SCI analyses were collected.

Microbial samples were analyzed qualitatively and quantitatively. The analyses addressed the presence of appropriate genetic material to produce the enzymes capable of TCE co-metabolism, the presence of active enzymes being produced by microbes in NWP core and control well groundwater samples, and the number of microbes in NWP sample populations that express the enzymes capable of TCE co-metabolism. Additionally, T-RFLP analyses of the study area groundwater samples were conducted to provide genetic characteristics of microbial populations at each study area location in order to evaluate the potential for biofouling to influence microbial samples and evaluations of the study. Changes in TCE SCIRs were evaluated for upgradient downgradient study area well pairs to determine if ^{13}C was being enriched along NWP flowpaths via microbial degradation processes. Enrichment of TCE ^{13}C is occurring along NWP flowpaths. Enrichment of ^{13}C provides an additional line of evidence for occurrence of aerobic microbial activity.

Analyses from project-specific study-area well locations were utilized to identify geochemical conditions existing at the time of sample collection and to determine if those conditions were consistent with the occurrence and sustenance of aerobic co-metabolic degradation. Historical field and laboratory groundwater data were evaluated relative to geochemical conditions in the RGA to support inferences of aerobic co-metabolic microbial degradation as well as sustainability of microbial activity. A limited set of soil data was evaluated to support discussion of the availability of carbon sources at the PGDP.

8.1. Application of results to Decision Rules developed during the Data Quality Objectives process.

The specific goals of this aerobic co-metabolism assessment were developed by the TCE Fate and Transport Team as part of the project scoping process. The results of the TCE Fate and Transport Biodegradation Investigation scoping resulted in the five decision/estimation statements below. The results of project activities are related to the decision/estimation statements in the following text.

Decision / Estimation Statement #1. *Based on use of specific "oxygenase" probes, determine whether bacteria capable of aerobically biodegrading TCE are present and therefore require an estimation of* *their impact on the plumes or recommend that other mechanisms of TCE degradation/attenuation be evaluated.*

Ten (10) RGA-NWP wells located along the approximate core of the NWP were sampled and analyzed to identify the presence of oxygenase-producing bacteria. Two (2) control wells located outside of the footprint of the NWP were also evaluated to determine the presence and activity of oxygenase producing microbes. The appropriate genetic material was identified in project samples to conclude that the potential exists for oxygenase enzymes to be produced by microbes in the NWP.

Decision/Estimation Statement #2. *Based on the use of stable carbon isotope (SCI) fractionation tests, determine whether SCI supports the occurrence of aerobic biodegradation processes and/or other biotic or abiotic degradation processes.*

Comparison of upgradient-downgradient location NWP-axis SCIR data indicates that ^{13}C in NWP TCE is being is being enriched and that TCE removal is occurring via microbial processes. SCI Decision Rule 4 evaluates whether removal expected from SCIRs is greater than the removal calculated from TCE/^{99}Tc concentration data and whether removal based on SCIR is plausible based on the variation in field-scale removal rates when the SCIR removal is less than that predicted by TCE/^{99}Tc concentration data. Decision Rule 5 evaluates whether the removal expected from the SCIR is too little to make aerobic biodegradation a plausible explanation for the change in TCE concentrations based on variation in removal rates at field scale. Decision Rule 6 evaluates whether the removal based on SCIR is significant (> 10 per cent) of the removal predicted from the TCE/^{99}Tc concentration data.

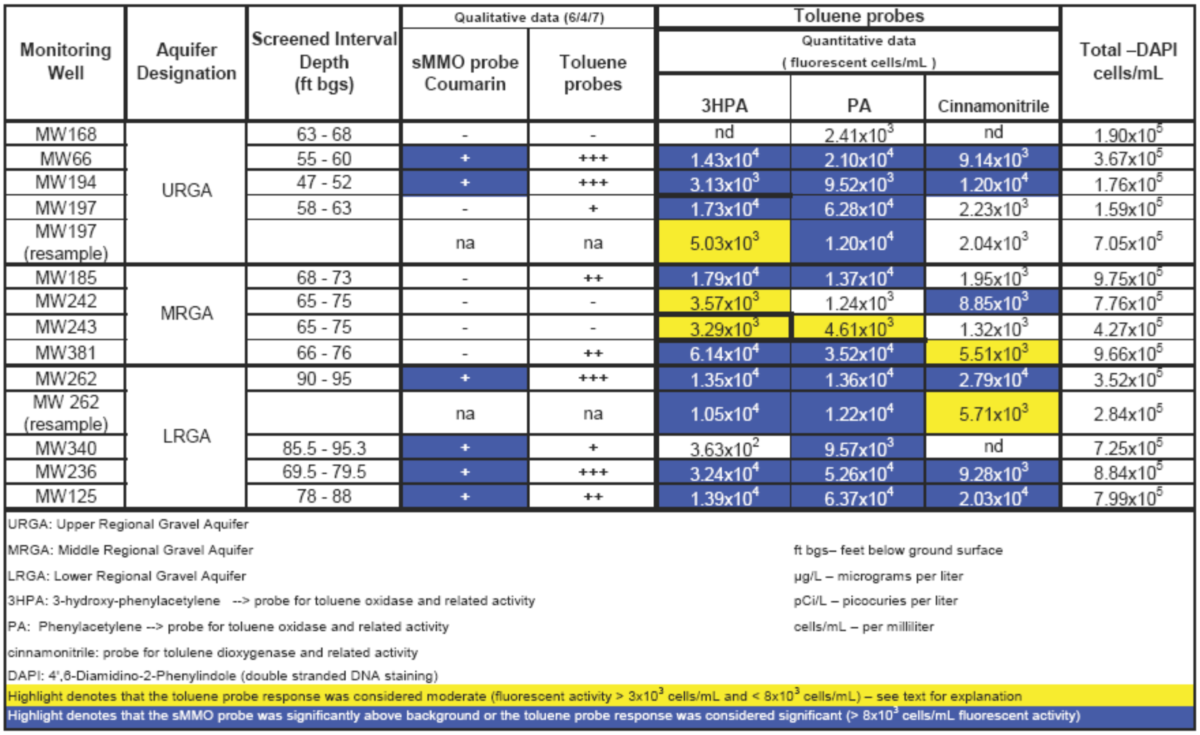
Application of SCI decision/estimation statements and decision rules to SCIR well-pair data provides support for the occurrence of aerobic co-metabolic degradation through a range of enrichment factor (ε) values (Table 38), including; - 1.1 from published literature, the 90% one-tailed confidence interval value on ε, -1.4 and the 95% one-tailed confidence interval on ε value, -1.68.

Table 38. Summary of SCI upgradient/downgradient δ13comparative evaluation.

Enrichment Factor (ε)	Total Up/Downgradient Comparisons Possible	Favorable Result Comparisons	Significant Result Comparisons
-1.1	10	8	6
-1.4	10	8	5
-1.68	10	7	5

Decision/Estimation Statement #3. *Estimate whether the distribution and number of bacteria are sufficient to significantly biodegrade TCE in RGA groundwater. If the distribution and number of microorganisms are sufficient to biodegrade TCE in RGA groundwater, determine whether biodegradation is sustainable. If it is determined that biodegradation is not sustainable, recommend that other mechanisms of TCE degradation/attenuation be evaluated.*

Sufficient numbers of microbes were present in project samples to meet the 1 x 10^3 cells/mL population count thresholds developed by the Project Team (Table 39) as an indicator of sufficient population to accomplish and sustain co-metabolic degradation of TCE. Professional judgment was applied to increase the threshold of significant sample microbial activity to approximately 8 X 10^3 cells/mL, which is a more conservative threshold that reflects population findings from other sites where aerobic co-metabolic degradation of TCE is currently being investigated (SRNL, 2008). Study area wells with



Monitoring Well	Aquifer Designation	Screened Interval Depth (ft bgs)	Qualitative data (6/4/7)		Toluene probes			Total –DAPI cells/mL
			sMMO probe Coumarin	Toluene probes	Quantitative data (fluorescent cells/mL)			
					3HPA	PA	Cinnamonitrile	
MW168	URGA	63 - 68	-	-	nd	2.41x10^{3}	nd	1.90x10^{5}
MW66		55 - 60	+	+++	1.43x10^{4}	2.10x10^{4}	9.14x10^{3}	3.67x10^{5}
MW194		47 - 52	+	+++	3.13x10^{3}	9.52x10^{3}	1.20x10^{4}	1.76x10^{5}
MW197		58 - 63	-	+	1.73x10^{4}	6.28x10^{4}	2.23x10^{3}	1.59x10^{5}
MW197 (resample)			na	na	5.03x10^{3}	1.20x10^{4}	2.04x10^{3}	7.05x10^{5}
MW185	MRGA	68 - 73	-	++	1.79x10^{4}	1.37x10^{4}	1.95x10^{3}	9.75x10^{5}
MW242		65 - 75	-	-	3.57x10^{3}	1.24x10^{3}	8.85x10^{3}	7.76x10^{5}
MW243		65 - 75	-	-	3.29x10^{3}	4.61x10^{3}	1.32x10^{3}	4.27x10^{5}
MW381		66 - 76	-	++	6.14x10^{4}	3.52x10^{4}	5.51x10^{3}	9.66x10^{5}
MW262	LRGA	90 - 95	+	+++	1.35x10^{4}	1.36x10^{4}	2.79x10^{4}	3.52x10^{5}
MW 262 (resample)			na	na	1.05x10^{4}	1.22x10^{4}	5.71x10^{3}	2.84x10^{5}
MW340		85.5 - 95.3	+	+	3.63x10^{2}	9.57x10^{3}	nd	7.25x10^{5}
MW236		69.5 - 79.5	+	+++	3.24x10^{4}	5.26x10^{4}	9.28x10^{3}	8.84x10^{5}
MW125		78 - 88	+	++	1.39x10^{4}	6.37x10^{4}	2.03x10^{4}	7.99x10^{5}

URGA: Upper Regional Gravel Aquifer
MRGA: Middle Regional Gravel Aquifer
LRGA: Lower Regional Gravel Aquifer
3HPA: 3-hydroxy-phenylacetylene --> probe for toluene oxidase and related activity
PA: Phenylacetylene --> probe for toluene oxidase and related activity
cinnamonitrile: probe for tolulene dioxygenase and related activity
DAPI: 4',6-Diamidino-2-Phenylindole (double stranded DNA staining)

ft bgs– feet below ground surface
µg/L – micrograms per liter
pCi/L – picocuries per liter
cells/mL – per milliliter

Highlight denotes that the toluene probe response was considered moderate (fluorescent activity > 3x10^{3} cells/mL and < 8x10^{3} cells/mL) – see text for explanation
Highlight denotes that the sMMO probe was significantly above background or the toluene probe response was considered significant (> 8x10^{3} cells/mL fluorescent activity)

Table 39. Qualitative and Quantitative EAP and microbial results.

the exception of MW 243 and MW 168 contained sufficient numbers of oxygenase producing microbes to meet the revised quantitative population criterion. Although MW 243 did not meet the revised criteria for any of the three quantitative EAPs, the cell counts did meet the original, 1 x 10^{3} cells/mL, established by the project team.

MW 168 (URGA on-site) is the study area well located in closest proximity to C-400 source areas for TCE and ^{99}Tc and exhibits the highest ^{99}Tc concentrations of the study area wells, 2,400 pCi/L. MW 168 did not contain sufficient oxygenase producing cells to quantitatively satisfy either 1 x 10^{3} or 8 x 10^{3} cells/mL EAP probe specific criteria. However, the total non-oxygenase-specific cell counts/mL in MW 168 is within the range (1 x 10^{5} cells/mL) of other study area wells.

The DOC concentration in RGA groundwater are likely to occur at concentrations below the PGDP's detection limit of 1 mg/L noted in project samples and the limited number of DOC analyses available in historical site data. Published information about the carbon cycle (Drever, 1982) indicates that most of the carbon in groundwater systems is contained in humic and fulvic acids that contain 40 to 60 % aromatic carbon compounds such as phenol, benzene and toluene. Because of chemical and biological influences encountered in the shallow subsurface, the DOC content of most groundwater decreases substantially with depth to concentrations of approximately 0.7 mg/L. This indicates that PGDP detection limits for DOC may preclude routine quantification of the concentrations of DOC likely to be found in PGDP groundwater.

TOC was detected in one project well, MW 197 (2.3 mg/L) and has been detected in 18 historical samples from study wells (1.10 to 5.0 mg/L). Site wide, TOC has been detected in historical URGA, MRGA, and LRGA samples (0.97 to 324.0 mg/L). TOC analyses of soils from UCRS, RGA, and McNairy matrices indicate that substantial amounts of organic carbon are present throughout the vertical profile of the PGDP flow system.

The presence, abundance, distribution and activity of aerobic microbial populations in NWP groundwater samples indicate that sufficient organic carbon must be present in the RGA to sustain microbial populations. Based on presence of microbial communities and the limited number of project and historical samples that quantify DOC at low concentrations, the RGA can be categorized as an oligotrophic "nutrient limited" groundwater environment relative to microbial activity (SRNL, 2008).

The number and distribution of bacteria appear sufficient to contribute to the biodegradation of TCE in RGA groundwater. The organic carbon in this oligotrophic, "nutrient limited" system is low and the microbial community appears to be stable and sustainable based on the similarity of total microbial population in the control wells and plume wells (SRNL, 2008).

Decision/Estimation Statement #4. *Determine whether conditions including, but not limited to, the existence of a bioavailable and sustainable substrate in the RGA and the presence of other geochemical parameters are conducive for ongoing and sustainable aerobic biodegradation of TCE* (Table 11). *If conditions are determined to be ongoing and sustainable, recommend that an evaluation of the biodegradation rate using a multiple lines of evidence approach be applied at the PGDP. If conditions are not determined to be ongoing and sustainable, recommend that other mechanisms of TCE degradation/attenuation be evaluated immediately.*

Based on 1) evaluation of geochemical data collected for this investigation, 2) the evaluation of historical geochemical data, and 3) the existence of microbial populations in NWP groundwater, the principal constituents required for occurrence and sustenance of aerobic co-metabolic degradation, dissolved oxygen and carbon, are present in the NWP. Dissolved oxygen concentrations are significantly above apparent minimum levels of 0.5 mg/L necessary to sustain aerobic microbial populations capable of co-metabolic degradation of TCE. Carbon must be present in sufficient concentrations to support the microbial populations identified in the DNA and EAP analyses.

Based on the information collected during this investigation phase of the TCE Fate and Transport Project, a follow-on kinetic / rate study (microcosm study) is recommended to develop an independent site-specific degradation rate constant. Determination of degradation rates in two wells, MW125 and either MW236 or MW381, is recommended (SRNL, 2008).

Decision/Estimation Statement #5. *Based upon a comparison to the calculated biodegradation rates (or range of rates) to those supported in literature, either accept the calculated rate(s) for use in future fate-and-transport modeling or assess the team's confidence in the unsupported results.*

The range of first-order rate constants derived for plume-scale TCE degradation in the RGA are similar to the range of rates derived at other sites where large aerobic plumes of contaminated groundwater are being investigated (SRNL, 2008). Those sites include Savannah River National Laboratory, Tinker Air Force Base, Idaho National Laboratory, and Sandia National Laboratory.

9.0. Conclusions.

Three lines of evidence were identified by this and previous studies that support the occurrence of aerobic co-metabolic degradation of TCE in the NWP at the PGDP. The three lines of supporting evidence are:

1. First-order degradation rate calculations indicate that TCE is being attenuated along NWP flowpaths at a rate faster than its co-contaminant ^{99}Tc.

2. EAP, DNA and T-RFLP analyses provide evidence that genetic material responsible for co-metabolism of TCE is present, actively occurring, and related to microorganisms indicative of populations in the aquifer.

   Geochemical conditions in the NWP are indicative of those found in aerobic, oligotrophic, "nutrient limited" aquifers that support the presence and activity of microbes capable of inducing aerobic co-metabolism of TCE. Geochemical conditions in the RGA, in particular the presence of DO and organic carbon, must be capable of supporting populations of aerobic microbes capable of co-metabolic destruction of TCE or the populations identified in EAP, DNA, and T-RFLP analyses would not be present. Organic carbon is available in the aquifer in sufficient concentrations to support the identified microbial populations.

3. Stable carbon isotope analyses and comparative evaluation of SCI upgradient/downgradient well-pair data indicate that along the core of the NWP ^{13}C is being enriched relative to ^{12}C by preferential microbial processes.

Based on the results of the activities conducted for this investigation, aerobic co-metabolic degradation of TCE is occurring in the RGA within the study area. The Project Team recommendation to DOE is to continue to characterize the occurrence of aerobic co-metabolic TCE degradation in the PGDP groundwater. A number of general or global recommendations relative to the primary recommendation are appropriate as a result of this investigation:

The conclusions of current project activities and historical evaluations of TCE degradation mechanisms in the NWP RGA can be summarized relative to the three (3) USEPA technical protocol lines of evidence as follows:

9.1 First-order Rate Constants

Line of Evidence I. *The first line of evidence is to demonstrate that microbial processes are actively achieving TCE or other contaminant degradation. .*

First-order rate constant calculations indicate that TCE is preferentially destructed along NWP flowpaths.

Several previous site investigations generated first-order rate constant estimations that mathematically describe the amount of time required for one-half of the dissolved phase TCE in the PGDP plumes to be removed by natural attenuation processes. Methods used for the derivation of first-order rate constants included a mass balance evaluation across plume cross-sections that estimated a TCE degradation rate of 0.0206 to 0.074 year^{-1} which is equivalent to a TCE half-life of 26.7 to 9.4 years. Subsequent tracer-corrected methods utilized the TCE co-contaminant ^{99}Tc and chloride as tracers. Starr, et al. (2005) utilized the tracer chloride and calculated a TCE half-life of seven (7) years in the NWP-lower RGA. The Southwest Plume Site Investigation (SWP SI) calculated degradation rates of 0.0603 to 0.1802 year^{-1} utilizing chloride and groundwater flow rates of 1 and 3 ft/day which correspond to a TCE half-life range of 11.5 to 3.8 years. Utilizing ^{99}Tc as the tracer, the SWP degradation rate was determined to be 0.0603 to 0.1802 year^{-1} and a TCE half-life range of 11.5 to 3.8 years. More recent first-order rate constant calculations statistically evaluated monitoring location data to identify the locations impacted by pump and treat operations and excluded the impacted location data from use in the calculations. Using groundwater flow rates of 1 to 3 ft/day, degradation rates using chloride and ^{99}Tc as tracers were calculated to be 0.0719 to .2149 year^{-1} and 0.0603 to 0.1802 year^{-1}, respectively. The corresponding TCE half-lives for chloride and ^{99}Tc are 9.6 to 3.2 years and 11.8 to 3.8 years. All of the first-order degradation methods estimate similar ranges of TCE attenuation in the NWP

9.2. EAP, Genetic, and Geochemical Conclusions

9.2.1. EAP, DNA, and T-RFLP Conclusions

Line of Evidence IIa. *The second line of evidence in the Technical Protocol addressed by this investigation has two parts: a) the identification of the actual processes responsible for TCE degradation and b) the existence of geochemical conditions capable of supporting the process(es). Enzyme Activity Probes and genetic profiling were utilized to address the second line of evidence along with evaluation of current and historical RGA geochemical trends.*

EAP and related activities were conducted to address the second line of evidence by identification of the actual processes responsible for TCE degradation. Summarily, aerobic co-metabolic degradation of TCE is occurring in the RGA based on evaluation of the EAP data, supporting DNA data, and number of microbial cells present in the NWP study area samples. Specific findings related to the study area are as follows (SRNL, 2008):

1) Genetic profiling indicates that microbial populations in NWP-RGA groundwater are representative of indigenous groundwater microbial populations and not biofouling-microbial populations.
2) DNA analyses of study area samples indicate that the appropriate genetic material is present to produce the enzymes capable of aerobic oxidation of aromatic compounds, lesser chlorinated anthropogenic compounds, and co-metabolic degradation of TCE.
3) Qualitative EAP analyses indicate that in-situ production of toluene and soluble methane monooxygenase enzymes is occurring in the RGA. Samples from nine of twelve study area locations exhibited positive responses to one or more of the three (3) toluene probes and/or the sMMO probe coumarin.
4) Quantitative EAP analyses enumerated microbial populations related to production of one or more of the three toluene enzymes in 11 of 12 study area samples.
5) Significant aromatic oxidation enzyme activity was measured in 10 out of the 12 wells sampled, and moderate aromatic oxidation enzyme activity was measured in 1 additional well.
6) sMMO activity was detected in 6 out of the 12 monitoring wells sampled.
7) sMMO activity was not detected at MW168, MW197, MW185, MW242, MW243 or MW381. However, the DNA control study demonstrated the presence of the gene sequences needed to produce sMMO in MW168, MW242 and MW243 indicating the potential for sMMO-related degradative microbial activity.
8) Toluene dioxygenase (TOD) activity, as detected by the cinnamonitrile enzyme probe, was low in MW168, MW197, MW185, MW243 and MW340. TOD activity was moderate in MW381. However, all monitoring locations except MW168 demonstrated a positive response to the TOD primers during the DNA control study indicating widespread genetic potential for TOD-related microbial degradation of organic compounds and co-metabolism of TCE. This potential was not expressed sufficiently to generate significant EAP assay responses in approximately 50% of the wells tested.

9) Toluene monooxygenase (TMO) activity, as indicated by the PA and 3HPA enzyme probes, was not detected in MW 168 moderate (MW242 and MW243) or significant in all tested wells.

10) For the sMMO probe:
   - Activity was detected in two of the four URGA wells, MW66 and MW194.
   - Activity was not detected in any of MRGA wells.
   - Activity was detected in all of the LRGA wells: MW262, MW340, MW236, and MW125.

11) For the aromatic toluene probes significant activity was detected in three of the four URGA wells: MW66, MW194, and MW197.

12) For the sMMO probe:
   - Activity was detected in two of the four URGA wells, MW66 and control well MW194, outside of the NWP.
   - Activity was not detected in any of MRGA wells.
   - Activity was detected in all of the LRGA wells: MW262, MW340, MW236, and MW125.

13) For the aromatic toluene probes:
   - Significant activity was detected in three of the four URGA wells: MW66, MW194, and MW197.
   - Significant activity was detected in three of the four MRGA wells (MW185, MW242, and MW381) and moderate activity was detected in the remaining well, MW243.
   - Significant activity was detected all four LRGA wells: MW262, MW236, MW340, and MW125.

9.2.2. Geochemical evaluation

Line of Evidence IIb. Relative to the part 2 of the Second Line of Technical Protocol Evidence, Geochemical Evaluation of the study area data and site wide data provide present and historical concentration and distribution data relative to the biogeochemical processes in the RGA.

1) Study area geochemical evaluations indicate the presence of DO in excess of 1 mg/L at all locations with the exception of control well MW197, on-site MW262, and one of two samples from MW242. In general DO is widely distributed in the RGA at concentrations that should support aerobic oxidation and aerobic co-metabolic degradation processes. As such, aquifer conditions present aerobic microbial populations with availability of dissolved oxygen which when present with sufficient carbon sources and redox conditions will result in the aerobic oxidation of lesser chlorinated organic compounds and provide for aerobic oxidation and co-metabolism of organic substances including TCE.

2) Detections of anaerobic TCE-degradation products cis-1,2-DCE and 1,1-DCE indicate that MW168, MW185, MW242, and MW243 are in close proximity to localized anaerobic TCE degradation zones, that the screened intervals of these wells intercept discrete anaerobic flow zones within the RGA.

3) Fe^{2+} detections in MW 185, MW242, MW243, and MW197 indicate that these locations may be impacted by local anaerobic zones where Fe^{3+} is reduced to Fe^{2+}. The Fe^{2+} detections in these wells may indicate that discrete anaerobic flow zones are intercepted within the generally-aerobic intervals of the well screens.

4) DOC, when analyzed, has been present at low concentrations in RGA samples and was detected in project samples from MW 168 and MW194 at concentrations of 8.2 and 2.0 mg/L respectively. TOC has been identified in RGA groundwater as well as in UCRS, Upper/Middle/Lower RGA and McNairy core samples.

5) DOC concentrations were evaluated in 16 historical samples and detected ten (10) of those samples

6) DOC <u>must</u> be present in project samples at sufficient concentrations to support the microorganisms indentified in EAP and related analyses.

Based on evaluation of geochemical data collected for this investigation, the evaluation of historical geochemical data, and the existence of microbial populations in NWP groundwater, the principal constituents required for occurrence and sustenance of aerobic co-metabolic degradation, dissolved oxygen and carbon-compound substrates, are present in the NWP. The geochemical conditions in general are similar to those observed in large aerobic groundwater plumes such as those at Tinker Air Force Base, Sandia National Laboratory, Savannah River National Laboratory, Idaho National Laboratory, and other sites (SRNL, 2008).

9.3. Stable Carbon Isotope Conclusions.

III. The third line of evidence addressed by this investigation was the utilization of compound specific isotope analyses (CSIA) as an additional, independent line of evidence supporting the occurrence of aerobic biodegradation of TCE in the RGA.

SCIs and comparative evaluation of SCIR upgradient/downgradient well-pair data indicate that ^{13}C is being enriched along core of the NWP flowpaths by microbial processes preferential to the utilization of the lighter isotope ^{12}C (Tables 38 & 40). Spatially, δ^{13}C values from laboratory analyses support the SCI conceptual site model developed during SCI scoping (Figure 28). As hypothesized in the conceptual site model , δ^{13}C values increase along the on-site flowpaths from MW 168 to MW 185. In the vicinity of MW 185 additional source contributions to the plume are evident. Another area of increasing δ^{13}C trends occurs from downgradient of MW 185 to the distal portions of the study area at MW's 381 and 236. SCI evaluation is summarized in Table 40 for flowpath well-pairs in the study area.

SCI Decision Rule 4 evaluates whether removal expected from SCIRs is greater than the removal calculated from TCE/^{99}Tc concentration data and whether removal based on SCIR is plausible based on the variation in field-scale removal rates when the SCIR removal is less than that predicted by TCE/^{99}Tc concentration data. Based on SCIRs (Decision Rule 4), eight (8) of the 10 well pairs evaluated using the published enrichment factor of -1.1 exhibit removal greater than the removal predicted by TCE/^{99}Tc concentration data or may have removal occurring at rates that indicate removal along well-pair flowpaths. Seven of the well pairs evaluated exhibit similar removal occurrence when evaluation of the well pair data utilizes enrichment factors of -1.4 and -1.68..

Decision Rule 5 evaluates whether the removal expected from the SCIR is too little to make aerobic biodegradation a plausible explanation for the change in TCE concentrations based on variation in removal rates at field scale. Two (2) well pairs were excluded from further evaluation utilizing epsilon values of -1.1 and -1.4 because removal rates predicted by SCIR did not indicate significant removal was occurring. Three (3) well pairs were excluded from further evaluation when utilizing an epsilon value of -1.68.

Decision Rule 6 evaluates whether the removal based on SCIR is significant (> 10 per cent) of the removal predicted from the TCE/^{99}Tc concentration data. SCIR evaluation indicated that six (6) of the eight (8) wells pairs had significant removal occurring along their flowpath when utilizing the published enrichment factor of -1.1. Five (5) of eight (8) well pairs exhibit significant rates of removal along their flowpaths utilizing an enrichment factor of -1.4 and five (5) of seven (7) well pairs indicate that significant removal is occurring utilizing and enrichment factor of -1.68.

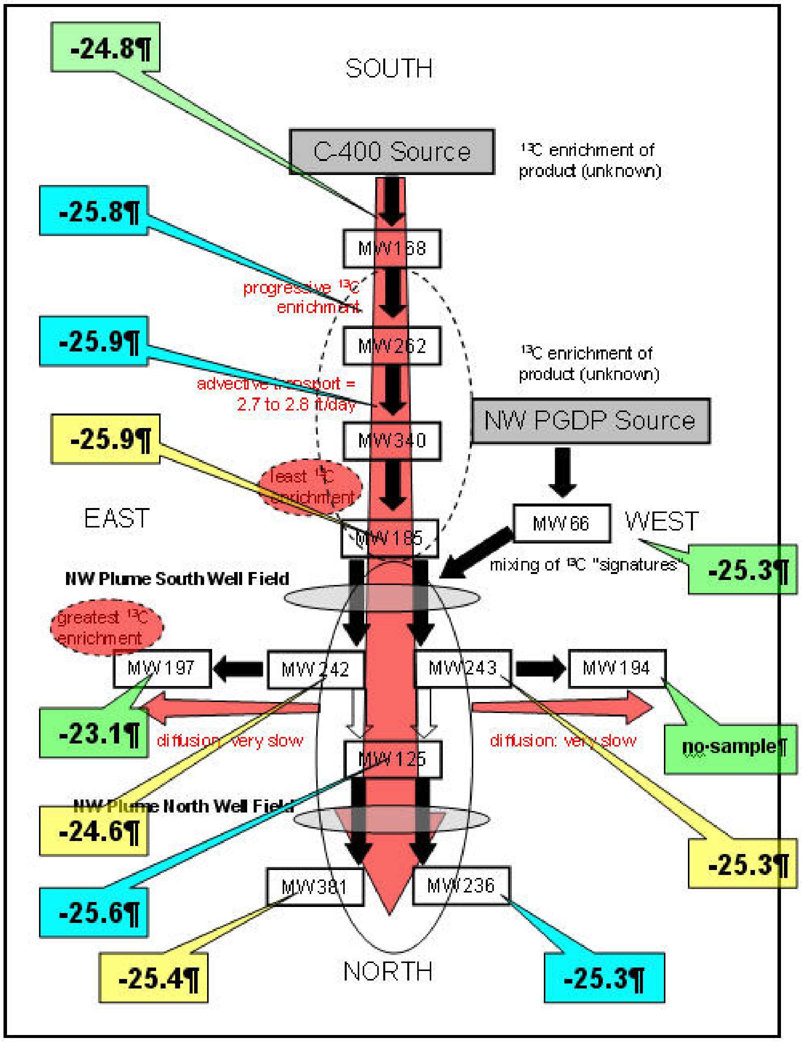


Figure 28. Distribution of δ^{13}C Values (permil) from Laboratory Analyses

Ovals indicate flowpaths that exhibit δ^{13}C enrichment trends. Green boxes = URGA samples, Yellow boxes = MRGA samples, and Blue boxes = LRGA samples.

Table 40. Summary of SCIR upgradient/downgradient comparative evaluation

	Averages						**SDev = 0.183**				**Criterion**	
Sample ID	**TCE d13C (permil)**		**C/Co**	**Percent Degradation**	**ln(C/Co)**	**Corrected for Uncertainty C/Co**	**Percent Degradation**	**ln(C/Co)**	**C/Co from field***	**ln(C/Co)**	**ln(C/Co)**	**Accepted against Criterion**
MW-168	-24.8	other source										
MW-262	-25.8	other source										
MW-340	-25.9	assumed source										
MW-185	-25.9	assumed source	1.000	0	0.000							
MW-66	-25.3	down gradient	0.580	42	-0.545	0.416	58	-0.878				
MW-242	-24.6	down gradient	0.307	69	-1.182	0.220	78	-1.515				
MW-243	-25.3	down gradient	0.580	42	-0.545	0.416	58	-0.878				
MW-197	-23.1	down gradient	0.078	92	-2.545	0.056	94	-2.878				
MW-125	-25.6	down gradient	0.761	24	-0.273	0.546	45	-0.605	0.40	-0.924	-0.30	Yes
MW-381	-25.4	down gradient	0.635	37	-0.455	0.455	54	-0.787	0.31	-1.176	-0.39	Yes
MW-236	-25.3	down gradient	0.580	42	-0.545	0.416	58	-0.878	0.31	-1.176	-0.39	Yes
MW-194	na	down gradient										

10.0. Recommendations

Based on the results of TCE FT Trichloroethene Biodegradation Investigation, the primary Project Team recommendation to DOE is to continue to characterize the occurrence of aerobic co-metabolic TCE degradation in the RGA. A number of general or global recommendations relative to the primary recommendation are appropriate as a result of these investigations:

Recommendation #1. Through a Project Team DQO process, develop a comprehensive Sampling and Analysis Plan (SAP) to expand the characterization of microbial degradation across the extents of the NWP.

The following activities should be considered for the expanded characterization:

1. Collect and evaluate data from distal portions of the NWP from the northern extraction well field to areas immediately south of the TVA and east of Little Bayou Creek. As the concentration of TCE in the RGA decreases, it should be anticipated that the rate of TCE degradation will increase.
2. Revisit well selection utilized for this investigation and expand the well selection to accommodate spatial characterization of the Upper, Middle, and Lower RGA.
3. Evaluate existing site data to identify the portions of the NWP RGA that are near sources and secondary source concentrations of TCE related to the NWP.
4. Evaluate the temporal and spatial inputs to the RGA and distribution of DO per considerations in Recommendation #5 below.
5. Evaluate the potential impacts of past, ongoing, and planned PGDP remedial activities on existing biogeochemical conditions in the RGA.
6. Identify and document the individuals in RGA groundwater microbial populations responsible for TCE degradation.
7. Consider enhancements to the RGA environment and potential impacts on biogeochemical processes from a range of proposed and potential remedial actions.
    a. Assess the need for bench scale and pilot studies if enhancements are to be pursued as part of a dissolved phase plume remediation option.

Recommendation #2. Through a Project Team DQO process, revisit first-order TCE degradation rate calculations.

The following activities should be considered for the first-order rate constant:

1. Conduct microcosm studies to provide an independent estimation of TCE degradation rates in the RGA. Utilize one or more of the locations in Table 41.

Table 41. Locations recommended for potential future microcosm studies.

Well	TCE (DEC-07)	Number of probes positive	Notes
MW125	700	3	
MW236	21	3	downgradient of MW125, along plume center
MW 381	50	2	downgradient of MW125, along plume center

2. Conduct compound specific isotope analyses for stable carbon and stable hydrogen isotopes and utilize data to independently calculate first-order degradation rate constants
3. Collect sufficient temporal data at one or more locations to satisfy statistical requirements of the student t-test (Appendix 3).
4. Develop a site-specific H-isotope enrichment factor.
5. Honor flowpaths in the choice of upgradient/downgradient wells in the URGA, MRGA, and LRGA utilized for first-order rate estimations.
6. Address the potential impact of sorption on TCE fate in the RGA and first-f0 order rate constant calculations.
7. Collect a representative number of cores from the discrete intervals in the URGA, MRGA, and LRGA.
8. Apply protocols identified in the *Workshop on Biogeochemical Transformation of Chlorinated Solvents* (AFCEE, 2008) to determine the potential biogeochemical impacts on sorption of VOCs and metals (AFCEE, 2008).
9. Provide DOE with recommendations for interim and final application of TCE degradation rate constants as TCE half-lives in groundwater modeling.
    a. Plume scale application.
    b. Discrete plume segment application.
    c. By RGA horizon.

Recommendation #3. Through a Project Team DQO process, conduct a degradation screening process for the UCRS, similar to this investigation, in order to identify the nature and extent of microbial degradation processes in the UCRS.

The following activities should be considered for the characterization of the UCRS:

1. Evaluate historical data to determine they are of sufficient extent to characterize aerobic, anaerobic, and abiotic degradation processes in the UCRS.
2. Utilize available data to characterize UCRS TCE degradation processes to the extent possible.
3. Provide DOE with recommendations for additional evaluation as necessary.

Recommendation #4. Through a Project Team DQO process, correlate existing NEP and NWP biogeochemical conditions to document the occurrence of aerobic biodegradation processes.

The goal of this activity would be the development of NEP and SWP SAP to support characterization and monitoring of biodegradation in the NEP and SWP.

Recommendation #5. As part of SAP development in the recommendations above, consider implementation of standard geochemical parameter collection to address existing data gaps related to evaluation of both the existence and sustenance of biological and abiotic degradation processes.

The following parameters should be considered:

1. Dissolved organic carbon (DOC) to detection limits less than 1 mg/L as a carbon substrate indicator.
2. Carbon dioxide (CO_2) as an end product of degradation processes.
3. Biochemical oxygen demand (BOD) as an indicator of carbon available for microbial processes.
4. Oxidation-reduction potential (ORP) as an indicator of redox conditions that support aerobic or anaerobic degradation processes.
5. Specific conductivity to augment characterization of the RGA at sub-plume scales.
6. Ammonia (NH_{4+}) as an indicator of anoxic conditions and as a substrate for organic compound degradation.

7. TCE degradation products cis-1,2-DCE, trans-1,1-DCE, and vinyl chloride as indicators of anoxic conditions in the RGA and UCRS.
8. Copper and copper-based compounds, as well as other substances TBD, from process and industrial operations that may have biocidal effects on microorganisms in the RGA and UCRS.
9. In order to complete characterization of the RGA relative to aerobic biodegradation processes, their occurrence and sustenance complete spatial characterization of the upper, middle and lower RGA relative to occurrence and distribution of sources of dissolved oxygen required to sustain aerobic degradation utilizing, but not limited to:
   a. DO concentrations.
   b. DO cycles
   c. Temperature.
   d. pH

11.0. References

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APPENDICES

Appendix Table of Contents

Appendix Figures

Appendix Tables

Appendix 1. Methods

Appendix 1.1. Stable Carbon Isotope Methods

Purge-and-trap extraction and compound-specific isotope ratio analysis

A typical purge and trap (P & T) method of extraction for VOC-class compounds was coupled with the GC-IRMS analyses for the SCI analysis. Specific parameters may change for different compounds to optimize purge and trap (P&T) efficiency or gas chromatography (GC) separation. The volatiles are extracted from the water by an OI 4560 purge and trap with the PT transfer line interfaced to either a Finnigan MAT 252 IRMS for the carbon analyses or a Finnigan Delta XL for hydrogen isotope analyses. A thermal conversion reactor installed as part of the GC–IRMS interface converts the analytes to CO_2 or H_2 without affecting chromatographic resolution (Merritt, 1993; Burgoyne and Hayes, 1998). A Nafion membrane installed prior to the IRMS removes water transferred from P&T and water resulting from combustion. P&T transfer line connects to a polar-phase precolumn used to separate water prior to cryofocusing. This setup is valid for target VOC compounds with DB-WAX retention times lower than that of toluene (including benzene, MTBE, DCE, DCA, TCE and PCE). For target compounds eluting later, the pre-column is not used and the transfer line is connected directly to the cryofocuser (e.g., for heavier fractions of gasoline). Analyte eluting from the precolumn is focused on liquid nitrogen trap and then the analytes are separated on a second GC column for compound-specific ratio determination. The two columns, cryofocuser and the transfer line are interfaced through a 6-port switching valve resulting with splitless refocusing of the P & T effluent. The combustion reactor for the carbon determination is a ceramic tube packed with oxidized nickel and platinum catalyst wires held at 980^{o}C and exposed to an auxiliary oxygen trickle. The pyrolysis reactor used for the δD determination is an empty ceramic tube with carbon deposit, held at 1440^{o}C. This setup permits determination of the carbon isotopic composition for most VOCs at single ppb's concentrations. Hydrogen isotope ratio of VOCs (does not apply for polar compounds and chlorinated compounds) can be determined at tens of ppb concentrations.

Example – analytical parameters for δ^{13}C analysis in cis-DCE, TCE and PCE:

1. P&T: 25 ml sample is purged for 12 min at 40 ml/min purge flow; sample temperature is 50^{o}C. Dry purge is set for 3 minutes. P&T trap is then desorbed for 5 min. P&T is baked 15 min after each run. Trap type is Vocarb 3000 (trap temperature program is the manufacturer's default for this type of sorbent)
2. Pre-column separation: 25 m x 0.25 mm i.d., 0.5 μm film DB-Carbowax, He carrier flow 8 ml/min., for 6 minutes.
3. The final separation column is DB-MTBE, 60 m x 0.32 mm i.d. He carrier flow 1.8 ml/min. GC is held isothermal at 40^{o}C for 10 mines, then ramped at 6^{o}C/minute. After data acquisition the GC oven is heated to 220^{o}C and held for 15 minutes to clean the column.
4. Combustion: standard CO_2 ratio analysis setup.
5. IRMS: standard CO_2 ratio analysis setup.
6. Detection limit (cis-DCE, TCE, PCE) ~2 ppb.

Quantification of isotope ratios in individual compounds by GC-IRMS

Raw output of GC-IRMS consists of three (carbon mode) or two (hydrogen mode) simultaneously acquired signal channels, corresponding to target analyte (CO_2 or H_2, respectively) with variable C-H-O isotope substitution. Rather than measuring the absolute ratios of isotope species, IRMS technique relies on data normalization relative to internal standard of known isotopic composition. A number of pulses of standard gas (CO_2 or hydrogen, respectively) and/or co-injected standard are introduced into the IRMS source during each run to provide a reference for sample-derived signal. GC separation of the analyte permits integration of individual chromatographic peaks, positioned over a uniform background noise. An automatic software routine detects peaks and assigns their background value. Integration of the individual channel outputs over the peak's retention time window provides a ratio of isotope species (D/H or ^{13}C/^{12}C), which in turn is automatically normalized relative to the standard of known isotopic composition. The final output of the automatic integrator has to be reviewed manually, in particular to eliminate errors upon the background determination. The data are reported in delta notation.

$\delta^{13}C = (R_{sample}/R_{standard} - 1) * 1000$

R_{sample} and $R_{standard}$ represent $^{13}C/^{12}C$ ratios of the sample and the international standard (VPDB), respectively.

Precision and accuracy of the P&T-GC-IRMS system are periodically checked by external or coinjected standard. Depending on the specific method used, numbers obtained by GC-IRMS may differ from true isotopic composition of a compound (method bias). The factors affecting the raw isotope ratios in P&T extraction and direct injection GC-IRMS analysis are:

1) The presence of excessive level of contaminants in the carrier gas – especially H_2O and O_2.
2) P&T temperature and time program – defines how much analyte is recovered from aq. sample, and thus defines the scale of isotope effect upon sample-vapor partitioning.
3) The specific batch (lot #) and age of P&T trap used.
4) Split ratio if split-splitless injection is used.
5) Temperature and condition of the thermal conversion reactor.

Water and oxygen may fluctuate during the run and affect IRMS performance by interfering with ion formation and possibly with the collector cup responses. The bias caused by the background O_2 and H_2O may be neutralized by application of standard gas pulses allowing raw output normalization, where both analyte and standard are subject to the same bias. With properly maintained instrument, factors 2-5 remain relatively stable over the period of weeks, resulting within highly reproducible net isotope effect. An exception is hydrogen isotope fractionation caused upon thermal conversion step, which may drift significantly faster and preferably should be checked for each consecutive sample. In the case of carbon isotope analysis, the bias tends to be at the level of decimal parts of a $\delta^{13}C$ ‰ unit, remaining stable in the period of weeks, while much larger fluctuations are normal for hydrogen isotope analysis. In the latter case, drift of the instrument may be significant in the time range of hours. Accordingly, each sample analyzed for hydrogen CSIA is bracketed by standard runs or has at least one standard run immediately before or after the run. Moreover, while only select samples are analyzed in duplicate for carbon CSIA, all hydrogen samples are treated in this way. Current deviation of the hydrogen GC-IRMS method is determined from the standard injections and the final analyte results are updated accordingly.

Typical routine for carbon CSIA, example taken from P&T-GC-IRMS cis-DCE, TCE and PCE analysis:

1) CO_2 standard gas pulses introduced adjacent (within 1 minute before and after the target analyte peaks).
2) Standard (cis-DCE, TCE and PCE, 7 ppb each) run by P&T-GC-IRMS daily or repeated after 10 samples.
3) Isotope ratio of the target analytes normalized relative to one of the CO_2 pulses.
4) Results from external standard (cis-DCE, TCE and PCE) run over the period of a specific sample series provide a correction (if any) to eliminate isotope ratio bias due to sample extraction, combustion etc. To date the bias of $\delta^{13}C$ of 0.5 ‰ or less was observed for TCE and PCE. The bias of cis-DCE varied from 0.5 to 1.2 ‰.
5) Selected samples analyzed in duplicate and the set of standard runs allow determining method precision.

The discussed quality control measures allow fast detection of malfunctions affecting isotope ratios. The corrective actions are taken to pinpoint the location of the problem and fix it. Three most common problems are: 1) failure of P & T sorbent trap; 2) failure of combustion reactor tube on GC-IRMS interface; 3) malfunction of GC-IRMS backflush valve or operator error resulting with large excess of water background. The corrective action in the former two examples is replacing the element, while in the latter case the back-flush valve performance has to be checked, possibly a valve program modified or the valve has to be rebuilt.

Appendix 2. Project Geochemistry-.

Appendix 2A. Project Specific Geochemical Data

Geochemical Sampling
Conducted 5/19/07

Paducah OREIS Report for ERI07-TCE*DEG*

MW125ENZ5-07 from: MW125 on 5/21/2007 Media: WG SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	33		mg/L			2		SW846-9056	/ X /
Nitrate	5.8		mg/L			4.4		SW846-9056	S / X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	19		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	302		umho/cm					FS	/ /
Dissolved Oxygen	2.77		mg/L					FS	/ /
pH	6.05		Std Unit					FS	/ /
Redox	303		mV					FS	/ /
Temperature	64.1		deg F					FS	/ /
METAL									
Calcium	21.8		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	8.44		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	31.9		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,1-Dichloroethane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,1-Dichloroethene	25		ug/L	U		25		SW846-8260	BL-TEMP
1,2-Dichloroethane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,2-Dichloropropane	25		ug/L	U		25		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	25		ug/L	U		25		SW846-8260	BL-TEMP
2-Butanone	50		ug/L	U		50		SW846-8260	BL-TEMP
2-Hexanone	50		ug/L	U		50		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	50		ug/L	U		50		SW846-8260	BL-TEMP
Acetone	50		ug/L	U		50		SW846-8260	BL-TEMP
Benzene	25		ug/L	U		25		SW846-8260	BL-TEMP
Bromodichloromethane	25		ug/L	U		25		SW 846-8260	BL-TEMP
Bromoform	25		ug/L	U		25		SW846-8260	BL-TEMP
Bromomethane	25		ug/L	U		25		SW846-8260	BL-TEMP
Carbon disulfide	25		ug/L	U		25		SW 846-8260	BL-TEMP
Carbon tetrachloride	25		ug/L	U		25		SW846-8260	BL-

						TEMP
Chlorobenzene	25	ug/L	U	25	SW846-8260	BL-TEMP
Chloroethane	25	ug/L	U	25	SW846-8260	BL-TEMP
Chloroform	25	ug/L	U	25	SW846-8260	BL-TEMP
Chloromethane	25	ug/L	JU	25	SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	25	ug/L	U	25	SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	25	ug/L	U	25	SW846-8260	BL-TEMP
CO2	76100	ug/L		13480	RSK175	/ X /
Dibromochloromethane	25	ug/L	U	25	SW846-8260	BL-TEMP
Ethylbenzene	25	ug/L	U	25	SW846-8260	BL-TEMP
m,p-Xylene	50	ug/L	U	50	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	25	ug/L	U	25	SW846-8260	BL-TEMP
Styrene	25	ug/L	U	25	SW846-8260	BL-TEMP
Tetrachloroethene	25	ug/L	U	25	SW846-8260	BL-TEMP
Toluene	25	ug/L	U	25	SW846-8260	BL-TEMP
Total Xylene	75	ug/L	U	75	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	25	ug/L	U	25	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	25	ug/L	U	25	SW846-8260	BL-TEMP
Trichloroethene	700	ug/L	D	5	SW846-8260	BL-TEMP
Vinyl acetate	50	ug/L	U	50	SW846-8260	BL-TEMP
Vinyl chloride	10	ug/L	U	10	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	91	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	91	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW168ENZ5-07 from: MW168 on 5/16/2007 Media: W G SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	92		mg/L			20		SW846-9056	S / X /
Nitrate	17		mg/L			4.4		SW846-9056	IS / X /
Orthophosphate	3.1		mg/L	BU		3.1		SW846-9056	/ X /
Sulfate	11		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	533		umho/cm					FS	/ /
Dissolved Oxygen	2.46		mg/L					FS	/ /
pH	5.76		Std Unit					FS	/ /
Redox	428		mV					FS	/ /
Temperature	65.1		deg F					FS	/ /
METAL									
Calcium	33.6		mg/L			1		SW846-6010B	S / X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	13.1		mg/L			0.025		SW846-6010B	S / X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	46.2		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	JU		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	JU		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	110000		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Ethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP

m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	110	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	JU	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	77	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	77	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	8.2	mg/L		1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	BU	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW185ENZ5-07 from: MW185 on 5/23/2007 Media: W G SmpMethod: GR

Comments: F001,
F002,
U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	57		mg/L			10		SW846-9056	S / X /
Nitrate	7.5		mg/L			4.4		SW846-9056	S / X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	12		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	437		umho/cm					FS	/ /
Dissolved Oxygen	1.96		mg/L					FS	/ /
pH	6.08		Std Unit					FS	/ /
Redox	527		mV					FS	/ /
Temperature	70.3		deg F					FS	/ /
METAL									
Calcium	39		mg/L			1		SW 846-6010B	S / X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	11.9		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	31.2		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	120		ug/L	U		120		SW 846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	120		ug/L	U		120		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	120		ug/L	U		120		SW 846-8260	BL-TEMP
1,1-Dichloroethane	120		ug/L	U		120		SW846-8260	BL-TEMP
1,1-Dichloroethene	120		ug/L	U		120		SW846-8260	BL-TEMP
1,2-Dichloroethane	120		ug/L	U		120		SW846-8260	BL-TEMP
1,2-Dichloropropane	120		ug/L	U		120		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	120		ug/L	U		120		SW846-8260	BL-TEMP
2-Butanone	250		ug/L	U		250		SW846-8260	BL-TEMP
2-Hexanone	250		ug/L	U		250		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	250		ug/L	U		250		SW846-8260	BL-TEMP
Acetone	250		ug/L	JU		250		SW846-8260	BL-TEMP
Benzene	120		ug/L	U		120		SW846-8260	BL-TEMP
Bromodichloromethane	120		ug/L	U		120		SW846-8260	BL-TEMP
Bromoform	120		ug/L	U		120		SW846-8260	BL-TEMP
Bromomethane	120		ug/L	U		120		SW846-8260	BL-TEMP
Carbon disulfide	120		ug/L	U		120		SW 846-8260	BL-TEMP
Carbon tetrachloride	120		ug/L	U		120		SW846-8260	BL-TEMP
Chlorobenzene	120		ug/L	U		120		SW846-8260	BL-TEMP
Chloroethane	120		ug/L	U		120		SW846-8260	BL-TEMP
Chloroform	120		ug/L	U		120		SW846-8260	BL-TEMP
Chloromethane	120		ug/L	JU		120		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	140		ug/L	D		120		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	120		ug/L	U		120		SW846-8260	BL-TEMP
CO2	74100		ug/L			13480		RSK175	/ X /
Dibromochloromethane	120		ug/L	U		120		SW846-8260	BL-TEMP

Ethylbenzene	120	ug/L	U	120	SW846-8260	BL-TEMP
m,p-Xylene	250	ug/L	U	250	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	120	ug/L	U	120	SW846-8260	BL-TEMP
Styrene	120	ug/L	U	120	SW846-8260	BL-TEMP
Tetrachloroethene	120	ug/L	U	120	SW846-8260	BL-TEMP
Toluene	120	ug/L	U	120	SW846-8260	BL-TEMP
Total Xylene	380	ug/L	U	380	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	120	ug/L	U	120	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	120	ug/L	U	120	SW846-8260	BL-TEMP
Trichloroethene	3300	ug/L	D	25	SW846-8260	H-TB, BL
Vinyl acetate	250	ug/L	U	250	SW846-8260	BL-TEMP
Vinyl chloride	50	ug/L	U	50	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	109	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	109	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW194ENZ5-07 from: MW194 on 5/17/2007 Media: W G SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	27		mg/L			2		SW846-9056	/ X /
Nitrate	7		mg/L			4.4		SW846-9056	S / X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	6.5		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	249		umho/cm					FS	/ /
Dissolved Oxygen	5.43		mg/L					FS	/ /
pH	5.98		Std Unit					FS	/ /
Redox	367		mV					FS	/ /
Temperature	61.5		deg F					FS	/ /
METAL									
Calcium	16		mg/L			1		SW 846-6010B	S / X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	6.84		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	27.8		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	JU		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	JU		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	52700		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Ethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP

m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	1	ug/L	U	1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	JU	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	72	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	72	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	X / BL-HS
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	X / BL-HS

MW197ENZ5-07 from: MW197 on 5/21/2007 Media: W G SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	65		mg/L			5		SW846-9056	S / X /
Nitrate	4.4		mg/L	U		4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	16		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	440		umho/cm					FS	/ /
Dissolved Oxygen	0.62		mg/L					FS	/ /
pH	6.01		Std Unit					FS	/ /
Redox	-7		mV					FS	/ /
Temperature	61.2		deg F					FS	/ /
METAL									
Calcium	24.6		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	23.9		mg/L			0.02		SM-3500-Fe D	/ X /
Magnesium	11.2		mg/L			0.025		SW846-6010B	S / X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	25.8		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	U		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	U		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	JU		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP

CO2	78900	ug/L		13480	RSK175	/ X /
Dibromochloromethane	5	ug/L	U	5	SW846-8260	BL-TEMP
Ethylbenzene	5	ug/L	U	5	SW846-8260	BL-TEMP
m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	27.7	ug/L		0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	3.9	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	U	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	78	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	78	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	2	mg/L		1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	2.3	mg/L		1	SW846-9060	/ X /

MW236DENZ5-07 from: MW236 on 5/22/2007 Media: W G SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	31		mg/L			2		SW846-9056	/ X /
Nitrate	7.3		mg/L			4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	21		mg/L			2		SW846-9056	/ X /
FS									
Conductivity	321		umho/cm					FS	/ /
Dissolved Oxygen	3.36		mg/L					FS	/ /
pH	6.19		Std Unit					FS	/ /
Redox	332		mV					FS	/ /
Temperature	62.4		deg F					FS	/ /
METAL									
Calcium	23.2		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	9.16		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	30.4		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	U		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	JU		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	JU		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	65800		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Ethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP

m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	22	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	U	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	92	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	92	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW242ENZ5-07 from: MW242 on 5/17/2007 Media: W G SmpMethod: GR

Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	63		mg/L			10		SW846-9056	/ X /
Nitrate	4.4		mg/L	U		4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	12		mg/L			2		SW846-9056	/ X /
FS									
Conductivity	358		umho/cm					FS	/ /
Dissolved Oxygen	1.5		mg/L					FS	/ /
pH	5.62		Std Unit					FS	/ /
Redox	166		mV					FS	/ /
Temperature	59.7		deg F					FS	/ /
METAL									
Calcium	23.9		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	8.13		mg/L			0.02		SM-3500-Fe D	/ X /
Magnesium	10.6		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	25.7		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	JU		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	JU		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	94700		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Ethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP

m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	110	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	JU	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	55	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	55	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	X / BL-HS
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	X / BL-HS

MW243ENZ5-07 from: MW243 on 5/15/2007 Media: WG SmpMethod: GR

Comments: F001,
F002,
U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	12		mg/L			2		SW846-9056	S / X /
Nitrate	4.4		mg/L	U		4.4		SW846-9056	/ X /
Orthophosphate	16		mg/L	BX		3.1		SW846-9056	/ X /
Sulfate	67		mg/L			5		SW846-9056	S / X /
FS									
Conductivity	439		umho/cm					FS	/ /
Dissolved Oxygen	5.94		mg/L					FS	/ /
pH	6.22		Std Unit					FS	/ /
Redox	252		mV					FS	/ /
Temperature	61.7		deg F					FS	/ /
METAL									
Calcium	18.2		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.0462		mg/L			0.02		SM-3500-Fe D	/ X /
Magnesium	7.38		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	63		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	U		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	U		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	74800		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP

Ethylbenzene	5	ug/L	U	5	SW846-8260	BL-TEMP
m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.5	ug/L		0.32	RSK175	X / BH-TB
Methylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	100	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	U	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	113	mg/L		10	EPA-310.1	S / X /
Bicarbonate as CaCO3	113	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	X / BL-HS
Phosphate as Phosphorous	5.3	mg/L	BX	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	X / BL-HS

MW262ENZ5-07 from: MW262 on 5/16/2007 Media: W G SmpMethod: GR

Comments: F001, F002, U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	110		mg/L			20		SW846-9056	/ X /
Nitrate	5.6		mg/L			4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	BU		3.1		SW846-9056	/ X /
Sulfate	39		mg/L			2		SW846-9056	/ X /
FS									
Conductivity	679		umho/cm					FS	/ /
Dissolved Oxygen	0.6		mg/L					FS	/ /
pH	5.89		Std Unit					FS	/ /
Redox	339		mV					FS	/ /
Temperature	64.6		deg F					FS	/ /
METAL									
Calcium	50.6		mg/L			1		SW846-6010B	S / X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	19.8		mg/L			0.025		SW846-6010B	S / X /
Potassium	2.3		mg/L			2		SW846-6010B	S / X /
Sodium	47		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,1-Dichloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,1-Dichloroethene	50		ug/L	U		50		SW846-8260	BL-TEMP
1,2-Dichloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,2-Dichloropropane	50		ug/L	U		50		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	50		ug/L	U		50		SW846-8260	BL-TEMP
2-Butanone	100		ug/L	JU		100		SW846-8260	BL-TEMP
2-Hexanone	100		ug/L	U		100		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	100		ug/L	U		100		SW846-8260	BL-TEMP
Acetone	100		ug/L	JU		100		SW846-8260	BL-TEMP
Benzene	50		ug/L	U		50		SW846-8260	BL-TEMP
Bromodichloromethane	50		ug/L	U		50		SW 846-8260	BL-TEMP
Bromoform	50		ug/L	U		50		SW846-8260	BL-TEMP
Bromomethane	50		ug/L	U		50		SW846-8260	BL-TEMP
Carbon disulfide	50		ug/L	U		50		SW 846-8260	BL-TEMP
Carbon tetrachloride	50		ug/L	U		50		SW846-8260	BL-TEMP
Chlorobenzene	50		ug/L	U		50		SW846-8260	BL-TEMP
Chloroethane	50		ug/L	U		50		SW846-8260	BL-TEMP
Chloroform	50		ug/L	U		50		SW846-8260	BL-TEMP
Chloromethane	50		ug/L	U		50		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	50		ug/L	U		50		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	50		ug/L	U		50		SW846-8260	BL-TEMP
CO2	110000		ug/L			13480		RSK175	/ X /
Dibromochloromethane	50		ug/L	U		50		SW846-8260	BL-TEMP
Ethylbenzene	50		ug/L	U		50		SW846-8260	BL-TEMP

m,p-Xylene	100	ug/L	U	100	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	50	ug/L	U	50	SW846-8260	BL-TEMP
Styrene	50	ug/L	U	50	SW846-8260	BL-TEMP
Tetrachloroethene	50	ug/L	U	50	SW846-8260	BL-TEMP
Toluene	50	ug/L	U	50	SW846-8260	BL-TEMP
Total Xylene	150	ug/L	U	150	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	50	ug/L	U	50	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	50	ug/L	U	50	SW846-8260	BL-TEMP
Trichloroethene	950	ug/L	D	10	SW846-8260	BL-TEMP
Vinyl acetate	100	ug/L	JU	100	SW846-8260	BL-TEMP
Vinyl chloride	20	ug/L	U	20	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	105	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	105	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	BU	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW340ENZ5-07 from: MW340 on 5/23/2007 Media: W G SmpMethod: GR

Comments: F001,
F002,
U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	61		mg/L			10		SW846-9056	S / X /
Nitrate	7.2		mg/L			4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	28		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	460		umho/cm					FS	/ /
Dissolved Oxygen	3.51		mg/L					FS	/ /
pH	5.94		Std Unit					FS	/ /
Redox	367		mV					FS	/ /
Temperature	74.1		deg F					FS	/ /
METAL									
Calcium	31.2		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	12.4		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	44.1		mg/L			2		SW846-6010B	S / X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	250		ug/L	U		250		SW 846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	250		ug/L	U		250		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	250		ug/L	U		250		SW 846-8260	BL-TEMP
1,1-Dichloroethane	250		ug/L	U		250		SW846-8260	BL-TEMP
1,1-Dichloroethene	250		ug/L	U		250		SW846-8260	BL-TEMP
1,2-Dichloroethane	250		ug/L	U		250		SW846-8260	BL-TEMP
1,2-Dichloropropane	250		ug/L	U		250		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	250		ug/L	U		250		SW846-8260	BL-TEMP
2-Butanone	500		ug/L	U		500		SW846-8260	BL-TEMP
2-Hexanone	500		ug/L	U		500		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	500		ug/L	U		500		SW846-8260	BL-TEMP
Acetone	500		ug/L	JU		500		SW846-8260	BL-TEMP
Benzene	250		ug/L	U		250		SW846-8260	BL-TEMP
Bromodichloromethane	250		ug/L	U		250		SW846-8260	BL-TEMP
Bromoform	250		ug/L	U		250		SW846-8260	BL-TEMP
Bromomethane	250		ug/L	U		250		SW846-8260	BL-TEMP
Carbon disulfide	250		ug/L	U		250		SW 846-8260	BL-TEMP
Carbon tetrachloride	250		ug/L	U		250		SW846-8260	BL-TEMP
Chlorobenzene	250		ug/L	U		250		SW846-8260	BL-TEMP
Chloroethane	250		ug/L	U		250		SW846-8260	BL-TEMP
Chloroform	250		ug/L	U		250		SW846-8260	BL-TEMP
Chloromethane	250		ug/L	JU		250		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	250		ug/L	U		250		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	250		ug/L	U		250		SW846-8260	BL-TEMP
CO2	204000		ug/L			13480		RSK175	/ X /
Dibromochloromethane	250		ug/L	U		250		SW846-8260	BL-TEMP

Ethylbenzene	250	ug/L	U	250	SW846-8260	BL-TEMP
m,p-Xylene	500	ug/L	U	500	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	250	ug/L	U	250	SW846-8260	BL-TEMP
Styrene	250	ug/L	U	250	SW846-8260	BL-TEMP
Tetrachloroethene	250	ug/L	U	250	SW846-8260	BL-TEMP
Toluene	250	ug/L	U	250	SW846-8260	BL-TEMP
Total Xylene	750	ug/L	U	750	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	250	ug/L	U	250	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	250	ug/L	U	250	SW846-8260	BL-TEMP
Trichloroethene	6500	ug/L	D	50	SW846-8260	H-TB, BL
Vinyl acetate	500	ug/L	U	500	SW846-8260	BL-TEMP
Vinyl chloride	100	ug/L	U	100	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	109	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	109	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW381ENZ5-07 from: MW381 on 5/22/2007 Media: W G SmpMethod: GR

Comments: F001,
F002, U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	41		mg/L			2		SW846-9056	S / X /
Nitrate	6.7		mg/L			4.4		SW846-9056	/ X /
Orthophosphate	3.1		mg/L	U		3.1		SW846-9056	/ X /
Sulfate	24		mg/L			2		SW846-9056	S / X /
FS									
Conductivity	372		umho/cm					FS	/ /
Dissolved Oxygen	3.23		mg/L					FS	/ /
pH	6.18		Std Unit					FS	/ /
Redox	286		mV					FS	/ /
Temperature	61		deg F					FS	/ /
METAL									
Calcium	27.2		mg/L			1		SW846-6010B	/ X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.02		mg/L	U		0.02		SM-3500-Fe D	/ X /
Magnesium	10.7		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	33.7		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
2-Butanone	10		ug/L	U		10		SW846-8260	BL-TEMP
2-Hexanone	10		ug/L	U		10		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	BL-TEMP
Acetone	10		ug/L	JU		10		SW846-8260	BL-TEMP
Benzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromodichloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromoform	5		ug/L	U		5		SW846-8260	BL-TEMP
Bromomethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Carbon disulfide	5		ug/L	U		5		SW 846-8260	BL-TEMP
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	BL-TEMP
Chlorobenzene	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloroform	5		ug/L	U		5		SW846-8260	BL-TEMP
Chloromethane	5		ug/L	JU		5		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	BL-TEMP
CO2	60500		ug/L			13480		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	BL-TEMP
Ethylbenzene	5		ug/L	U		5		SW846-8260	BL-TEMP

m,p-Xylene	10	ug/L	U	10	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
ethylene chloride	5	ug/L	U	5	SW846-8260	BL-TEMP
Styrene	5	ug/L	U	5	SW846-8260	BL-TEMP
Tetrachloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
Toluene	5	ug/L	U	5	SW846-8260	BL-TEMP
Total Xylene	15	ug/L	U	15	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	BL-TEMP
Trichloroethene	50	ug/L		1	SW846-8260	BL-TEMP
Vinyl acetate	10	ug/L	U	10	SW846-8260	BL-TEMP
Vinyl chloride	2	ug/L	U	2	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	98	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	98	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

MW66ENZ5-07 from: MW66 on 5/15/2007 Media: W G SmpMethod: GR

Comments: F001, F002, U228

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
ANION									
Chloride	13		mg/L			2		SW846-9056	/ X /
Nitrate	5.8		mg/L			4.4		SW846-9056	S / X /
Orthophosphate	3.1		mg/L	BUX		3.1		SW846-9056	/ X /
Sulfate	11		mg/L			2		SW846-9056	/ X /
FS									
Conductivity	213		umho/cm					FS	/ /
Dissolved Oxygen	5.78		mg/L					FS	/ /
pH	6.01		Std Unit					FS	/ /
Redox	304		mV					FS	/ /
Temperature	65.9		deg F					FS	/ /
METAL									
Calcium	18.8		mg/L			1		SW846-6010B	S / X /
Copper	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
Iron (2+)	0.0353		mg/L			0.02		SM-3500-Fe D	/ X /
Magnesium	6.21		mg/L			0.025		SW846-6010B	/ X /
Potassium	2		mg/L	U		2		SW846-6010B	/ X /
Sodium	16.2		mg/L			2		SW846-6010B	/ X /
METAL-D									
Copper, Dissolved	0.025		mg/L	BU		0.025		SW846-6010B	/ X /
VOA									
1,1,1-Trichloroethane	100		ug/L	U		100		SW 846-8260	BL-TEMP
1,1,2,2-Tetrachloroethane	100		ug/L	U		100		SW846-8260	BL-TEMP
1,1,2-Trichloroethane	100		ug/L	U		100		SW 846-8260	BL-TEMP
1,1-Dichloroethane	100		ug/L	U		100		SW846-8260	BL-TEMP
1,1-Dichloroethene	100		ug/L	U		100		SW846-8260	BL-TEMP
1,2-Dichloroethane	100		ug/L	U		100		SW846-8260	BL-TEMP
1,2-Dichloropropane	100		ug/L	U		100		SW846-8260	BL-TEMP
1,2-Dimethylbenzene	100		ug/L	U		100		SW846-8260	BL-TEMP
2-Butanone	200		ug/L	U		200		SW846-8260	BL-TEMP
2-Hexanone	200		ug/L	U		200		SW846-8260	BL-TEMP
4-Methyl-2-pentanone	200		ug/L	U		200		SW846-8260	BL-TEMP
Acetone	200		ug/L	U		200		SW846-8260	BL-TEMP
Benzene	100		ug/L	U		100		SW846-8260	BL-TEMP
Bromodichloromethane	100		ug/L	U		100		SW846-8260	BL-TEMP
Bromoform	100		ug/L	U		100		SW846-8260	BL-TEMP
Bromomethane	100		ug/L	U		100		SW846-8260	BL-TEMP
Carbon disulfide	100		ug/L	U		100		SW 846-8260	BL-TEMP
Carbon tetrachloride	100		ug/L	U		100		SW846-8260	BL-TEMP
Chlorobenzene	100		ug/L	U		100		SW846-8260	BL-TEMP
Chloroethane	100		ug/L	U		100		SW846-8260	BL-TEMP
Chloroform	100		ug/L	U		100		SW846-8260	BL-TEMP
Chloromethane	100		ug/L	U		100		SW846-8260	BL-TEMP
cis-1,2-Dichloroethene	100		ug/L	U		100		SW846-8260	BL-TEMP
cis-1,3-Dichloropropene	100		ug/L	U		100		SW846-8260	BL-TEMP
CO2	57400		ug/L			13480		RSK175	/ X /
Dibromochloromethane	100		ug/L	U		100		SW846-8260	BL-TEMP
Ethylbenzene	100		ug/L	U		100		SW846-8260	BL-TEMP

m,p-Xylene	200	ug/L	U	200	SW846-8260	BL-TEMP
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	100	ug/L	U	100	SW846-8260	BL-TEMP
Styrene	100	ug/L	U	100	SW846-8260	BL-TEMP
Tetrachloroethene	100	ug/L	U	100	SW846-8260	BL-TEMP
Toluene	100	ug/L	U	100	SW846-8260	BL-TEMP
Total Xylene	300	ug/L	U	300	SW846-8260	BL-TEMP
trans-1,2-Dichloroethene	100	ug/L	U	100	SW846-8260	BL-TEMP
trans-1,3-Dichloropropene	100	ug/L	U	100	SW846-8260	BL-TEMP
Trichloroethene	700	ug/L	D	20	SW846-8260	BL-TEMP
Vinyl acetate	200	ug/L	U	200	SW846-8260	BL-TEMP
Vinyl chloride	40	ug/L	U	40	SW846-8260	BL-TEMP
WETCHEM						
Alkalinity	72	mg/L		10	EPA-310.1	/ X /
Bicarbonate as CaCO3	72	mg/L		10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	X / BL-HS
Phosphate as Phosphorous	1	mg/L	BUX	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	X / BL-HS

FB1ENZ5-07from: QC on 5/22/2007 Media: W Q SmpMethod: Comments:

Analysis	Results CouError	Units nting	Result Qual Foot Note	Reporting Limit	TPU Method	V/V/A*
ANION						
Chloride	2	mg/L	U	2	SW846-9056	/ X /
Nitrate	4.4	mg/L	U	4.4	SW846-9056	/ X /
Orthophosphate	3.1	mg/L	U	3.1	SW846-9056	/ X /
Sulfate	2	mg/L	U	2	SW846-9056	/ X /
METAL						
Calcium	1	mg/L	U	1	SW 846-6010B	/ X /
Copper	0.025	mg/L	BU	0.025	SW846-6010B	/ X /
Iron (2+)	0.02	mg/L	U	0.02	SM-3500-Fe D	/ X /
Magnesium	0.025	mg/L	U	0.025	SW846-6010B	/ X /
Potassium	2	mg/L	U	2	SW846-6010B	/ X /
Sodium	2	mg/L	U	2	SW846-6010B	/ X /
VOA						
1,1,1-Trichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1,2-Trichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1-Dichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dichloropropane	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dimethylbenzene	5	ug/L	U	5	SW846-8260	/ X /
2-Butanone	10	ug/L	U	10	SW846-8260	/ X /
2-Hexanone	10	ug/L	U	10	SW846-8260	/ X /
4-Methyl-2-pentanone	10	ug/L	U	10	SW846-8260	/ X /
Acetone	14	ug/L	J	10	SW846-8260	/ X /
Benzene	5	ug/L	U	5	SW846-8260	/ X /
Bromodichloromethane	5	ug/L	U	5	SW846-8260	/ X /
Bromoform	5	ug/L	U	5	SW846-8260	/ X /
Bromomethane	5	ug/L	U	5	SW846-8260	/ X /
Carbon disulfide	5	ug/L	U	5	SW 846-8260	/ X /
Carbon tetrachloride	5	ug/L	U	5	SW846-8260	/ X /
Chlorobenzene	5	ug/L	U	5	SW846-8260	/ X /
Chloroethane	5	ug/L	U	5	SW846-8260	/ X /
Chloroform	5	ug/L	U	5	SW846-8260	/ X /
Chloromethane	5	ug/L	JU	5	SW846-8260	/ X /
cis-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
cis-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	/ X /
CO2	674	ug/L	U	674	RSK175	/ X /
Dibromochloromethane	5	ug/L	U	5	SW846-8260	/ X /
Ethylbenzene	5	ug/L	U	5	SW846-8260	/ X /
m,p-Xylene	10	ug/L	U	10	SW846-8260	/ X /
Methane	0.32	ug/L	U	0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	/ X /
Styrene	5	ug/L	U	5	SW846-8260	/ X /
Tetrachloroethene	5	ug/L	U	5	SW846-8260	/ X /
Toluene	5	ug/L	U	5	SW846-8260	/ X /
Total Xylene	15	ug/L	U	15	SW846-8260	/ X /
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	/ X /
Trichloroethene	1	ug/L	U	1	SW846-8260	/ X /
Vinyl acetate	10	ug/L	U	10	SW846-8260	/ X /

Vinyl chloride	2	ug/L	U	2	SW846-8260	/ X /
WETCHEM						
Alkalinity	10	mg/L	U	10	EPA-310.1	/ X /
Bicarbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

RI1ENZ5-07from: QC on 5/22/2007 Media: W Q SmpMethod: Comments:

Analysis	Results CouError	Units nting	Result Qual Foot Note	Reporting Limit	TPU Method	V/V/A*
ANION						
Chloride	2	mg/L	U	2	SW846-9056	/ X /
Nitrate	4.4	mg/L	U	4.4	SW846-9056	/ X /
Orthophosphate	3.1	mg/L	U	3.1	SW846-9056	/ X /
Sulfate	2	mg/L	U	2	SW846-9056	/ X /
METAL						
Calcium	1	mg/L	U	1	SW 846-6010B	/ X /
Copper	0.025	mg/L	BU	0.025	SW846-6010B	/ X /
Iron (2+)	0.02	mg/L	U	0.02	SM-3500-Fe D	/ X /
Magnesium	0.025	mg/L	U	0.025	SW846-6010B	/ X /
Potassium	2	mg/L	U	2	SW846-6010B	/ X /
Sodium	2	mg/L	U	2	SW846-6010B	/ X /
VOA						
1,1,1-Trichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1,2-Trichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1-Dichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,1-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dichloroethane	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dichloropropane	5	ug/L	U	5	SW846-8260	/ X /
1,2-Dimethylbenzene	5	ug/L	U	5	SW846-8260	/ X /
2-Butanone	10	ug/L	U	10	SW846-8260	/ X /
2-Hexanone	10	ug/L	U	10	SW846-8260	/ X /
4-Methyl-2-pentanone	10	ug/L	U	10	SW846-8260	/ X /
Acetone	54	ug/L	J	10	SW846-8260	/ X /
Benzene	5	ug/L	U	5	SW846-8260	/ X /
Bromodichloromethane	5	ug/L	U	5	SW846-8260	/ X /
Bromoform	5	ug/L	U	5	SW846-8260	/ X /
Bromomethane	5	ug/L	U	5	SW846-8260	/ X /
Carbon disulfide	5	ug/L	U	5	SW 846-8260	/ X /
Carbon tetrachloride	5	ug/L	U	5	SW846-8260	/ X /
Chlorobenzene	5	ug/L	U	5	SW846-8260	/ X /
Chloroethane	5	ug/L	U	5	SW846-8260	/ X /
Chloroform	5	ug/L	U	5	SW846-8260	/ X /
Chloromethane	5	ug/L	JU	5	SW846-8260	/ X /
cis-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
cis-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	/ X /
CO2	674	ug/L	U	674	RSK175	/ X /
Dibromochloromethane	5	ug/L	U	5	SW846-8260	/ X /
Ethylbenzene	5	ug/L	U	5	SW846-8260	/ X /
m,p-Xylene	10	ug/L	U	10	SW846-8260	/ X /
Methane	1.01	ug/L		0.32	RSK175	/ X /
Methylene chloride	5	ug/L	U	5	SW846-8260	/ X /
Styrene	5	ug/L	U	5	SW846-8260	/ X /
Tetrachloroethene	5	ug/L	U	5	SW846-8260	/ X /
Toluene	5	ug/L	U	5	SW846-8260	/ X /
Total Xylene	15	ug/L	U	15	SW846-8260	/ X /
trans-1,2-Dichloroethene	5	ug/L	U	5	SW846-8260	/ X /
trans-1,3-Dichloropropene	5	ug/L	U	5	SW846-8260	/ X /
Trichloroethene	1	ug/L	U	1	SW846-8260	/ X /
Vinyl acetate	10	ug/L	U	10	SW846-8260	/ X /
Vinyl chloride	2	ug/L	U	2	SW846-8260	/ X /
WETCHEM						

Alkalinity	10	mg/L	U	10	EPA-310.1	/ X /
Bicarbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Carbonate as CaCO3	10	mg/L	U	10	SM-2320 B 17	/ X /
Dissolved Organic Carbon	1	mg/L	U	1	SW 846-9060	/ X /
Phosphate as Phosphorous	1	mg/L	U	1	SW846-9056	/ X /
Total Organic Carbon (TOC)	1	mg/L	U	1	SW846-9060	/ X /

TB1ENZ5-07from: QC on 5/15/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	U		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	U		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	U		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	0.923		ug/L			0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1		ug/L	U		1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	U		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

TB2ENZ5-07from: QC on 5/16/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	JU		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	JU		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	U		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	1.07		ug/L			0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1		ug/L	U		1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	JU		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

TB3ENZ5-07from: QC on 5/17/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	JU		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	JU		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	U		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	0.904		ug/L			0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1		ug/L	U		1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	JU		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

TB4ENZ5-07from: QC on 5/21/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	U		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	U		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	JU		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	0.829		ug/L			0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1		ug/L	U		1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	U		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

TB5ENZ5-07from: QC on 5/22/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	U		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	JU		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	JU		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	1.16		ug/L			0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1		ug/L	U		1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	U		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

TB6ENZ5-07from: QC on 5/23/2007 Media: W Q SmpMethod: Comments:

Analysis	Results	Counting Error	Units	Result Qual	Foot Note	Reporting Limit	TPU	Method	V/V/A*
VOA									
1,1,1-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2,2-Tetrachloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1,2-Trichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,1-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloroethane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dichloropropane	5		ug/L	U		5		SW846-8260	/ X /
1,2-Dimethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
2-Butanone	10		ug/L	U		10		SW846-8260	/ X /
2-Hexanone	10		ug/L	U		10		SW846-8260	/ X /
4-Methyl-2-pentanone	10		ug/L	U		10		SW846-8260	/ X /
Acetone	10		ug/L	JU		10		SW846-8260	/ X /
Benzene	5		ug/L	U		5		SW846-8260	/ X /
Bromodichloromethane	5		ug/L	U		5		SW846-8260	/ X /
Bromoform	5		ug/L	U		5		SW846-8260	/ X /
Bromomethane	5		ug/L	U		5		SW846-8260	/ X /
Carbon disulfide	5		ug/L	U		5		SW 846-8260	/ X /
Carbon tetrachloride	5		ug/L	U		5		SW846-8260	/ X /
Chlorobenzene	5		ug/L	U		5		SW846-8260	/ X /
Chloroethane	5		ug/L	U		5		SW846-8260	/ X /
Chloroform	5		ug/L	U		5		SW846-8260	/ X /
Chloromethane	5		ug/L	JU		5		SW846-8260	/ X /
cis-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
cis-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
CO2	674		ug/L	U		674		RSK175	/ X /
Dibromochloromethane	5		ug/L	U		5		SW846-8260	/ X /
Ethylbenzene	5		ug/L	U		5		SW846-8260	/ X /
m,p-Xylene	10		ug/L	U		10		SW846-8260	/ X /
Methane	0.32		ug/L	U		0.32		RSK175	/ X /
Methylene chloride	5		ug/L	U		5		SW846-8260	/ X /
Styrene	5		ug/L	U		5		SW846-8260	/ X /
Tetrachloroethene	5		ug/L	U		5		SW846-8260	/ X /
Toluene	5		ug/L	U		5		SW846-8260	/ X /
Total Xylene	15		ug/L	U		15		SW846-8260	/ X /
trans-1,2-Dichloroethene	5		ug/L	U		5		SW846-8260	/ X /
trans-1,3-Dichloropropene	5		ug/L	U		5		SW846-8260	/ X /
Trichloroethene	1.7		ug/L			1		SW846-8260	/ X /
Vinyl acetate	10		ug/L	U		10		SW846-8260	/ X /
Vinyl chloride	2		ug/L	U		2		SW846-8260	/ X /

Geochemical Sampling
12/19/08
Conducted during Stable Carbon Isotope Sample Collection
Paducah OREIS Report for ERI08-TCEDEG

Paducah OREIS Report for ERI08-TCEDEG

Projectid	Client Sample ID	Station	Date Collected	Med Type	Samp Method	Sample Type	Ana Type	Analysis	Result	Error	Units	Qualifier	Detection Limit	TPE_VAL	LabCode	ANA_ METHOD	VerificationCode	ValidationCode	Dilution Factor
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,1,1-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,1-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,1,2,2-Tetrachloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,2,2-Tetrachloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,1,2-Trichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1,2-Trichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1.2		ug/L	U	1.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	25		ug/L	U	25		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	10		ug/L	U	10		PGDP	8260B		X	10

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ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	80		ug/L	U	80		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1-Dichloroethane	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	2.8		ug/L	D	1.2		PGDP	8260B	S	X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	25		ug/L	U	25		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	1.8		ug/L		1		PGDP	8260B	S	X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	10		ug/L	U	10		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	80		ug/L	U	80		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,1-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,1-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1

Projectid	Client Sample ID	Station	Date Collected	Med Type	Samp Method	Sample Type	Ana Type	Analysis	Result	Error	Units	Qualifier	Detection Limit	TPE_VAL	LabCode	ANA_METHOD	VerificationCode	ValidationCode	Dilution Factor
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,2-Dichloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dichloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,2-Dichloropropane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dichloropropane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	1,2-Dimethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	1,2-Dimethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	2-Butanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	2-Butanone	12		ug/L	U	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	2-Butanone	250		ug/L	U	250		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	2-Butanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	2-Butanone	100		ug/L	U	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	2-Butanone	800		ug/L	U	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	2-Butanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	2-Butanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	2-Hexanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	2-Hexanone	12		ug/L	U	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	2-Hexanone	250		ug/L	U	250		PGDP	8260B		X	25

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	2-Hexanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	2-Hexanone	100		ug/L	U	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	2-Hexanone	800		ug/L	U	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	2-Hexanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	2-Hexanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	12		ug/L	U	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	250		ug/L	U	250		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	100		ug/L	U	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	800		ug/L	U	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	4-Methyl-2-pentanone	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	4-Methyl-2-pentanone	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Acetone	50		ug/L	JU	50		PGDP	8260B		X	5

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Acetone	12		ug/L	JU	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Acetone	250		ug/L	JU	250		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Acetone	50		ug/L	JU	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Acetone	100		ug/L	JU	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Acetone	800		ug/L	JU	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Acetone	50		ug/L	JU	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Acetone	10		ug/L	JU	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				METEO	Barometric Pressure	30.21		Inches/Hg				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Benzene	25		ug/L	U	25		PGDP	8260B		X	5

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Benzene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Benzene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Benzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Benzene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Benzene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Benzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Benzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Bromodichloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromodichloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Bromoform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Bromoform	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Bromoform	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Bromoform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Bromoform	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Bromoform	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Bromoform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromoform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Bromomethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Bromomethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Bromomethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Bromomethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Bromomethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Bromomethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	MW66CARB 12-07	MW66	12/19/2007	WG	GR	REG	VOA	Bromomethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Bromomethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CAR B12-07	MW125	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CAR B12-07	MW168	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CAR B12-07	MW185	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CAR B12-07	MW194	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CAR B12-07	MW197	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CAR B12-07	MW236	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CAR B12-07	MW242	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CAR B12-07	MW243	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CAR B12-07	MW262	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CAR B12-07	MW340	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CAR B12-07	MW381	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB 12-07	MW66	12/19/2007	WG	GR	REG	VOA	Carbon disulfide	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Carbon disulfide	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CAR B12-07	MW125	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CAR B12-07	MW168	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CAR B12-07	MW185	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CAR B12-07	MW194	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CAR B12-07	MW197	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CAR B12-07	MW236	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CAR B12-07	MW242	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CAR B12-07	MW243	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CAR B12-07	MW262	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	50		ug/L	U	50		PGDP	8260B		X	10

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ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Carbon tetrachloride	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Carbon tetrachloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Chlorobenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chlorobenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Chloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Chloroethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Chloroethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Chloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Chloroethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Chloroethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Chloroethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloroethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Chloroform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Chloroform	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Chloroform	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Chloroform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Chloroform	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Chloroform	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Chloroform	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloroform	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Chloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Chloromethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Chloromethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Chloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Chloromethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Chloromethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Chloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Chloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	1.2		ug/L	U	1.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	76		ug/L	D	25		PGDP	8260B	I	X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	4.4		ug/L		1		PGDP	8260B	S	X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	11		ug/L	D	10		PGDP	8260B	S	X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	80		ug/L	U	80		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	cis-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	cis-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	120		ug/L	U	120		PGDP	8260B		X	25

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	cis-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	cis-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				WETCHEM	Conductivity	310		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				WETCHEM	Conductivity	492		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				WETCHEM	Conductivity	382		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				WETCHEM	Conductivity	251		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				WETCHEM	Conductivity	424		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				WETCHEM	Conductivity	502		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				WETCHEM	Conductivity	395		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				WETCHEM	Conductivity	378		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				WETCHEM	Conductivity	601		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				WETCHEM	Conductivity	453		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				WETCHEM	Conductivity	502		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				WETCHEM	Conductivity	190		umho/cm				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				PHYSC	Depth to Water	54.1		ft				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				PHYSC	Depth to Water	54.45		ft				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				PHYSC	Depth to Water	51.26		ft				FS	FS		X	

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				PHYSC	Depth to Water	33.75		ft				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				PHYSC	Depth to Water	46.25		ft				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				PHYSC	Depth to Water	48.71		ft				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				PHYSC	Depth to Water	46.84		ft				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				PHYSC	Depth to Water	45.05		ft				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				PHYSC	Depth to Water	50.64		ft				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				PHYSC	Depth to Water	51.69		ft				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				PHYSC	Depth to Water	48.71		ft				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				PHYSC	Depth to Water	48.55		ft				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Dibromochloromethane	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Dibromochloromethane	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	75		ug/L	U	75		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	19		ug/L	U	19		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	380		ug/L	U	380		PGDP	8260B		X	25

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	75		ug/L	U	75		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	150		ug/L	U	150		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	1200		ug/L	U	1200		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Dimethylbenzene, Total	75		ug/L	U	75		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Dimethylbenzene, Total	15		ug/L	U	15		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				PHYSC	Dissolved Oxygen	2.88		mg/L				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				PHYSC	Dissolved Oxygen	3.13		mg/L				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				PHYSC	Dissolved Oxygen	1.68		mg/L				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				PHYSC	Dissolved Oxygen	3.61		mg/L				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				PHYSC	Dissolved Oxygen	0.72		mg/L				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				PHYSC	Dissolved Oxygen	6.07		mg/L				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				PHYSC	Dissolved Oxygen	0.8		mg/L				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				PHYSC	Dissolved Oxygen	3.81		mg/L				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				PHYSC	Dissolved Oxygen	0.76		mg/L				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				PHYSC	Dissolved Oxygen	3.17		mg/L				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				PHYSC	Dissolved Oxygen	6.07		mg/L				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				PHYSC	Dissolved Oxygen	5.69		mg/L				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	120		ug/L	U	120		PGDP	8260B		X	25

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Ethylbenzene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Ethylbenzene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	12		ug/L	U	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	250		ug/L	U	250		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	100		ug/L	U	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	800		ug/L	U	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	meta/para Xylene	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	meta/para Xylene	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Methylene chloride	25		ug/L	U	25		PGDP	8260B		X	5

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Methylene chloride	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Methylene chloride	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Methylene chloride	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Methylene chloride	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Methylene chloride	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Methylene chloride	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Methylene chloride	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				PHYSC	Oxidation-Reduction Potential	400		mV				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				PHYSC	Oxidation-Reduction Potential	233		mV				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				PHYSC	Oxidation-Reduction Potential	269		mV				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				PHYSC	Oxidation-Reduction Potential	114		mV				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				PHYSC	Oxidation-Reduction Potential	2		mV				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				PHYSC	Oxidation-Reduction Potential	261		mV				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				PHYSC	Oxidation-Reduction Potential	63		mV				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				PHYSC	Oxidation-Reduction Potential	150		mV				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				PHYSC	Oxidation-Reduction Potential	218		mV				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				PHYSC	Oxidation-Reduction Potential	254		mV				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				PHYSC	Oxidation-Reduction Potential	261		mV				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				PHYSC	Oxidation-Reduction Potential	285		mV				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				PHYSC	pH	6.11		Std Unit				FS	FS		X	

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				PHYSC	pH	5.87		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				PHYSC	pH	6.1		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				PHYSC	pH	6.2		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				PHYSC	pH	6.13		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				PHYSC	pH	6.65		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				PHYSC	pH	6.09		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				PHYSC	pH	5.96		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				PHYSC	pH	5.97		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				PHYSC	pH	6.04		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				PHYSC	pH	6.65		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				PHYSC	pH	6.01		Std Unit				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Styrene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Styrene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Styrene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Styrene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Styrene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Styrene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Styrene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Styrene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	RADS	Technetium-99	220	17.8	pCi/L		16.7	18.6	PGDP	RL-7100	I	X	

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	RADS	Technetium-99	2400	45.1	pCi/L		16.7	74.7	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	RADS	Technetium-99	696	26.4	pCi/L		16.1	31.6	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	RADS	Technetium-99	6.11	11.5	pCi/L	U	16.1	11.5	PGDP	RL-7100		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	RADS	Technetium-99	-8.38	11.4	pCi/L	U	16.7	11.4	PGDP	RL-7100		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	RADS	Technetium-99	29.1	12.7	pCi/L		16.7	12.7	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	RADS	Technetium-99	110	15.1	pCi/L		16.7	15.3	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	RADS	Technetium-99	306	19.4	pCi/L		16.1	20.9	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	RADS	Technetium-99	519	23.4	pCi/L		16.1	26.7	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	RADS	Technetium-99	647	25.6	pCi/L		16.1	30.2	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	RADS	Technetium-99	21.5	12.5	pCi/L		16.7	12.5	PGDP	RL-7100		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	RADS	Technetium-99	530	23.7	pCi/L		16.1	27.1	PGDP	RL-7100	I	X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				PHYSC	Temperature	55.8		deg F				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				PHYSC	Temperature	62.7		deg F				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				PHYSC	Temperature	59.4		deg F				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				PHYSC	Temperature	57.6		deg F				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				PHYSC	Temperature	57.7		deg F				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				PHYSC	Temperature	57.8		deg F				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				PHYSC	Temperature	57		deg F				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				PHYSC	Temperature	57.2		deg F				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				PHYSC	Temperature	61.6		deg F				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				PHYSC	Temperature	60.7		deg F				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				PHYSC	Temperature	57.8		deg F				FS	FS		X	
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007				PHYSC	Temperature	60.3		deg F				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	120		ug/L	U	120		PGDP	8260B		X	25

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ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Tetrachloroethene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Tetrachloroethene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Toluene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Toluene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Toluene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Toluene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Toluene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Toluene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Toluene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Toluene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5

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ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1.2		ug/L	U	1.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	25		ug/L	U	25		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	10		ug/L	U	10		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	80		ug/L	U	80		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	trans-1,2-Dichloroethene	5		ug/L	U	5		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	trans-1,2-Dichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	6.2		ug/L	U	6.2		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	120		ug/L	U	120		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	50		ug/L	U	50		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	400		ug/L	U	400		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	trans-1,3-Dichloropropene	25		ug/L	U	25		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1

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ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	trans-1,3-Dichloropropene	5		ug/L	U	5		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Trichloroethene	620		ug/L	D	5		PGDP	8260B	I	X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Trichloroethene	110		ug/L	D	1.2		PGDP	8260B	I	X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Trichloroethene	3600		ug/L	D	25		PGDP	8260B	I	X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Trichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Trichloroethene	3.5		ug/L		1		PGDP	8260B	I	X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Trichloroethene	72		ug/L		1		PGDP	8260B	I	X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Trichloroethene	150		ug/L		1		PGDP	8260B	I	X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Trichloroethene	590		ug/L	D	5		PGDP	8260B	I	X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Trichloroethene	1400		ug/L	D	10		PGDP	8260B	I	X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Trichloroethene	9700		ug/L	D	80		PGDP	8260B	IS	X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Trichloroethene	47		ug/L		1		PGDP	8260B	IS	X	1
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Trichloroethene	930		ug/L	D	10		PGDP	8260B	I	X	10
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Trichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Trichloroethene	1		ug/L	U	1		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007				WETCHEM	Turbidity	20.2		NTU				FS	FS		X	
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007				WETCHEM	Turbidity	65.1		NTU				FS	FS		X	
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007				WETCHEM	Turbidity	7.2		NTU				FS	FS		X	
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007				WETCHEM	Turbidity	5.9		NTU				FS	FS		X	
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007				WETCHEM	Turbidity	43.5		mV				FS	FS		X	
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007				WETCHEM	Turbidity	4.3		NTU				FS	FS		X	
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007				WETCHEM	Turbidity	63.3		NTU				FS	FS		X	
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007				WETCHEM	Turbidity	2.3		NTU				FS	FS		X	
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007				WETCHEM	Turbidity	20.7		NTU				FS	FS		X	
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007				WETCHEM	Turbidity	6.5		NTU				FS	FS		X	
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007				WETCHEM	Turbidity	4.3		NTU				FS	FS		X	

Projectid	Client Sample ID	Station	Date Collected	Med Type	Samp Method	Sample Type	Ana Type	Analysis	Result	Error	Units	Qualifier	Detection Limit	TPE_VAL	LabCode	ANA_ METHOD	VerificationCode	ValidationCode	Dilution Factor
ERI08-TCEDEG	MW66CARB 12-07	MW66	12/19/2007				WETCHEM	Turbidity	7.1		NTU				FS	FS		X	
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	12		ug/L	U	12		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	250		ug/L	U	250		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	100		ug/L	U	100		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	800		ug/L	U	800		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW66CARB 12-07	MW66	12/19/2007	WG	GR	REG	VOA	Vinyl acetate	50		ug/L	U	50		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Vinyl acetate	10		ug/L	U	10		PGDP	8260B		X	1
ERI08-TCEDEG	MW125CARB12-07	MW125	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	10		ug/L	U	10		PGDP	8260B		X	5
ERI08-TCEDEG	MW168CARB12-07	MW168	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2.5		ug/L	U	2.5		PGDP	8260B		X	1.25
ERI08-TCEDEG	MW185CARB12-07	MW185	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	50		ug/L	U	50		PGDP	8260B		X	25
ERI08-TCEDEG	MW194CARB12-07	MW194	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1
ERI08-TCEDEG	MW197CARB12-07	MW197	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1
ERI08-TCEDEG	MW236CARB12-07	MW236	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1
ERI08-TCEDEG	MW242CARB12-07	MW242	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1
ERI08-TCEDEG	MW243CARB12-07	MW243	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	10		ug/L	U	10		PGDP	8260B		X	5
ERI08-TCEDEG	MW262CARB12-07	MW262	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	20		ug/L	U	20		PGDP	8260B		X	10
ERI08-TCEDEG	MW340CARB12-07	MW340	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	160		ug/L	U	160		PGDP	8260B		X	80
ERI08-TCEDEG	MW381CARB12-07	MW381	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1

Projectid	Client Sample ID	Station	Date Collected	Med Type	Samp Method	Sample Type	Ana Type	Analysis	Result	Error	Units	Qualifier	Detection Limit	TPE_VAL	LabCode	ANA_METHOD	VerificationCode	ValidationCode	Dilution Factor
ERI08-TCEDEG	MW66CARB12-07	MW66	12/19/2007	WG	GR	REG	VOA	Vinyl chloride	10		ug/L	U	10		PGDP	8260B		X	5
ERI08-TCEDEG	TB1CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1
ERI08-TCEDEG	TB2CARB12-07	QC	12/19/2007	WQ	GR	TB	VOA	Vinyl chloride	2		ug/L	U	2		PGDP	8260B		X	1

Appendix 2B. Geochemical Plots for Project Specific Sampling Locations

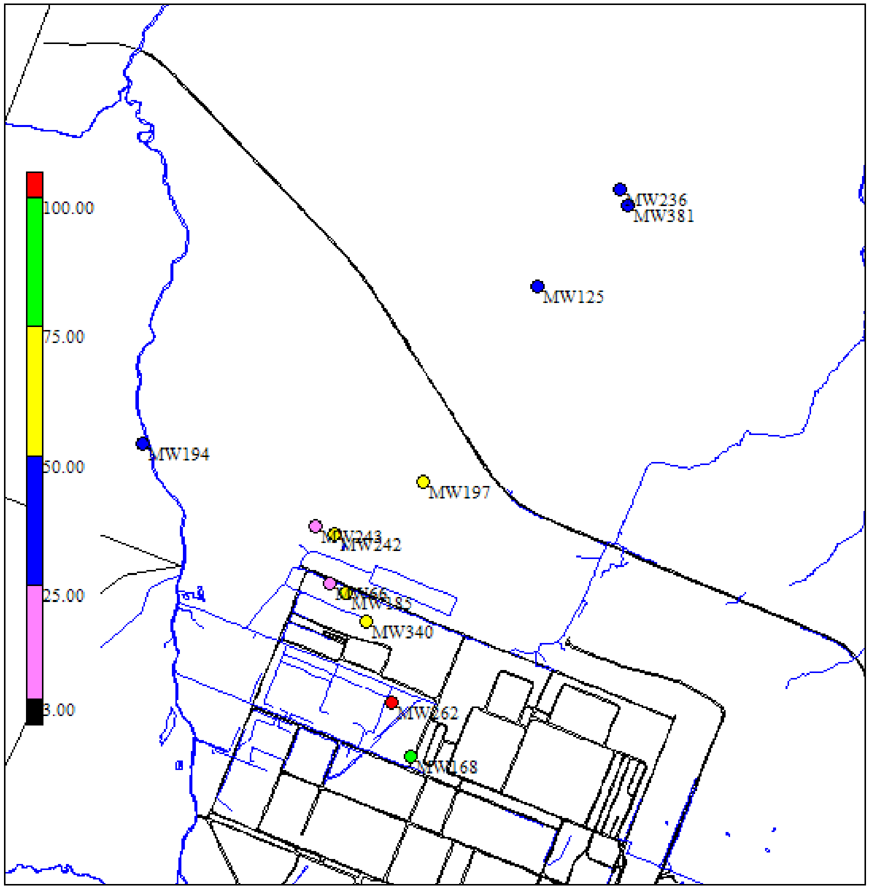


Figure 2B.1. Chloride (mg/liter) – All Locations all values (no filtering of data based on detection limit). Water from all wells exceeded the sample detection limit.

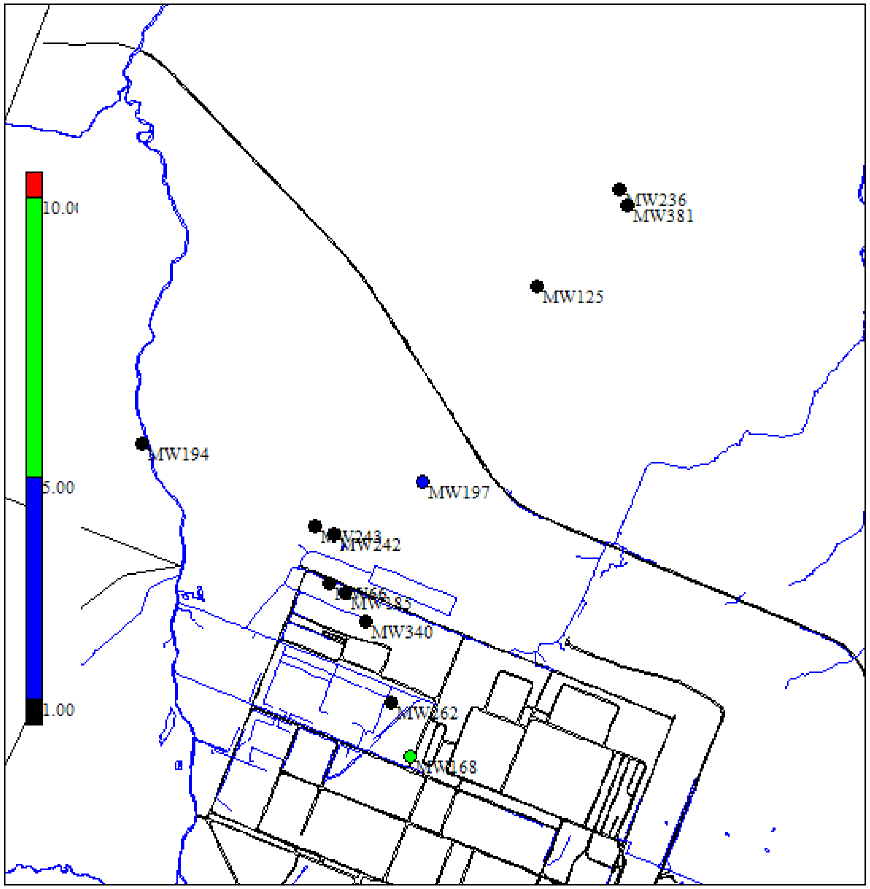


Figure 2B.2. Dissolved Organic Carbon (mg/liter) – All Locations all values (no filtering of data based on detection limit). Water from two wells (MW168, MW197) exceeded the sample detection limit of 1 mg/liter**.**

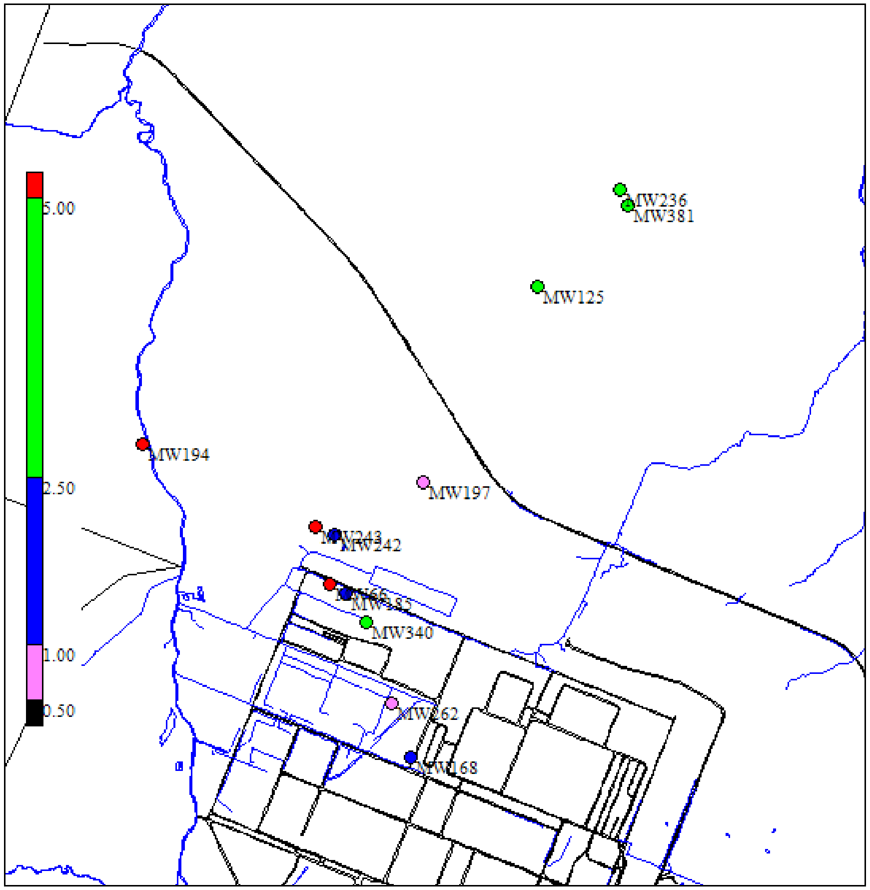


Figure 2B.3. Dissolved Oxygen (mg/liter) – All Locations all values.

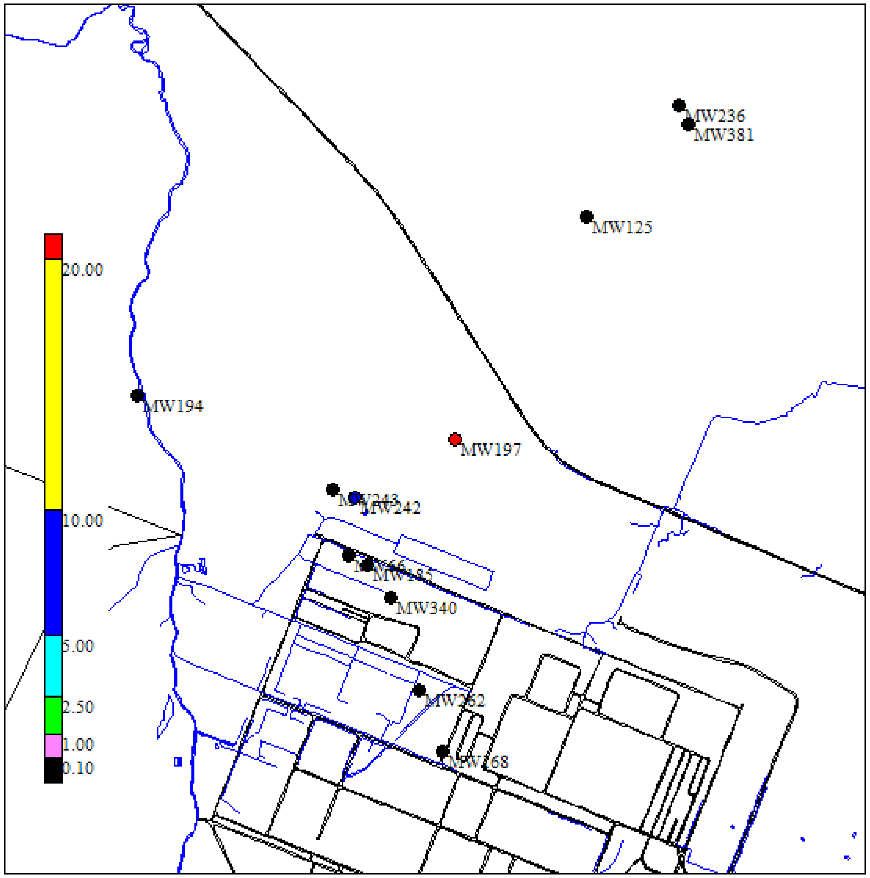


Figure 2B.4. Fe2+ (mg/liter) - All Locations all values (no filtering of data based on detection limit). Water from four wells (MW197, MW242, MW243, MW66) exceeded the detection limit of 0.02 mg/liter.

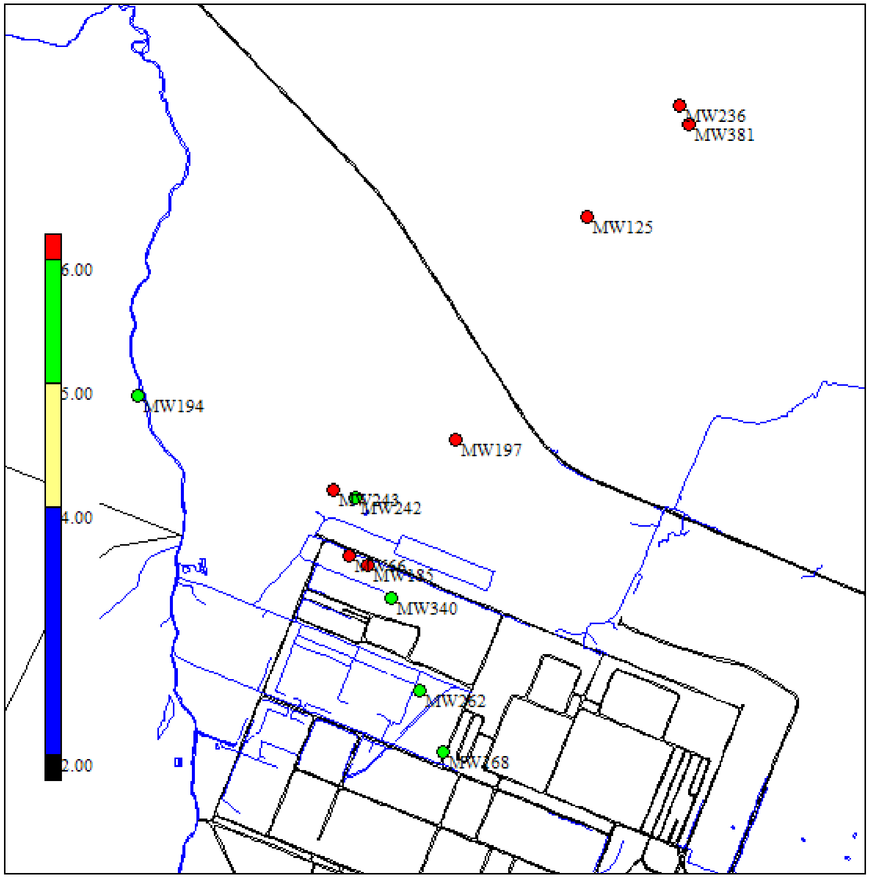


Figure 2B. 5. pH - All Locations all values.

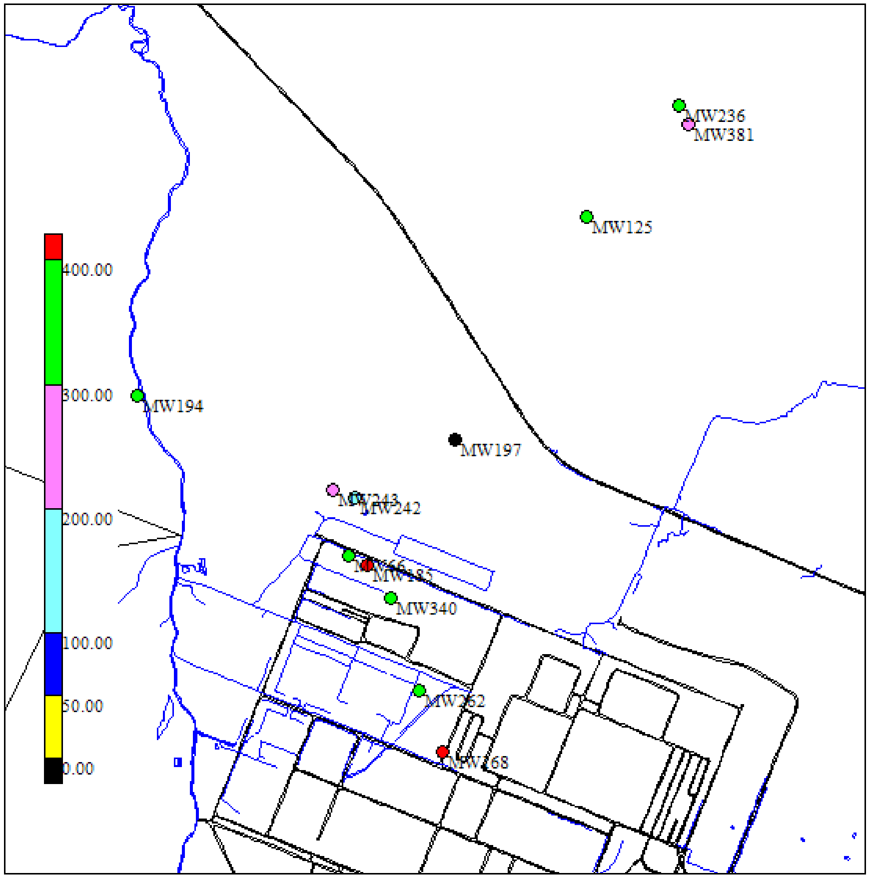


Figure 2B.6. Redox (mV) – All Location all values.

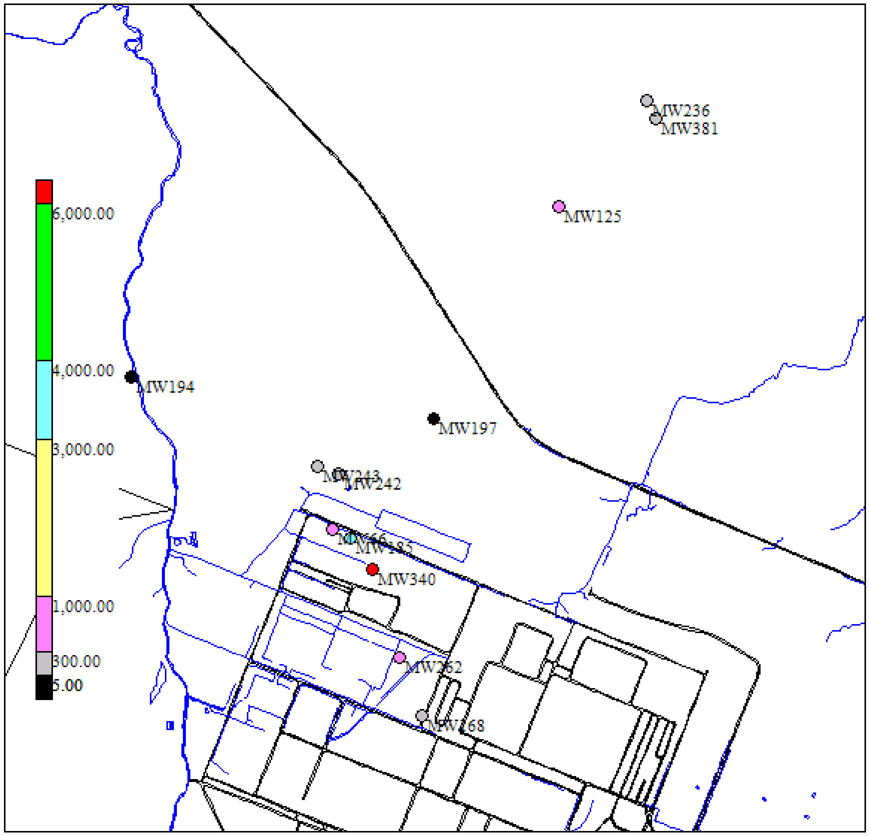


Figure 2B.7TCE (µg/liter) – All Locations all values (no filtering of data based on detection limit). Water from all wells except MW197 exceeded the sample detection limit.

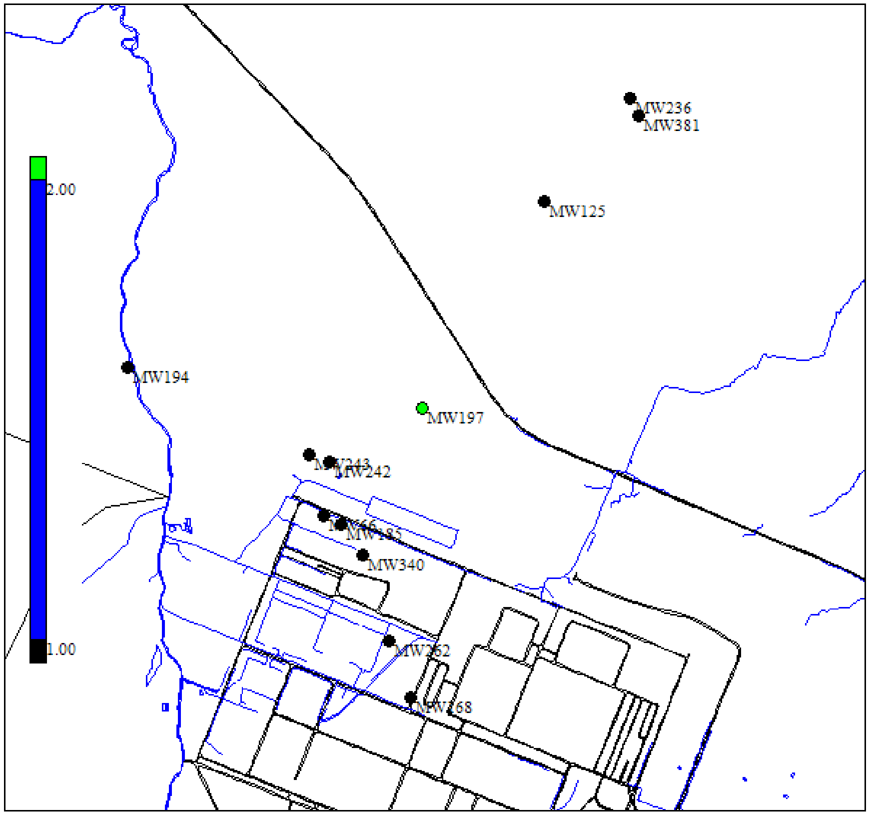


Figure 2B.8. Total Organic Carbon (mg/liter) – All Locations all values (no filtering of data based on detection limit). Water from all wells except MW197 did not exceeded the sample detection limit.

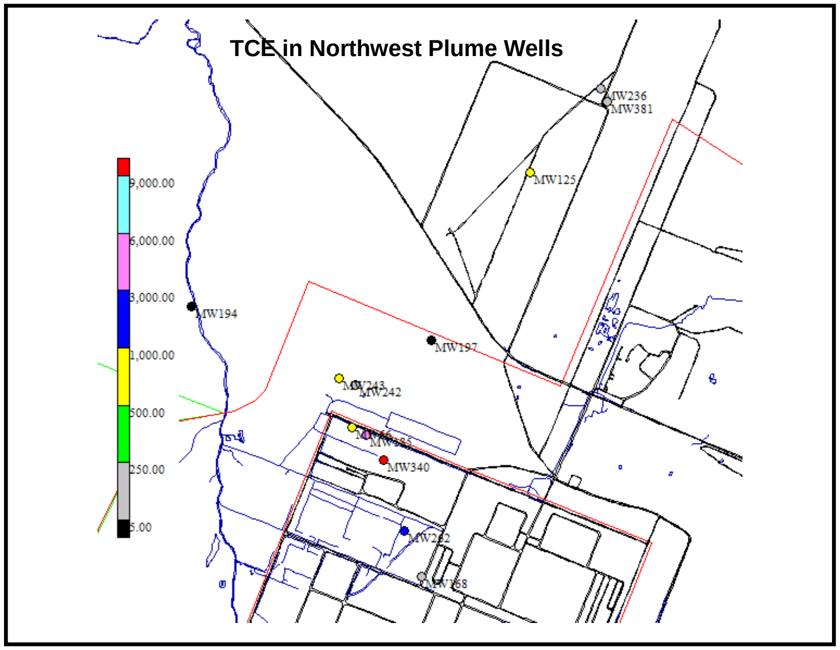


Figure 2B.9. TCE in groundwater December 2007 (ug/liter).

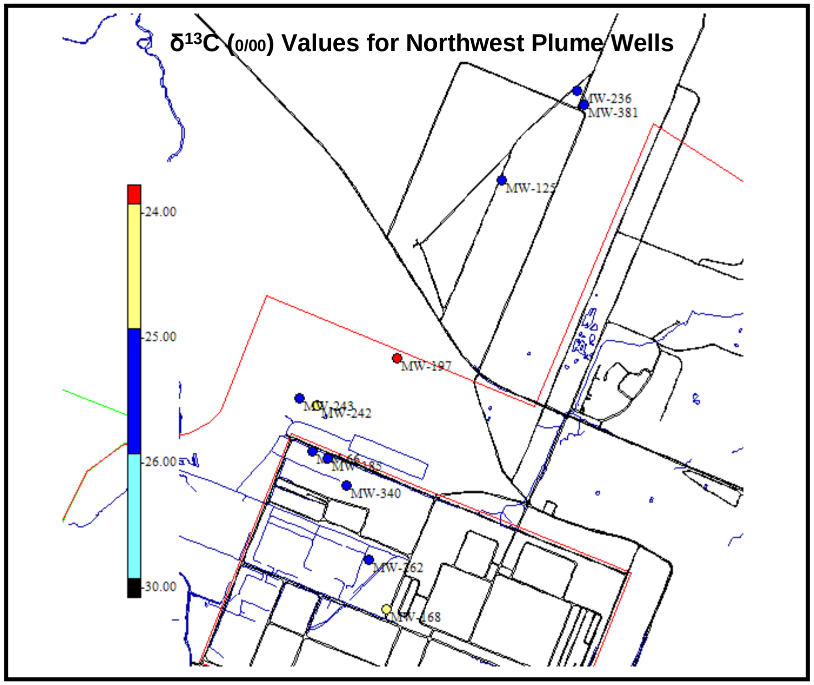


Figure 2B.10. Delta Carbon-13 (0/00) values for NWP wells from December 2007 sampling event

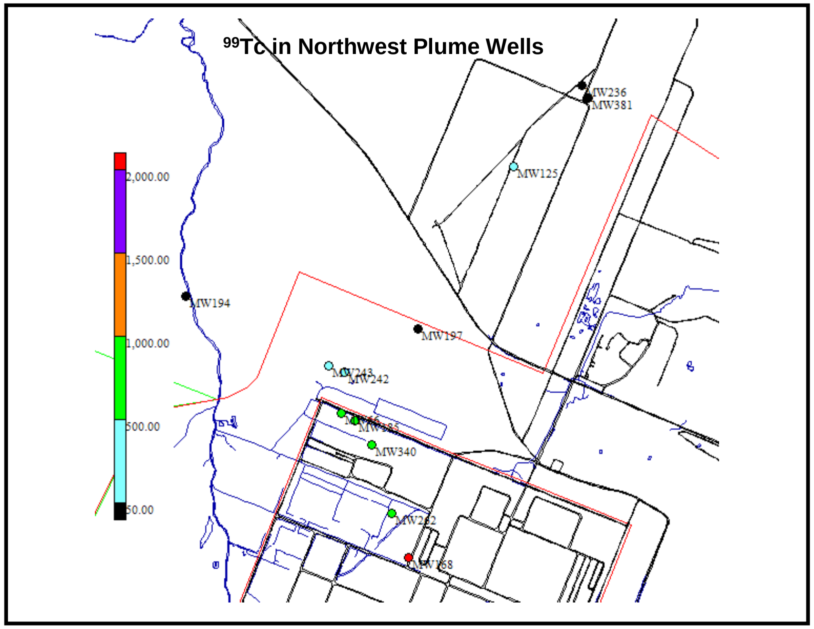
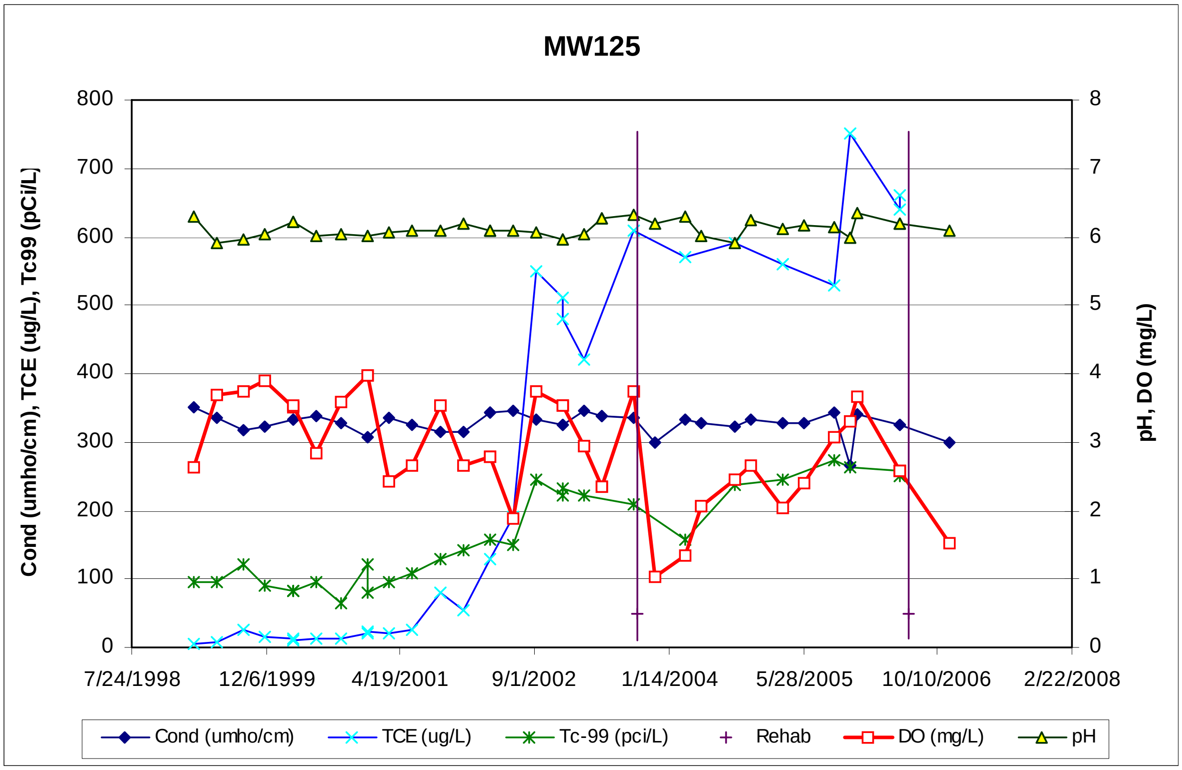
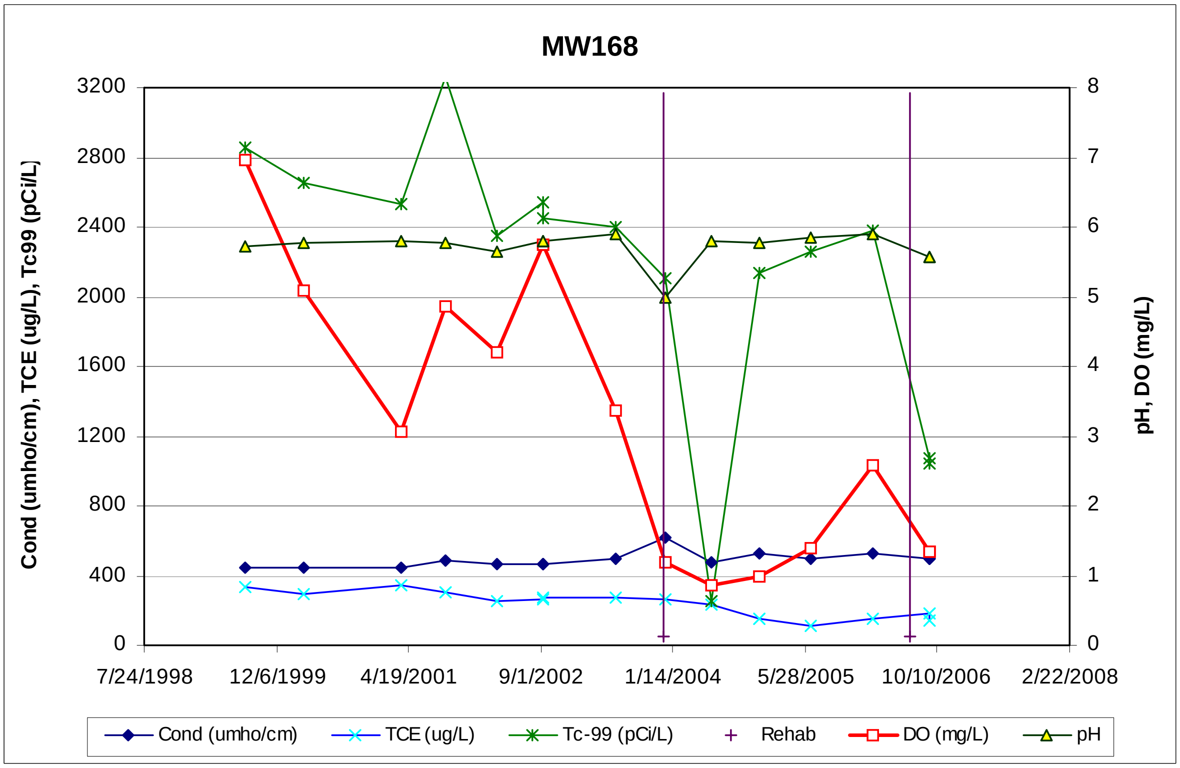
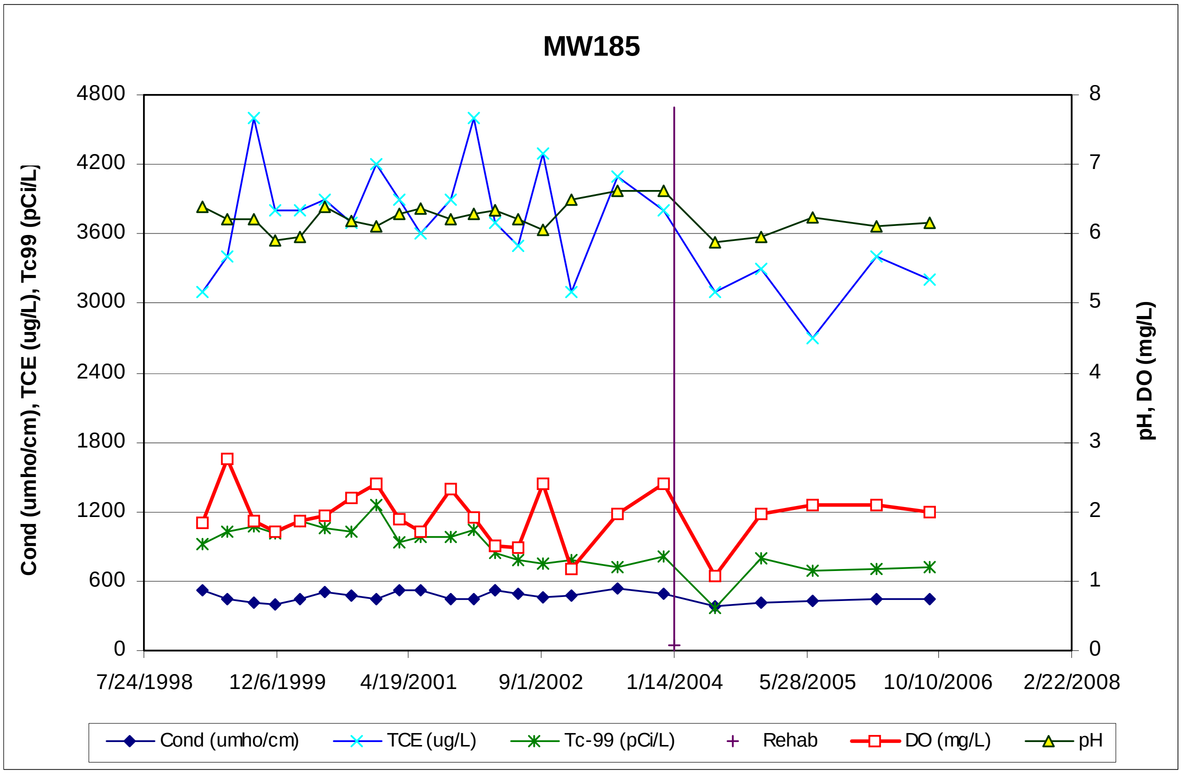


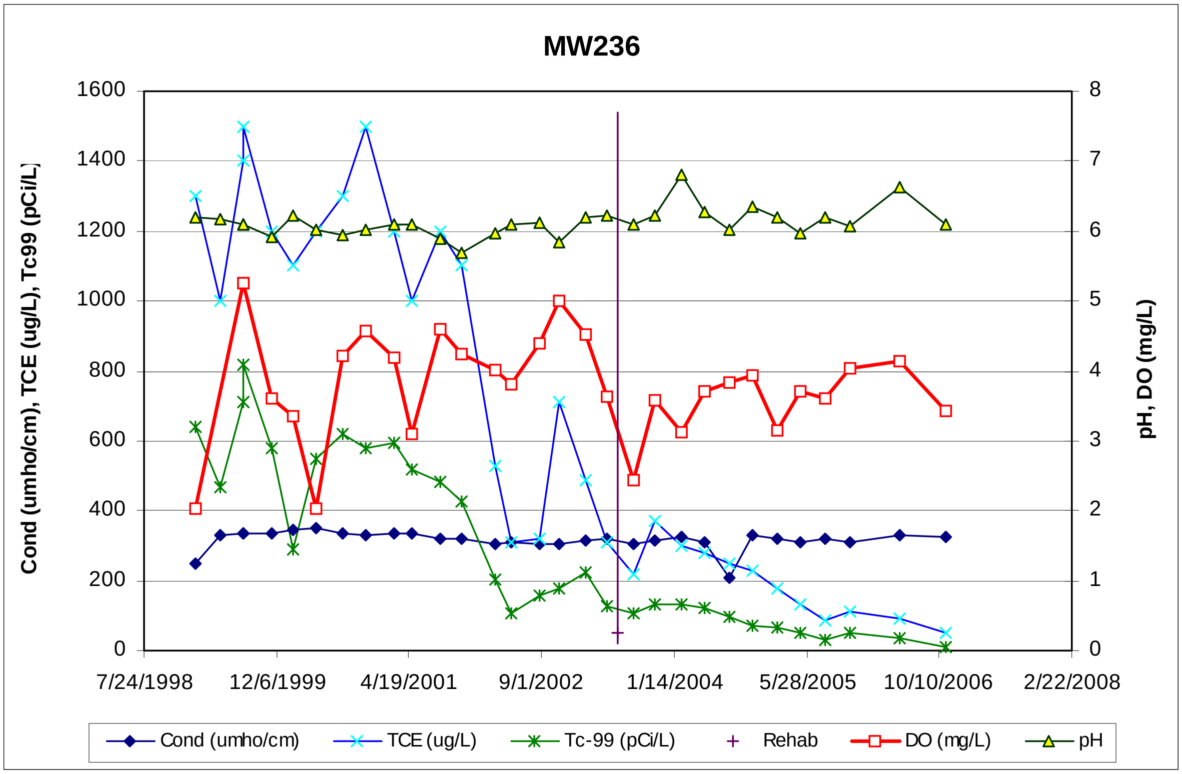
Figure 2B.11. Technetium-99 in groundwater December 2007 (ug/liter).

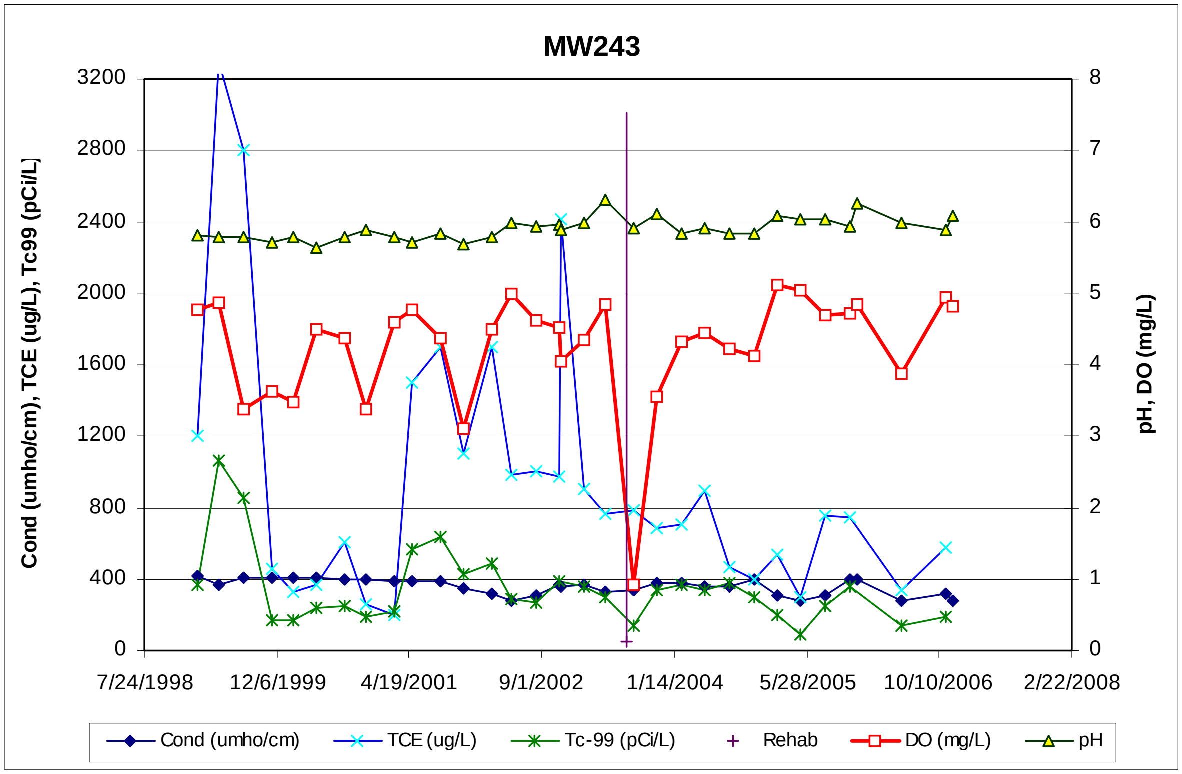
Appendix 2C. Graphical Analysis of Select Project Sampling Location Geochemical Data

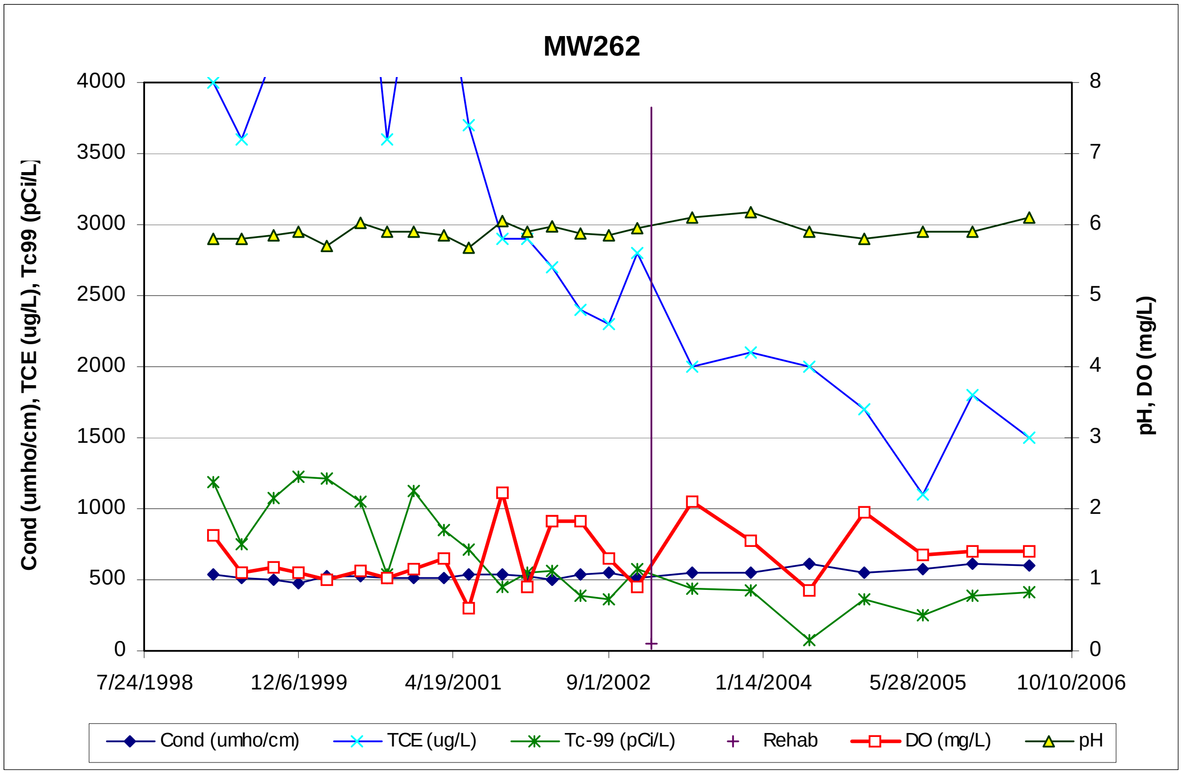

MW125
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
800
700
600
500
400
300
200
100
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pci/L)
Rehab
DO (mg/L)
pH

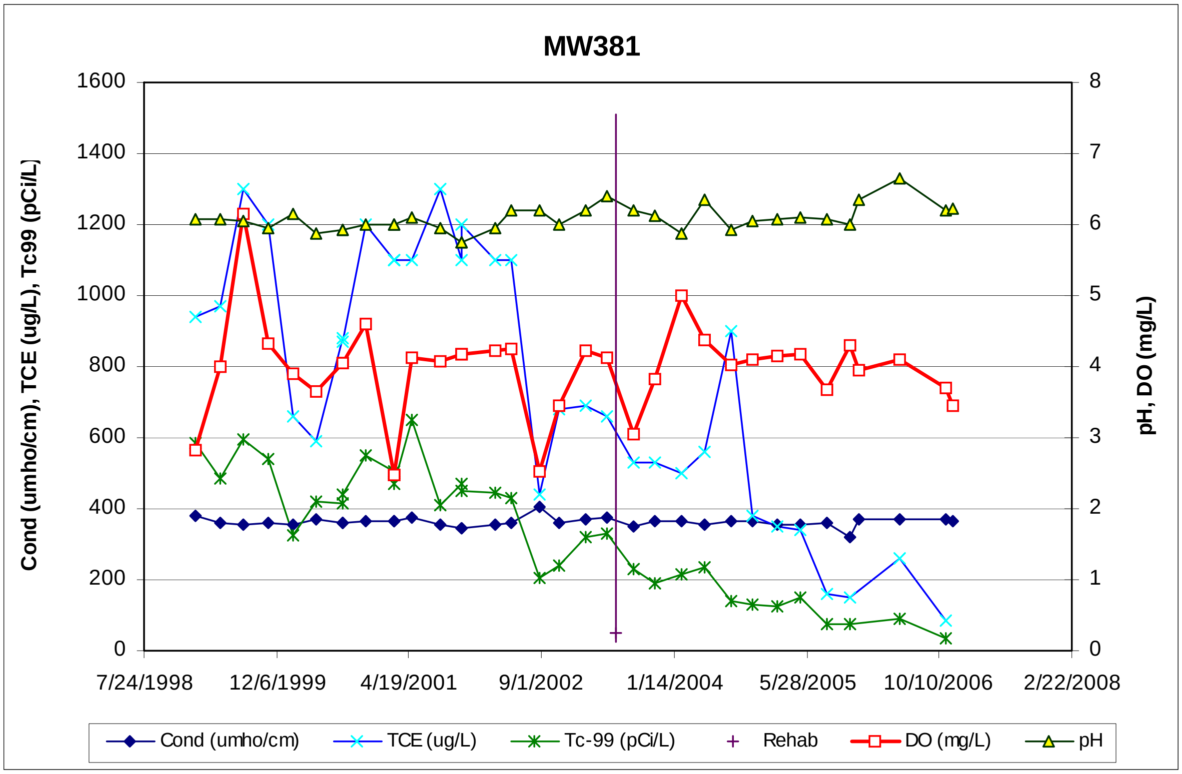

MW168
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
3200
2800
2400
2000
1600
1200
800
400
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH

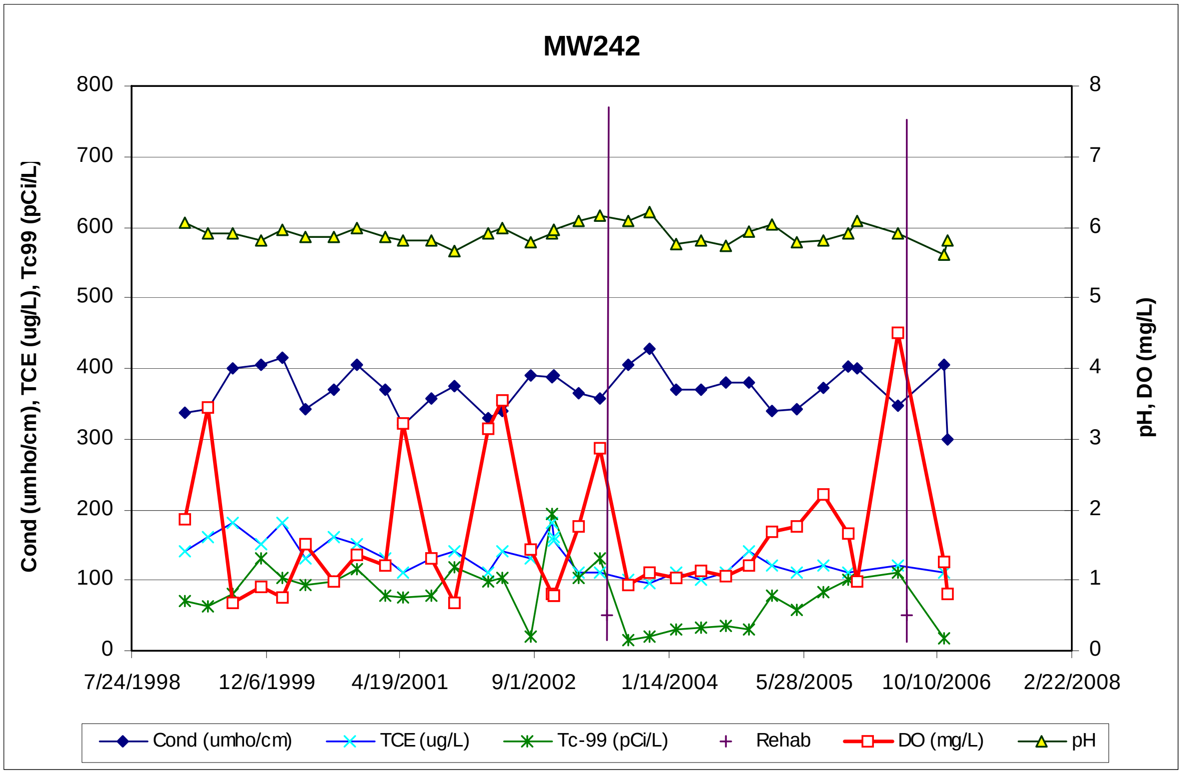

MW185
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
4800
4200
3600
3000
2400
1800
1200
600
0
8
7
6
5
4
3
2
1
0
pH, DO (mg/L)
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH

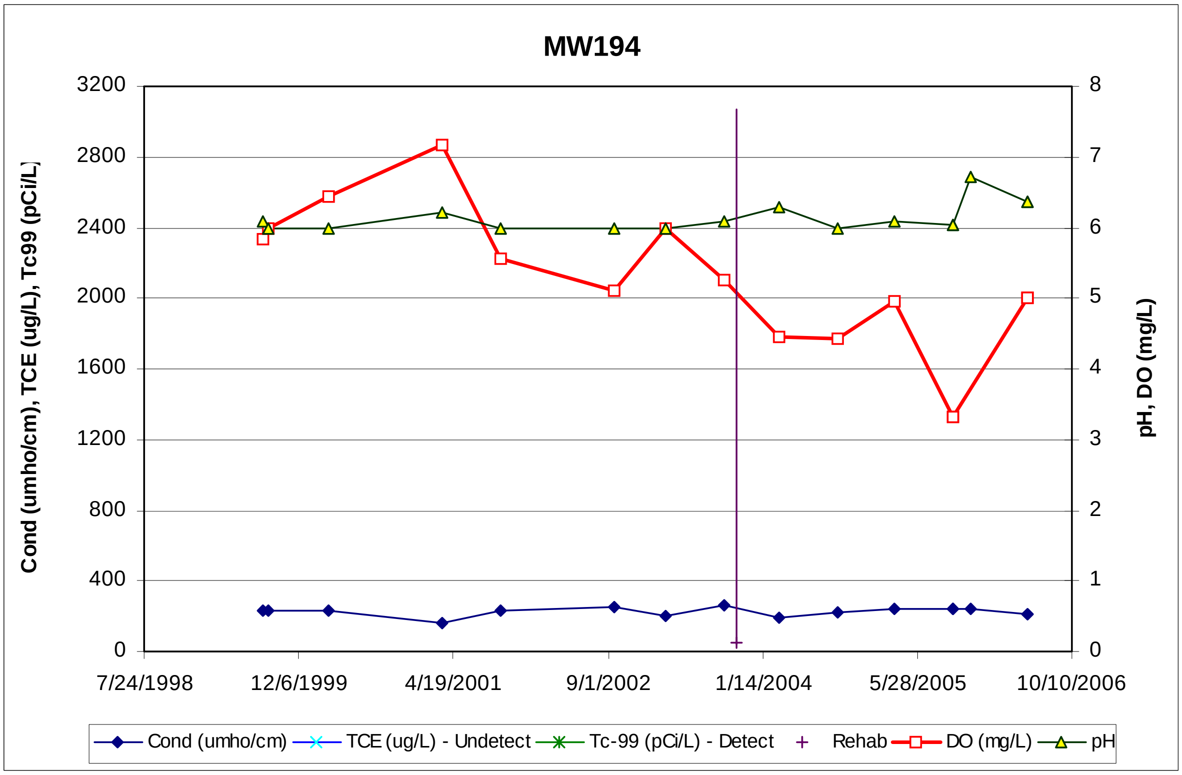

MW236
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
1600
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
pH, DO (mg/L)
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH

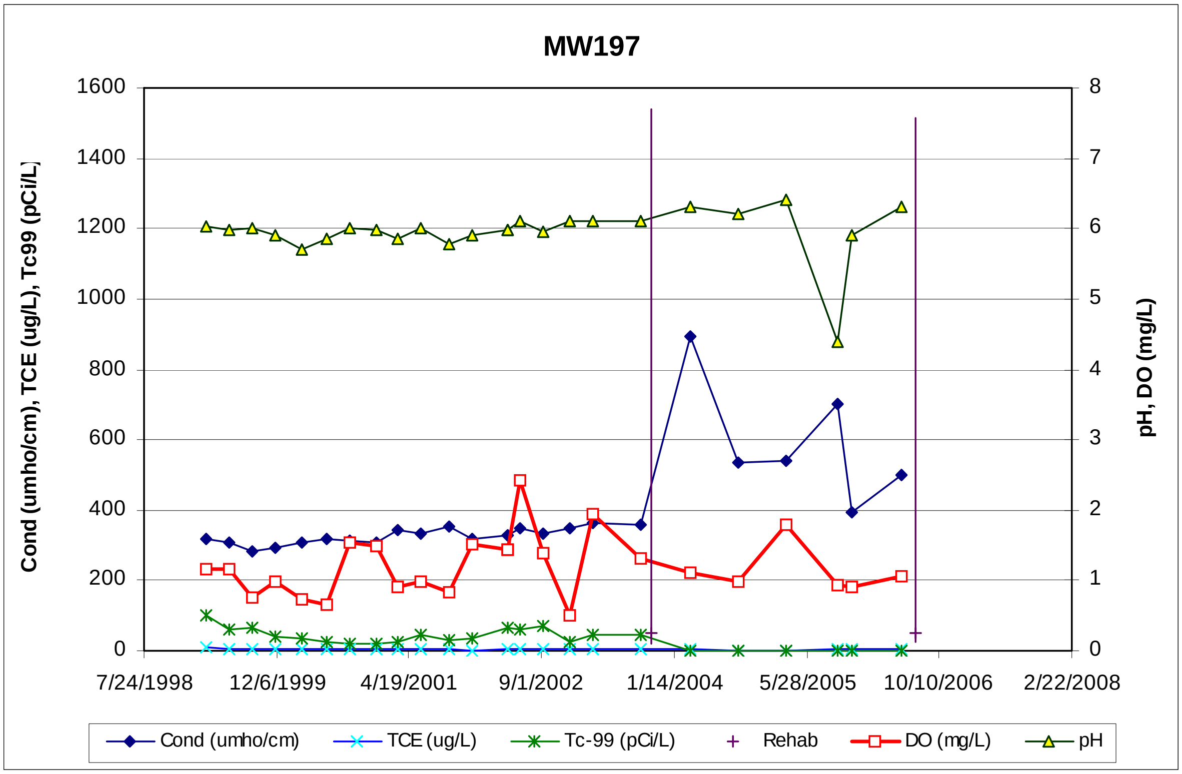

MW243
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
3200
2800
2400
2000
1600
1200
800
400
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH


MW262
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH


MW381
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
1600
1400
1200
1000
800
600
400
200
0
pH, DO (mg/L)
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH


MW242
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
800
700
600
500
400
300
200
100
0
pH, DO (mg/L)
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH


MW194
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
3200
2800
2400
2000
1600
1200
800
400
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
Cond (umho/cm)
TCE (ug/L) - Undetect
Tc-99 (pCi/L) - Detect
Rehab
DO (mg/L)
pH


MW197
Cond (umho/cm), TCE (ug/L), Tc99 (pCi/L)
pH, DO (mg/L)
1600
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
Cond (umho/cm)
TCE (ug/L)
Tc-99 (pCi/L)
Rehab
DO (mg/L)
pH

Appendix 2D. Spatial Evaluation of Select Quarterly Geochemical Data

(Upper, Middle, and Lower RGA Annual Groundwater Mapping Monitoring Locations)

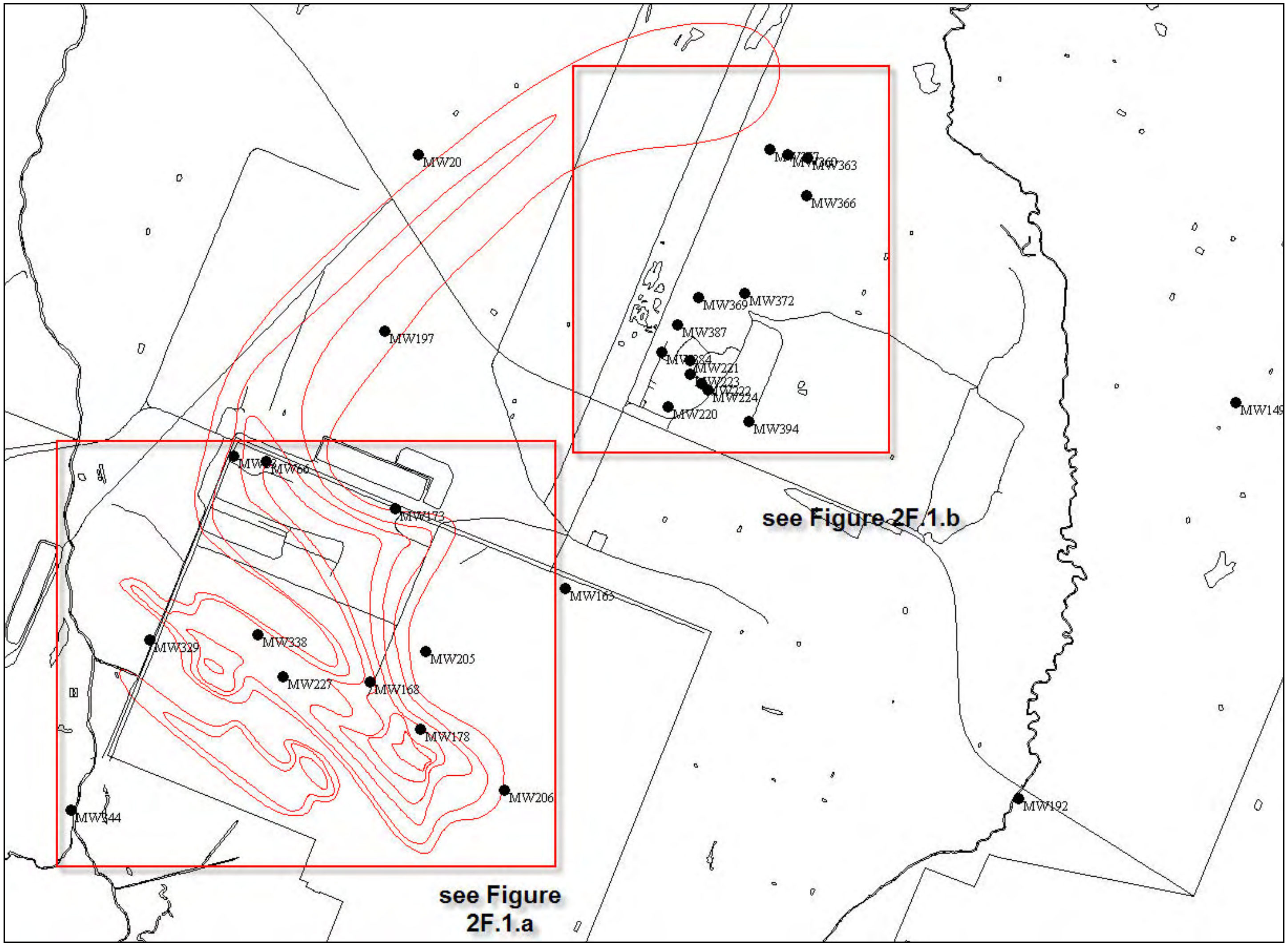


Figure 2D.1. URGA Quarterly Monitoring Locations.

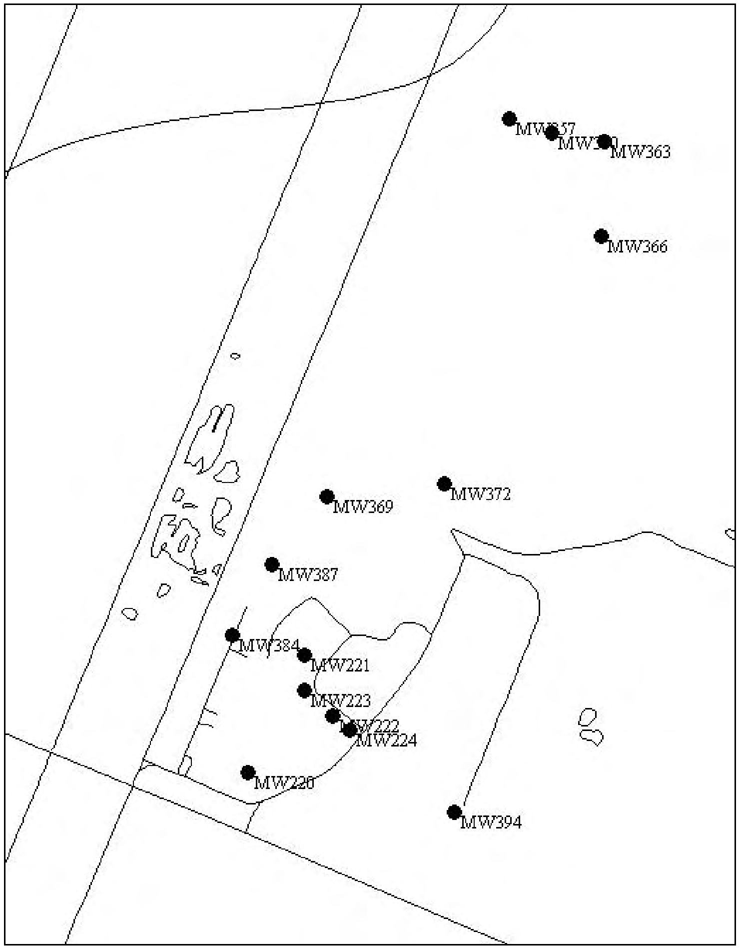


Figure 2D.1.a. URGA Quarterly Monitoring Locations.

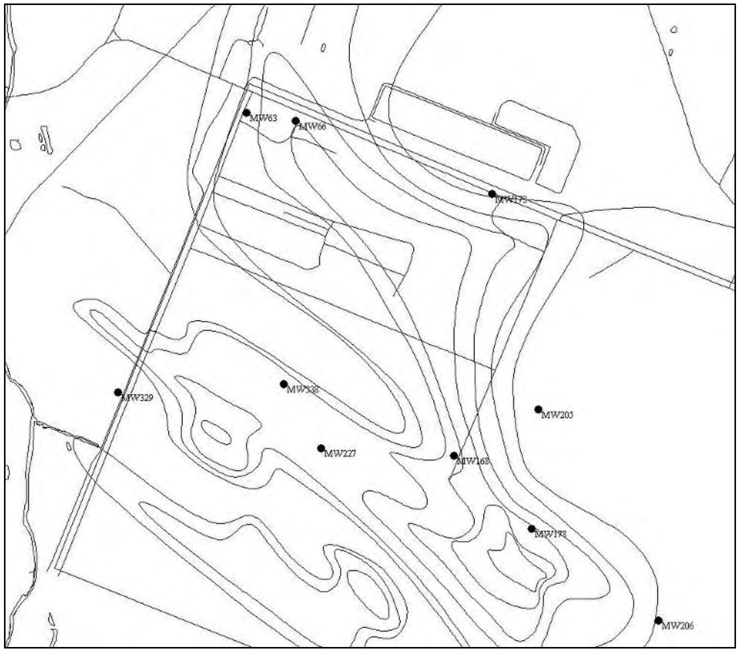


Figure 2D.1.b. URGA Quarterly Monitoring Locations

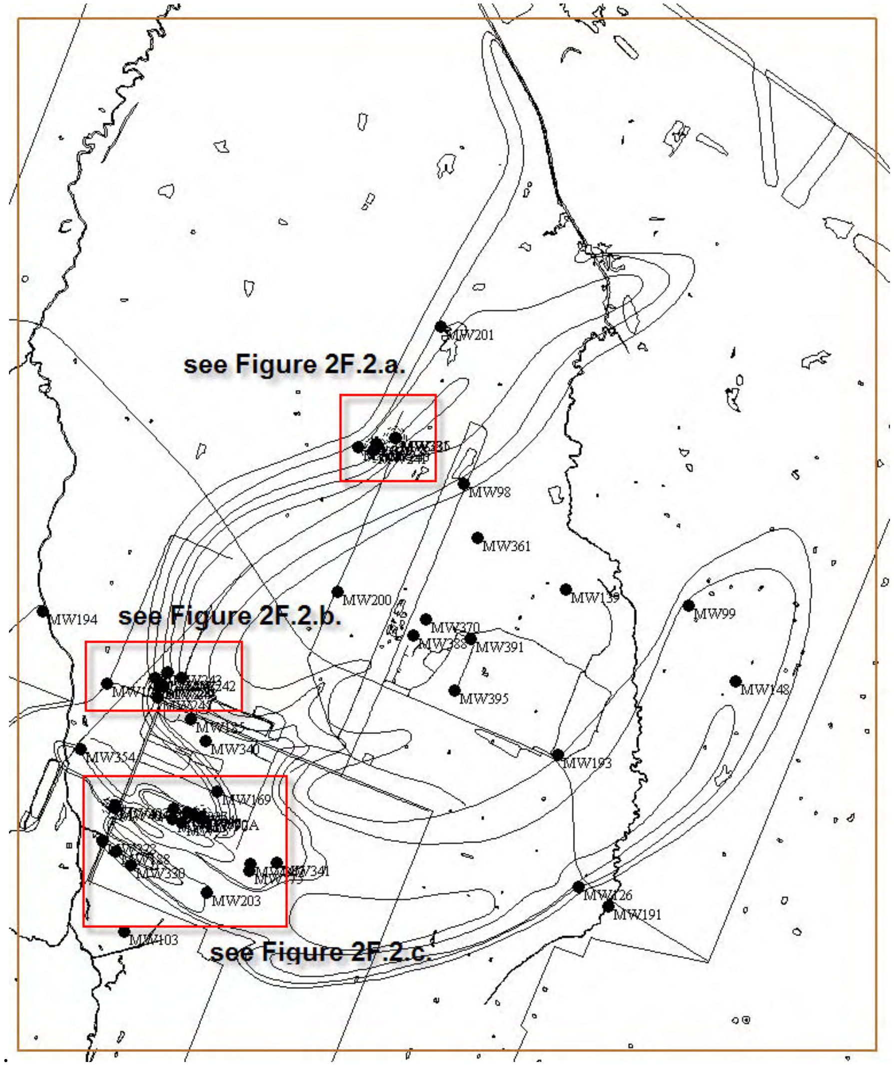


Figure 2D.2. MRGA Quarterly Monitoring Locations.

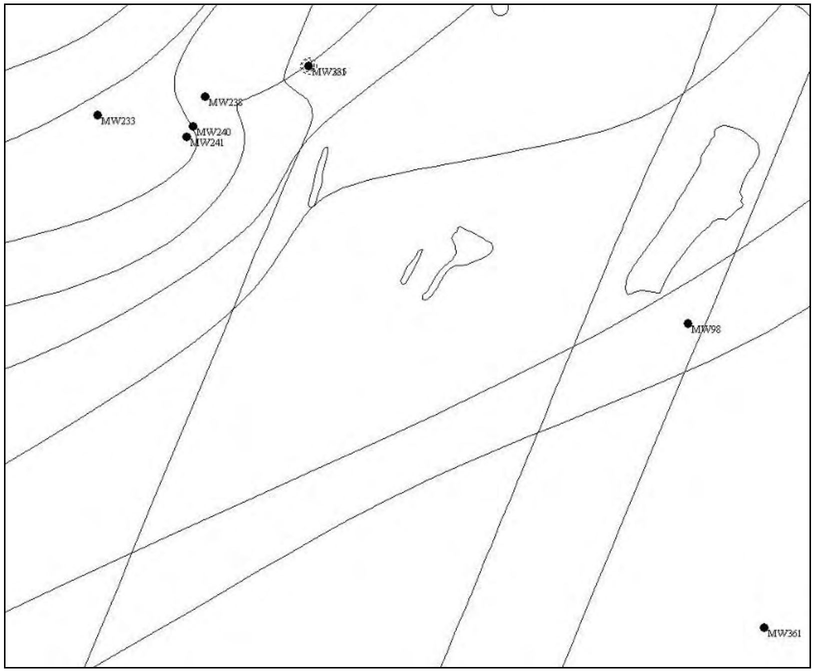


Figure 2D.2a. MRGA Quarterly Monitoring Locations.

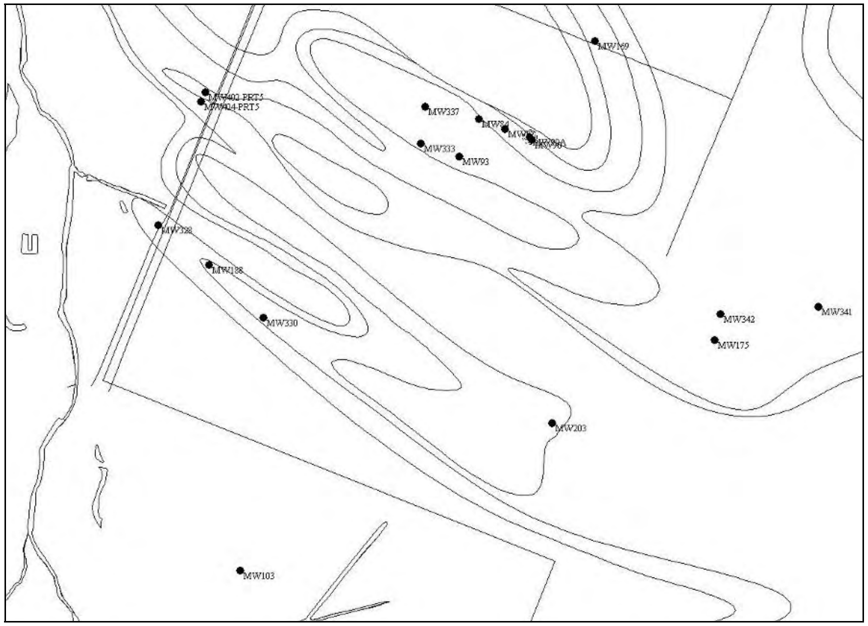


Figure 2D.2c. MRGA Quarterly Monitoring Locations.

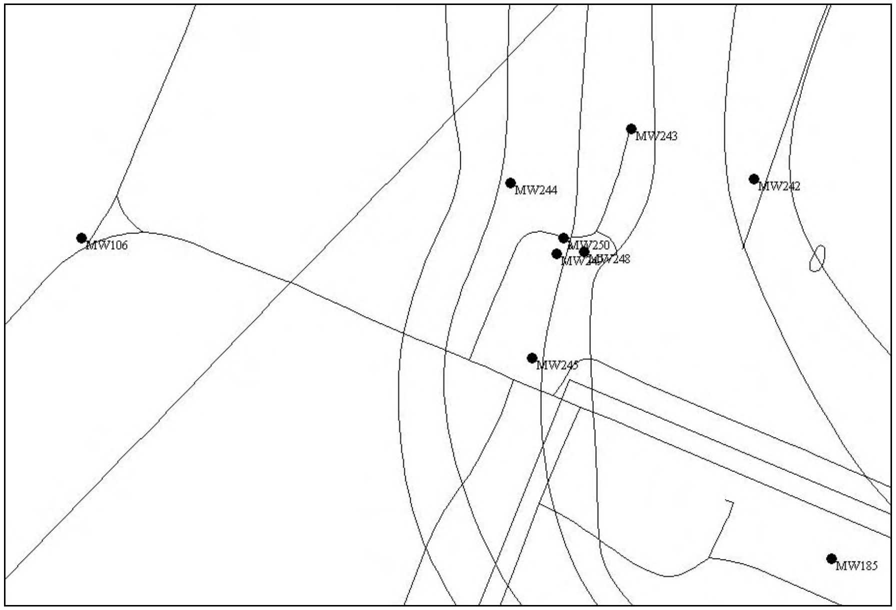


Figure 2D.2b. MRGA Quarterly Monitoring Locations.

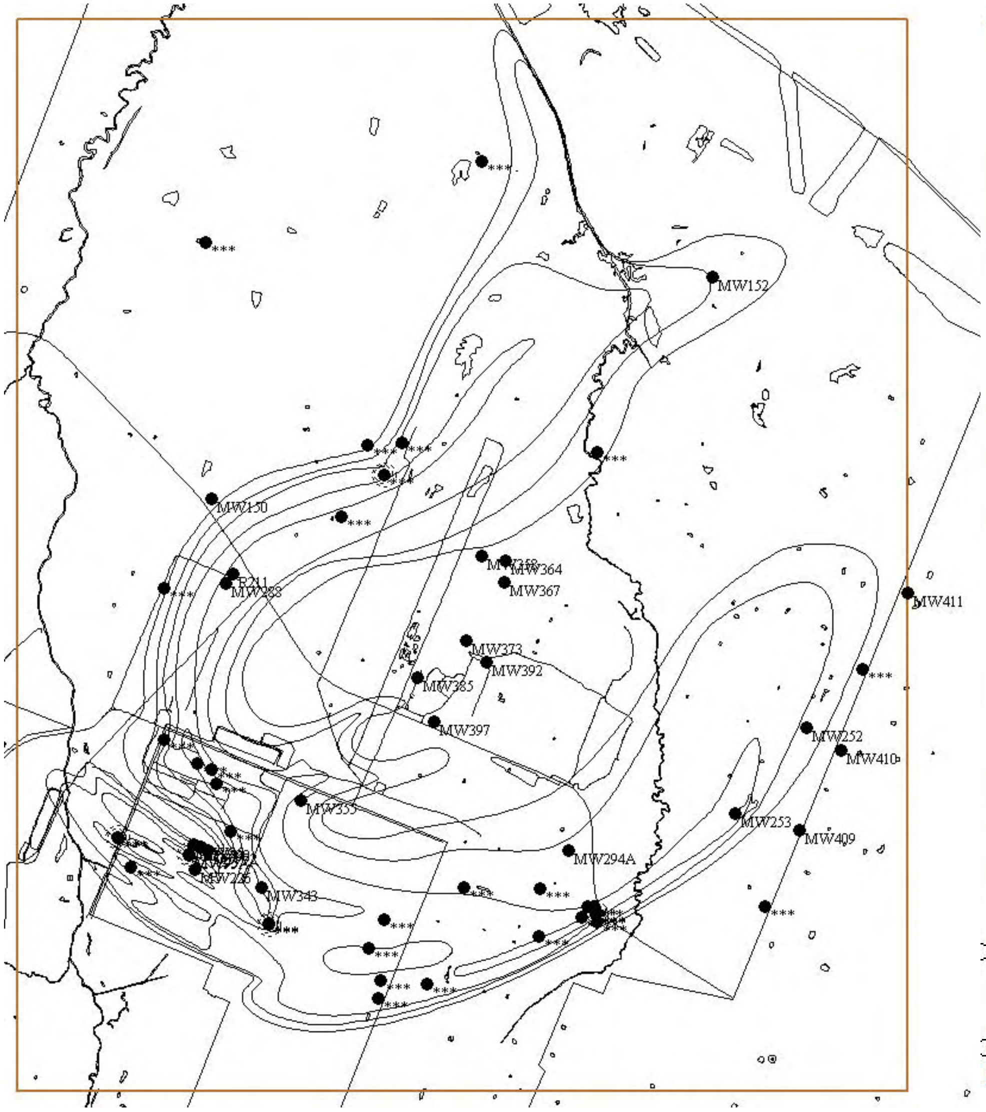


Figure 2D.3. LRGA Quarterly Monitoring Locations.

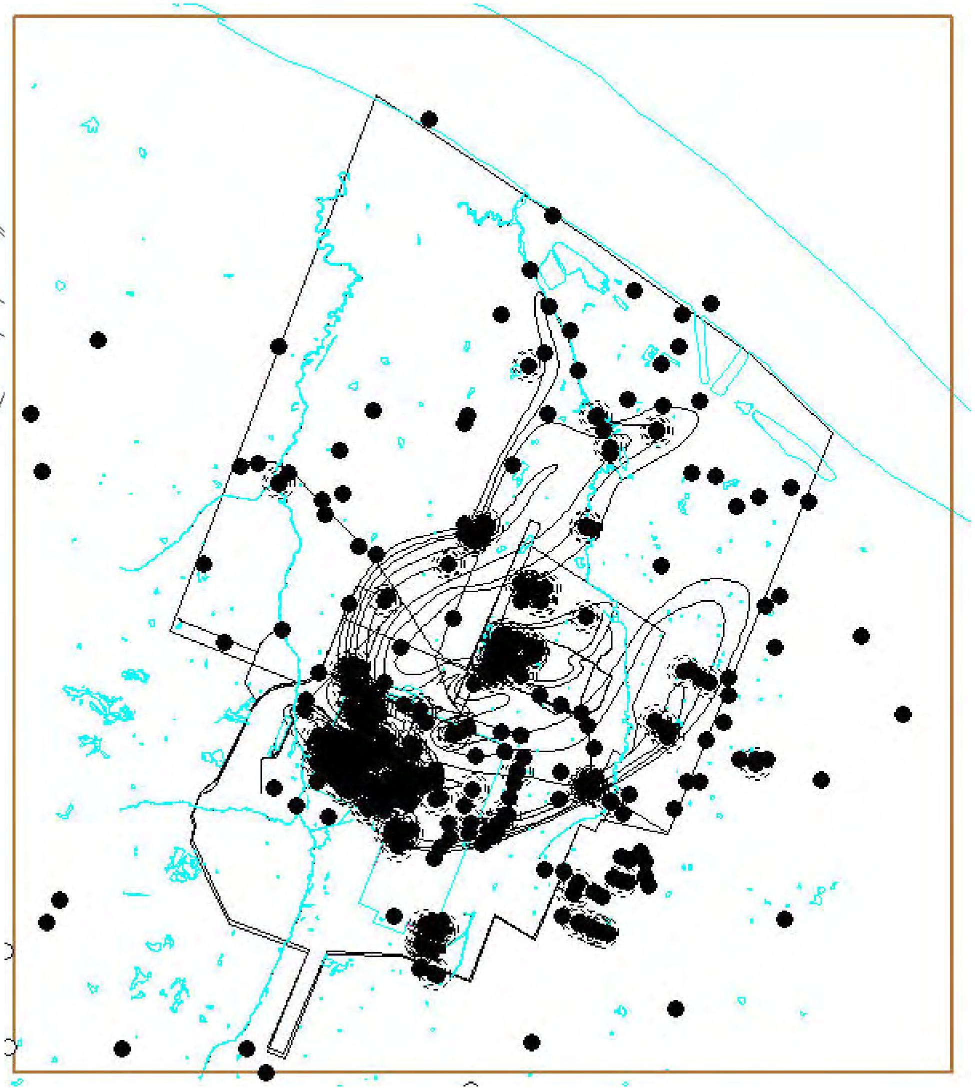


Figure 2D.4. All RGA Locations

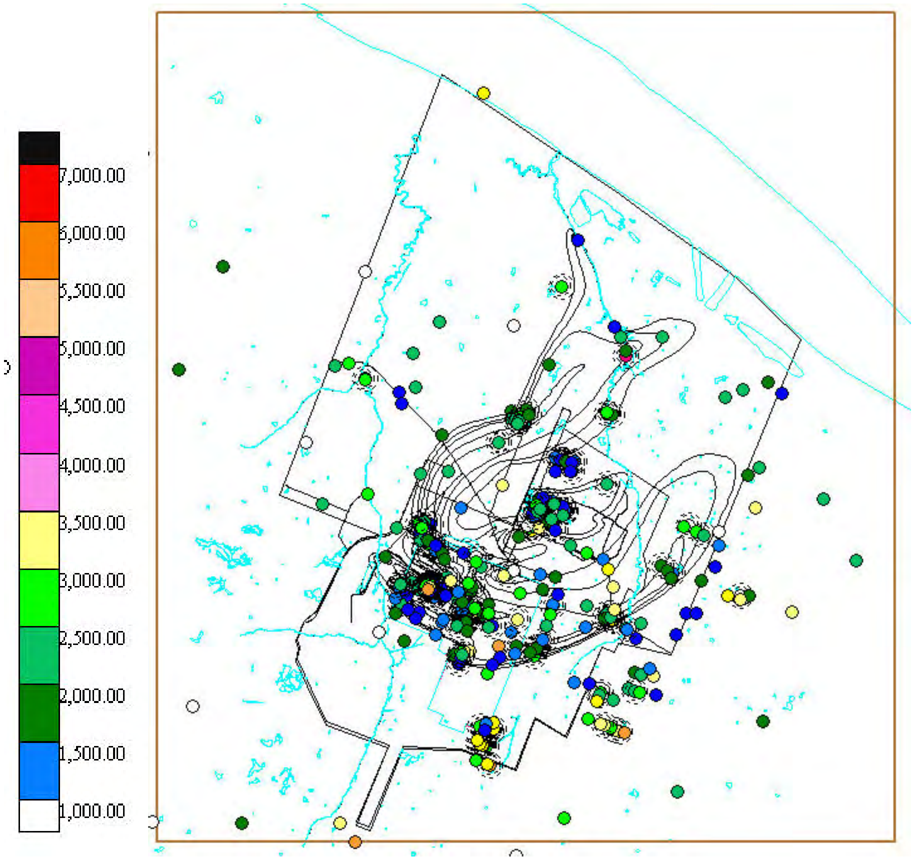


Figure 2D.5. All RGA Dissolved Oxygen average concentrations 1988 – 2006 (ug/L).

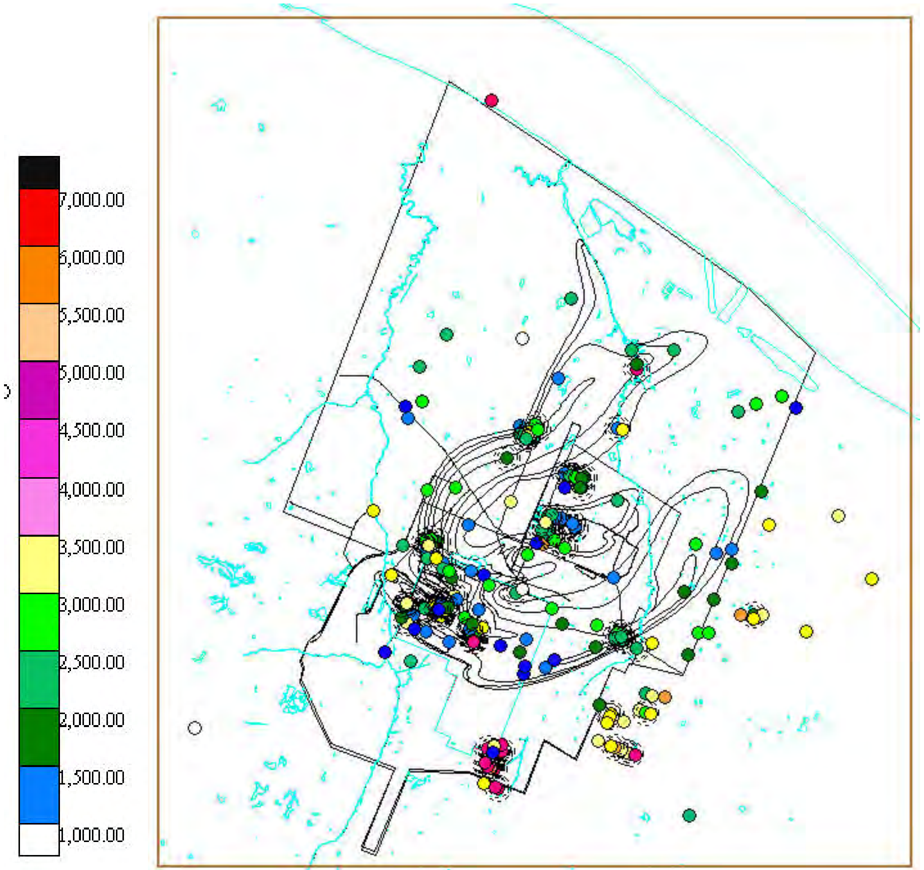


Figure 2D.6. All RGA Dissolved Oxygen maximum concentrations 2001 – 2006 (ug/L).

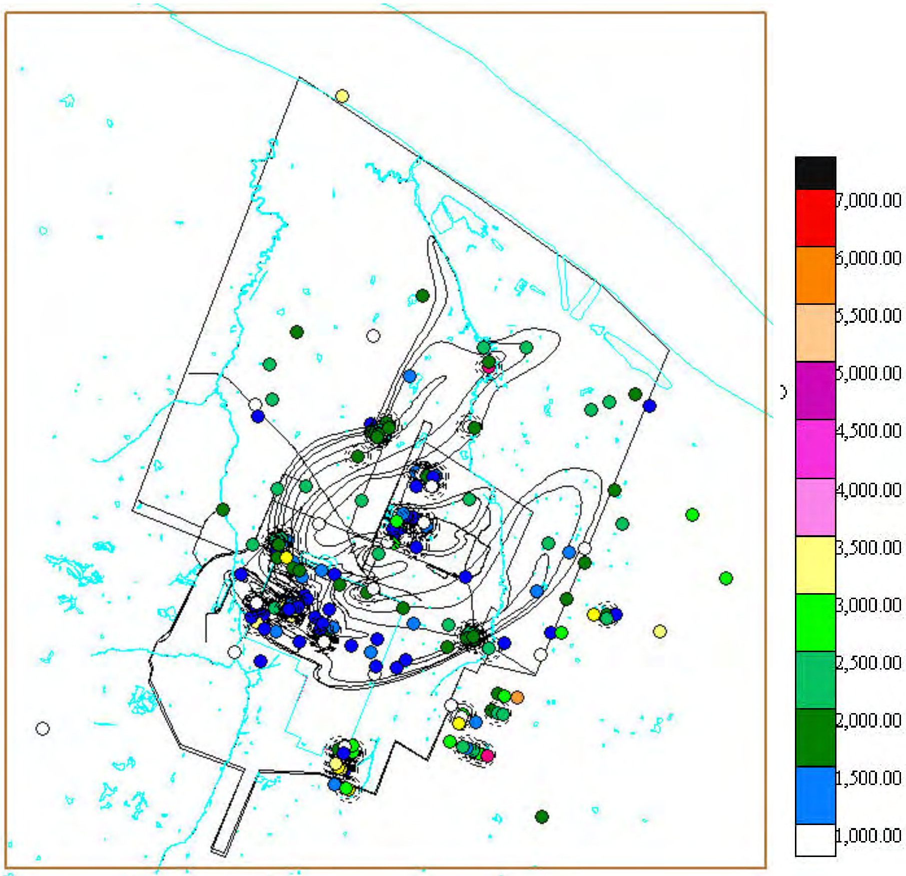


Figure 2D.7. All RGA Dissolved Oxygen concentrations most recent value (ug/L).

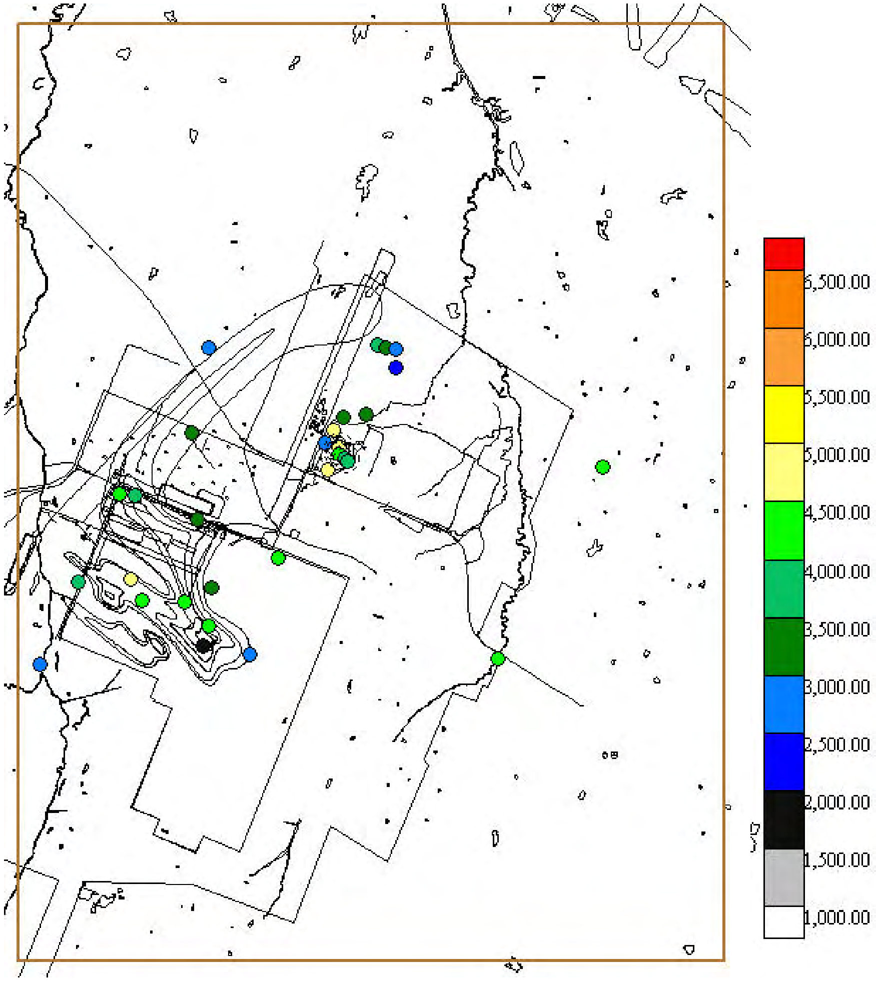


Figure 2D.8. URGA average Dissolved Oxygen concentrations 1996 -2006. (ug/L).

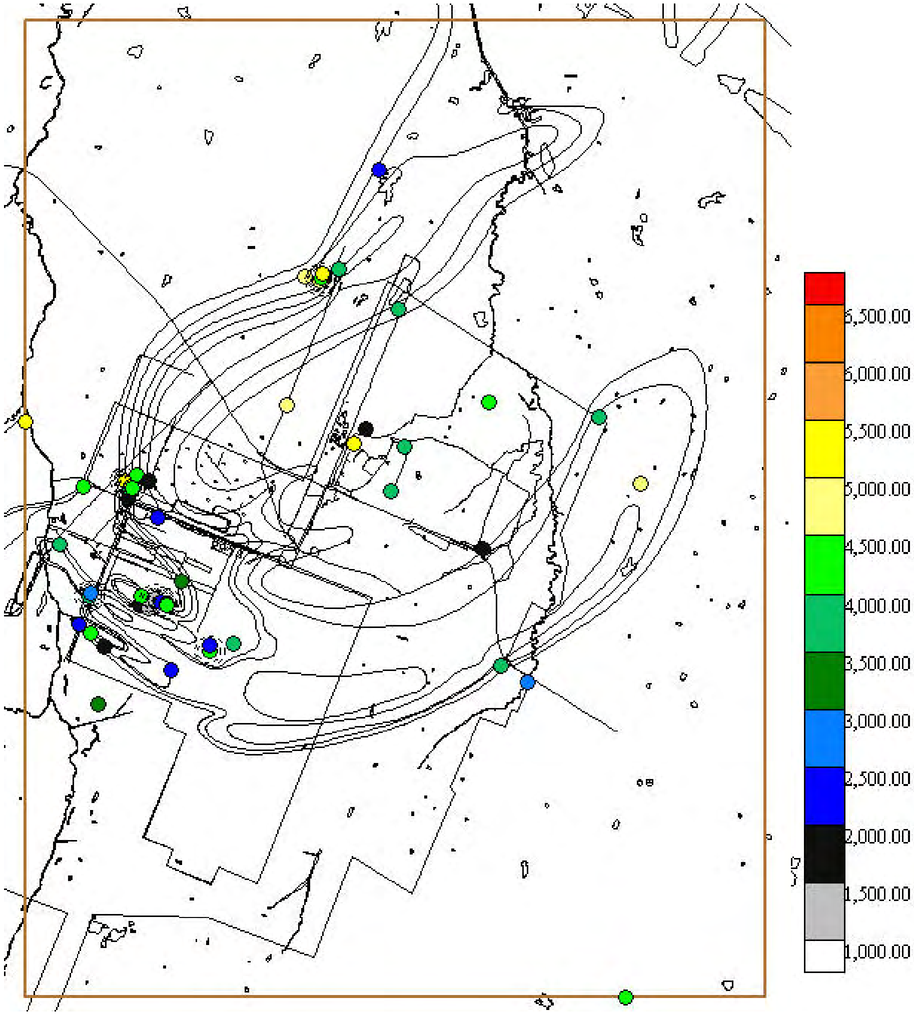


Figure 2D.9. MRGA average Dissolved Oxygen concentrations 1996 -2006 (ug/L)

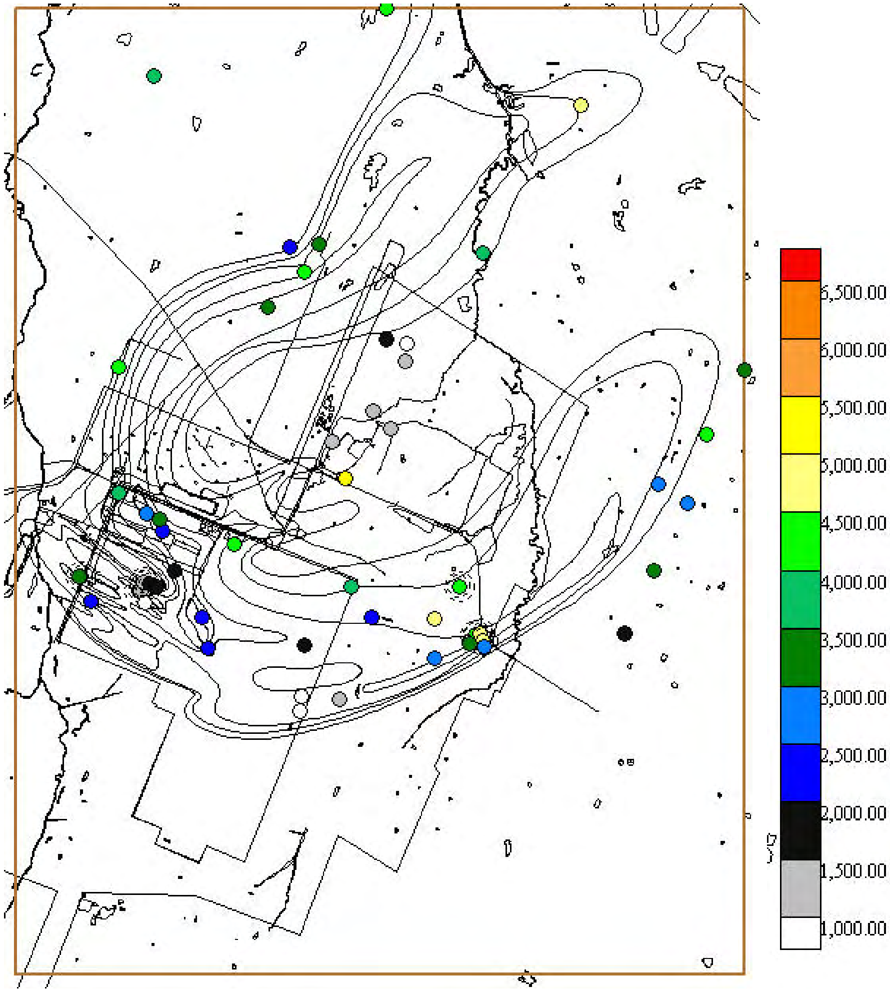


Figure 2D.10. LRGA average Dissolved Oxygen Concentration 1996 to 2006 (ug/L).

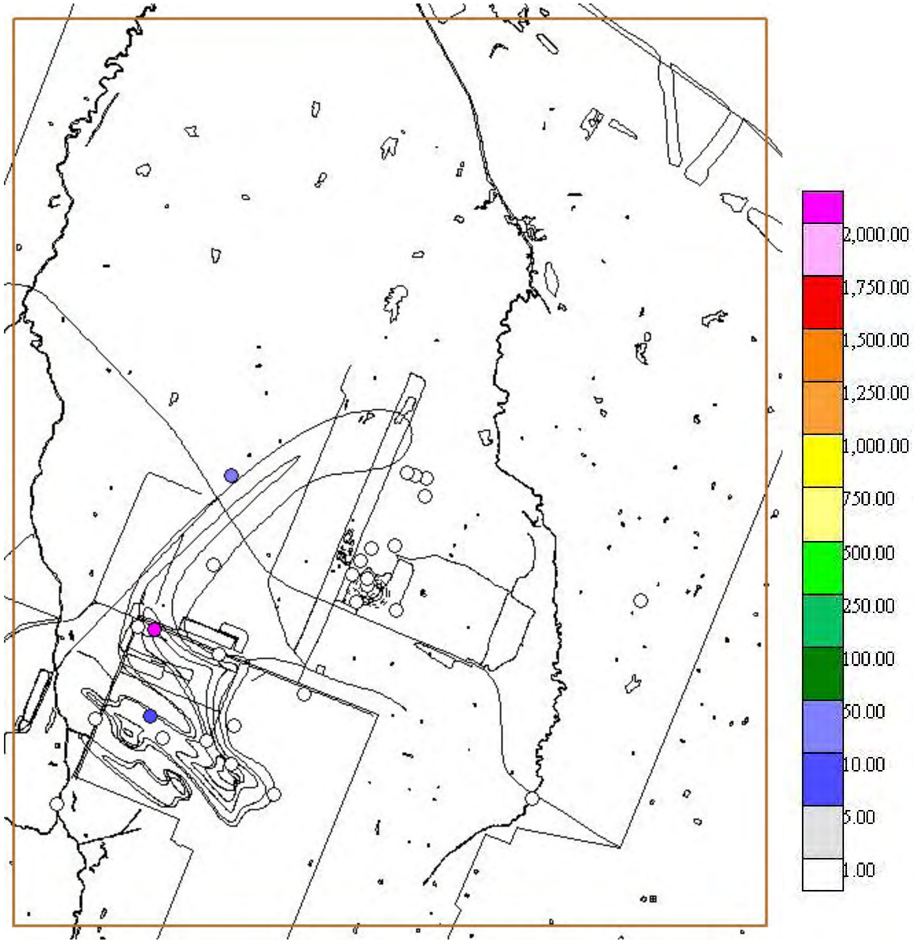


Figure 2D.11. URGA cis-1,2, DCE maximum concentrations 1988 – 2006 (ug/L).

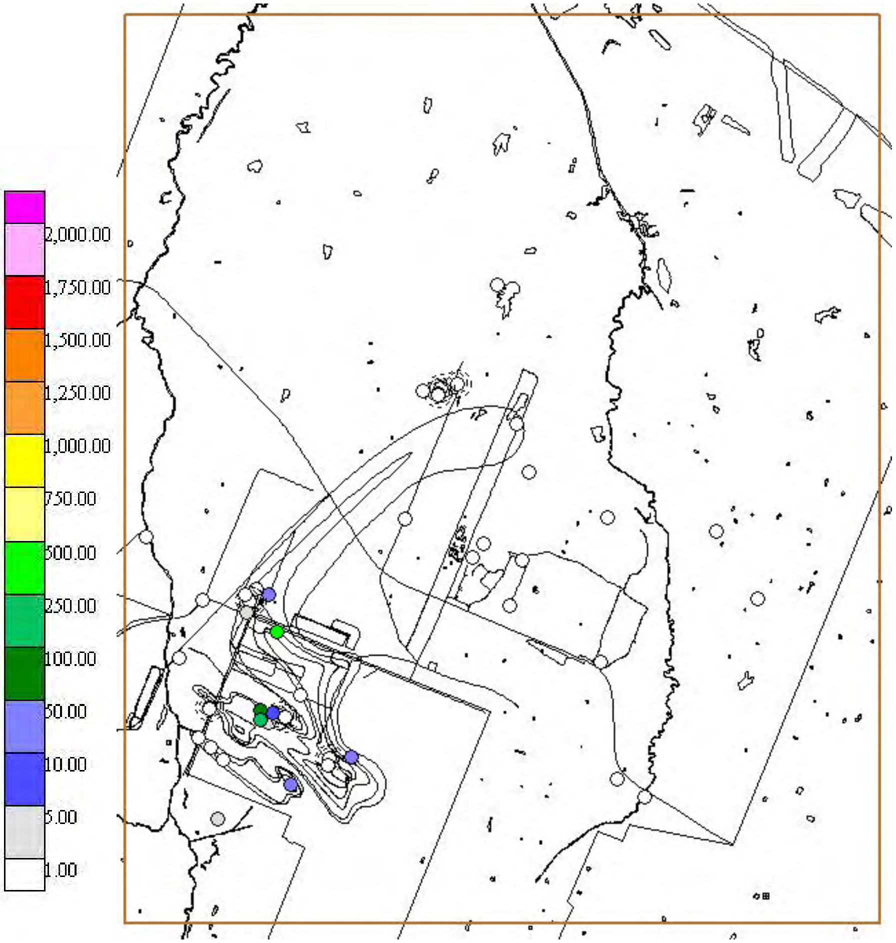


Figure 2D.12. URGA cis-1,2, DCE maximum concentrations 1988 – 2006 (ug/L)

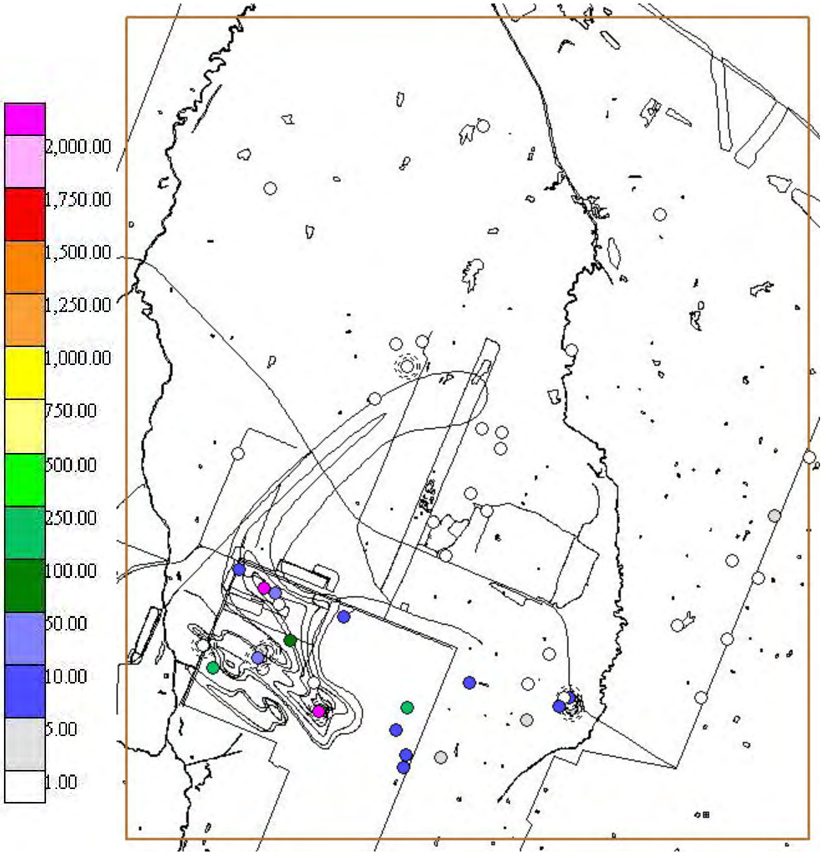


Figure 2D.13. LRGA cis-1,2, DCE maximum concentrations 1988 – 2006 (ug/L).

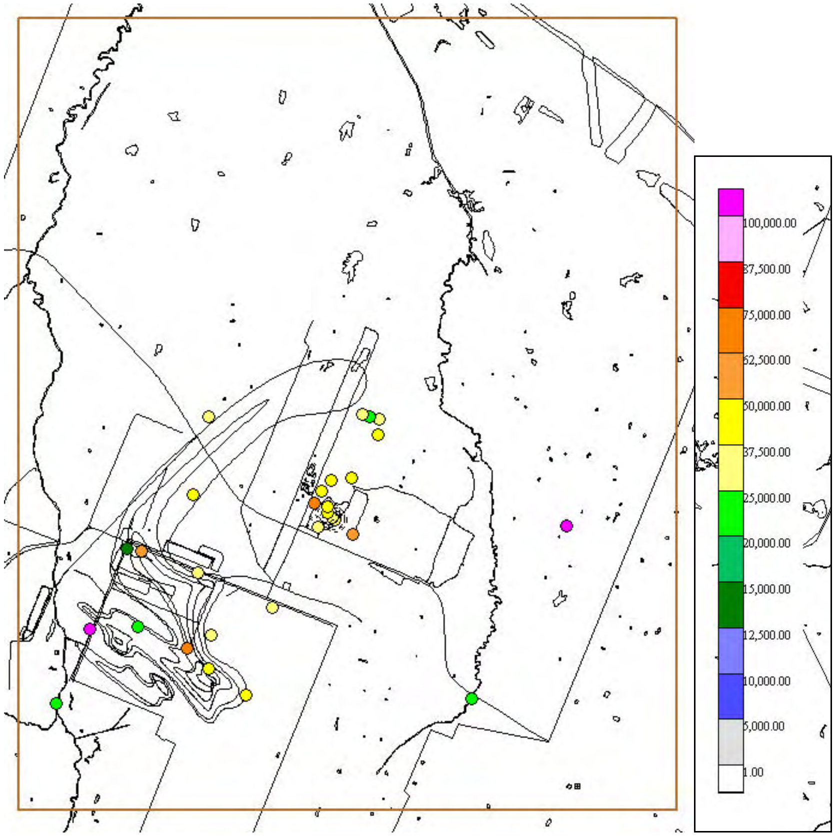


Figure 2D.14. URGA Chloride average detects 1988 – 2006 (ug/L).

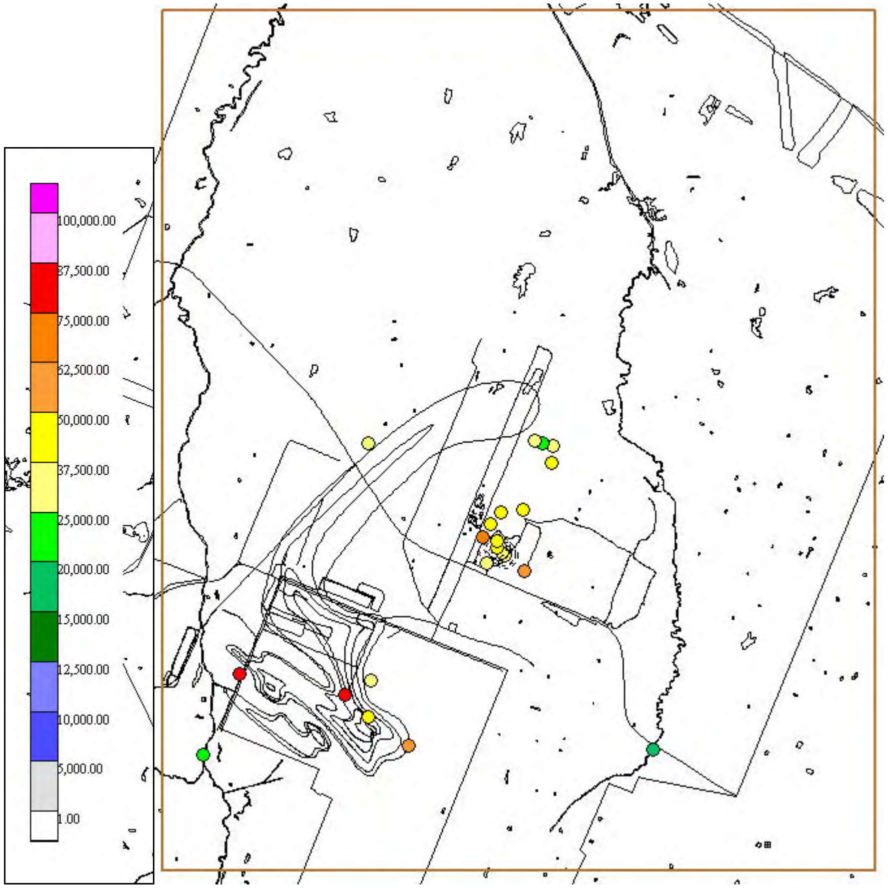


Figure 2D.15. URGA Chloride average detects 2001 – 2006 (ug/L).

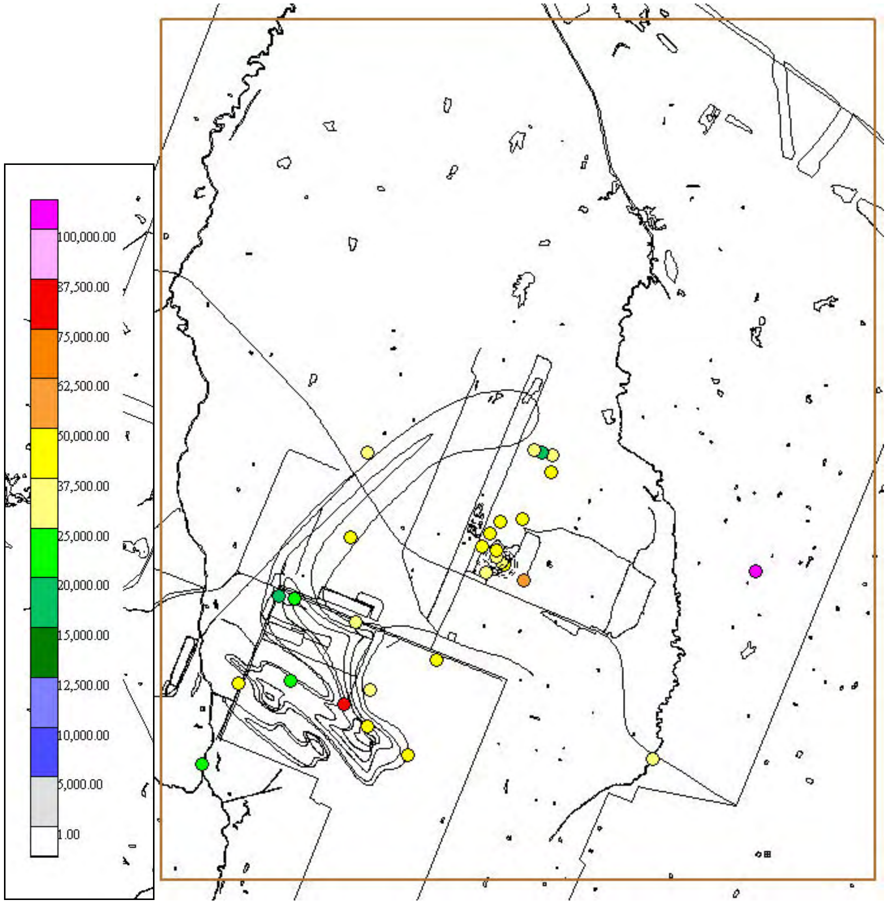


Figure 2D.16. URGA Chloride most recent value (ug/L).

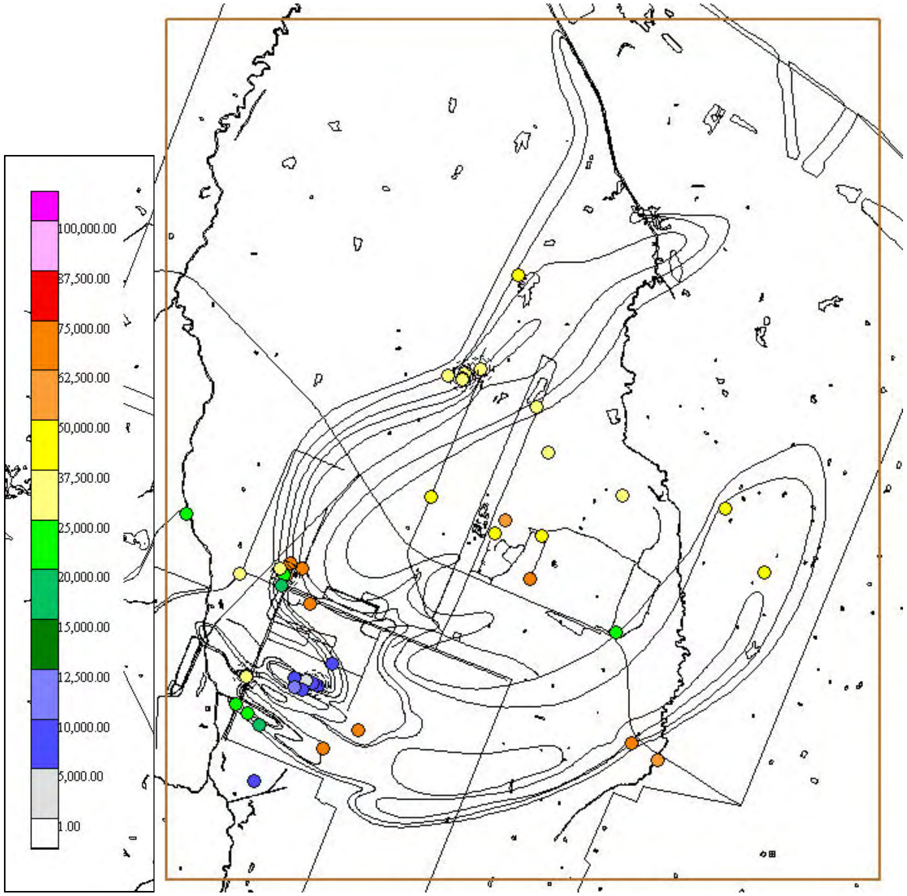


Figure 2D.17. MRGA Chloride average detect 1988 - 2006**.**

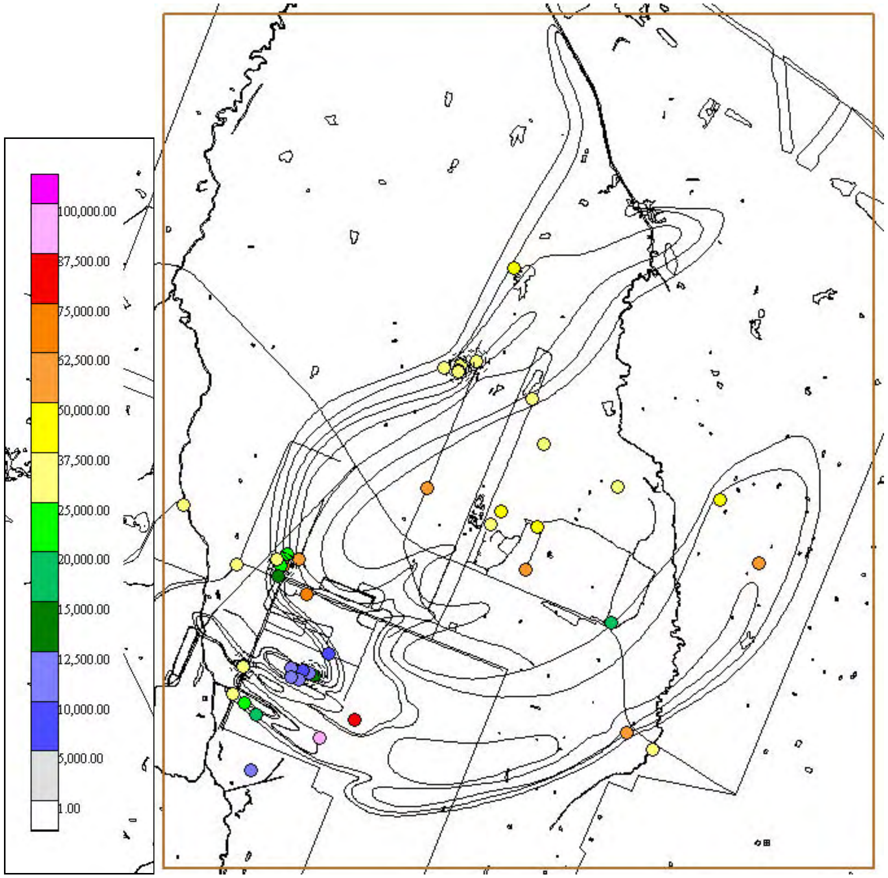


Figure 2D.18. MRGA Chloride most recent value**.**

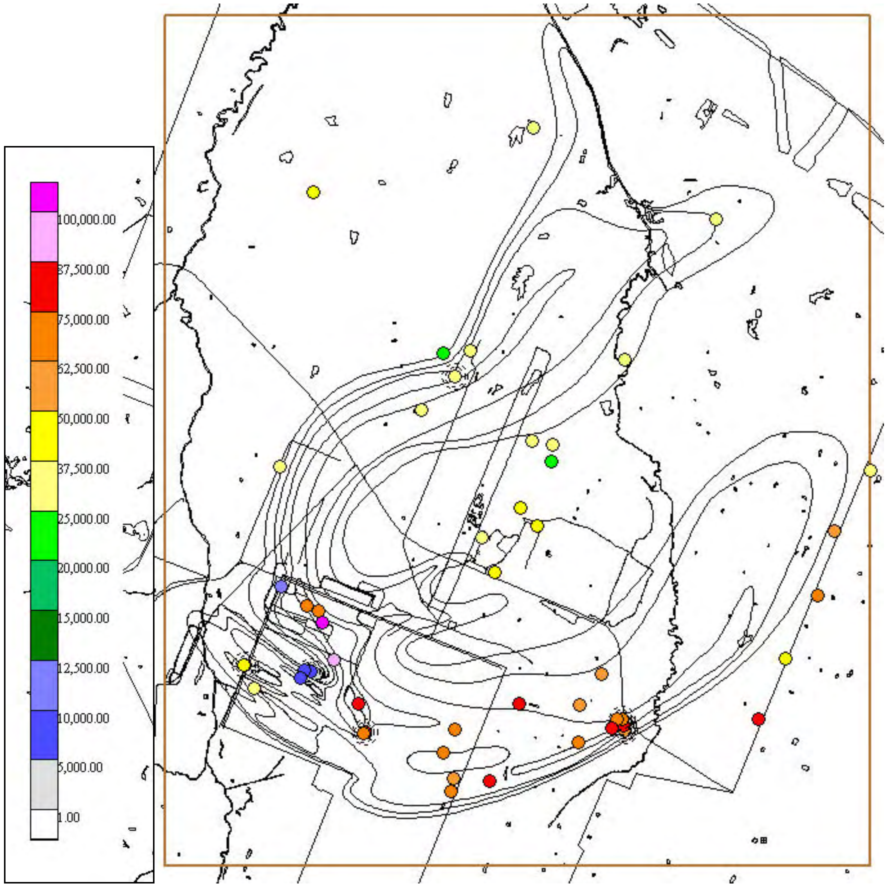


Figure 2D.19. LRGA chloride average detects 1988 - 2006.

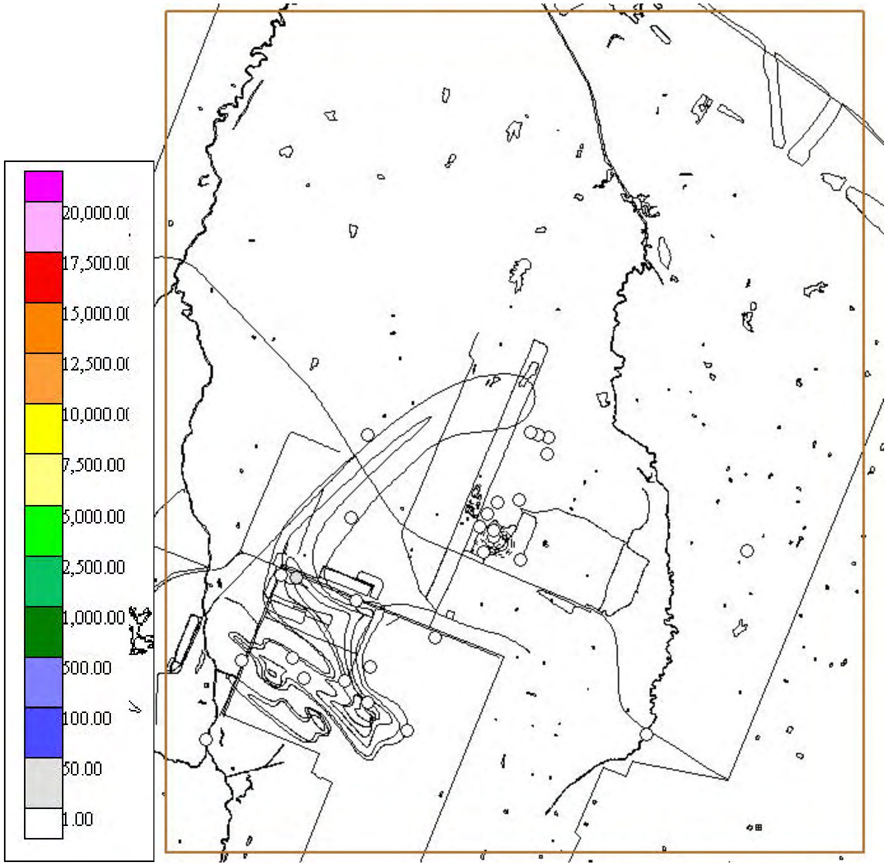


Figure 2D.20. URGA toluene maximum detects 1988 - 2006.

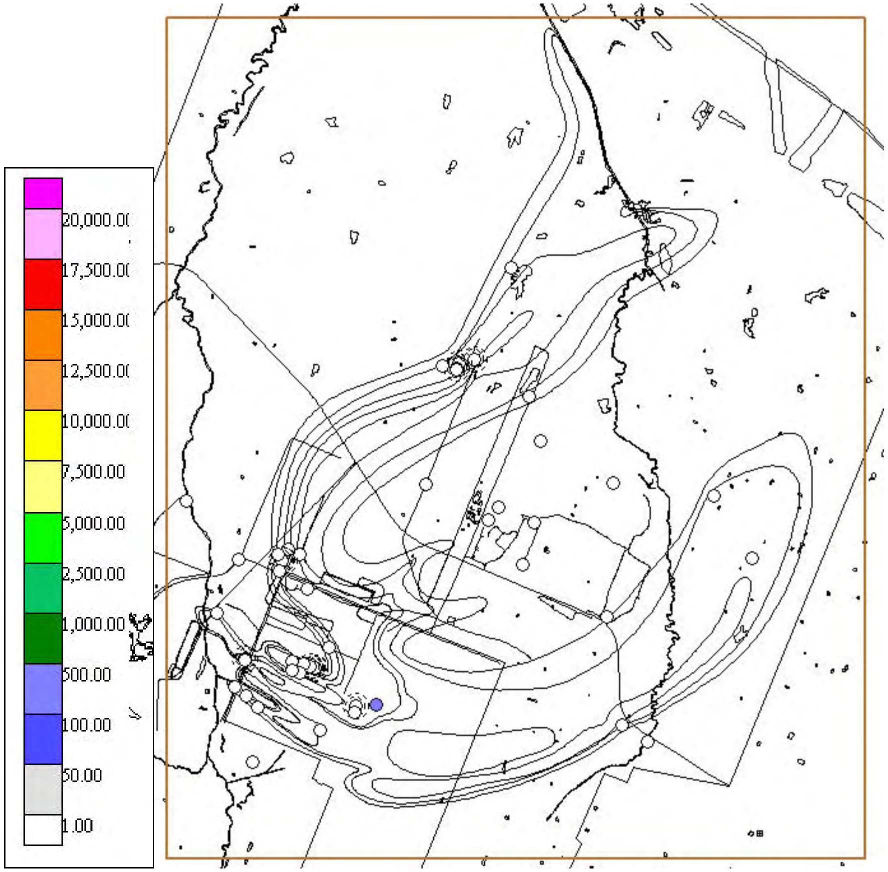


Figure 2D.21. MRGA toluene maximum detects 1988 - 2006**.**

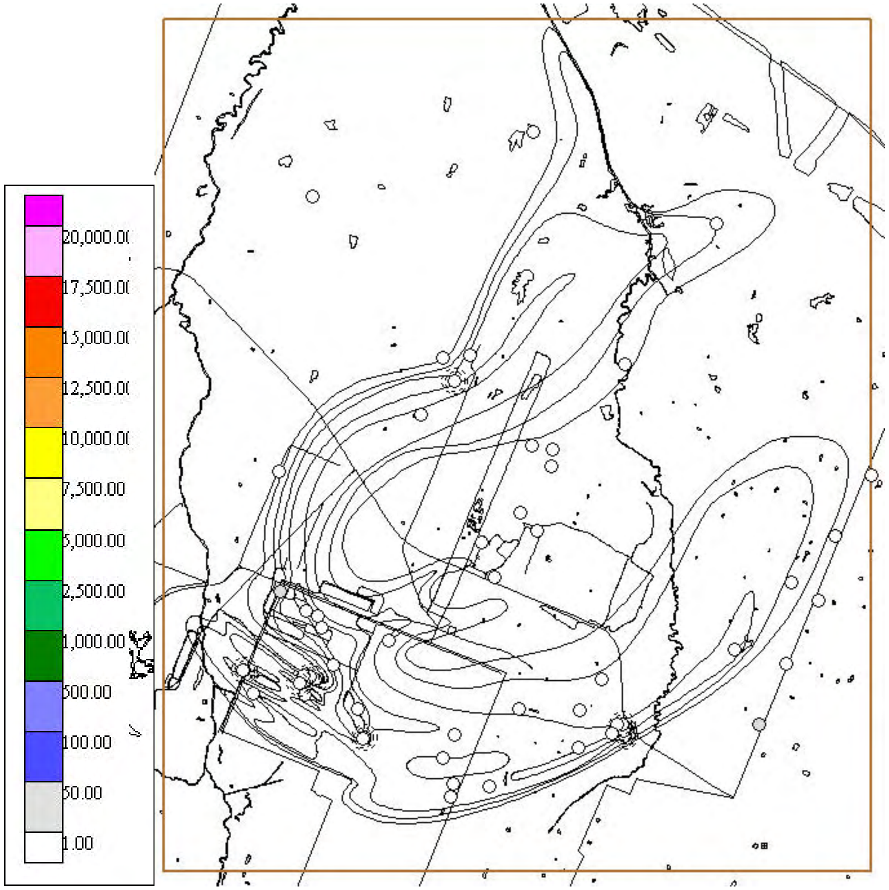


Figure 2D.22. LRGA toluene maximum detects 1988 - 2006.

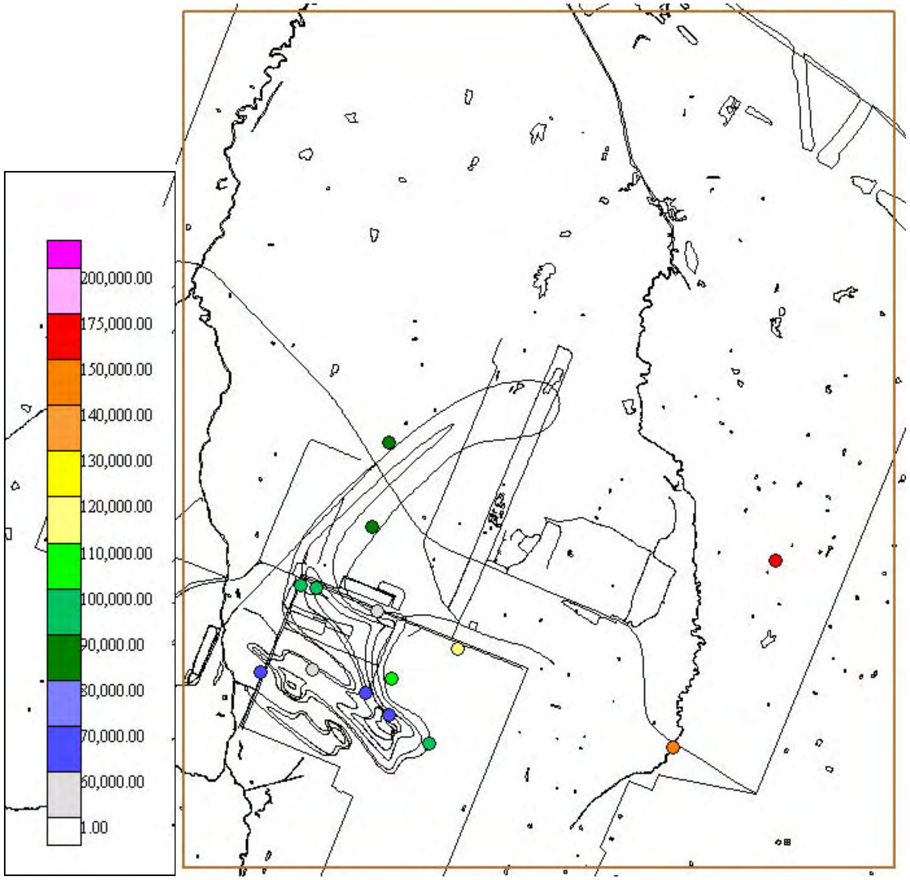


Figure 2D.23. URGA alkalinity average detects 1988 - 2006**.**

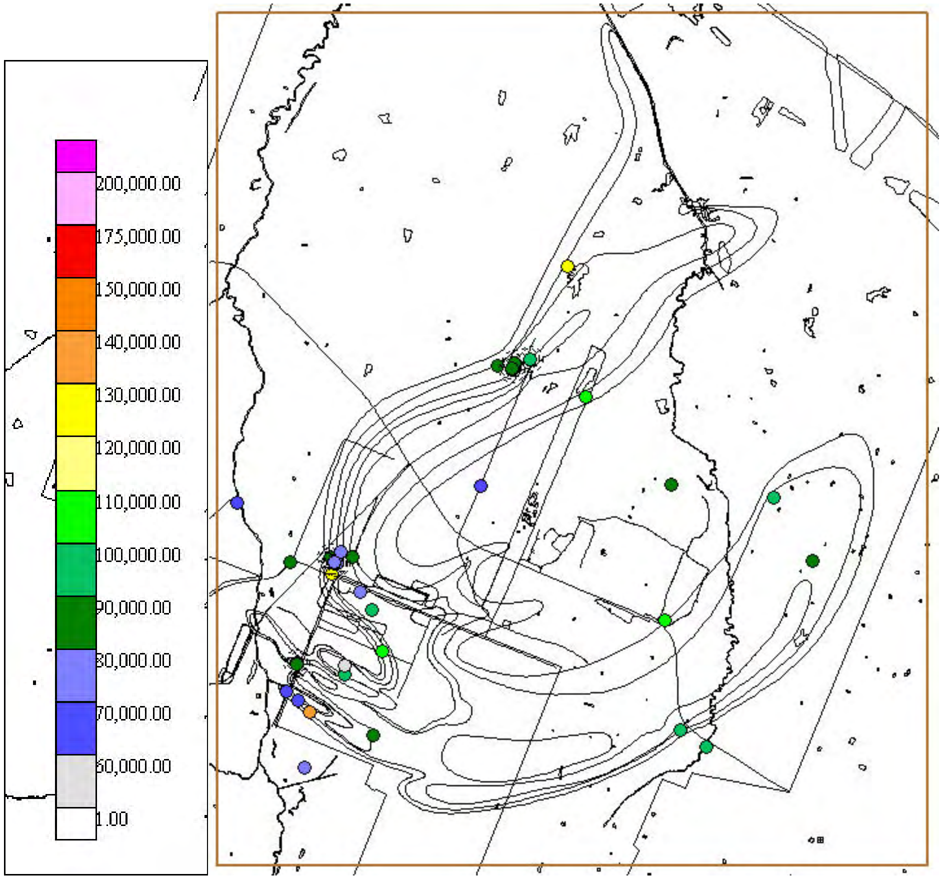


Figure 2D.24. MRGA alkalinity average detects 1988 - 2006.

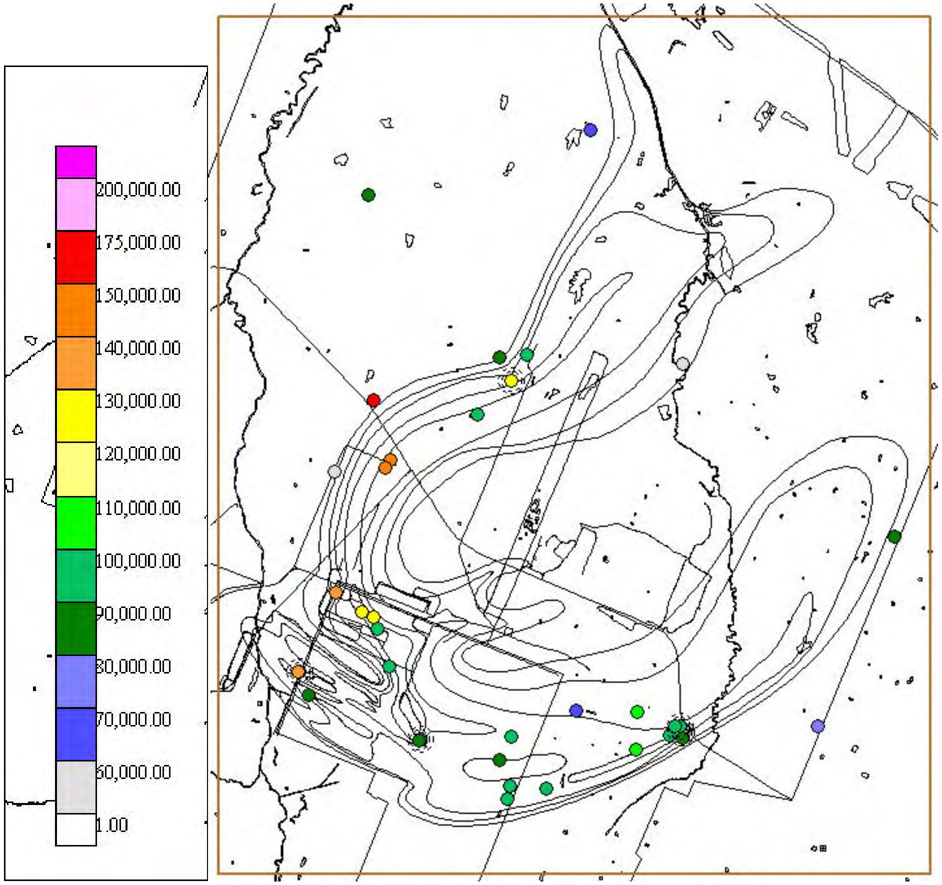


Figure 2D.25. LRGA alkalinity average detects 1988 - 2006.

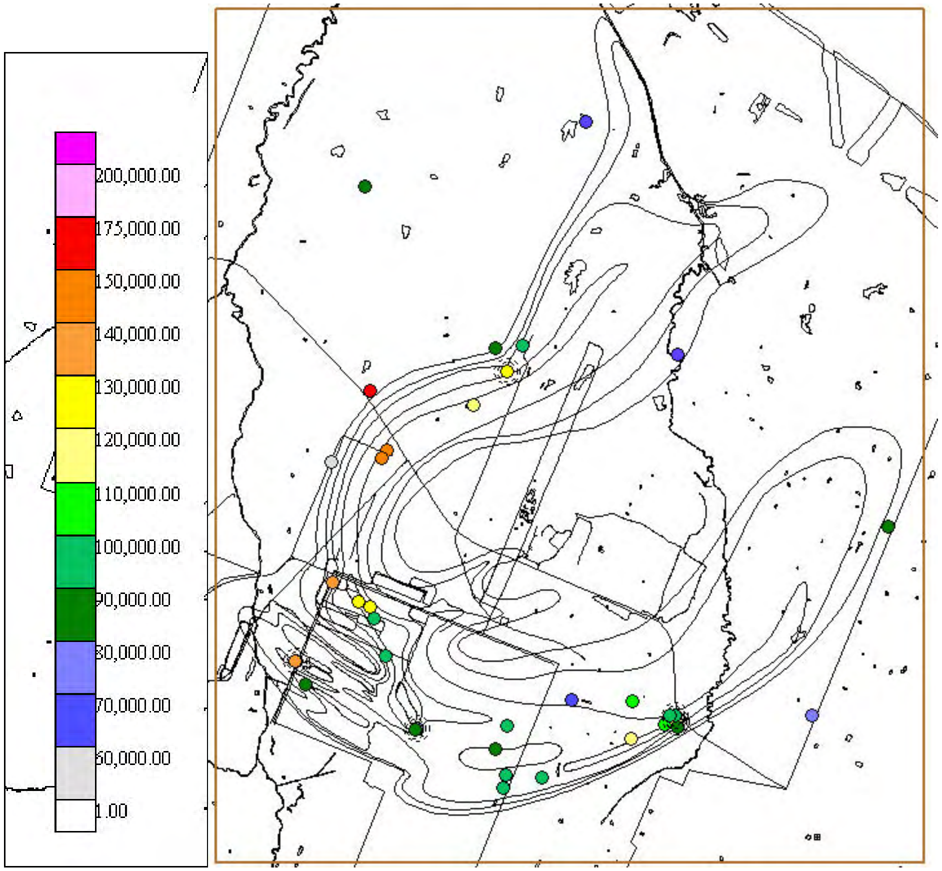


Figure 2D.26. LRGA alkalinity maximum detects 1988 - 2006

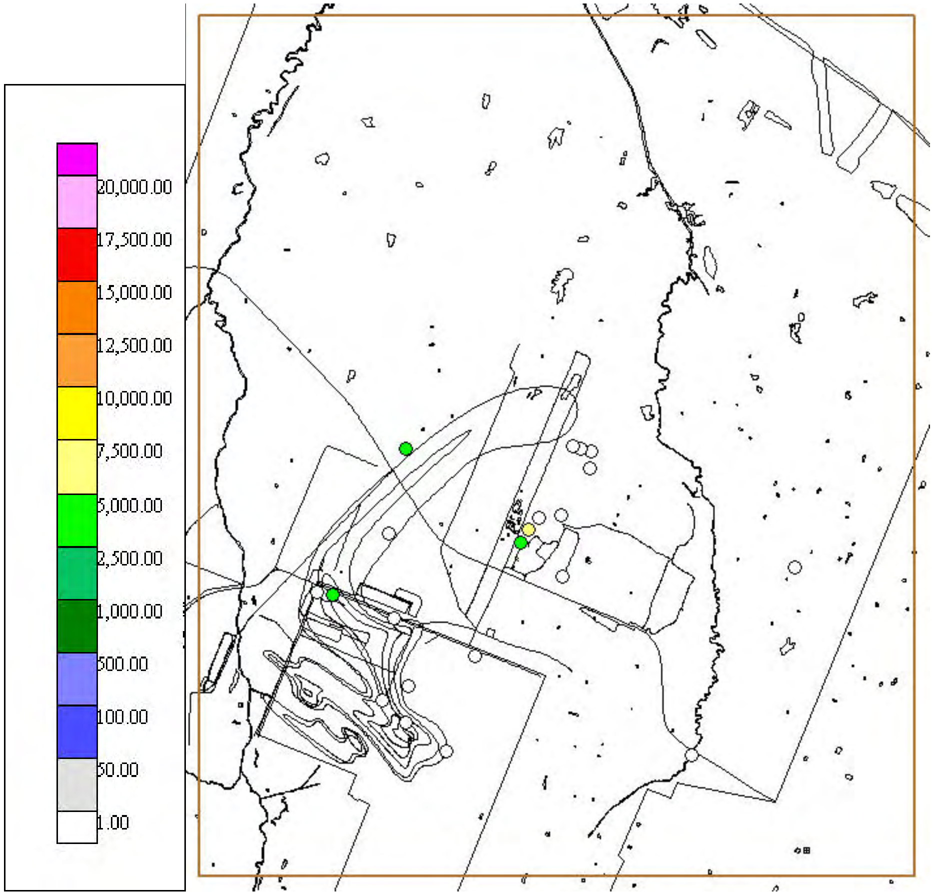


Figure 2D.27. URGA sulfide maximum detects 1988 - 2006

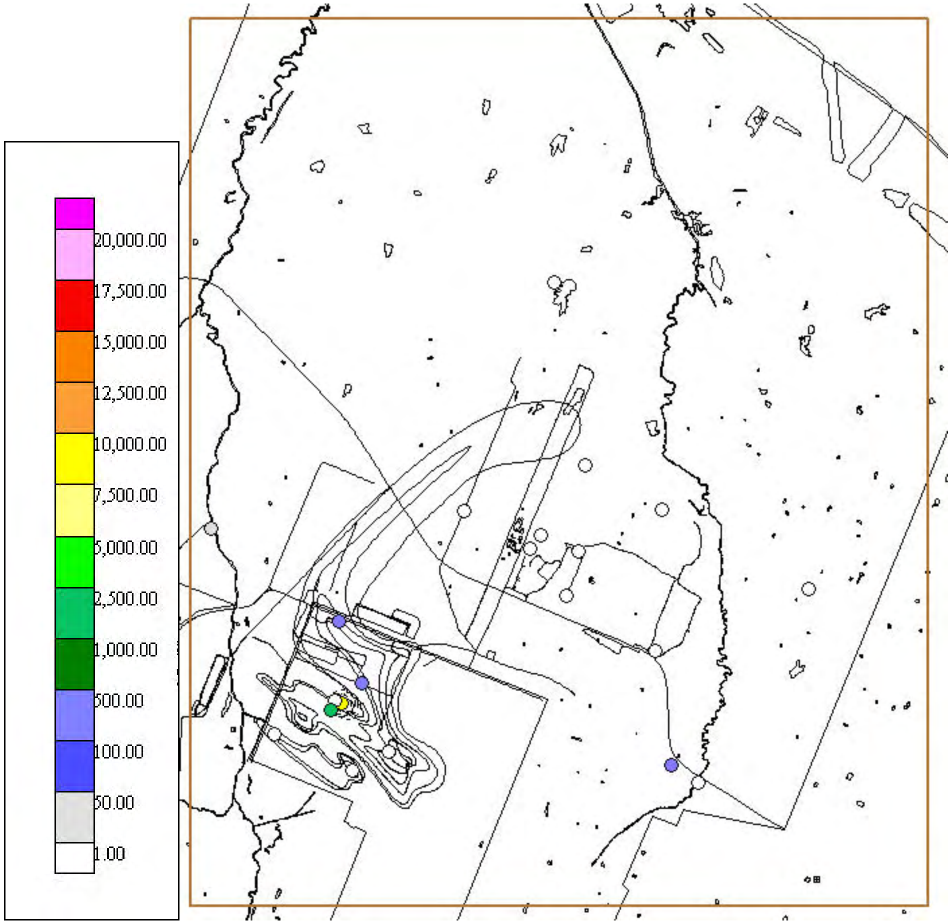


Figure 2D.28. MRGA sulfide maximum detects 1988 - 2006

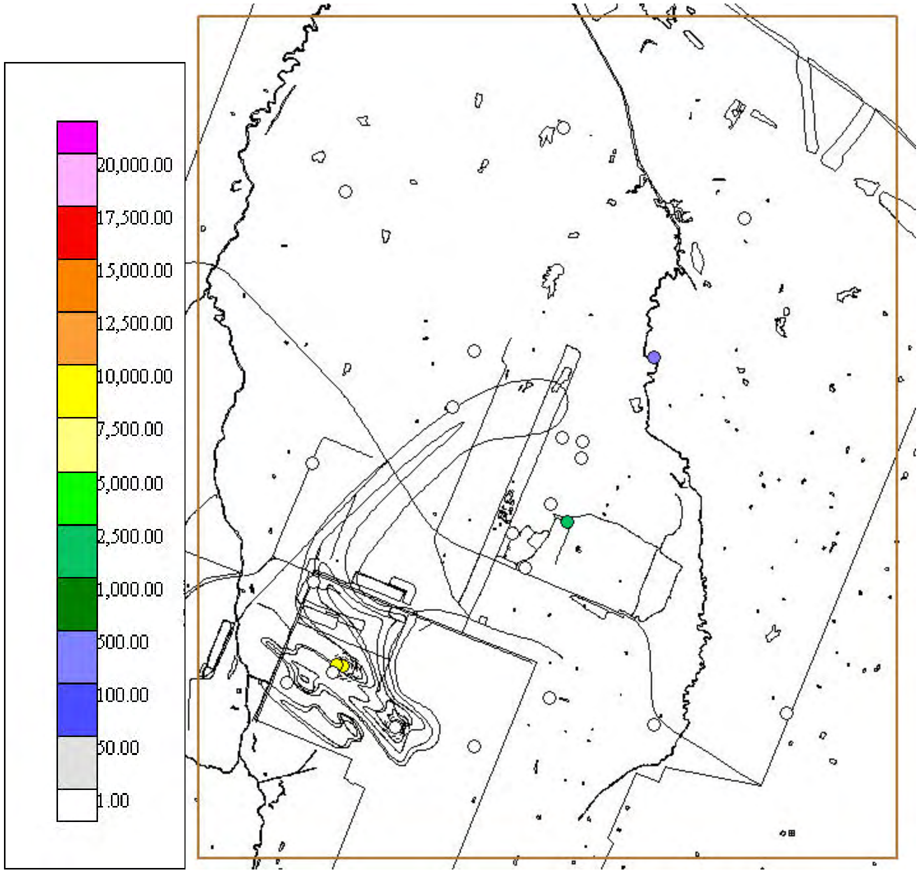


Figure 2D.29. LRGA sulfide maximum detects 1988 - 2006

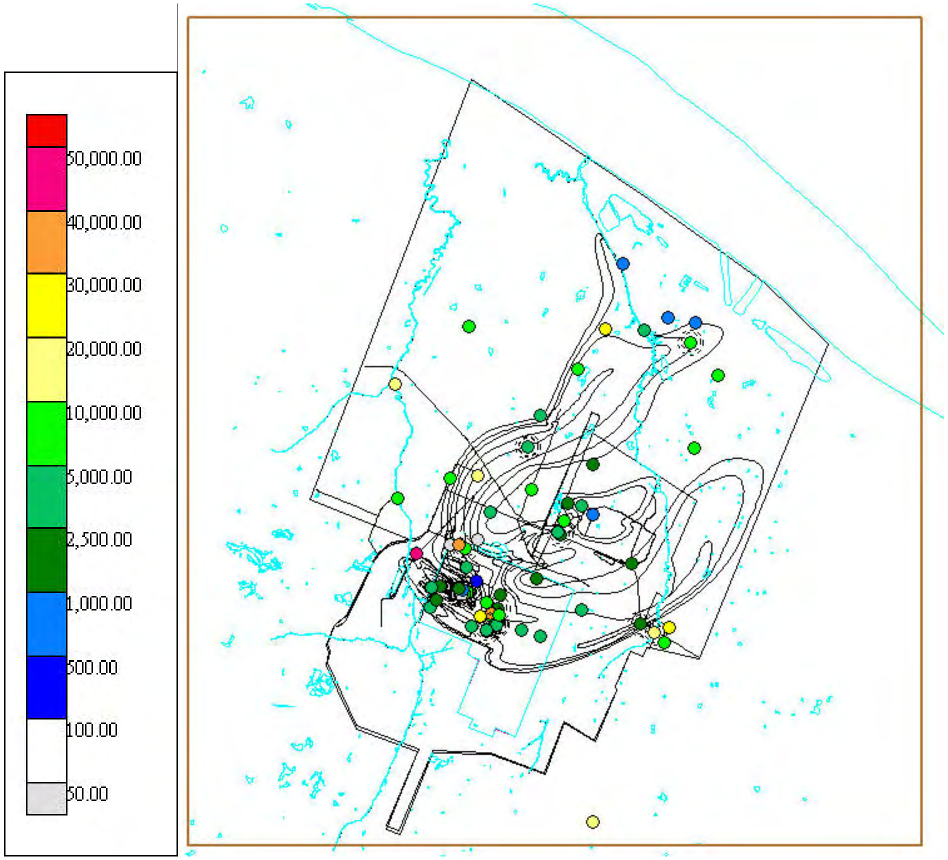


Figure 2D.30. All-RGA nitrate average detects 1988 - 2006

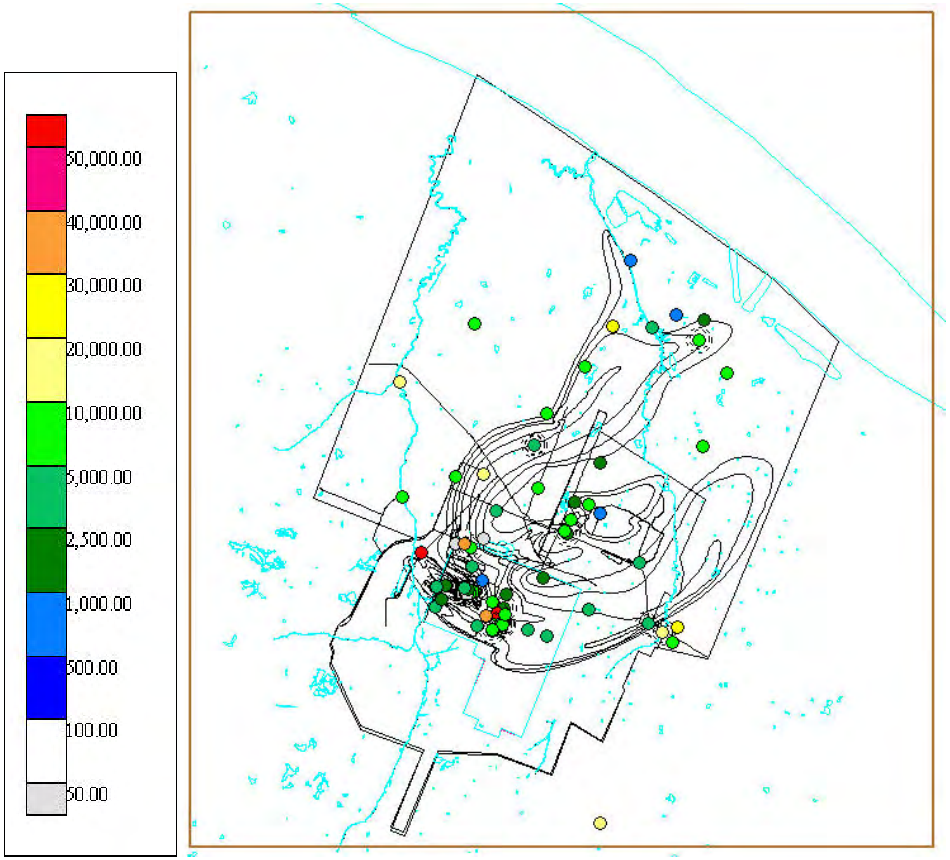


Figure 2D.31. All-RGA nitrate maximum detects 1988 - 2006

Appendix 2E. Spatial Distibution of TOC in soil samples from 0 to 145' bgs.

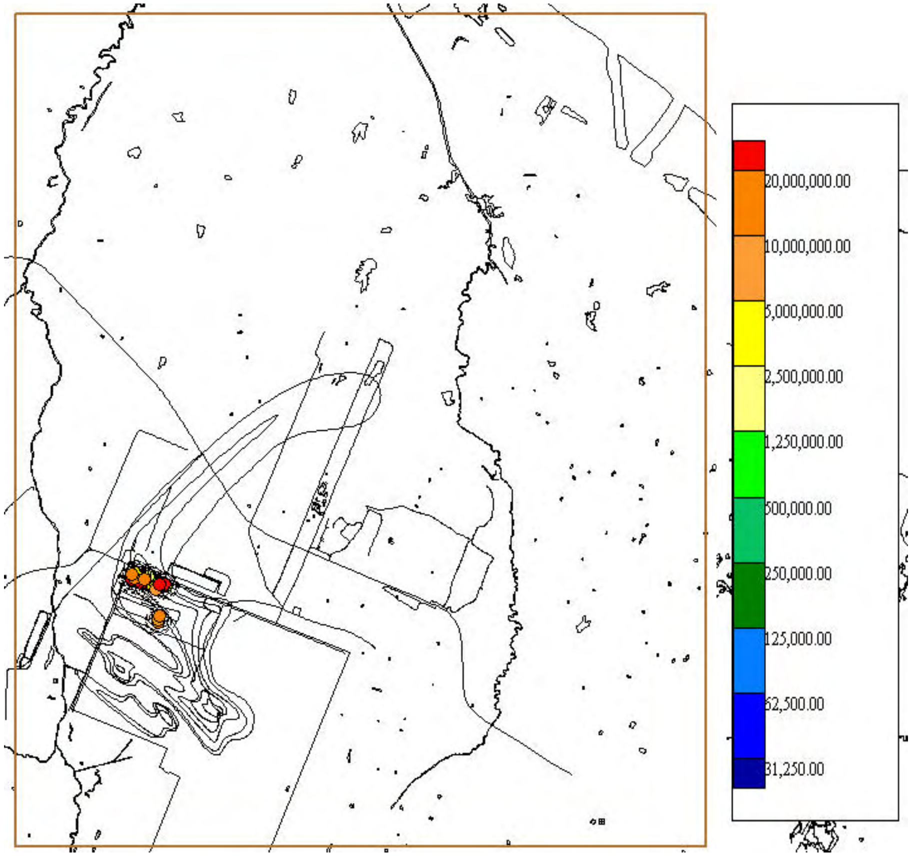


Figure 2EG.1. Total organic carbon in soil 0 to 6' bgs (ug/kg).

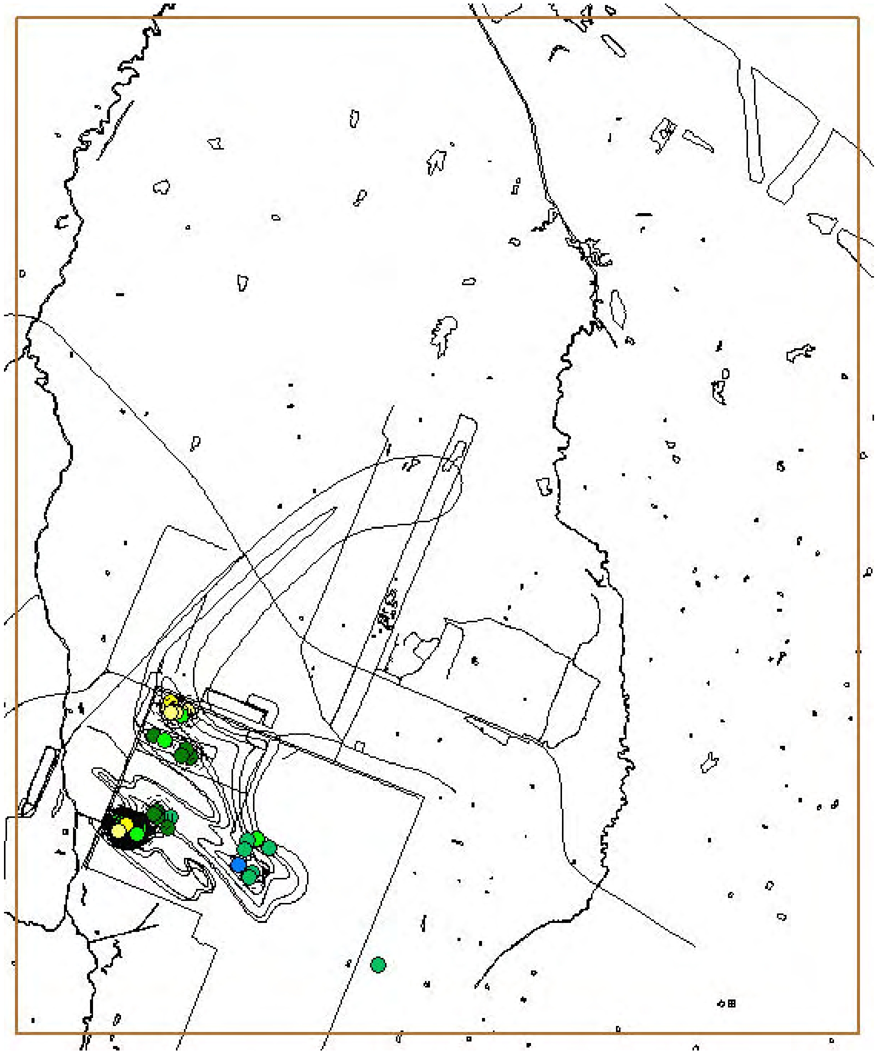


Figure 2E.2. Total organic carbon in soil 6 to 60' bgs (ug/kg).

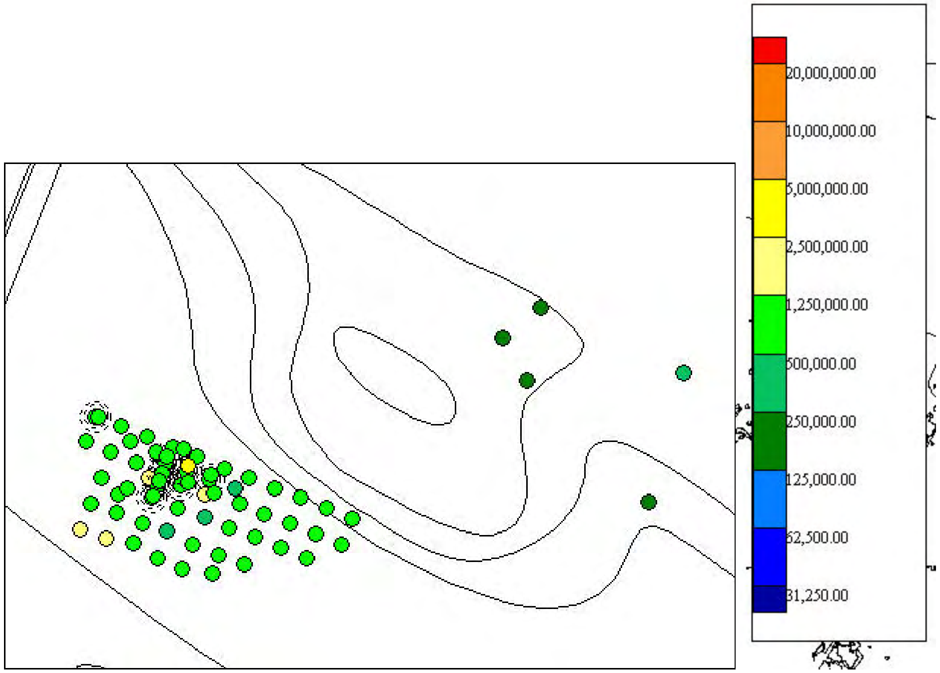


Figure 2E.3. Total organic carbon in soil 6 to 60’ bgs at SWMU 1 (ug/kg).

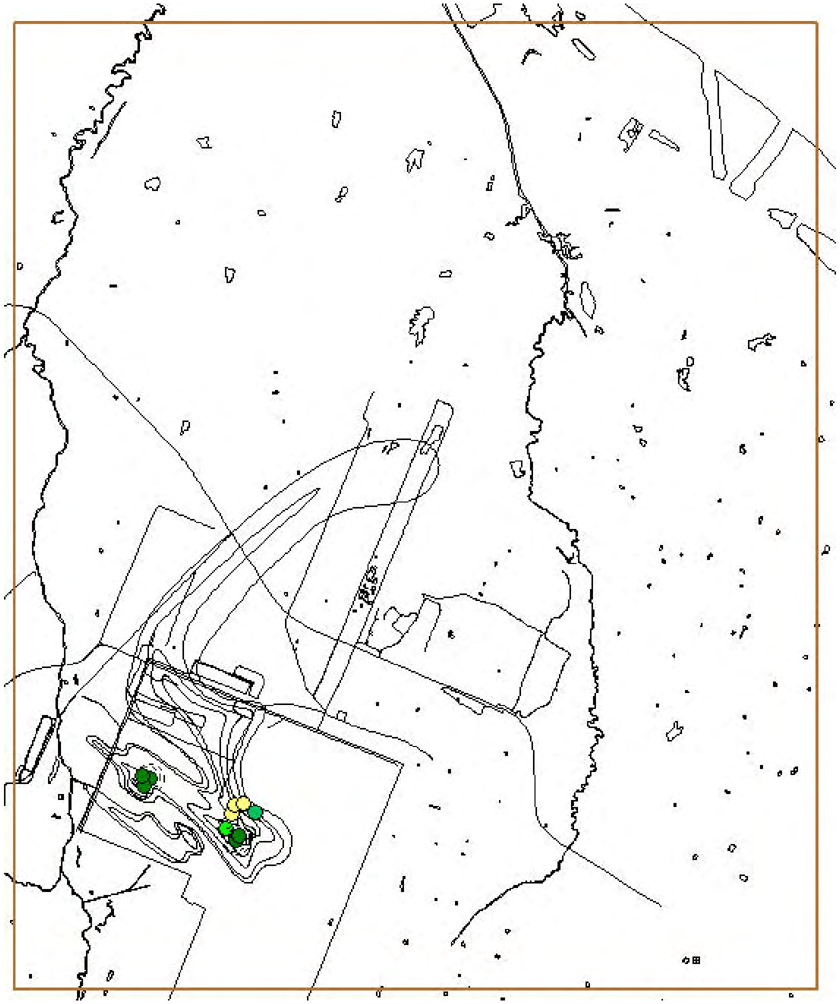


Figure 2E.4. Total organic carbon in soil (RGA) 60 to 120’ bgs (ug/kg).

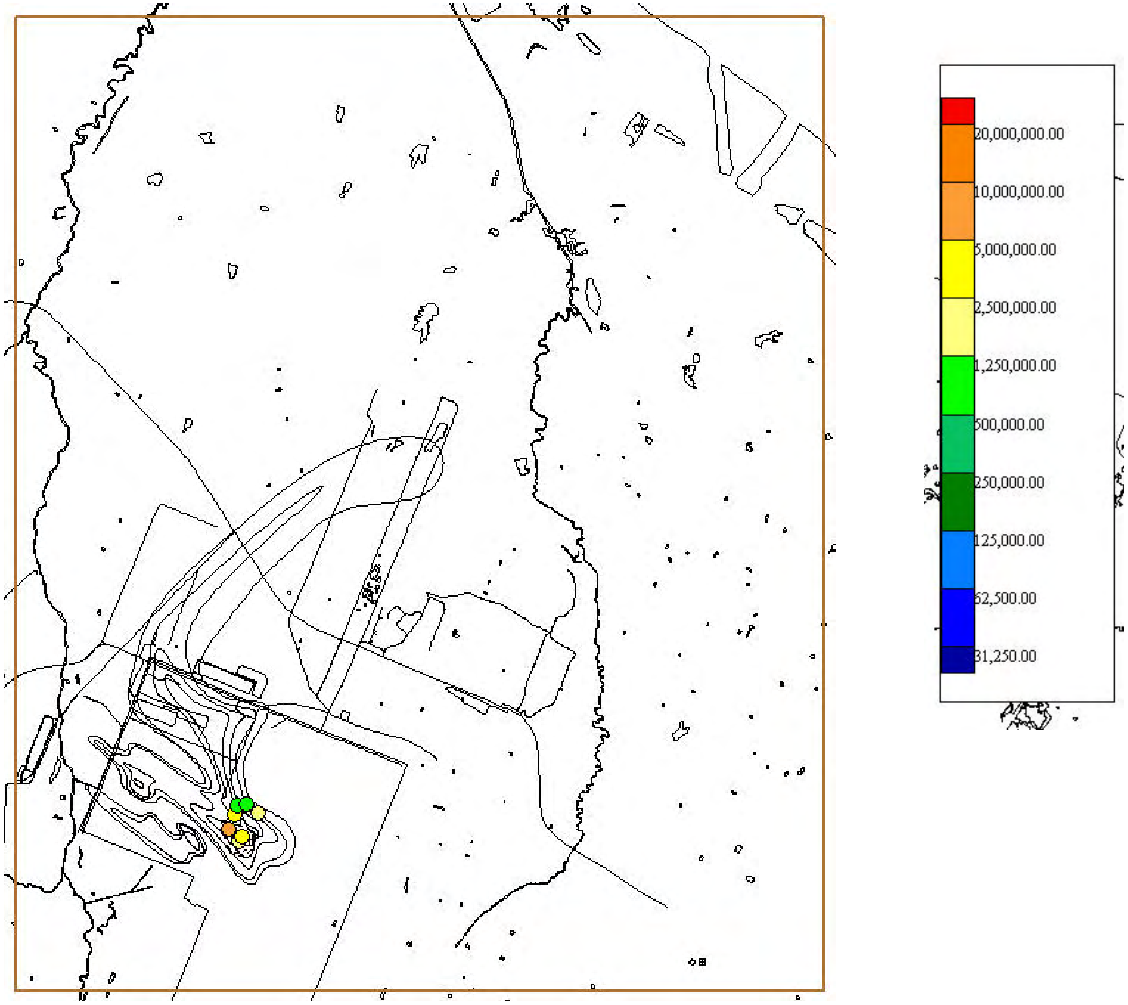


Figure 2E.5. Total organic carbon in (McNairy Formation) soil 120 to 140’ bgs (ug/kg**).**

Appendix 2F. UCRS Groundwater Spatial Plots.

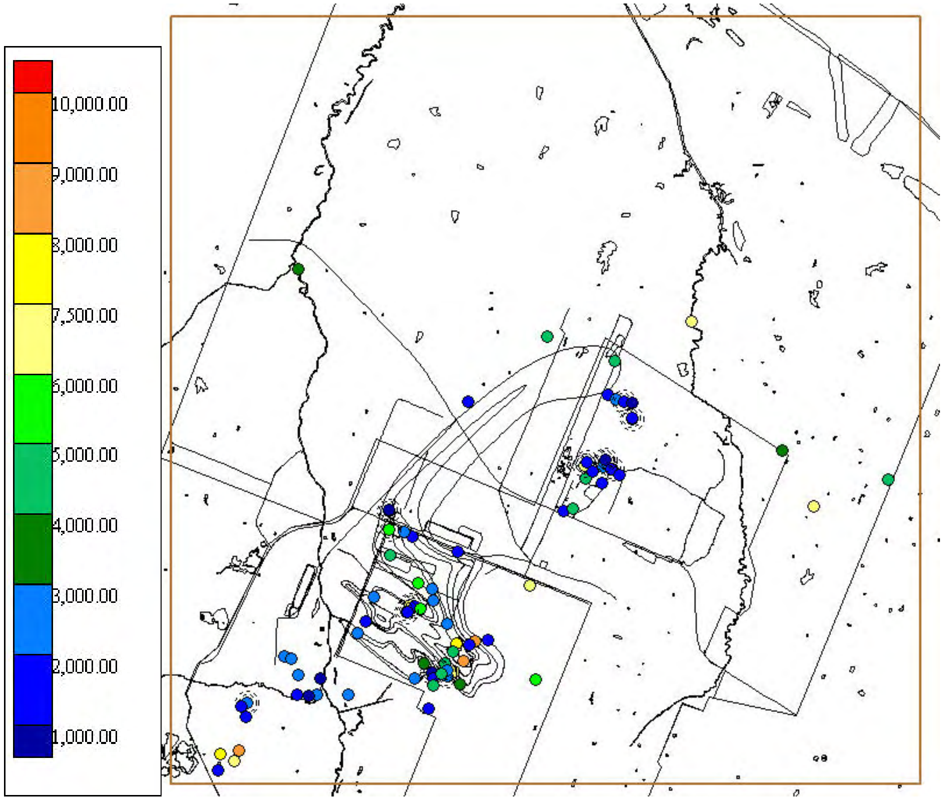


Figure 2F.1. Average UCRS GW Dissolved Oxygen concentrations 1988 – 2006 (ug/L).

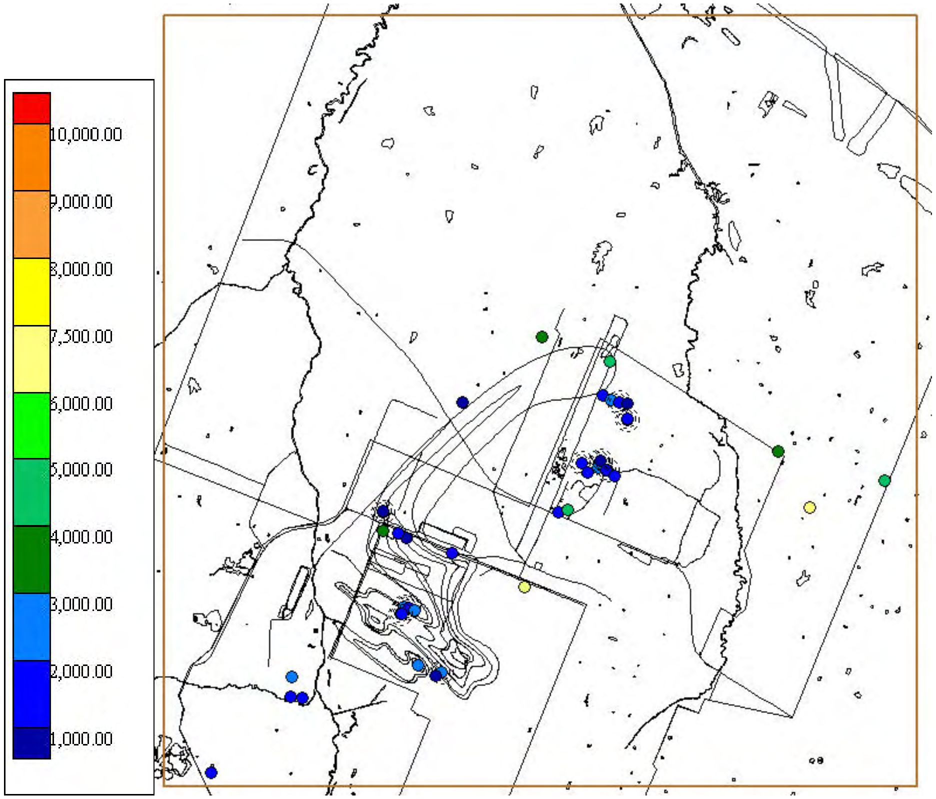
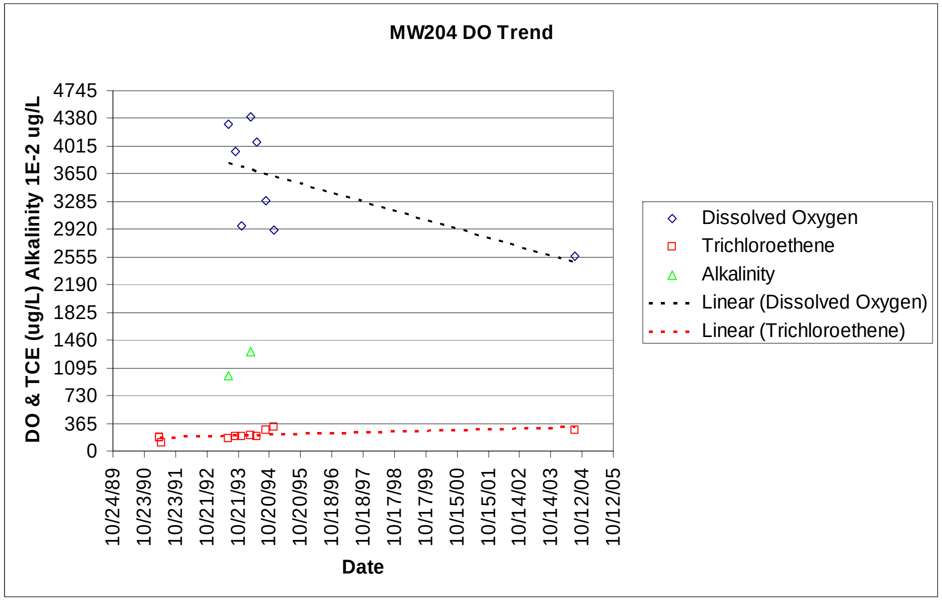
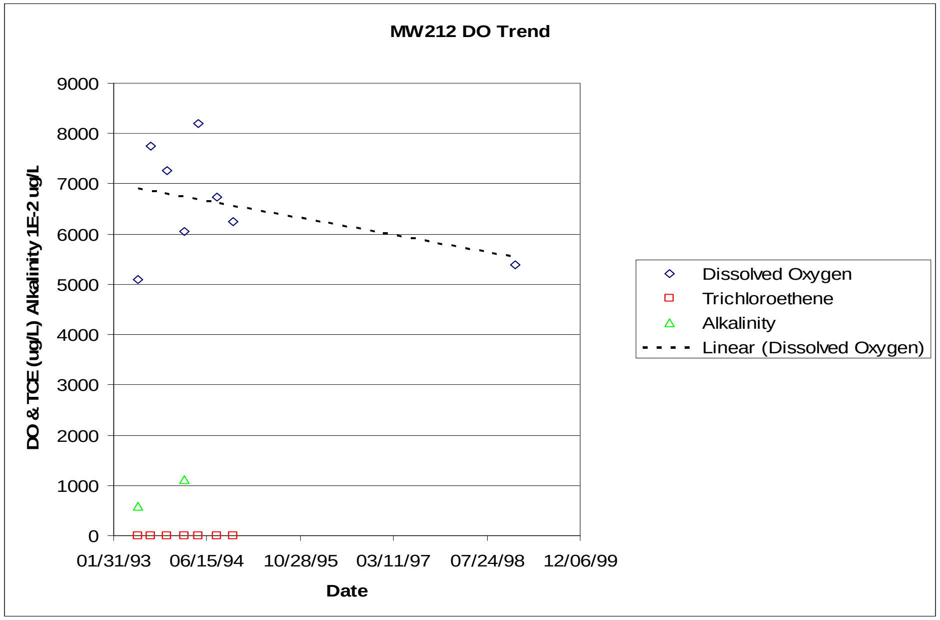
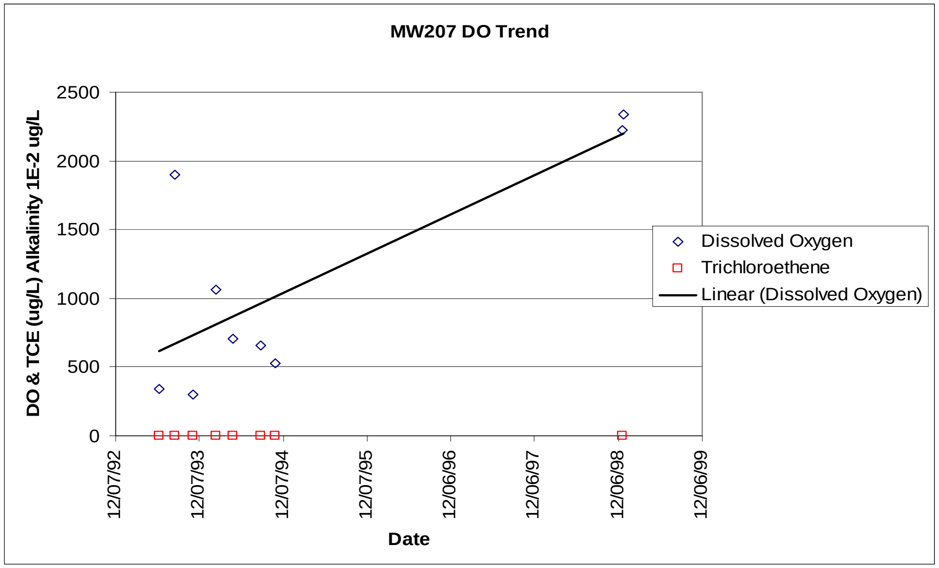


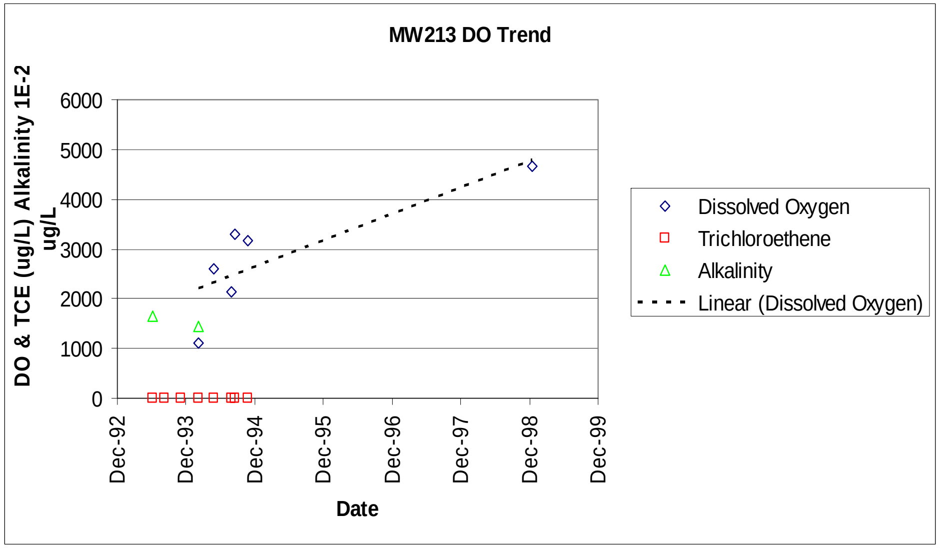
Figure 2F.2. Average UCRS GW Dissolved Oxygen concentrations 2001 – 2006 (ug/L).

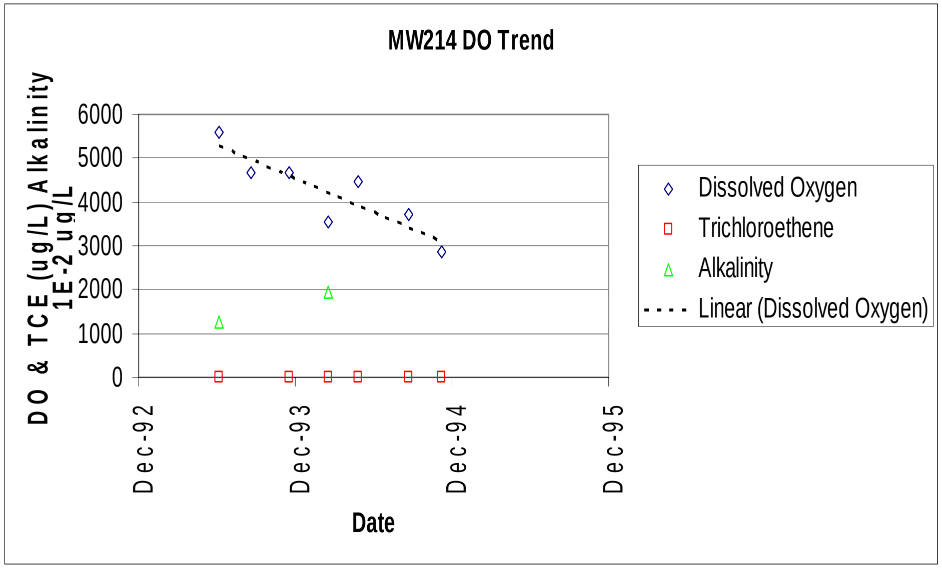
Appendix 2G.1 UCRS DO Trends

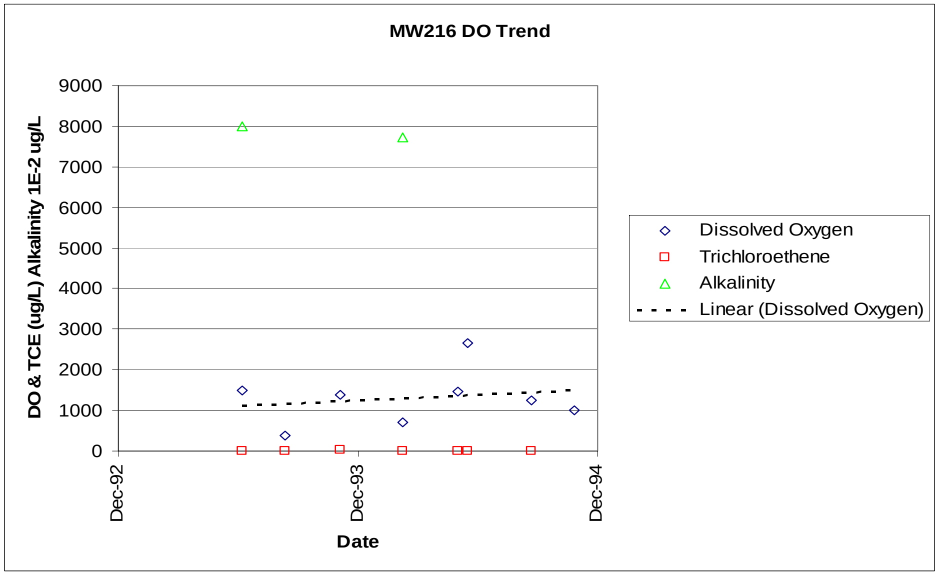

MW204 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
4745
4380
4015
3650
3285
2920
2555
2190
1825
1460
1095
730
365
0
10/24/89
10/23/90
10/23/91
10/21/92
10/21/93
10/20/94
10/20/95
10/18/96
10/18/97
10/17/98
10/17/99
10/15/00
10/15/01
10/14/02
10/14/03
10/12/04
10/12/05
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)
Linear (Trichloroethene)

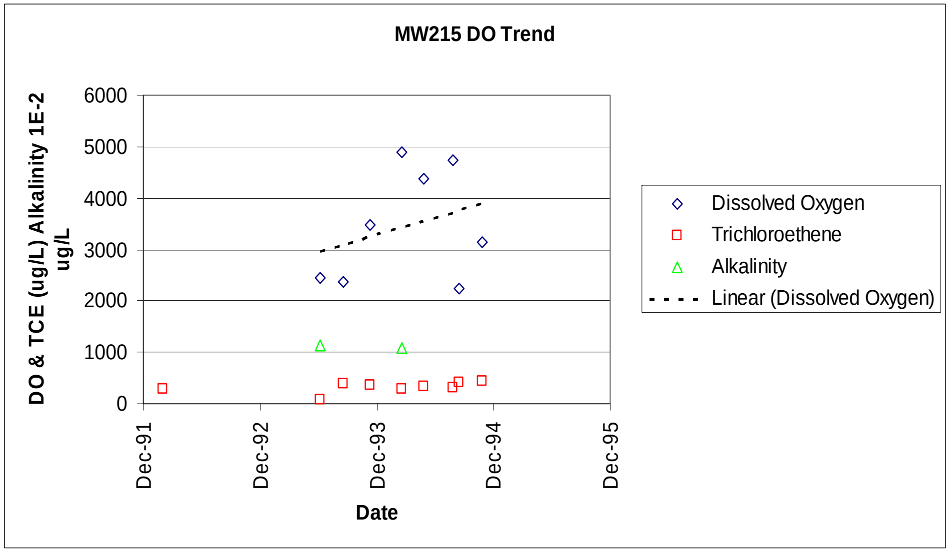

MW212 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
01/31/93
06/15/94
10/28/95
03/11/97
07/24/98
12/06/99
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)

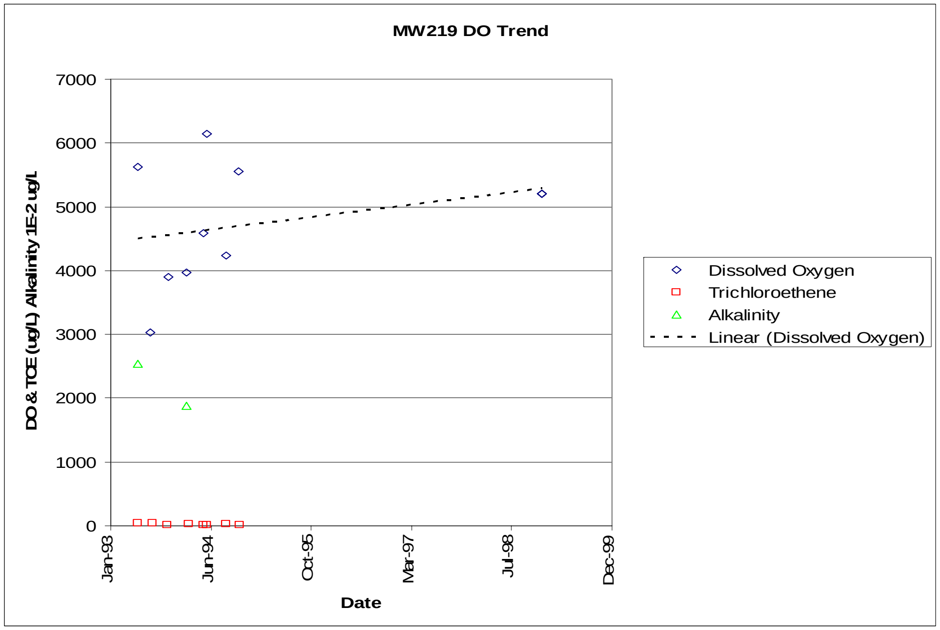

MW207 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
2500
2000
1500
1000
500
0
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
Date
◇ Dissolved Oxygen
□ Trichloroethene
Linear (Dissolved Oxygen)

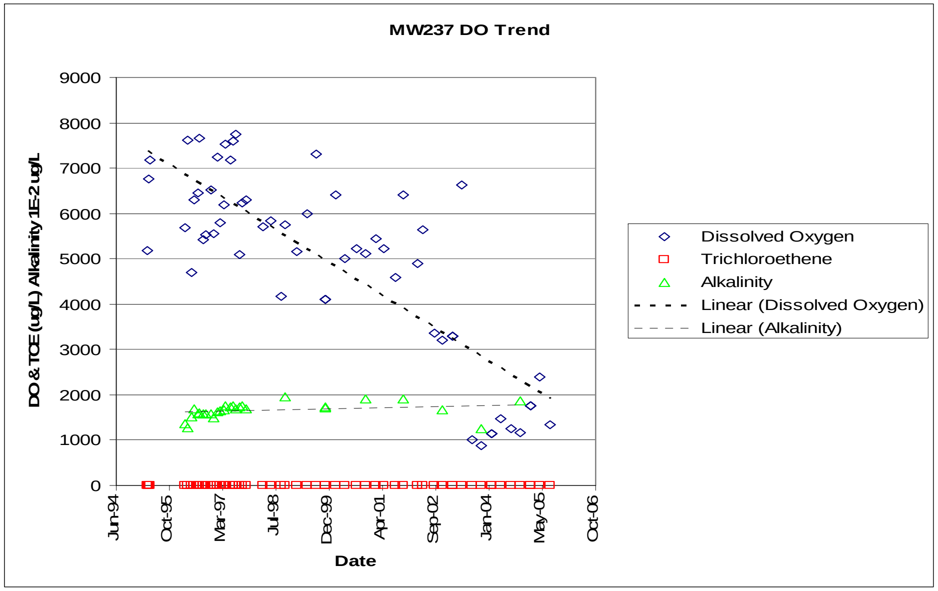

MW213 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
6000
5000
4000
3000
2000
1000
0
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)

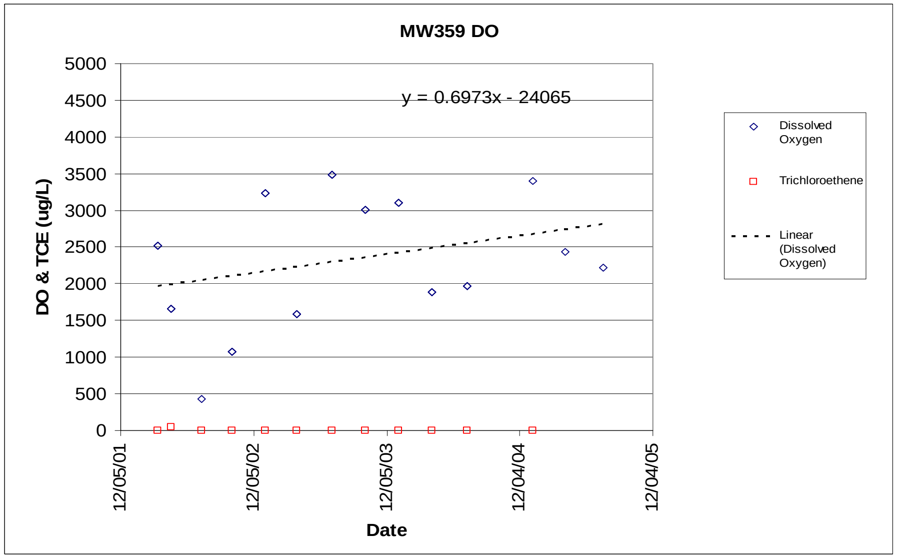

MW214 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
6000
5000
4000
3000
2000
1000
0
Dec-92
Dec-93
Dec-94
Dec-95
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)

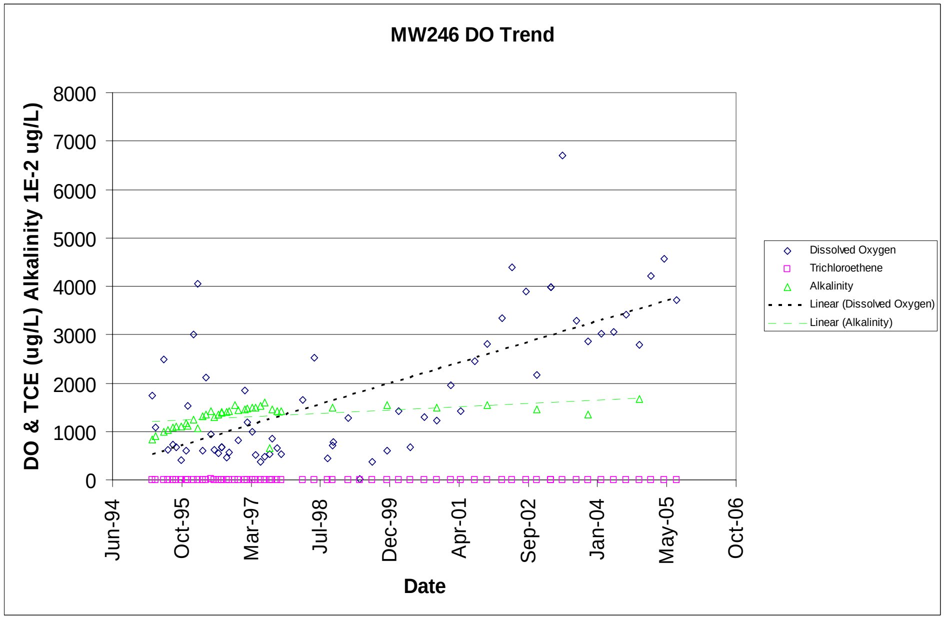

MW216 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-92
Dec-93
Dec-94
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)

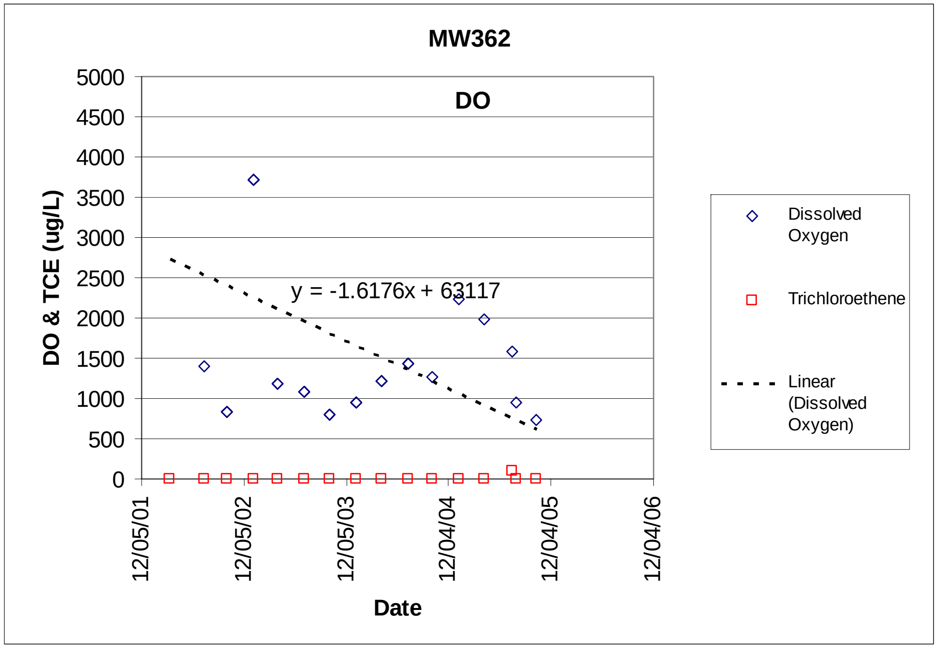

MW215 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
6000
5000
4000
3000
2000
1000
0
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)


MW219 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
7000
6000
5000
4000
3000
2000
1000
0
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Date
◇ Dissolved Oxygen
□ Trichloroethene
△ Alkalinity
Linear (Dissolved Oxygen)

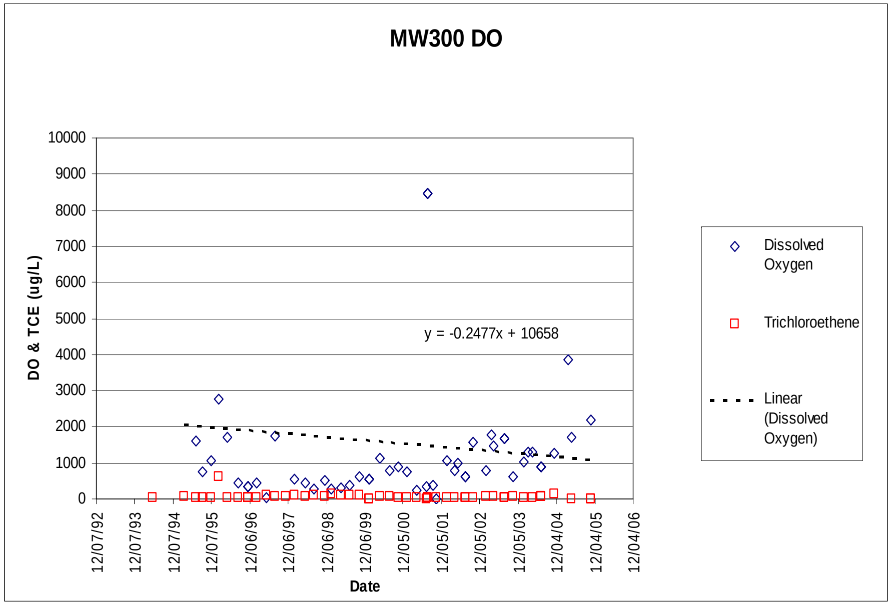

MW237 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Date
Dissolved Oxygen
Trichloroethene
Alkalinity
Linear (Dissolved Oxygen)
Linear (Alkalinity)

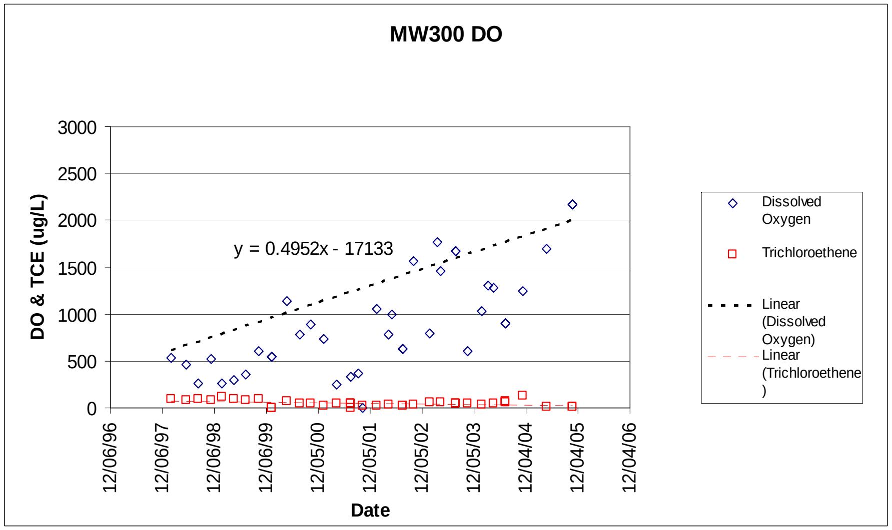

MW359 DO
DO & TCE (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
y = 0.6973x - 24065
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

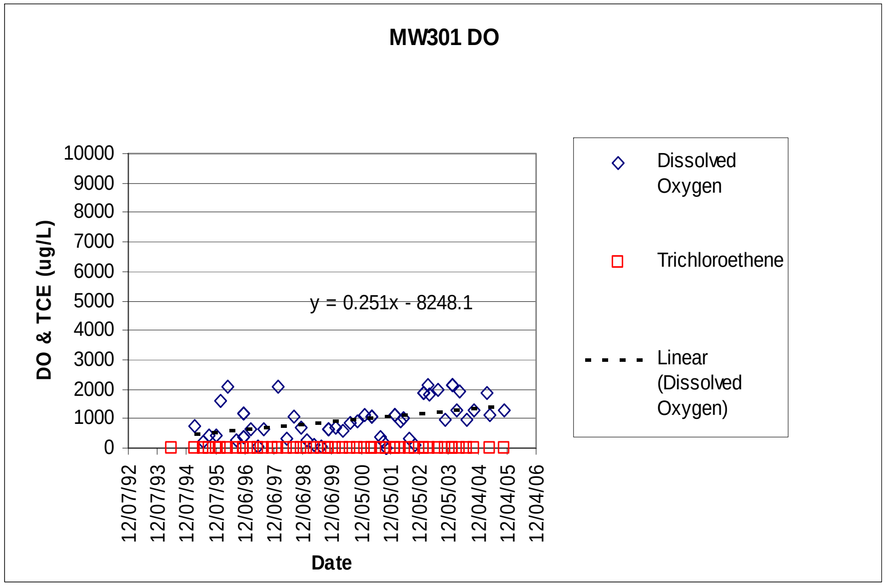

MW246 DO Trend
DO & TCE (ug/L) Alkalinity 1E-2 ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Date
Dissolved Oxygen
Trichloroethene
Alkalinity
Linear (Dissolved Oxygen)
Linear (Alkalinity)

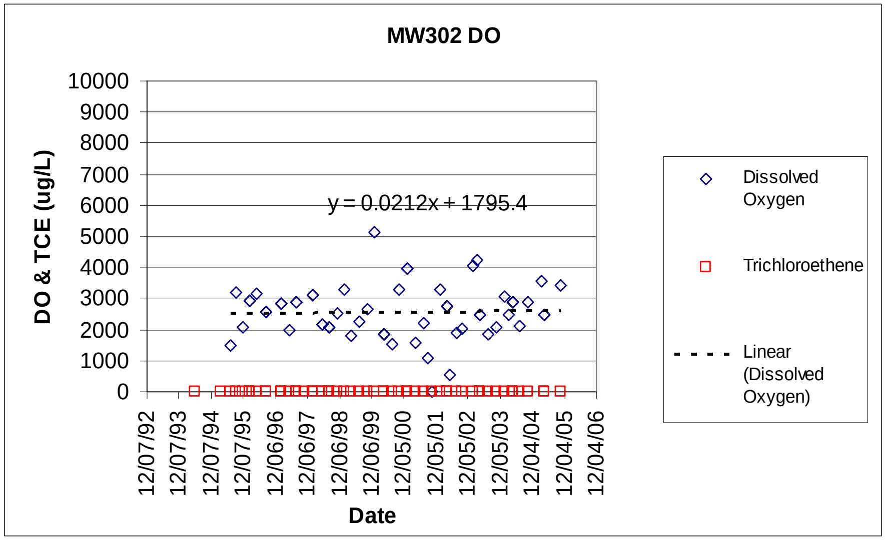

MW362
DO
DO & TCE (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
y = -1.6176x + 63117
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

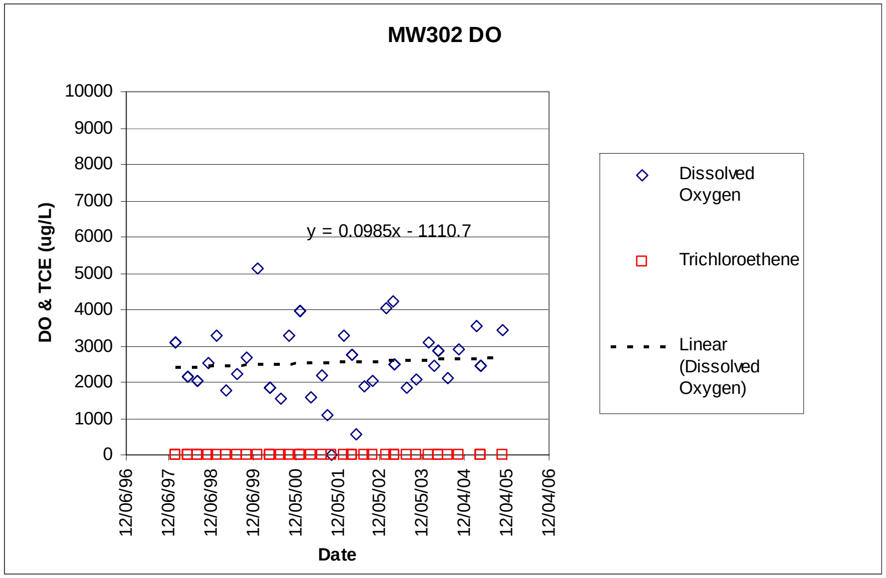
Appendix 2G.2 Terrace Gravel and Eocene Sands DO Trends

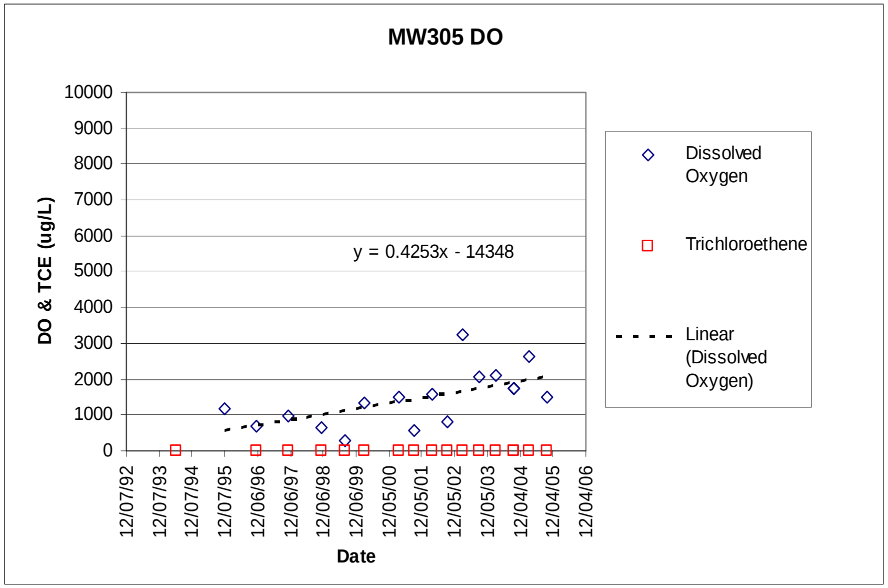

MW300 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = -0.2477x + 10658
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

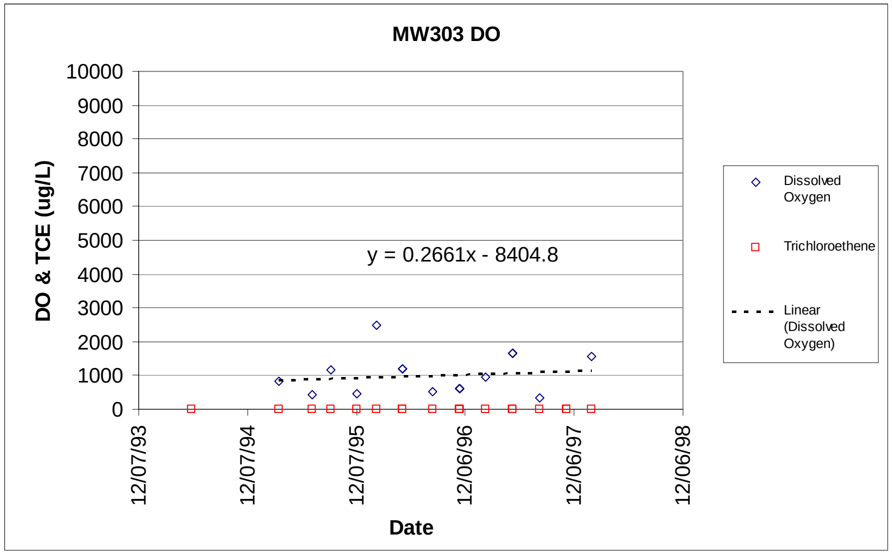

MW300 DO
DO & TCE (ug/L)
3000
2500
2000
1500
1000
500
0
y = 0.4952x - 17133
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)
Linear (Trichloroethene)

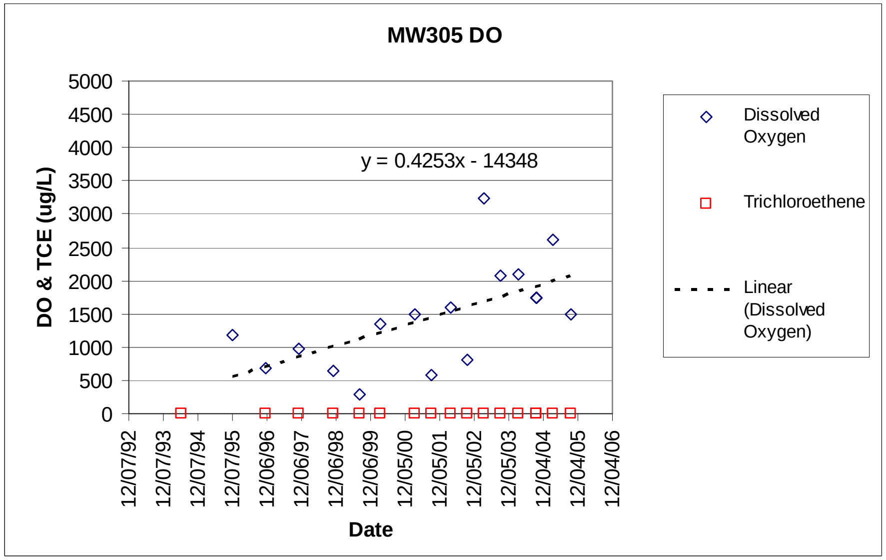

MW301 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = 0.251x - 8248.1
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)


MW302 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = 0.0212x + 1795.4
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

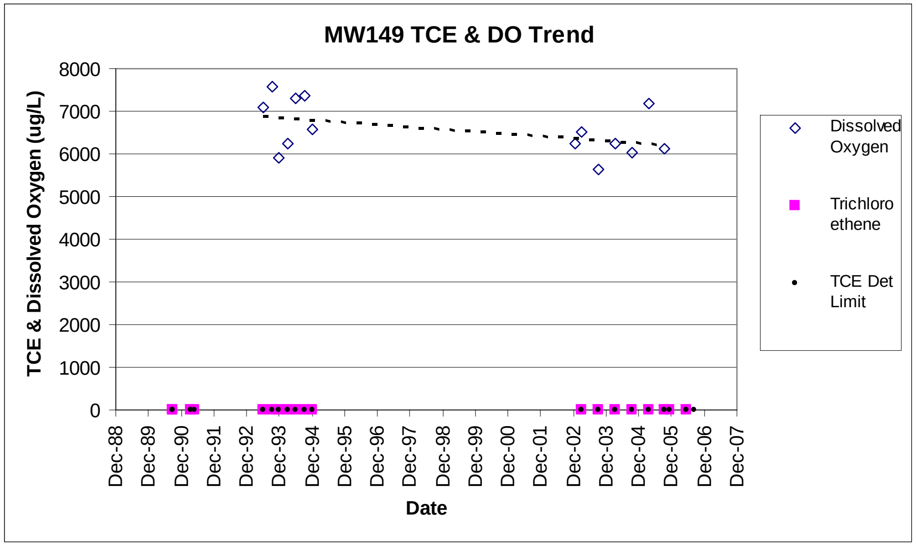

MW302 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = 0.0985x - 1110.7
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

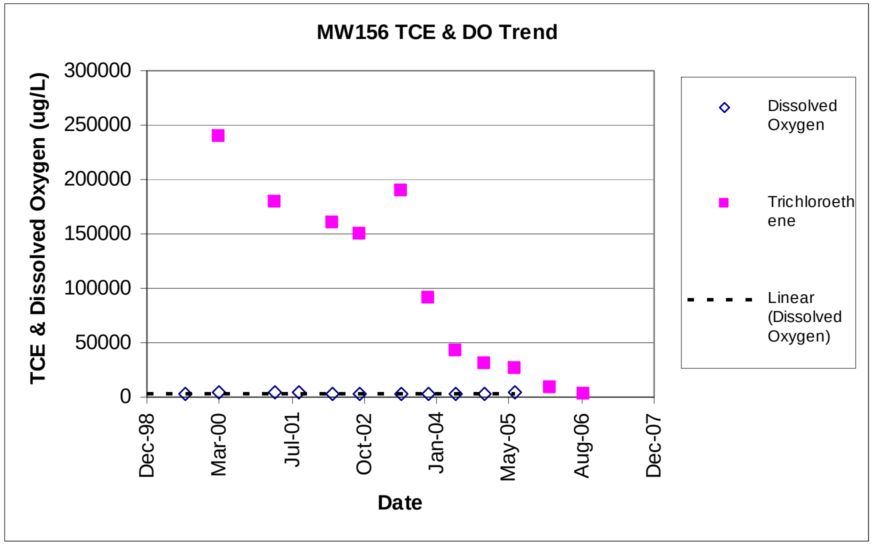

MW305 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = 0.4253x - 14348
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

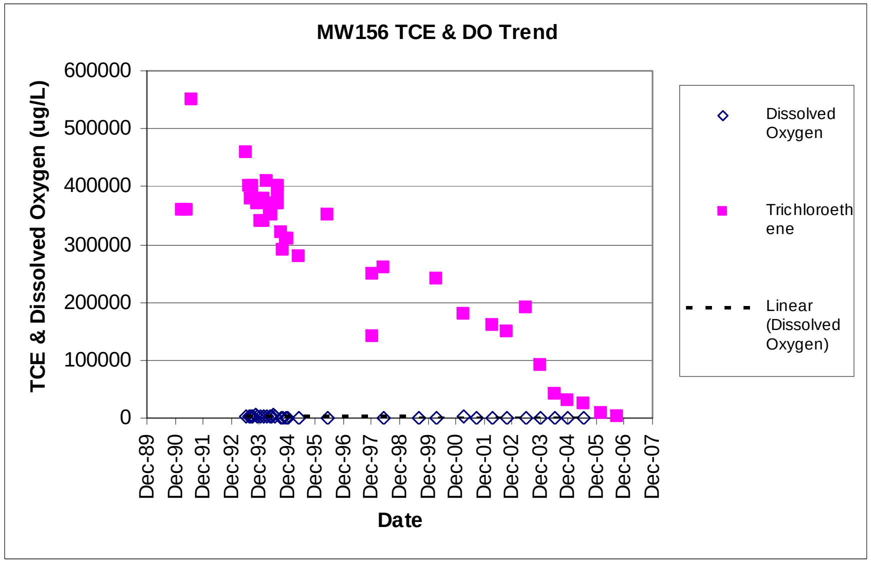

MW303 DO
DO & TCE (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
y = 0.2661x - 8404.8
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

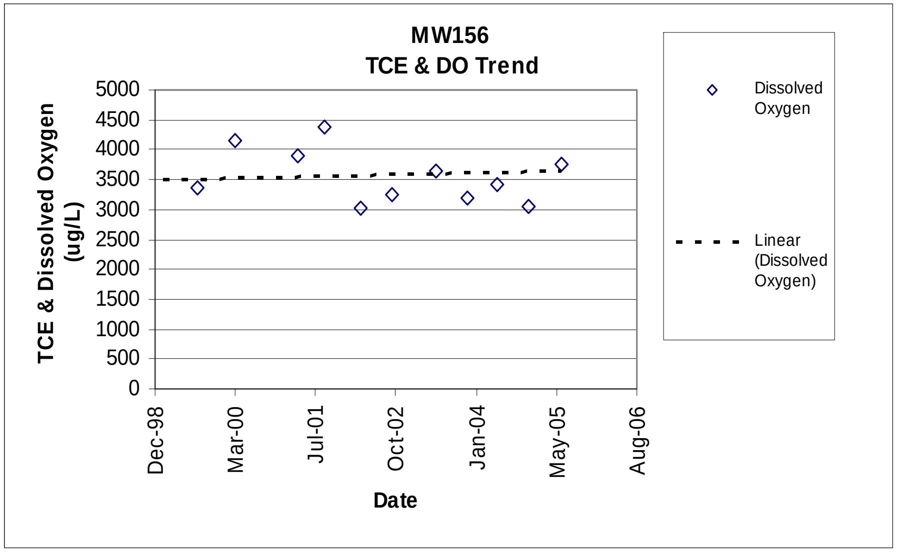

MW305 DO
DO & TCE (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
y = 0.4253x - 14348
12/07/92
12/07/93
12/07/94
12/07/95
12/06/96
12/06/97
12/06/98
12/06/99
12/05/00
12/05/01
12/05/02
12/05/03
12/04/04
12/04/05
12/04/06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

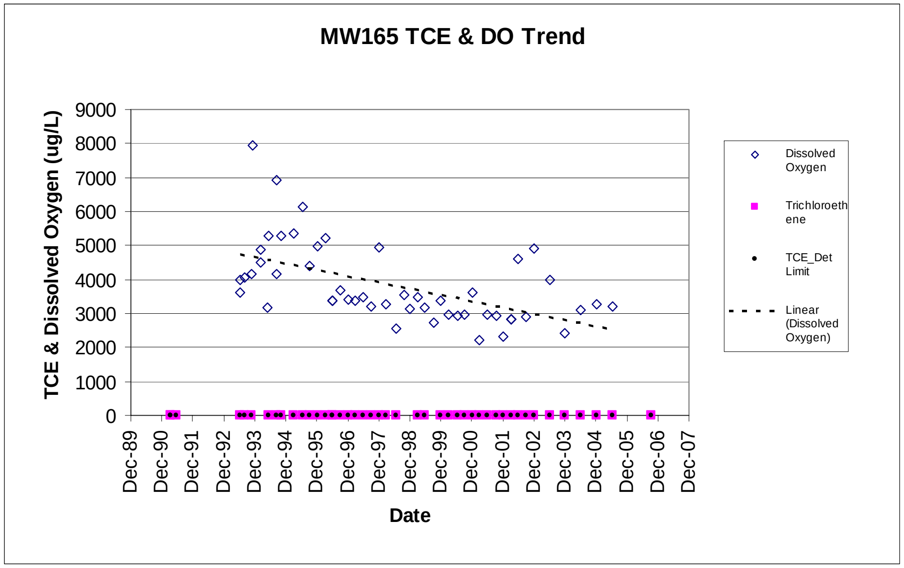
Appendix 2H.1 DO Trend Plots from Select URGA Wells

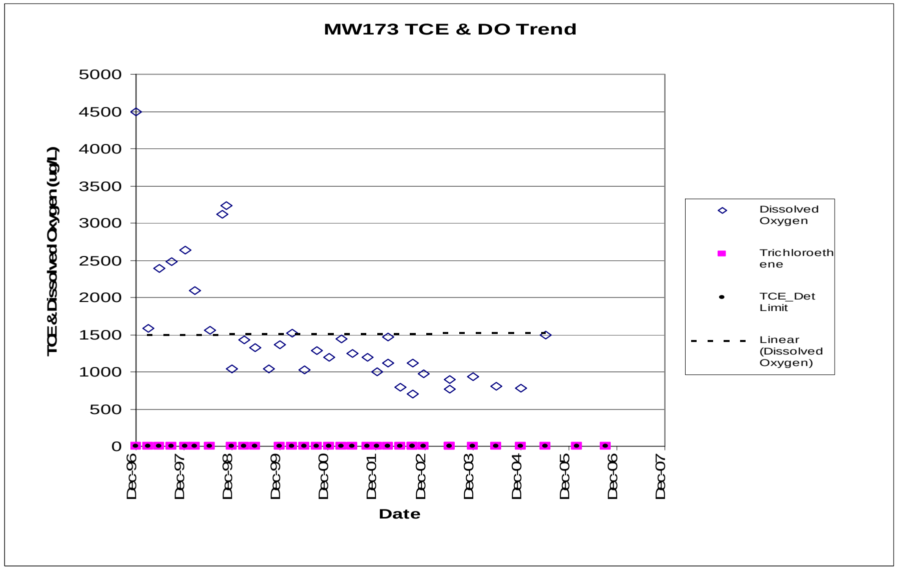

MW149 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
◇ Dissolved Oxygen
■ Trichloroethene
• TCE Det Limit

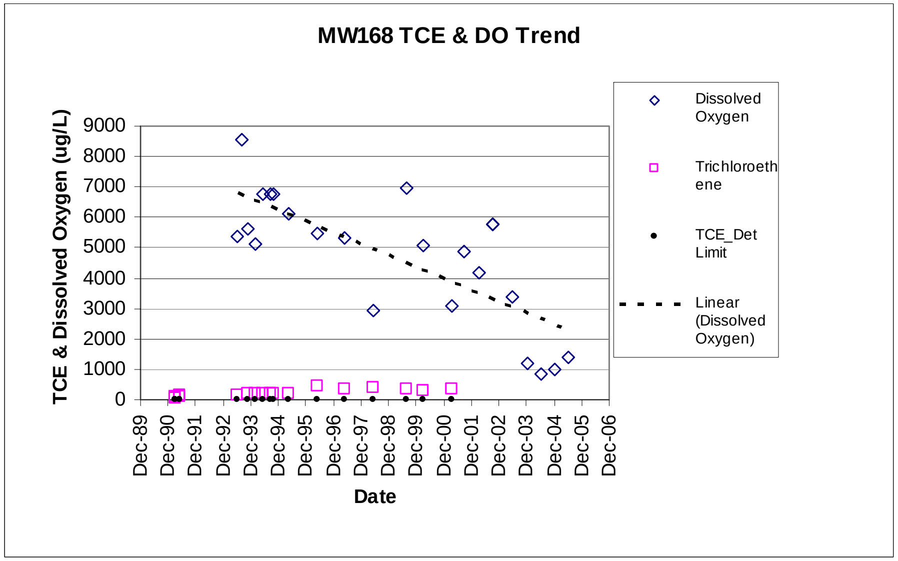

MW156 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
300000
250000
200000
150000
100000
50000
0
Dec-98
Mar-00
Jul-01
Oct-02
Jan-04
May-05
Aug-06
Dec-07
Date
◇ Dissolved Oxygen
■ Trichloroethene
- - - Linear (Dissolved Oxygen)

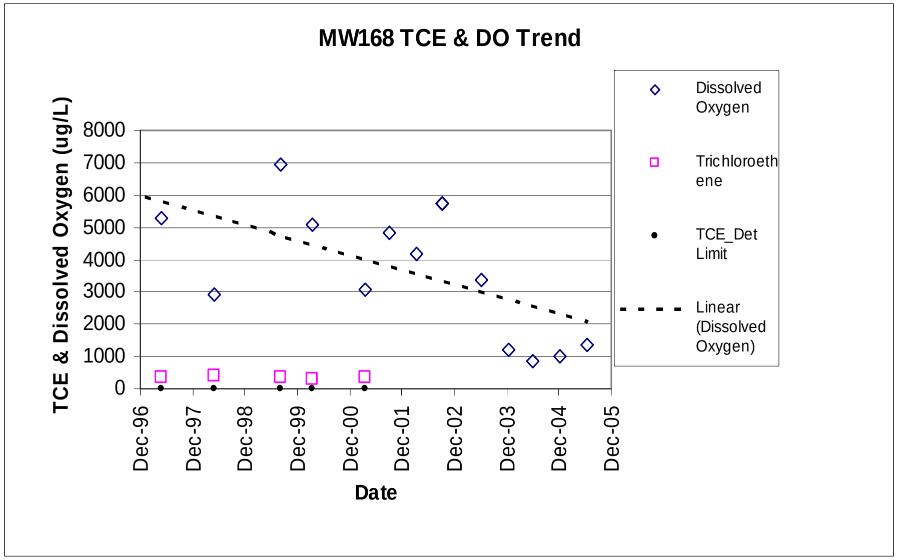

MW156 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
600000
500000
400000
300000
200000
100000
0
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
◇ Dissolved Oxygen
■ Trichloroethene
- - - Linear (Dissolved Oxygen)

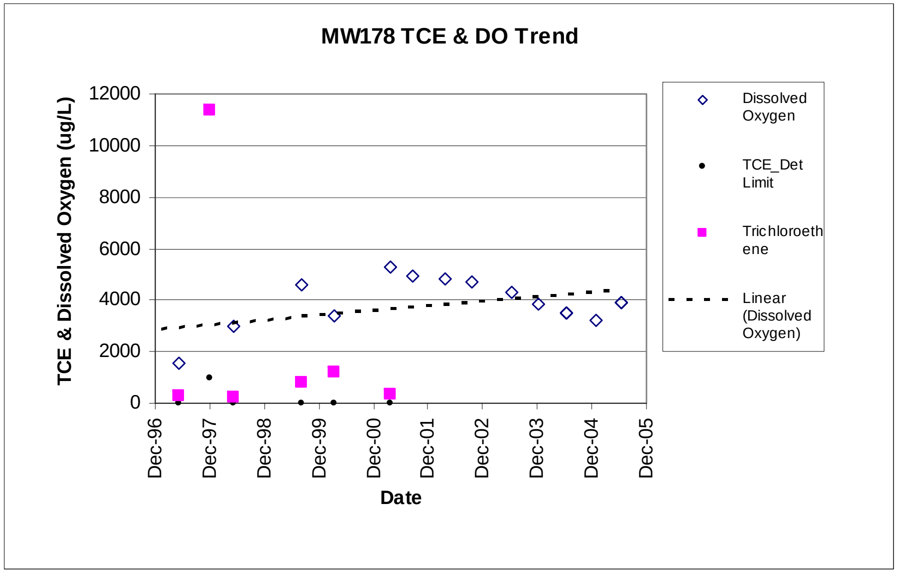

MW156
TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-98
Mar-00
Jul-01
Oct-02
Jan-04
May-05
Aug-06
Date
◇ Dissolved Oxygen
- - - Linear (Dissolved Oxygen)

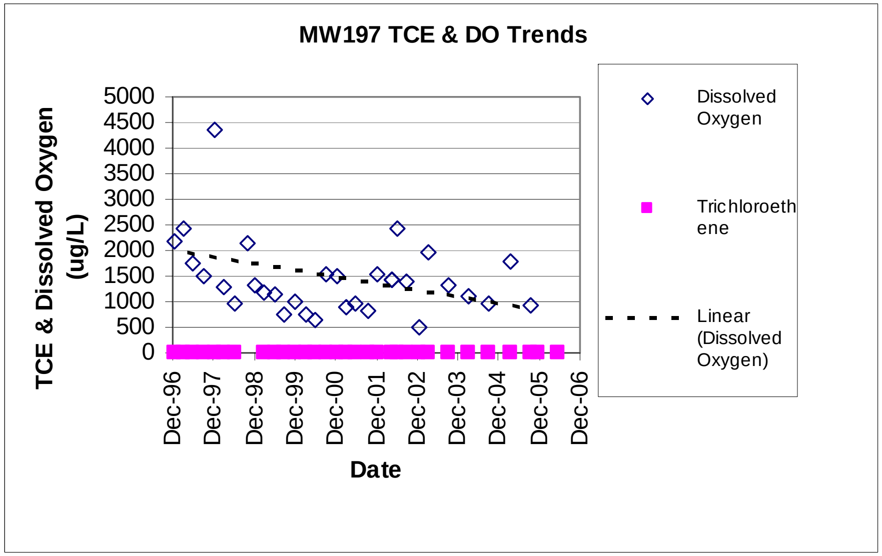

MW165 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

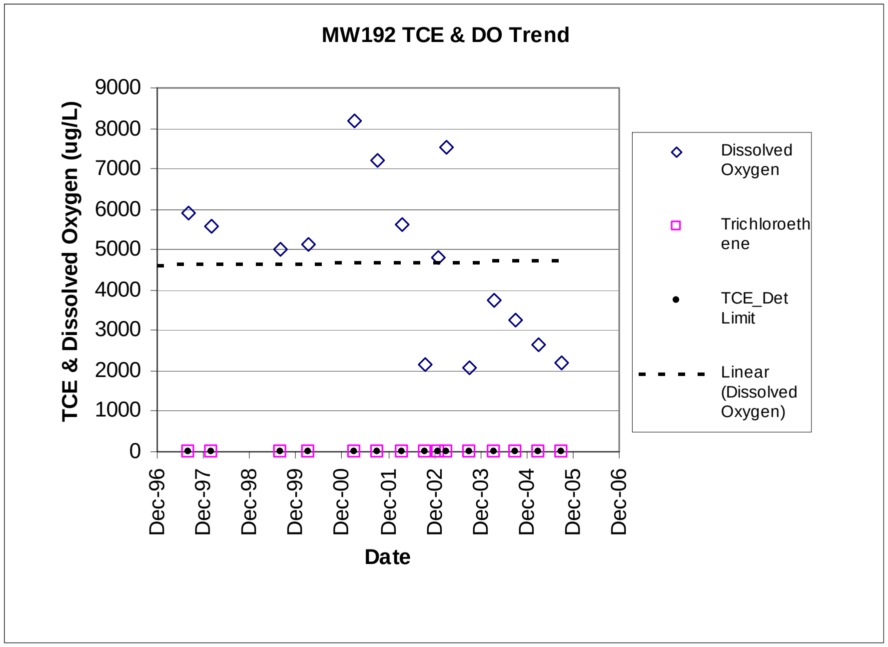

MW173 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

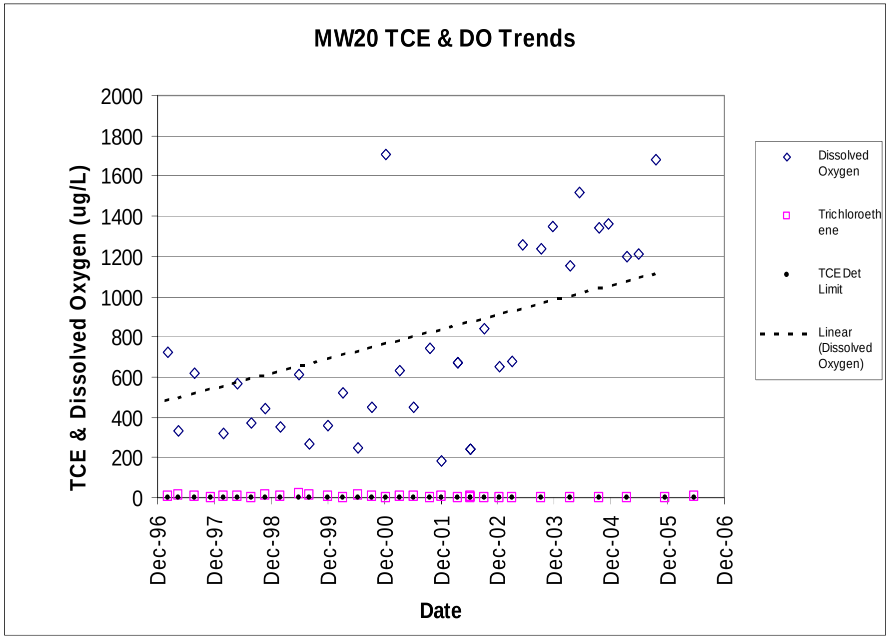

MW168 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

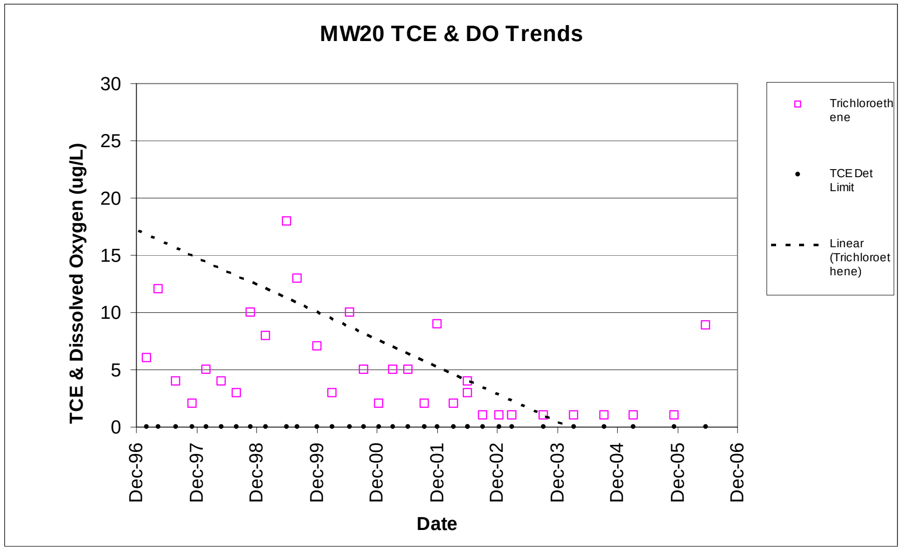

MW168 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

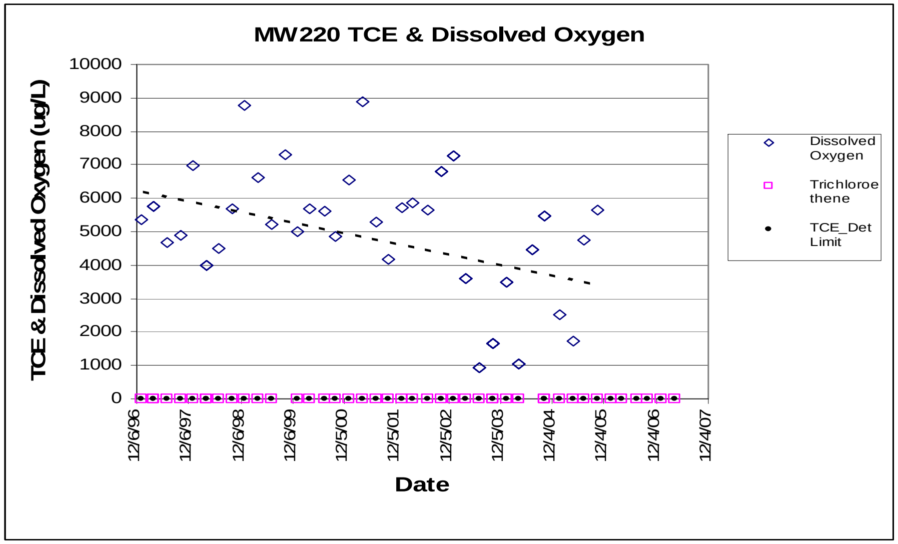

MW178 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
12000
10000
8000
6000
4000
2000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Date
Dissolved Oxygen
TCE_Det Limit
Trichloroethene
Linear (Dissolved Oxygen)

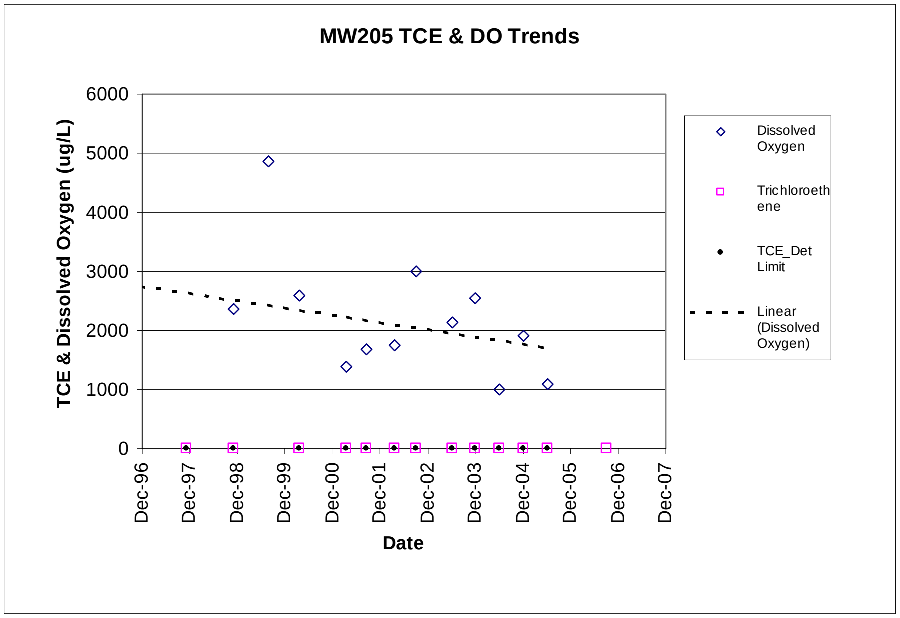

MW197 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
Linear (Dissolved Oxygen)

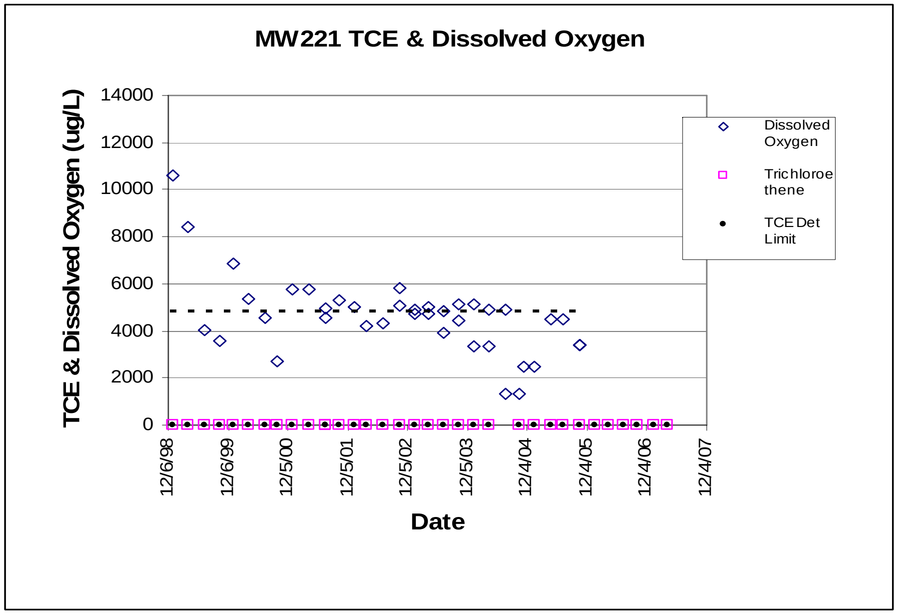

MW192 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

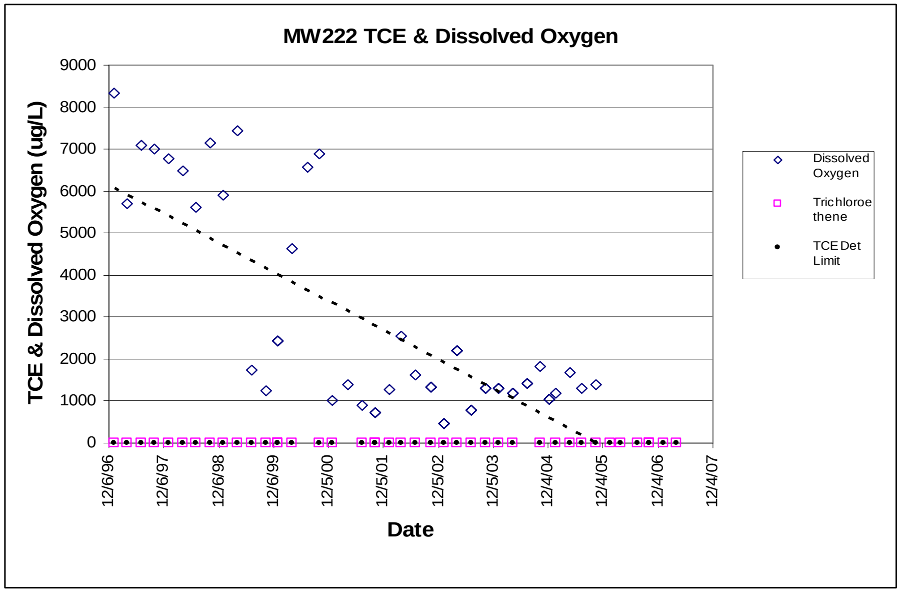

MW20 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit
Linear (Dissolved Oxygen)

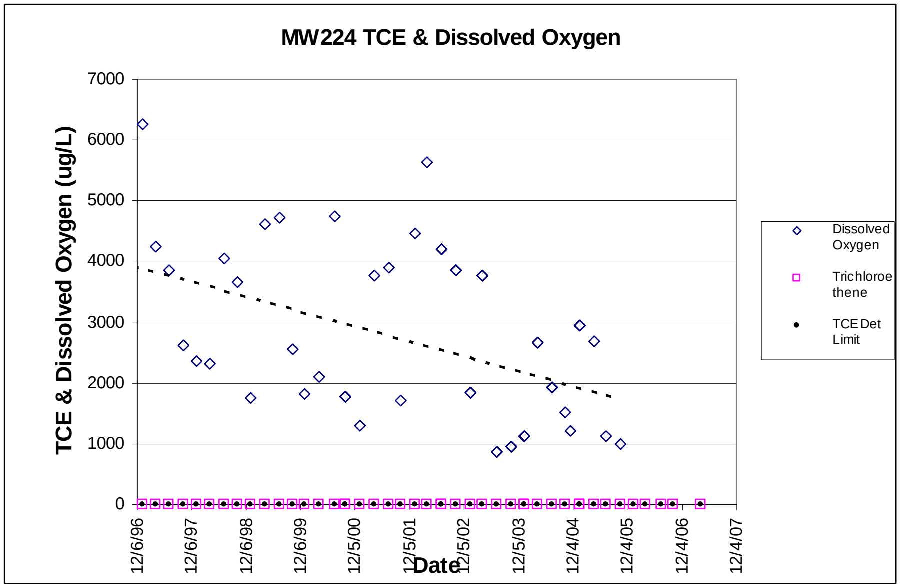

MW20 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
30
25
20
15
10
5
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Trichloroethene
TCE Det Limit
Linear (Trichloroethene)

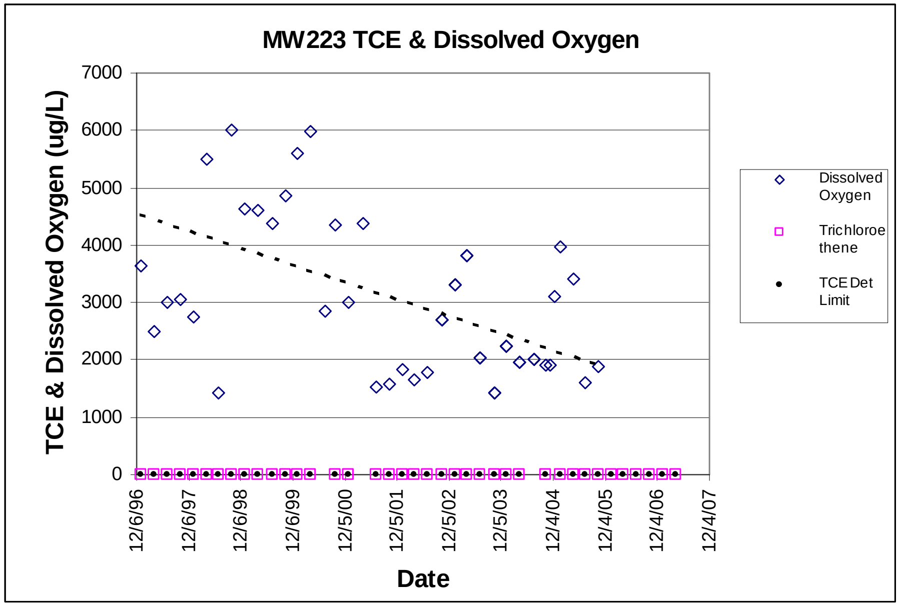

MW220 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit

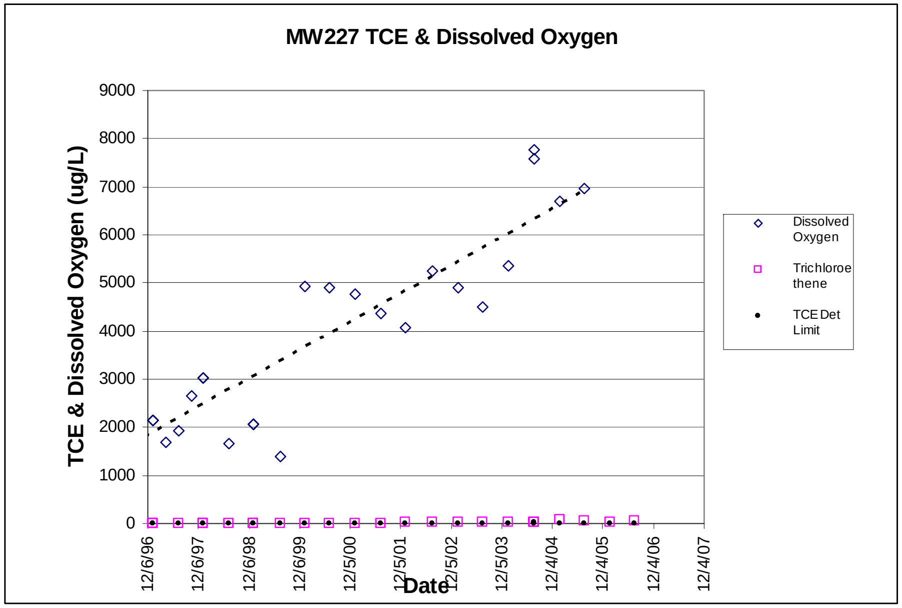

MW205 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)


MW221 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
14000
12000
10000
8000
6000
4000
2000
0
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

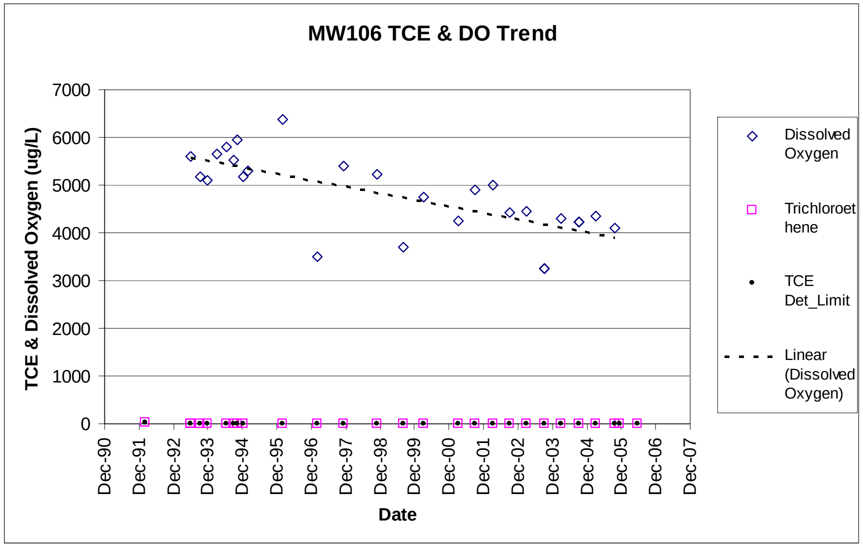

MW222 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

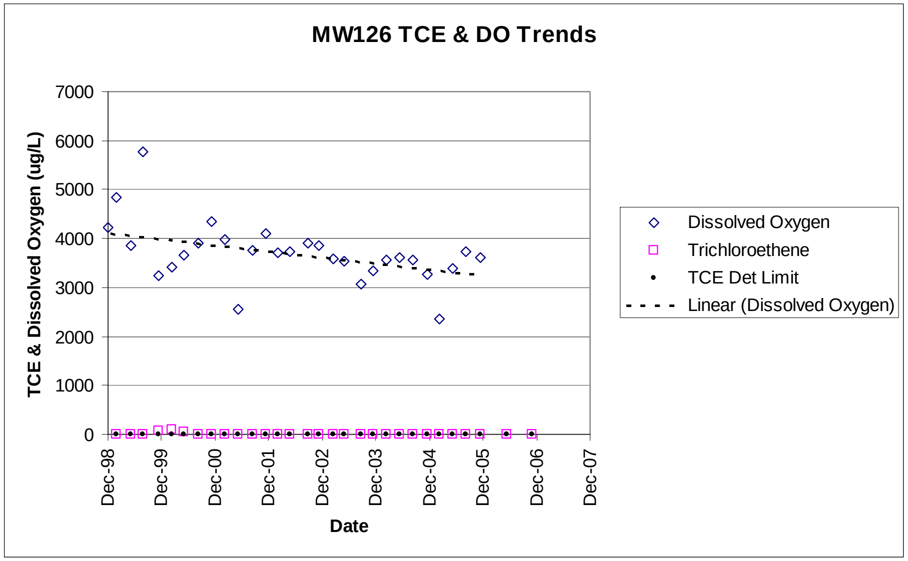

MW224 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

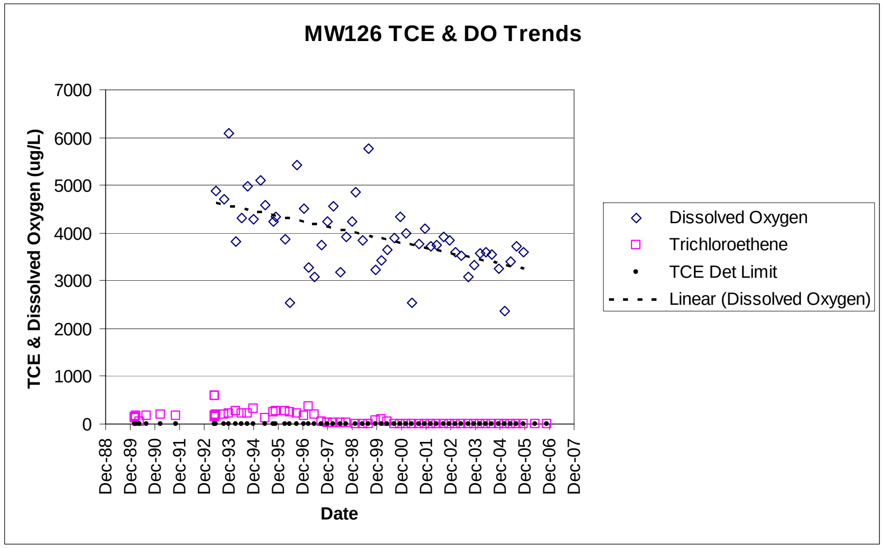

MW223 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

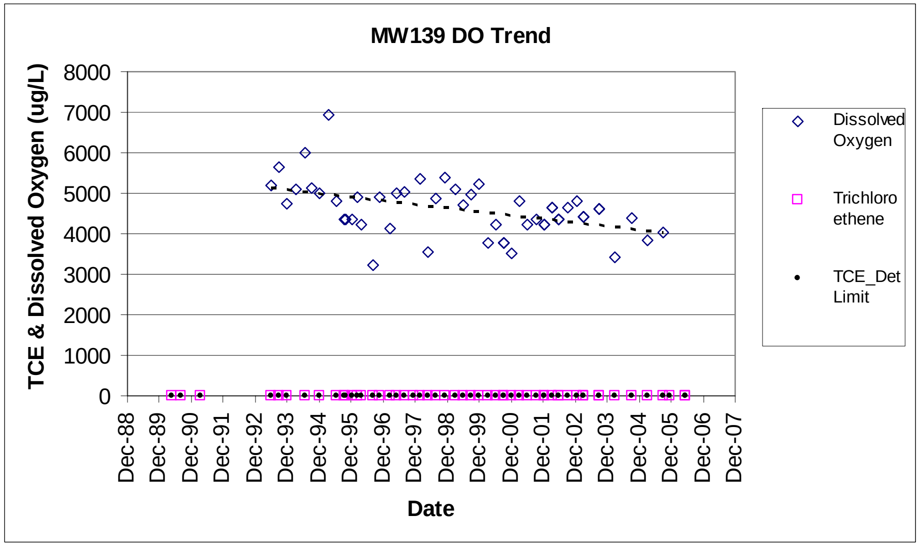

MW227 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

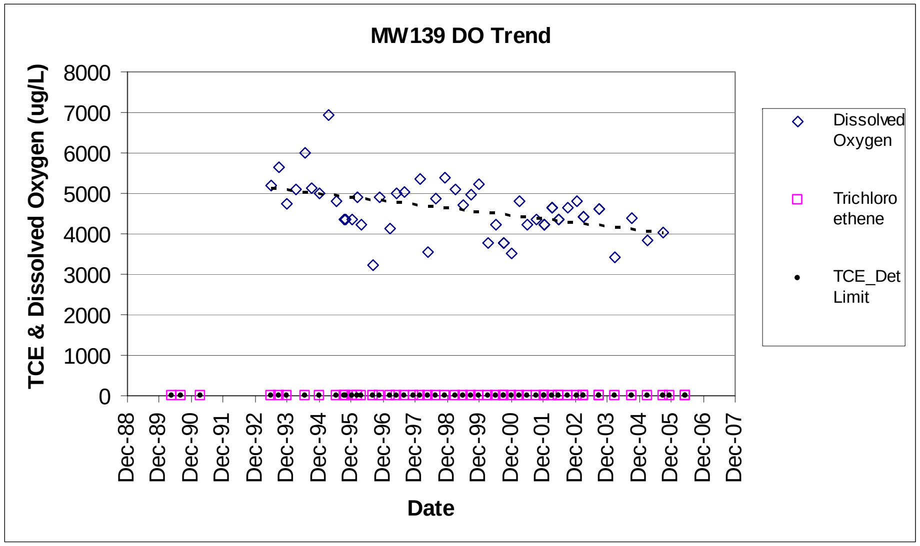
Appendix 2H.2 DO Trend Plots from Select MRGA Wells

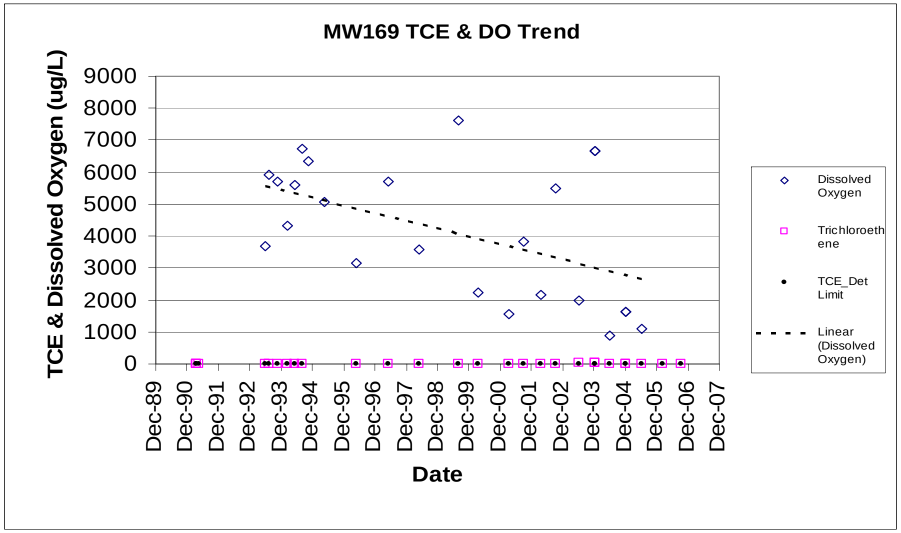

MW106 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE Det_Limit
Linear (Dissolved Oxygen)

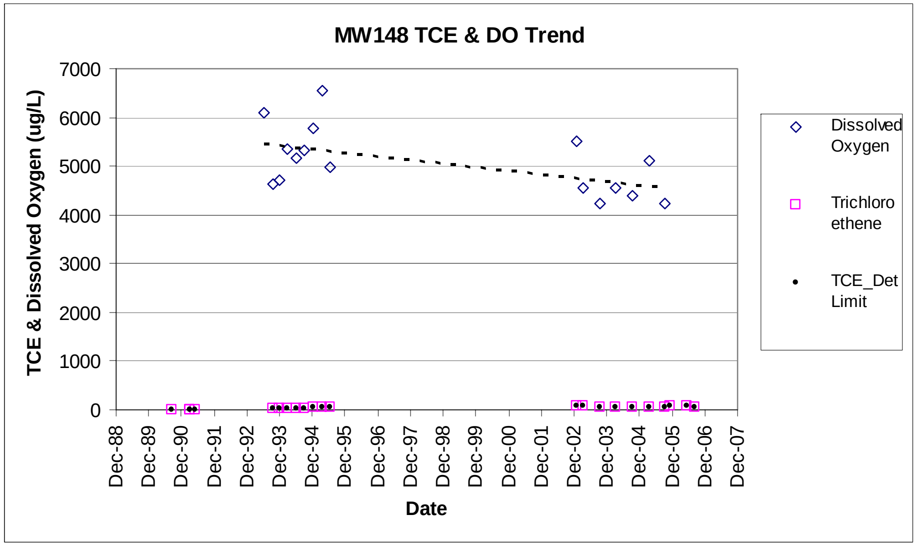

MW126 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit
Linear (Dissolved Oxygen)

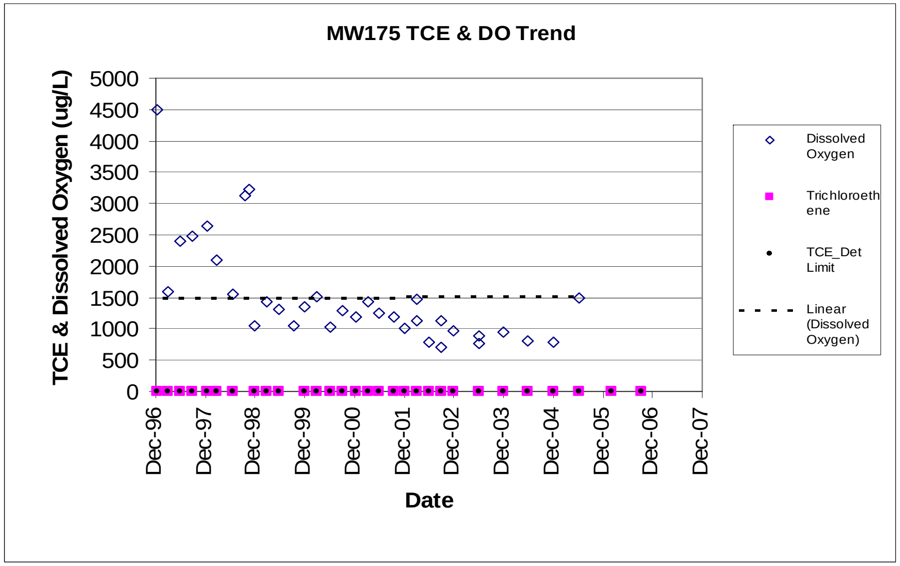

MW126 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit
Linear (Dissolved Oxygen)

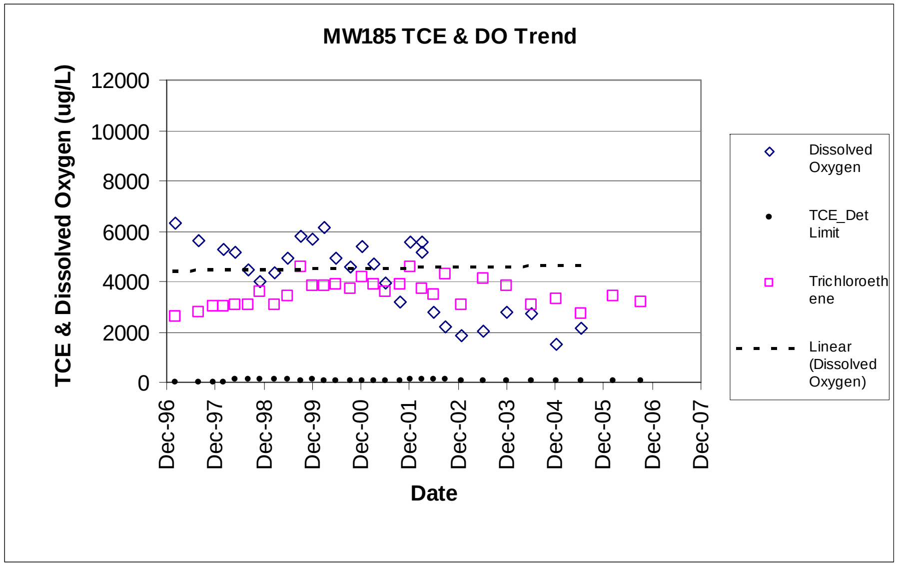

MW139 DO Trend
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit

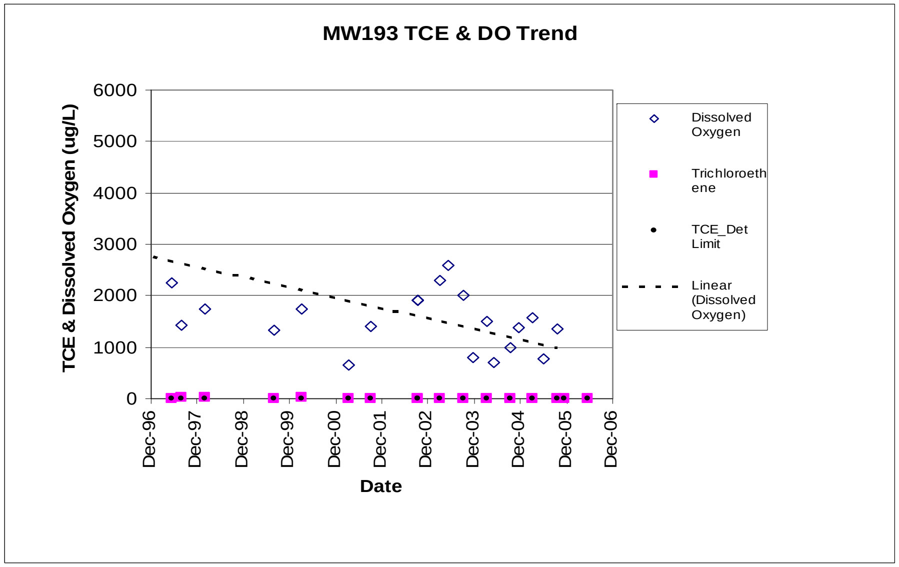

MW139 DO Trend

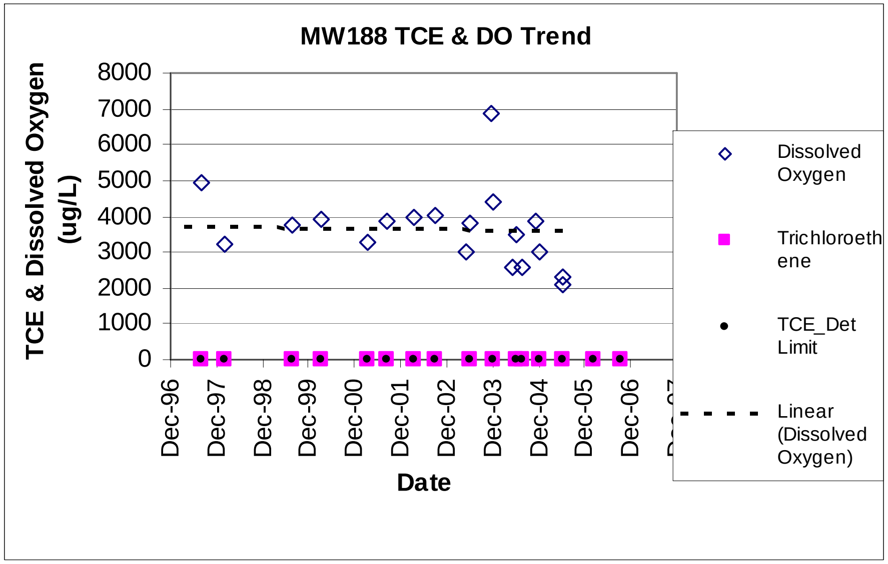

MW169 TCE & DO Trend

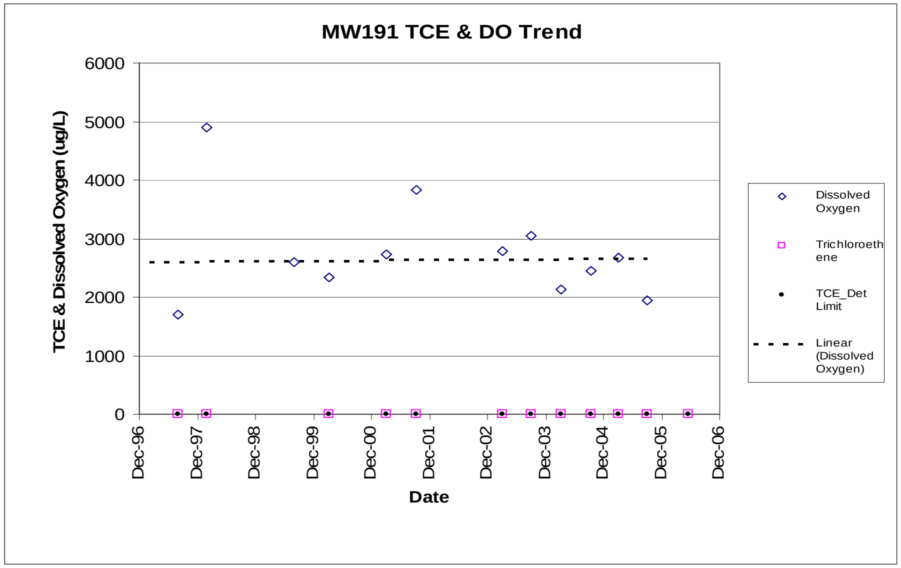

MW148 TCE & DO Trend

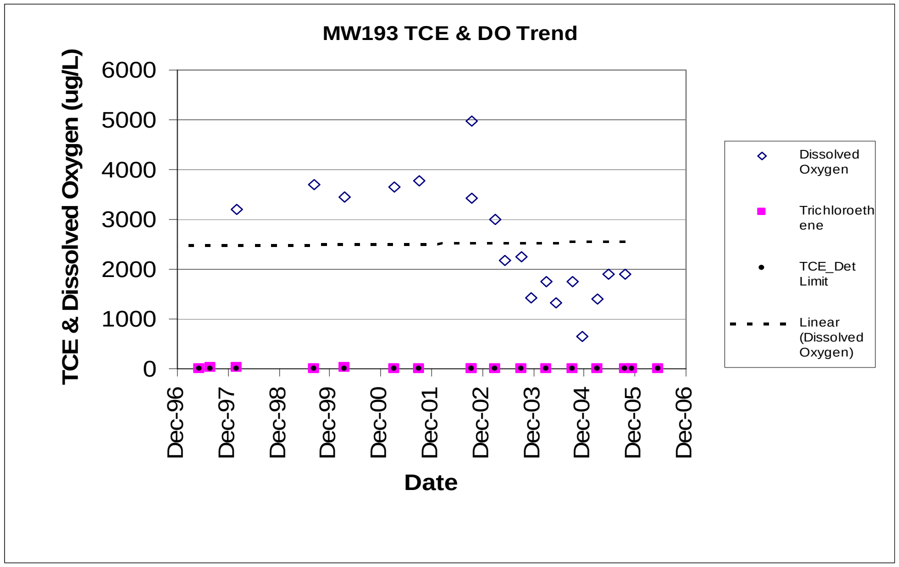

MW175 TCE & DO Trend

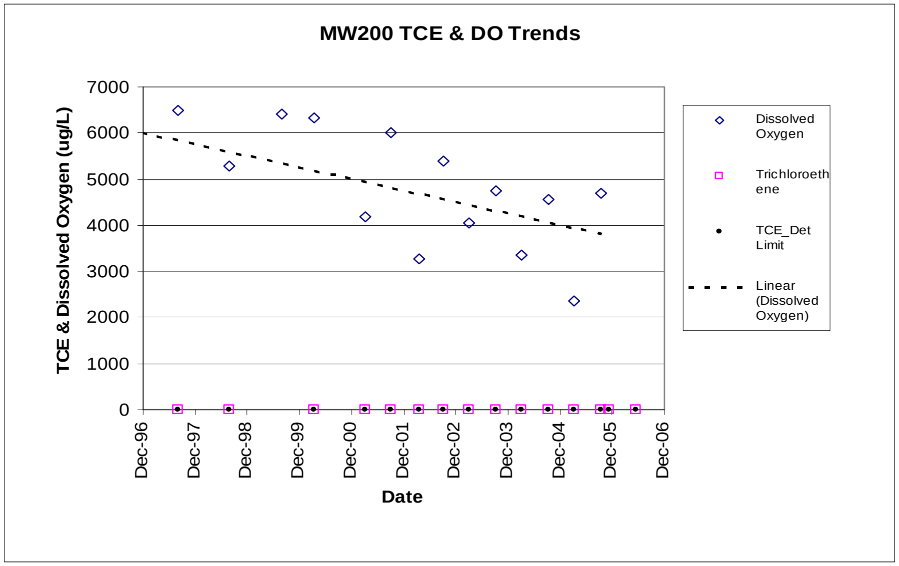

MW185 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
12000
10000
8000
6000
4000
2000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
TCE_Det Limit
Trichloroethene
Linear (Dissolved Oxygen)

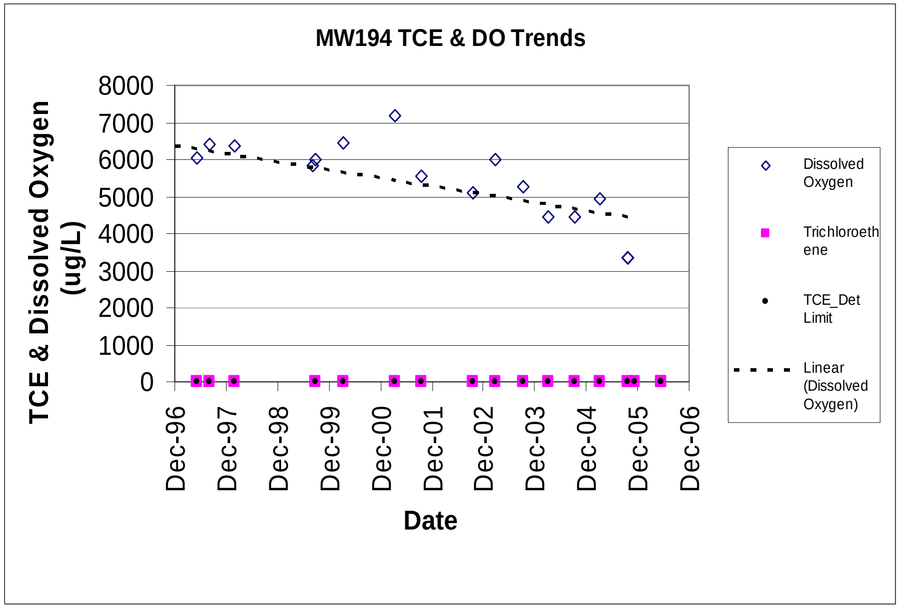

MW193 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

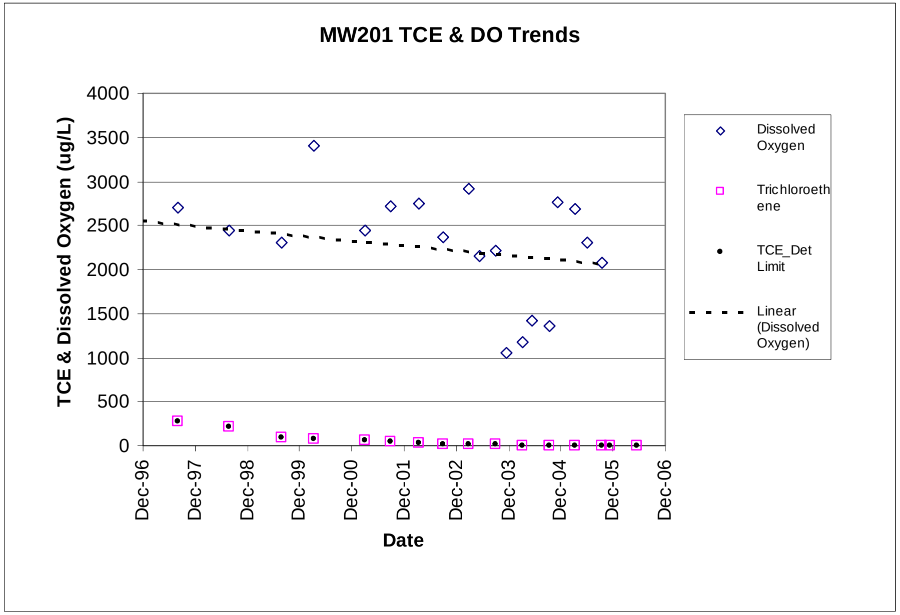

MW188 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

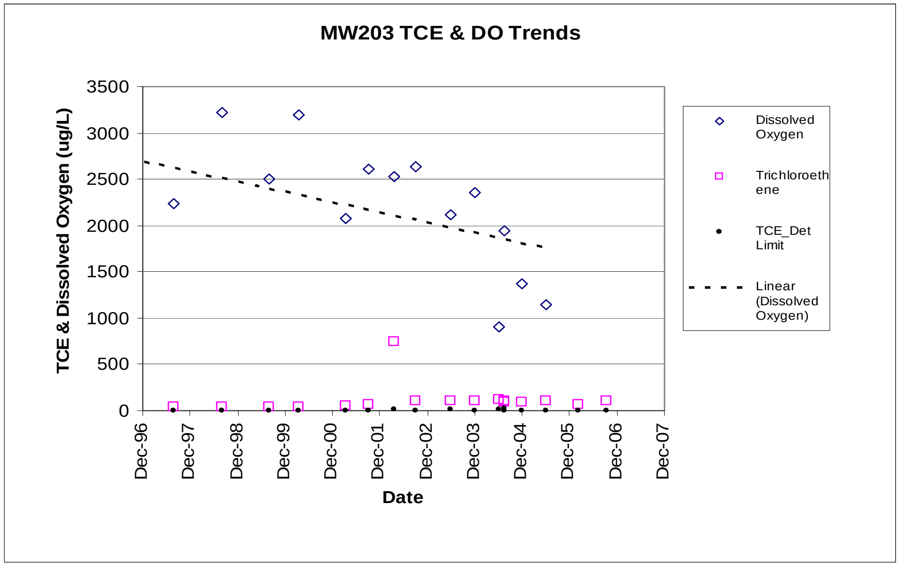

MW191 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

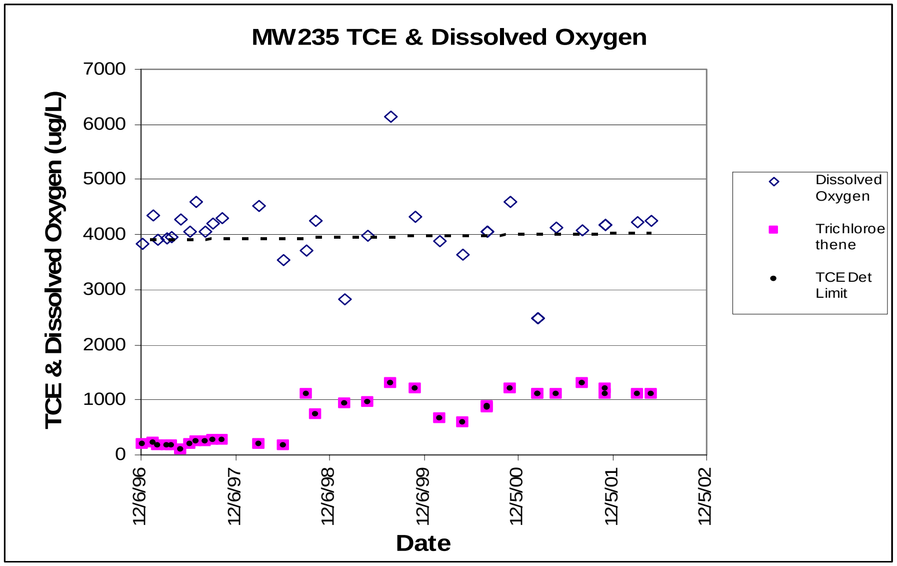

MW193 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

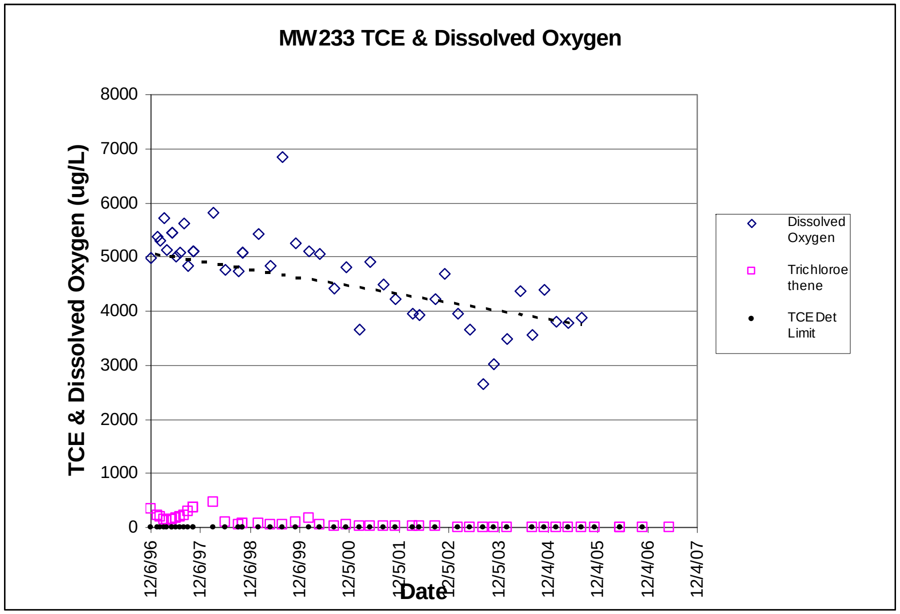

MW200 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

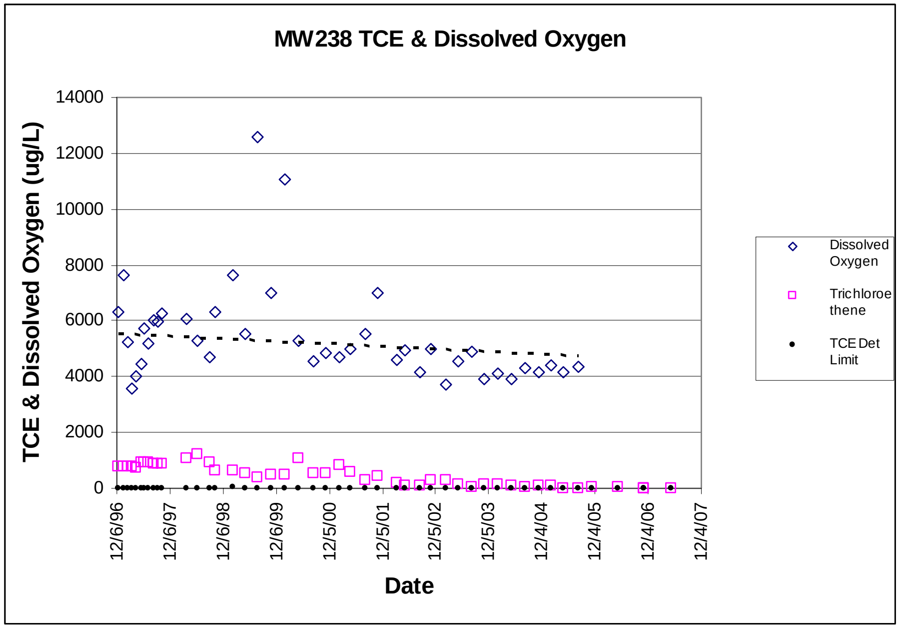

MW194 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

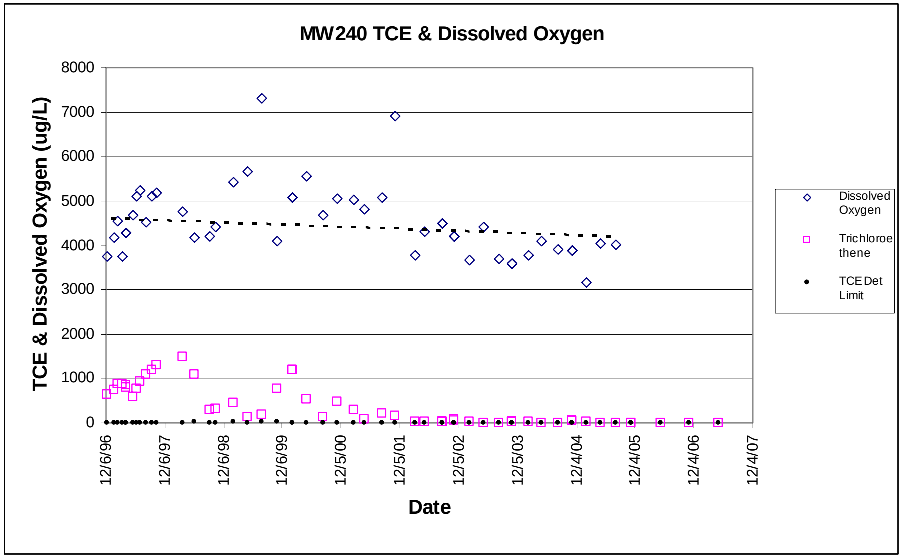

MW201 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

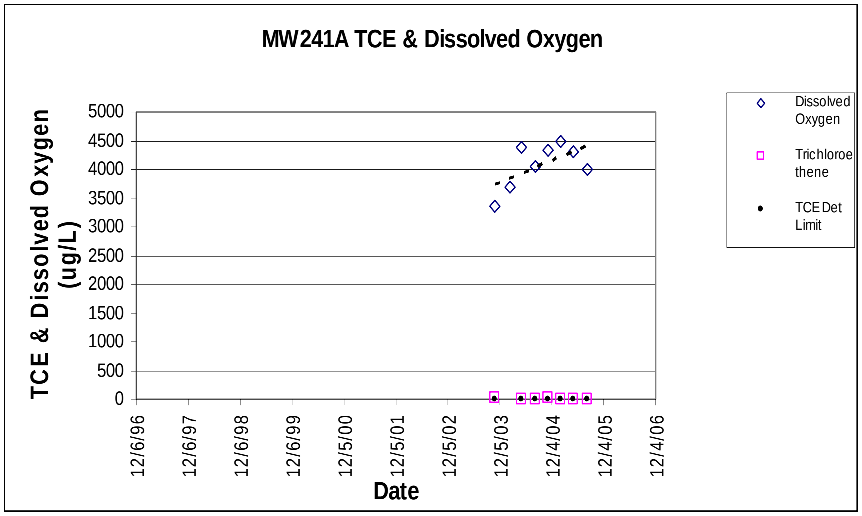

MW203 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
3500
3000
2500
2000
1500
1000
500
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

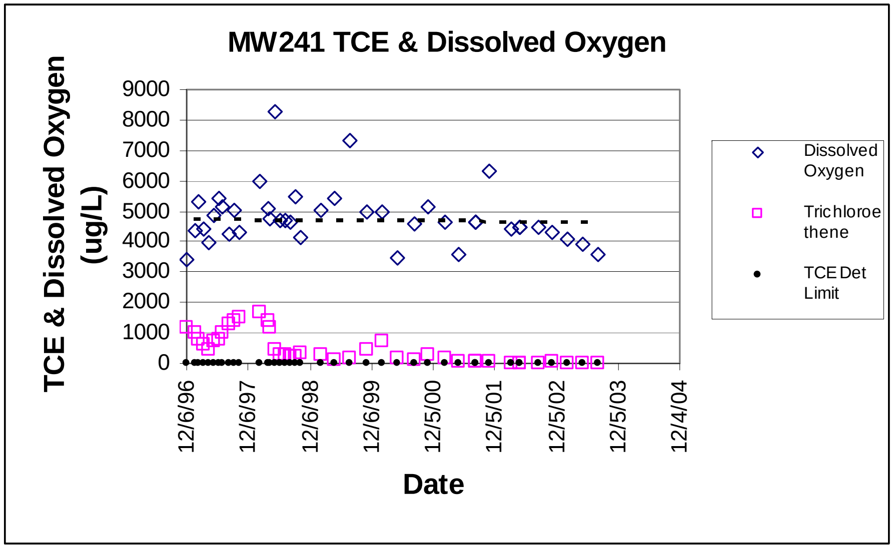

MW235 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

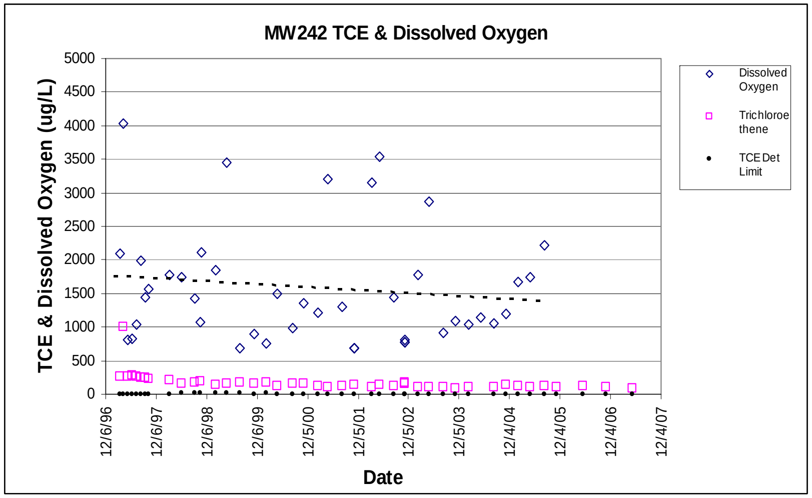

MW233 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

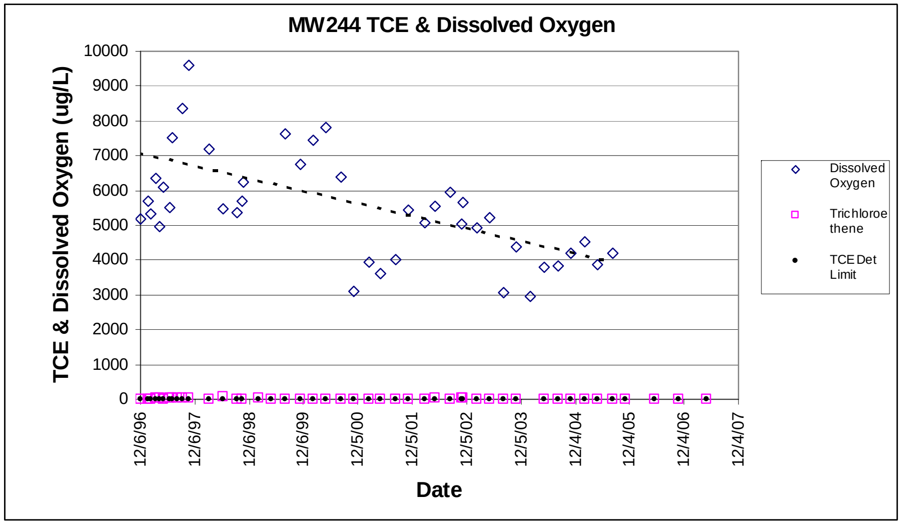

MW238 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
14000
12000
10000
8000
6000
4000
2000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit


MW240 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

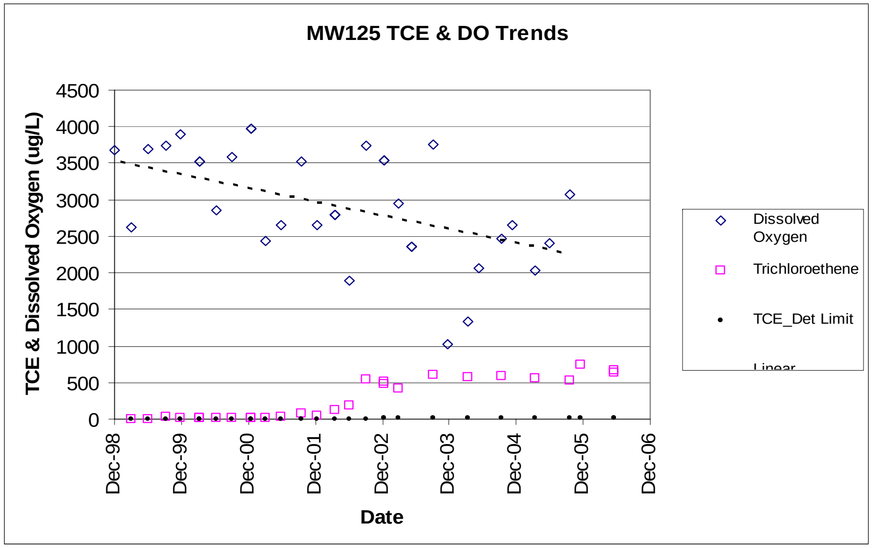

MW241A TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

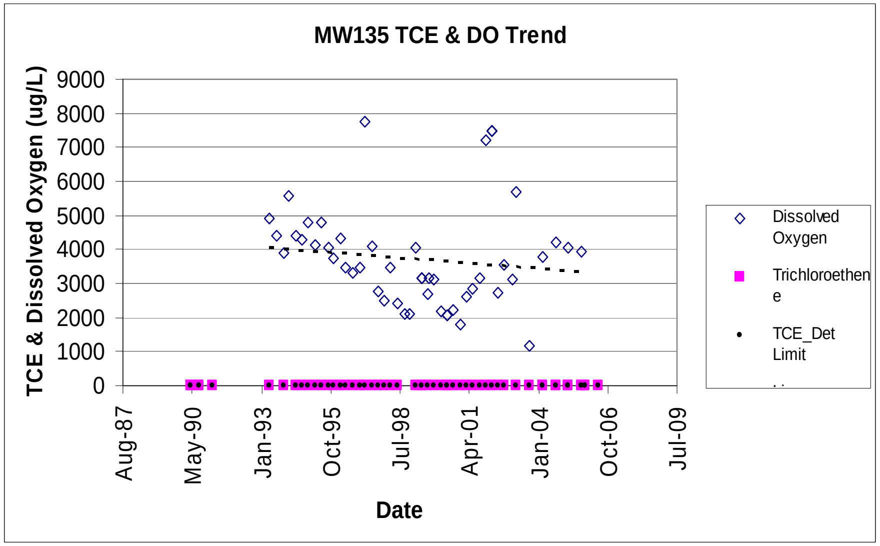

MW241 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

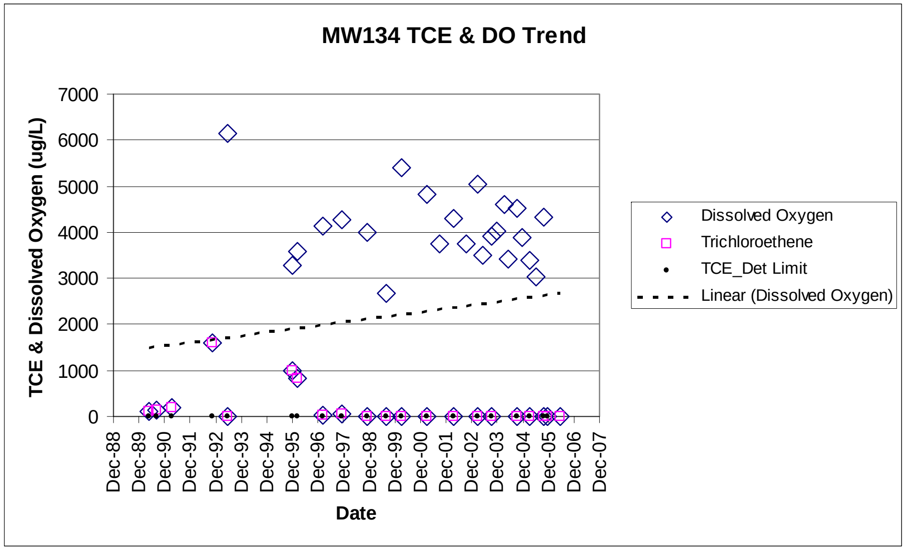

MW242 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

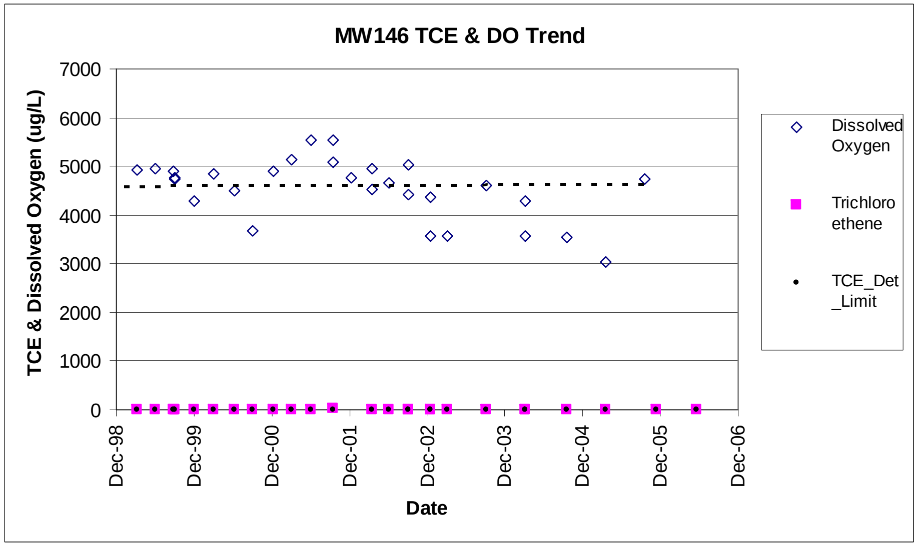

MW244 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

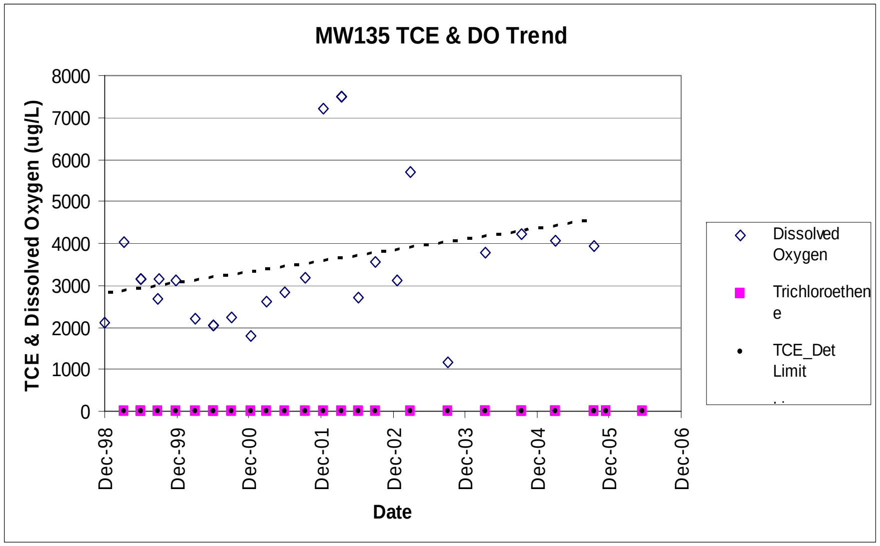
Appendix 2H.3 DO Trend Plots from Select LRGA Wells

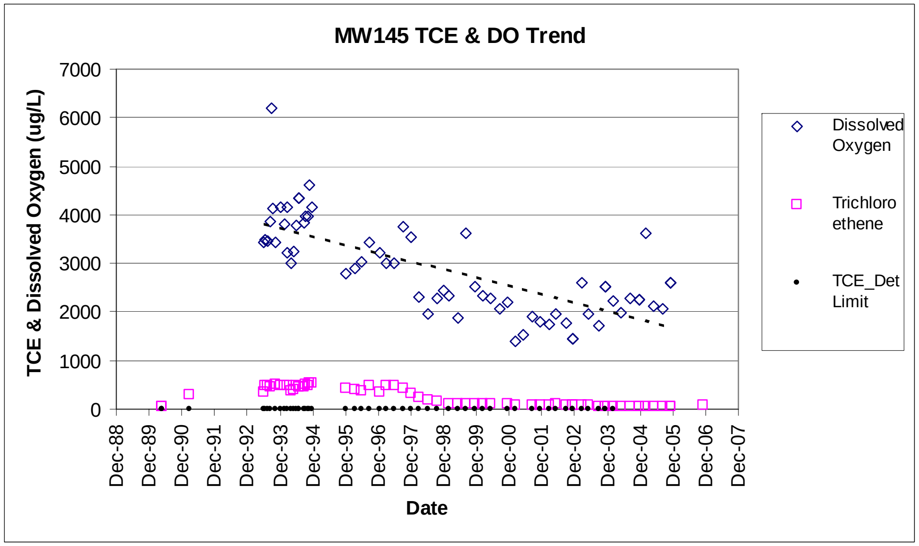

MW125 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear

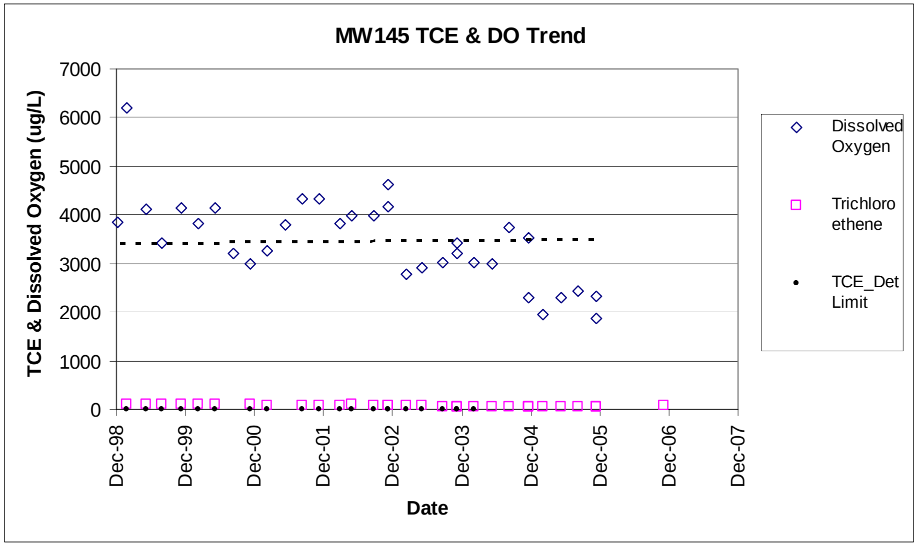

MW135 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Aug-87
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Oct-06
Jul-09
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit

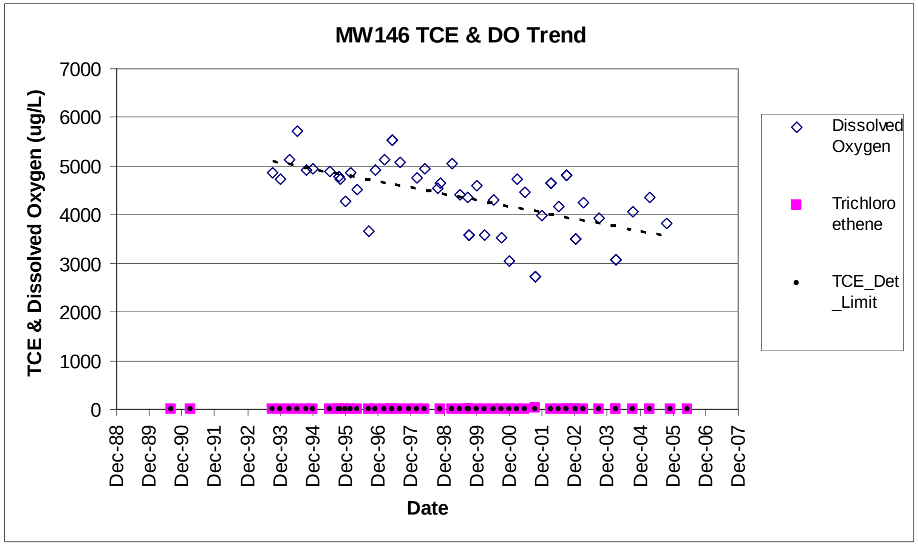

MW134 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)

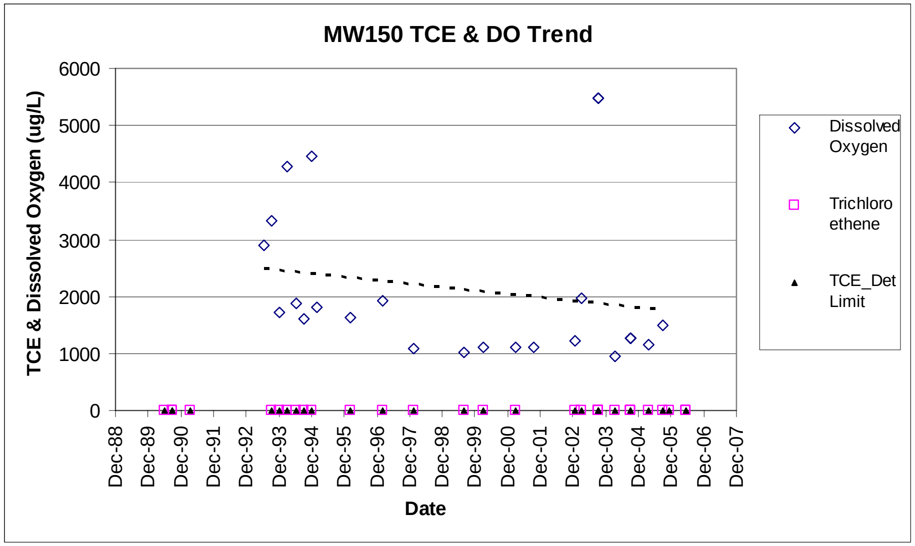

MW146 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE_Det_Limit

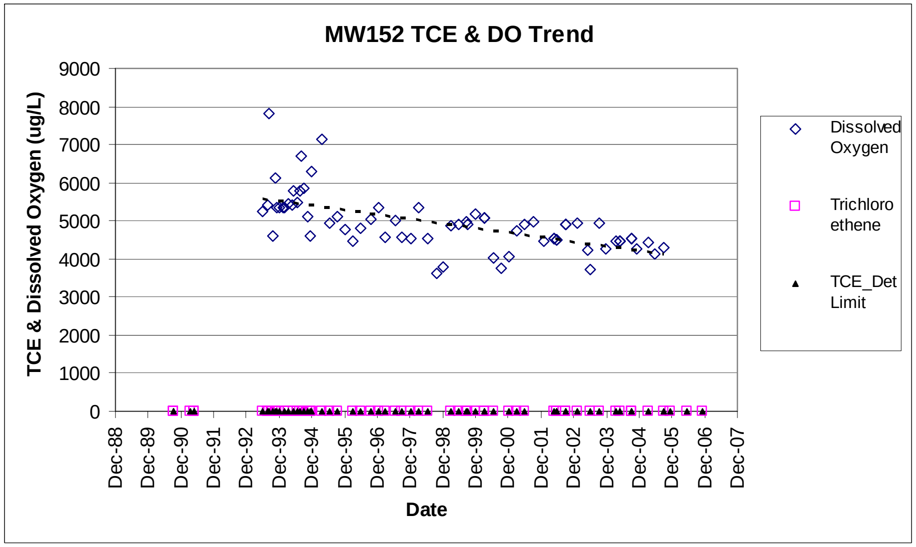

MW135 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethen e
TCE_Det Limit

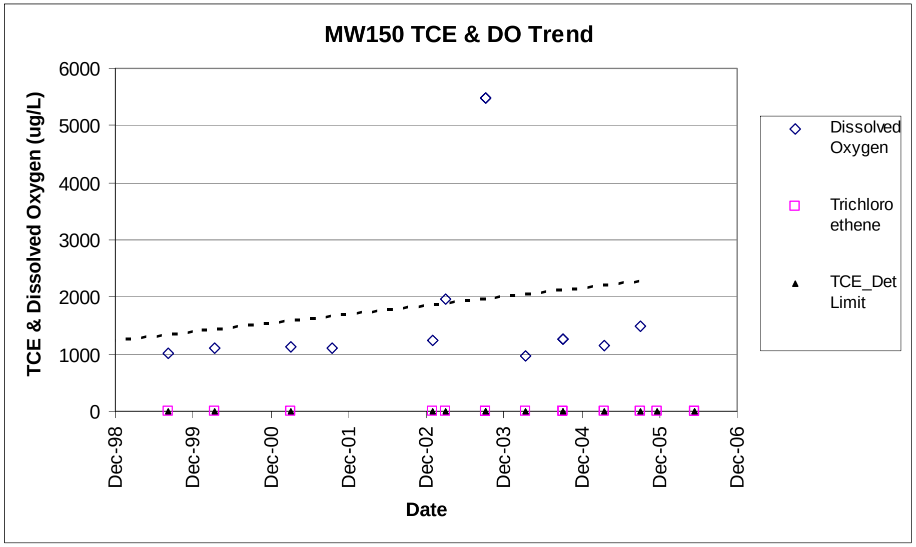

MW145 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit

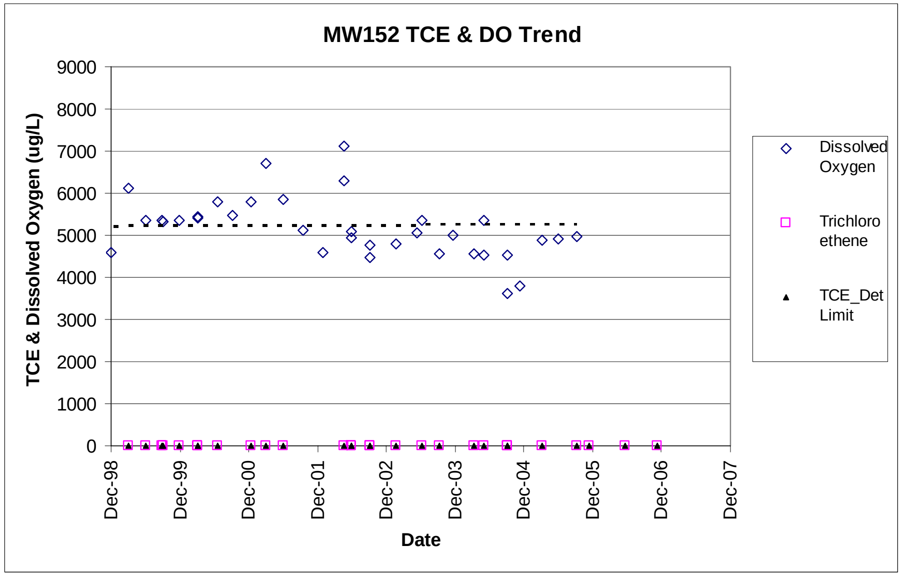

MW145 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit

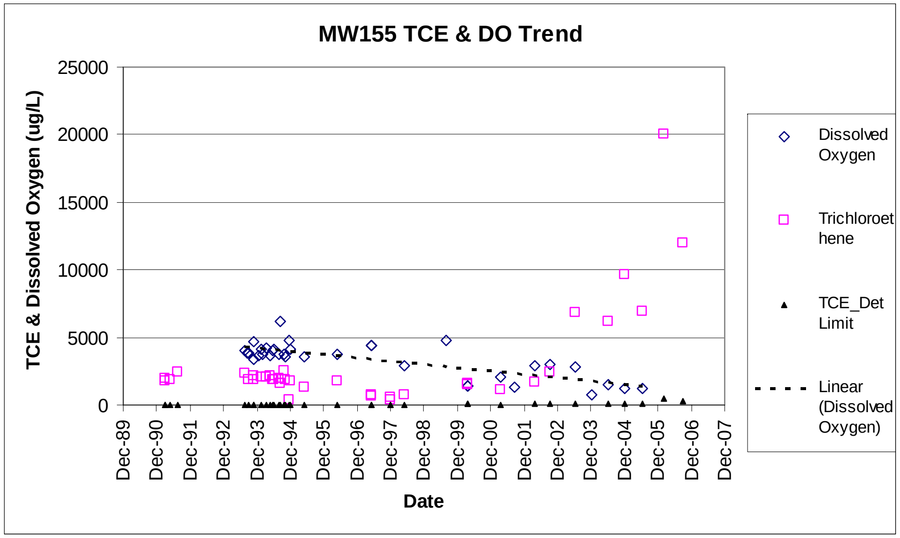

MW146 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det _Limit


MW150 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit

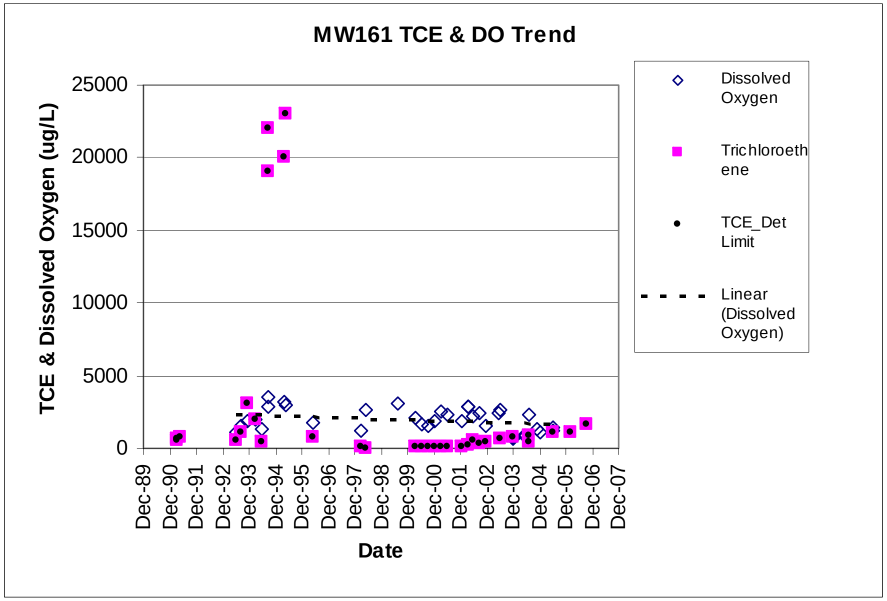

MW152 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-88
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit


MW150 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit

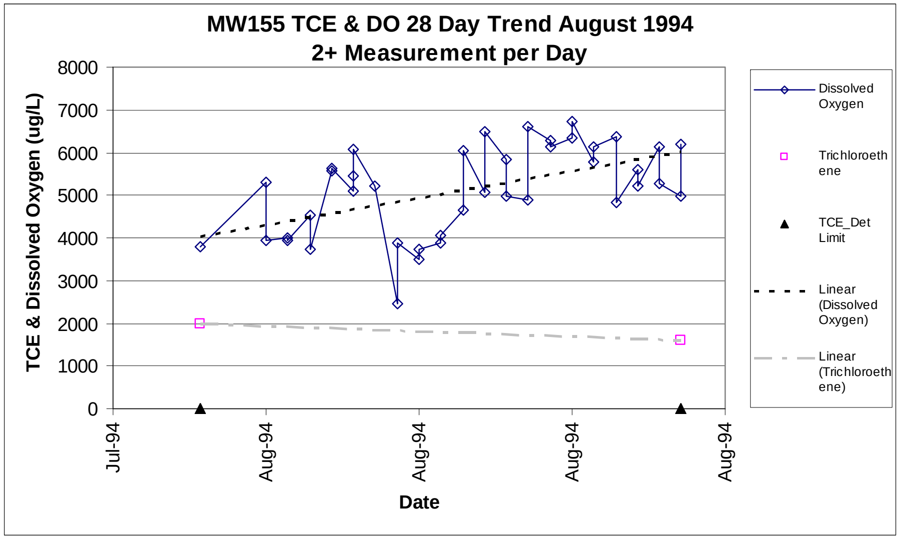

MW152 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloro ethene
TCE_Det Limit



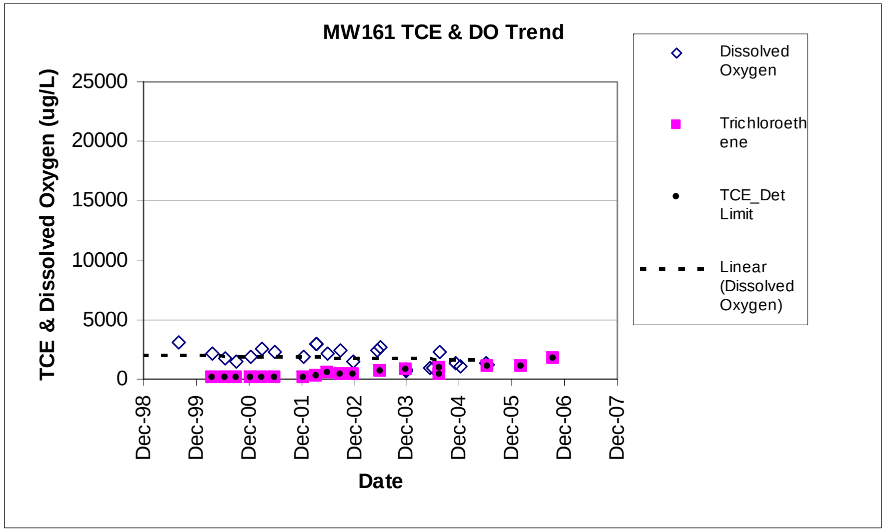
MW155 TCE & DO Trend



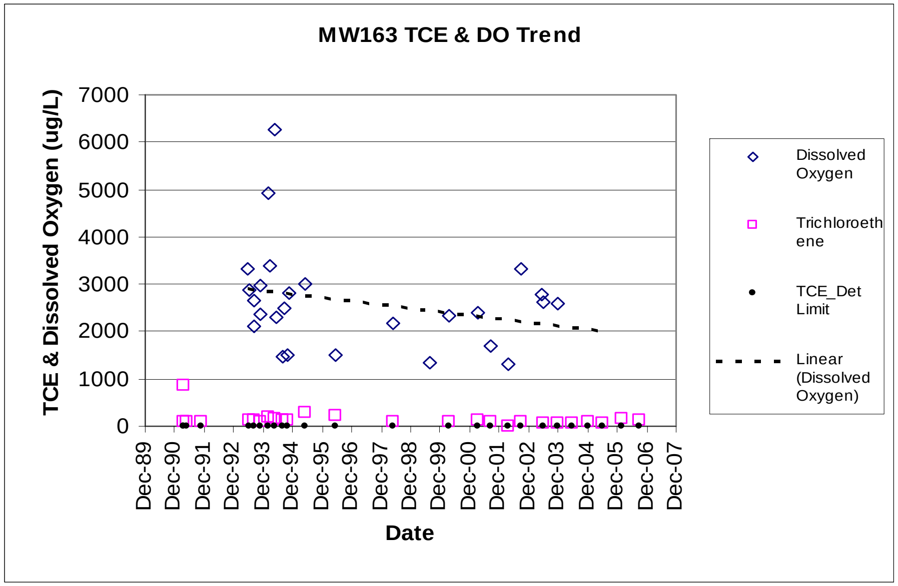
MW161 TCE & DO Trend

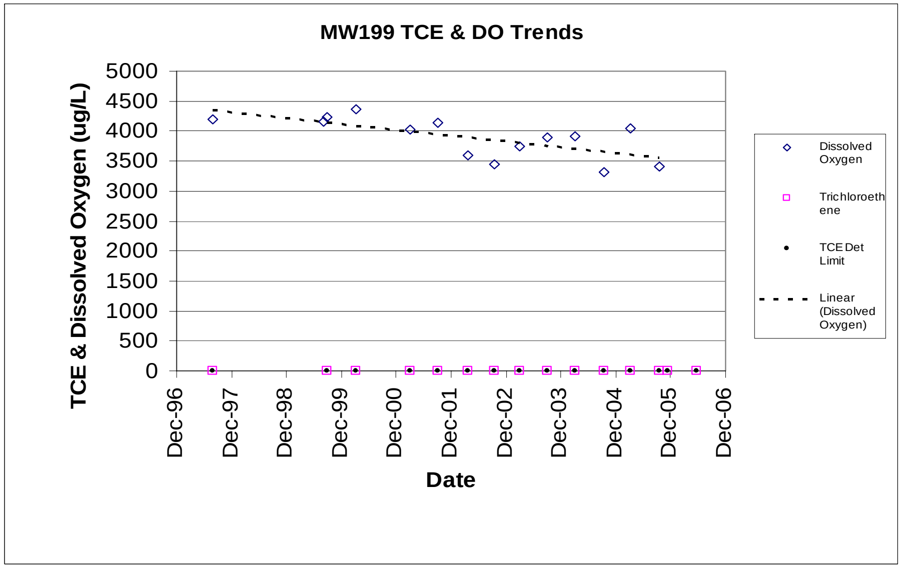


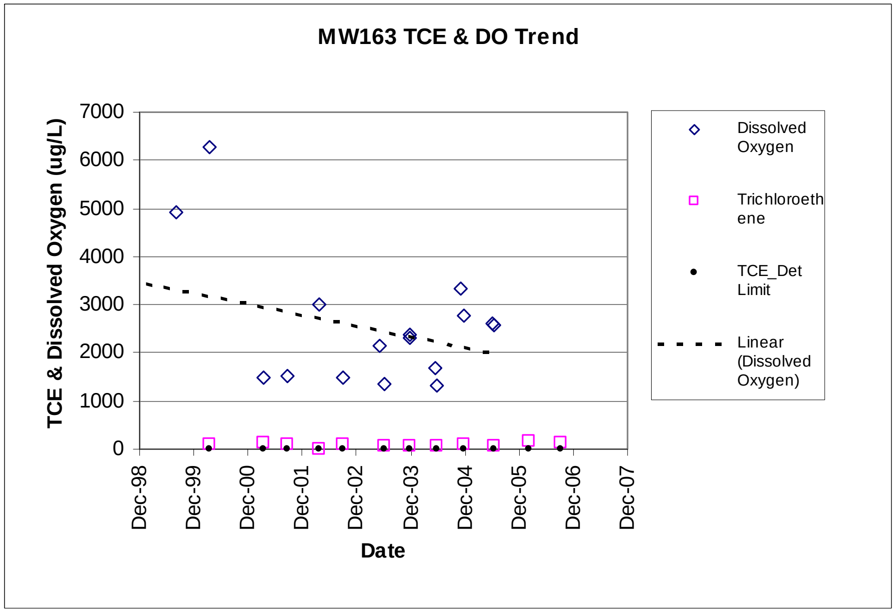
MW155 TCE & DO 28 Day Trend August 1994
2+ Measurement per Day

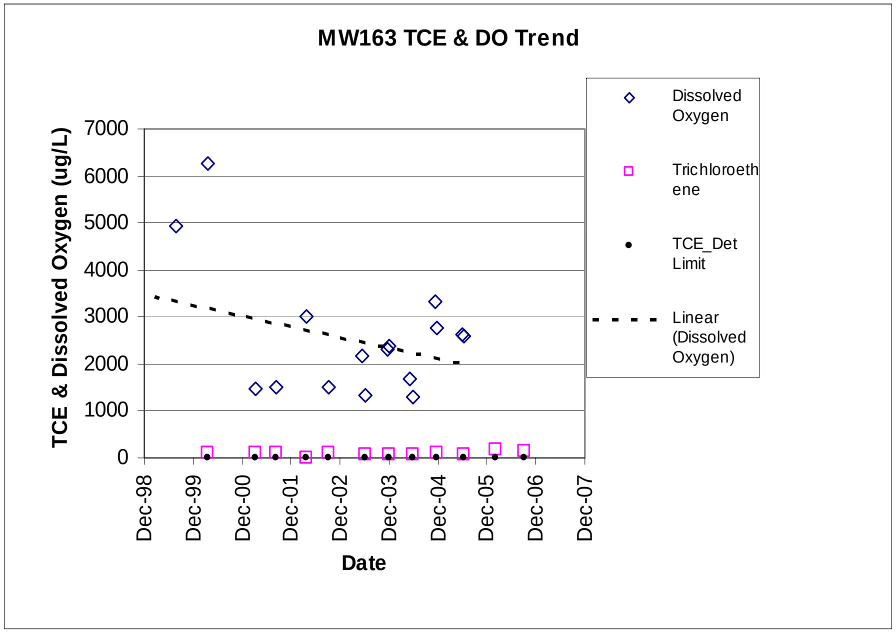


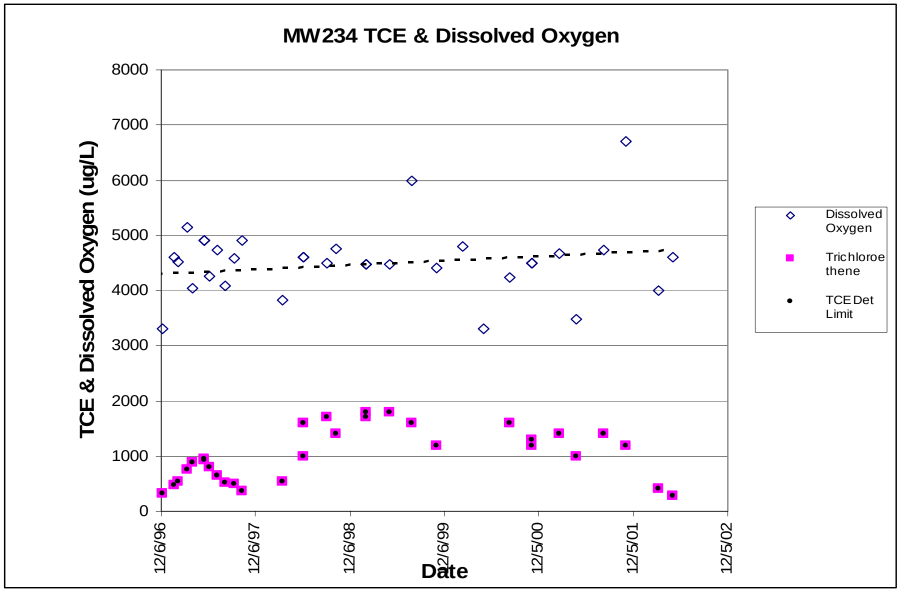
MW161 TCE & DO Trend

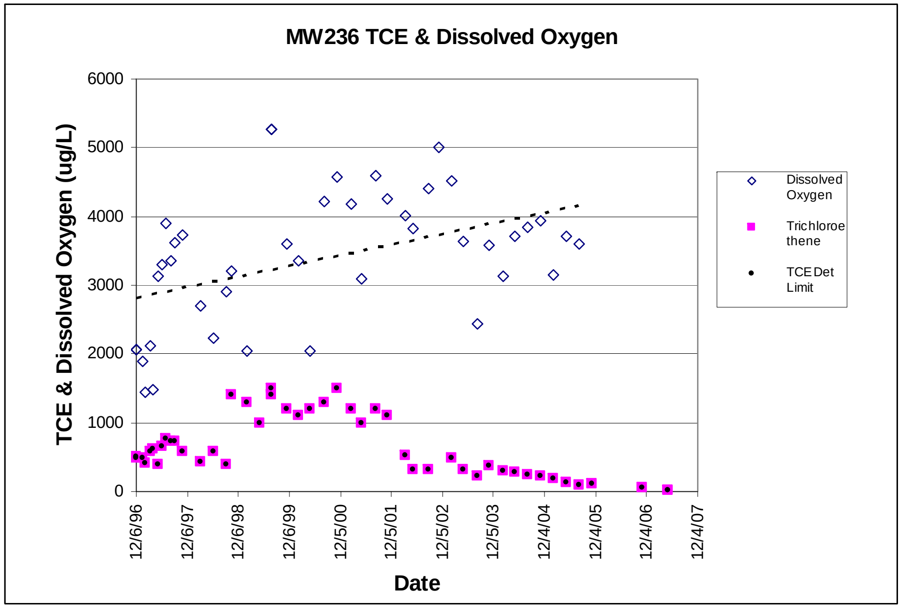

MW163 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-89
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)


MW199 TCE & DO Trends
TCE & Dissolved Oxygen (ug/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit
Linear (Dissolved Oxygen)


MW163 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)


MW163 TCE & DO Trend
TCE & Dissolved Oxygen (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Date
Dissolved Oxygen
Trichloroethene
TCE_Det Limit
Linear (Dissolved Oxygen)


MW234 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit


MW236 TCE & Dissolved Oxygen
TCE & Dissolved Oxygen (ug/L)
6000
5000
4000
3000
2000
1000
0
12/6/96
12/6/97
12/6/98
12/6/99
12/5/00
12/5/01
12/5/02
12/5/03
12/4/04
12/4/05
12/4/06
12/4/07
Date
Dissolved Oxygen
Trichloroethene
TCE Det Limit

Appendix 3. Stable Carbon Isotope Evaluation

Appendix 3A. Stable Carbon Isotope Laboratory Data

Averages	
Sample ID	**TCE d13C (permil)**
MW-66	-25.3
MW-125	-25.6
MW-168	-24.8
MW-185	-25.9
MW-194	na
MW-197	-23.1
MW-236	-25.3
MW-242	-24.6
MW-243	-25.3
MW-262	-25.8
MW-340	-25.9
MW-381	-25.4

Table 3A.1. Fractionation measurements from University of Oklahoma.

Client	Univ. Kentucky
Project name #	ER108-TCEDEG
OU Project Ref. #	230
Number/Type of Samples	12 water (11 analyzed)
Analysis Required	TCE, d13C
Date Received	12/21/2007
Date Analysis Completed	1/25/2008

notes:

na–not analyzed, sample below quantitation limit

highlighted values–d13C accuracy is reduced by ± 1 permil due to low TCE concentration

Replicate runs

Run #	**Sample ID**	**Dilution x**	**TCE d13C (permil)**
7383	MW-66	63	-25.2
7399	MW-66	63	-25.4
7393	MW-125	42	-25.7
7401	MW-125	42	-25.5
7390	MW-168	7	-24.8
7386	MW-185	250	-25.9
7397	MW-197	1	-23.1
7402	MW-197	1	-23.1
7392	MW-236	5	-25.3
7388	MW-242	10	-24.6
7394	MW-243	36	-25.3
7391	MW-262	83	-25.8
7387	MW-340	625	-25.9
7395	MW-381	3	-25.4
7396	MW-381	3	-25.4

Averages

Sample ID	**TCE d13C (permil)**
MW-66	-25.3
MW-125	-25.6
MW-168	-24.8
MW-185	-25.9
MW-194	na
MW-197	-23.1
MW-236	-25.3
MW-242	-24.6
MW-243	-25.3
MW-262	-25.8
MW-340	-25.9
MW-381	-25.4

QAQC – precision

StDev of replicate

Sample ID	d13C TCE
MW-66	0.1
MW-125	0.1
MW-197	0.0
MW-381	0.0

QAQC – external standards

Run #	Sample ID	TCE d13C (permil)
7377	STANDARD	-30.2
7378	STANDARD	-30.6
7384	STANDARD	-30.5
7389	STANDARD	-30.3
	average d13C	-30.4
	stdev n=4	0.2
	max stdev n=2	0.3
	off-line d13C of Std compound	-30.7
	sample standard deviation	**0.182574186**

Appendix 3B. Stable Carbon Isotope Enrichment Factor Data & Calculations

Appendix 3B.1. Published Data.

C/Co (measured)	**ln(C/Co)**	**measured**
1	0	-31.95
0.845386193	-0.167961723	-31.85
0.831740356	-0.184234959	-32.07
0.691131692	-0.369424891	-32.14
0.713971216	-0.336912631	-32.18
0.581064936	-0.542892763	-31.29
0.608408371	-0.496908959	-31.57
0.416766507	-0.875229149	-30.95
0.421040003	-0.865027431	-31.19
0.313040334	-1.161423234	-30.52
0.372324895	-0.987988432	-30.79
0.286021881	-1.251686965	-30.56
0.447278995	-0.804572728	-31.17

Table 3B.1.1. Fractionation calculations from Chu, et.al. (2007).

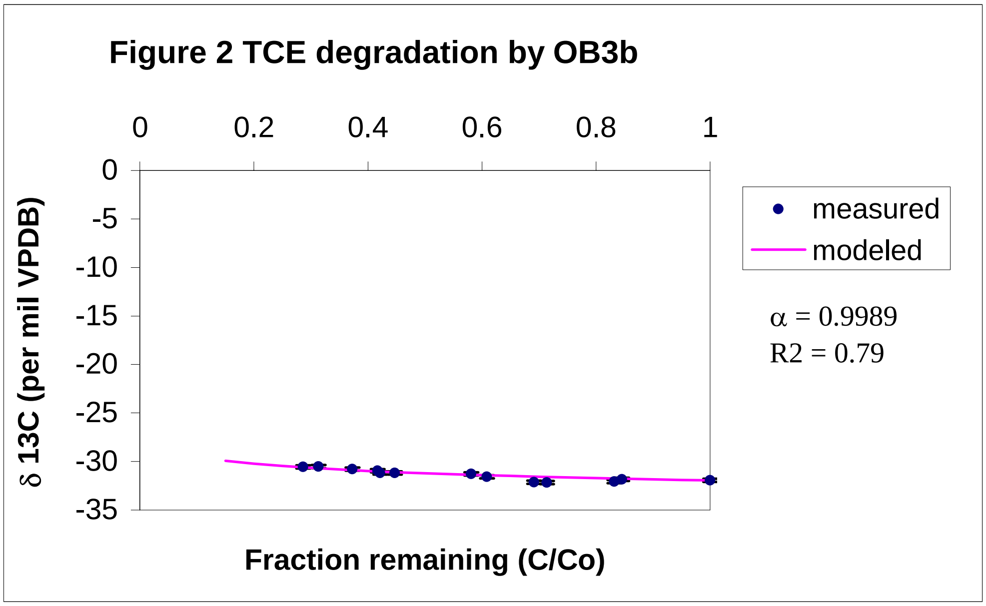


Table 3B.1.2. Fractionation calculations from Chu, et.al. (2007).

Appendix 3B.2. Statistical Workup of Published Data

SUMMARY OUTPUT 90% one tailed confidence interval

Regression Statistics	
Multiple R	0.93548242
R Square	0.87512736
Adjusted R Square	0.8637753
Standard Error	0.22100101
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.765174862	3.765175	77.08975	2.66846E-06
Residual	11	0.537255907	0.048841		
Total	12	4.302430769			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 80.0%*	*Upper 80.0%*
Intercept	-32.2667124	0.115972303	-278.228	1.62E-22	-32.52196574	-32.01145911	-32.4248326	-32.10859227
X Variable 1	**-1.39692851**	0.159102082	-8.78008	2.67E-06	-1.747109832	-1.04674719	**-1.61385311**	-1.180003909

The value of epsilon is -1.40

The value of the 90% one tailed confidence interval on epsilon is -1.61

Table 3B.2.1. 90% one-tailed confidence interval on epsilon derived from Chu, et.al. (2007).

SUMMARY OUTPUT 95% one tailed confidence interval

Regression Statistics	
Multiple R	0.935482419
R Square	0.875127356
Adjusted R Square	0.863775297
Standard Error	0.221001009
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.765174862	3.765175	77.08975	2.66846E-06
Residual	11	0.537255907	0.048841		
Total	12	4.302430769			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 90.0%*	*Upper 90.0%*
Intercept	-32.2667124	0.115972303	-278.228	1.62E-22	-32.52196574	-32.01145911	-32.47498532	-32.0584395
X Variable 1	**-1.39692851**	0.159102082	-8.78008	2.67E-06	-1.747109832	-1.04674719	**-1.682657524**	-1.1111995

The value of epsilon is -1.40

The value of the 95% one tailed confidence interval on epsilon is -1.68

Table 3B.2.2. 95% one-tailed confidence interval on epsilon derived from Chu et.al. (2007).

Appendix 3C. Strawman approach for SCI Data Reduction and Evaluation

Strawman approach for SCI Data Reduction and Evaluation

Strawman on approach to evaluate SCIR data on TCE to evaluate biodegradation, or a process to get to a decision estimation statement

For the wells sampled and sent to OU for analysis in Paul Philp's lab, DOD will provide a calculation of the apparent extent of removal of TCE (measured concentration divided by original concentration) based on concentrations of TCE normalized to concentrations of ^{99}Tc. The up gradient well will be the well with the highest concentration of TCE that is in a plausible flow path to the down gradient well. The up gradient well must be one of the wells sampled and sent to Paul Philp.

$$C/C_o = \text{TCE}_{\text{down gradient}} /(\text{TCE}_{\text{up gradient}} *[\,^{99}\text{Tc}_{\text{down gradient}}\ /^{99}\text{Tc}_{\text{up gradient}}\,])$$

Then, based on the results of the carbon isotopic analysis, C/Co will be independently calculated from the following formula

$$\text{C/Co} = e^{((\delta^{13}C_{downgradient} - \delta^{13}C_{upgradient})/\varepsilon)}$$

Where $\delta^{13}C_{\text{upgradient}}$ is the carbon isotopic ratio in TCE in the up gradient well, where $\delta^{13}C_{\text{downgradient}}$ is the carbon isotopic ratio in TCE in the down gradient well, and ε, the isotopic fractionation factor for aerobic biodegradation of TCE through co-metabolism (subject to revision based availability of more literature), will be -1.1 ‰. This value of ε is provided by Chu, K.-H., Mahendra, S., Song, D.L., Conrad, M.E., and Cohen, L.A. (2004) Stable carbon isotope fractionation during aerobic degradation of chlorinated ethenes. *Environmental Science & Technology* 38: 3126-3130.

The stable isotope analyses will be evaluated by comparing the rate of TCE transformation as predicted from the analyses to the rate of TCE transformation extracted from the field monitoring data. If the rate of TCE transformation predicted from the extent of removal of TCE based on stable isotope measurements is at least one third the rate extracted from the field data, then the stable isotope analyses will be considered to provide a third line of evidence for MNA processes as defined in United States Environmental Protection Agency. 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. Office of Solid Waste and Emergency Response, Directive 9200.4-17P. http://www.epa.gov/swerust1/directiv/d9200417.htm.

Assuming pseudo first order kinetics:

$$C / Co = e^{-kt}$$

Where k is the first order rate constant for attenuation and t is time of travel from the up gradient to the down gradient well. Taking the natural logarithm of both sides:

$$\ln(C / Co) = -kt$$

Because t is the same for the estimate based on TCE concentrations or the estimate based on stable isotope ratios, it can be scaled as "one travel time." The value of t in both cases is one.

If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more negative than natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, or if the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is no more than a factor of 0.33 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide a third line of evidence for MNA processes.

As an example:

Assume the normalized value of C/Co for measured TCE concentrations is 5.5 µg/L down gradient and 200 µg/L upgradient. The value of C/Co is 0.0275 and the value of ln(C/Co) is -3.59. Multiplying -3.59 by 0.33 produces a criterion of -1.18. The stable isotope data will be considered to provide the third line of evidence if the value of ln(C/co) estimated from the stable isotope ratios is less than -1.18.

Assume the value of $\delta^{13}C_{upgradient}$ is -30.20‰ and the value of $\delta^{13}C_{downgradient}$ is -28.10‰. If ε is -1.1‰, the value of C/Co predicted from the stable isotope ratios is 0.148 and the value of ln(C/C0) is -1.91. Because -1.91 is less than -1.18, the criterion would be satisfied and the stable isotope data would be considered to provide the third line of evidence.

If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more than a factor of 0.33 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide no interpretable information, and will not be used to support a decision.

Assume the value of $\delta^{13}C_{upgradient}$ is -30.20‰ and the value of $\delta^{13}C_{downgradient}$ is -29.00‰. If ε is -1.1‰, the value of C/Co predicted from the stable isotope ratios is 0.336 and the value of ln(C/C0) is -1.09. Because -1.09 is greater than -1.18, the criterion would not be satisfied and the stable isotope data would be considered to provide no interpretable information, and will not be used to support a decision.

To allow for statistical uncertainty in the determination of δ^{13}C analyses, the value of $\delta^{13}C_{upgradient}$ will be replaced with $\delta^{13}C_{upgradient}$ plus the sample standard deviation of the analysis, and $\delta^{13}C_{downgradient}$ will be replaced with $\delta^{13}C_{downgradient}$ minus the sample standard deviation of the analysis.

If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is not more than a factor of 0.10 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide a third line of evidence for MNA processes. If the natural logarithm of the value of C/Co provided from the analysis of stable isotope ratios is more than a factor of 0.1 more positive than the natural logarithm of the value of C/Co as calculated from measured concentrations of TCE as normalized to the measured concentrations of ^{99}Tc, the stable isotope analyses will be considered to provide no interpretable information, and will not be used to support a decision.

The value of ln(C/Co) for the normalized TCE field data was -3.59. Multiplying -3.59 by 0.10 produces a criterion of -0.359.

Assume the value of $\delta^{13}C_{upgradient}$ is -30.2‰ and the value of $\delta^{13}C_{downgradient}$ is -28.1‰. Also assume the sample standard deviation is 0.25‰. The values modified by the standard deviation are -29.95‰ and -28.35‰. If ε is -1.1‰, the value of C/Co predicted from the stable isotope ratios is 0.234 and the value of ln(C/C0) is -1.45. Because -1.45 is less than -0.359, the criterion would be satisfied and the stable isotope data would still be considered to provide the third line of evidence, despite its measured uncertainty.

If the parties choose to accept this outline to negotiate a decision estimation statement, they should negotiate the factors of 0.33 and 0.01, and the value for ε.

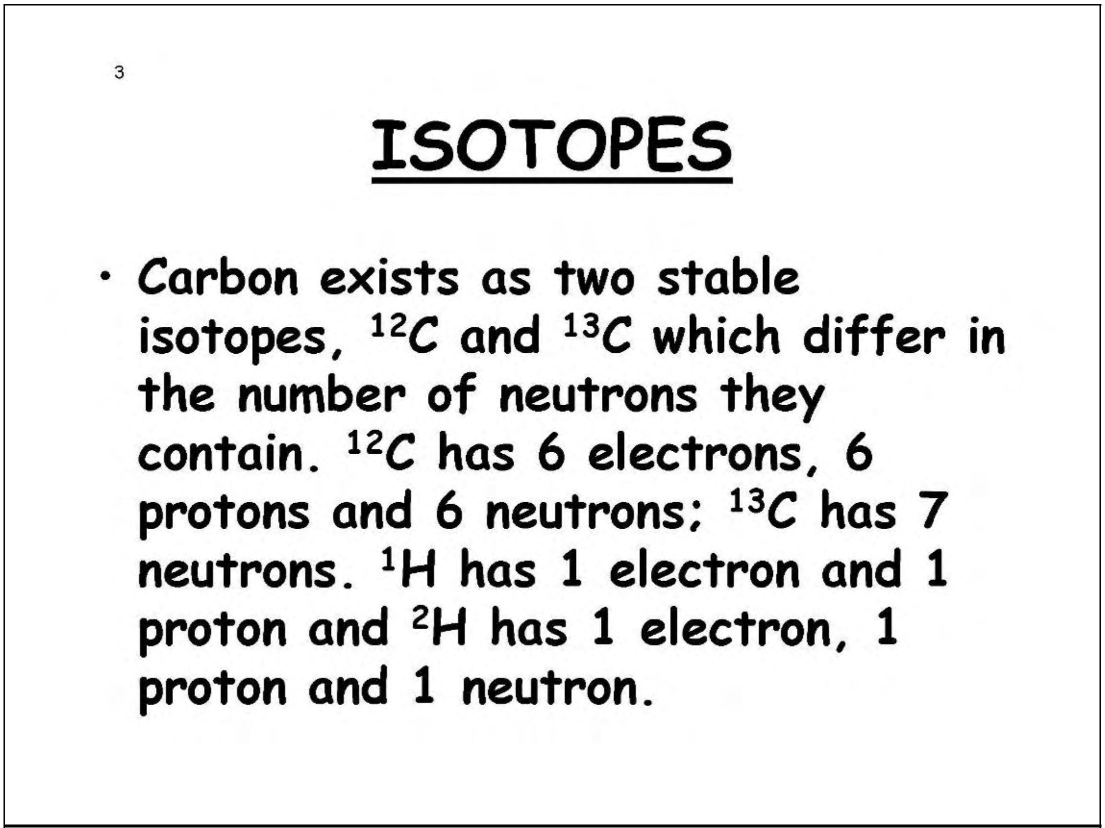
Appendix 3D. University of Oklahoma MTBE CSIA Slide Presentation

An Evaluation of the use of Stable Isotopes as a Tool for Studying the Origin and Fate of MTBE

R. Paul Philip, Tomasz Kuder, and Jon Allen, School of Geology and Geophysics, University of Oklahoma, Norman, OK. 73019.

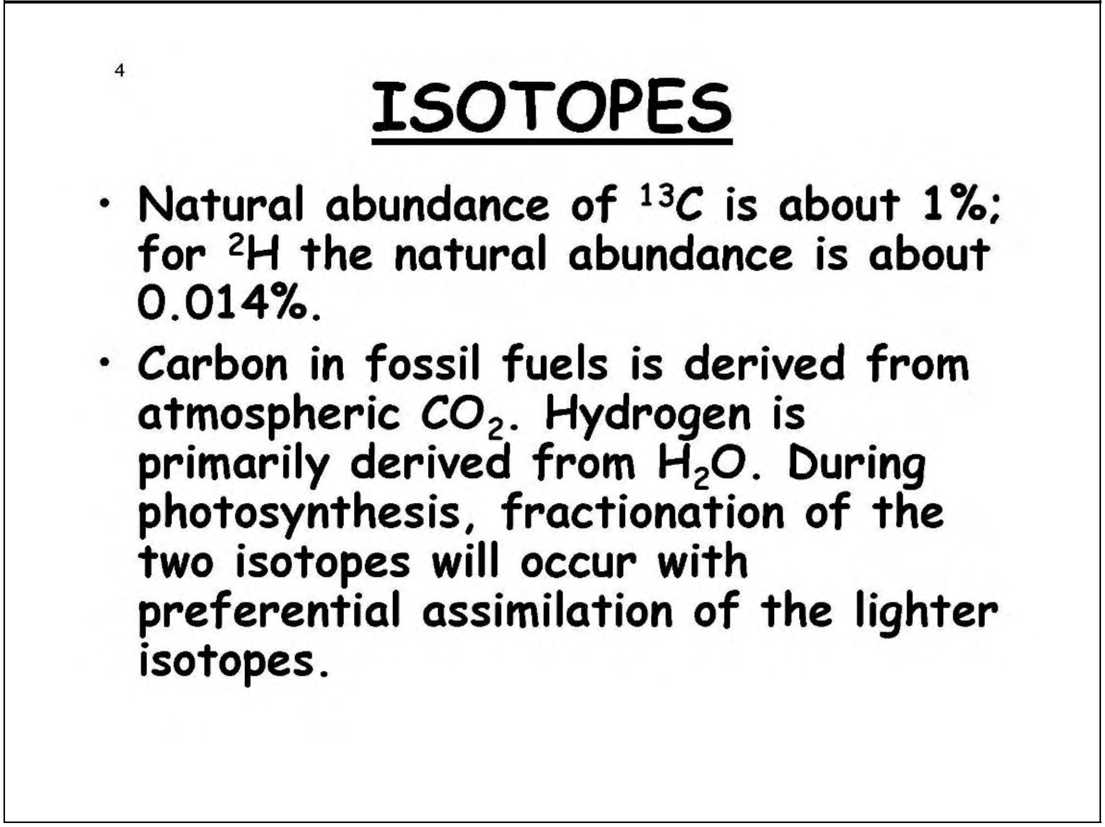
Topics to be covered

- What is a stable isotope?
- Why use isotopes?
- What type of information can we obtain?
- Examples



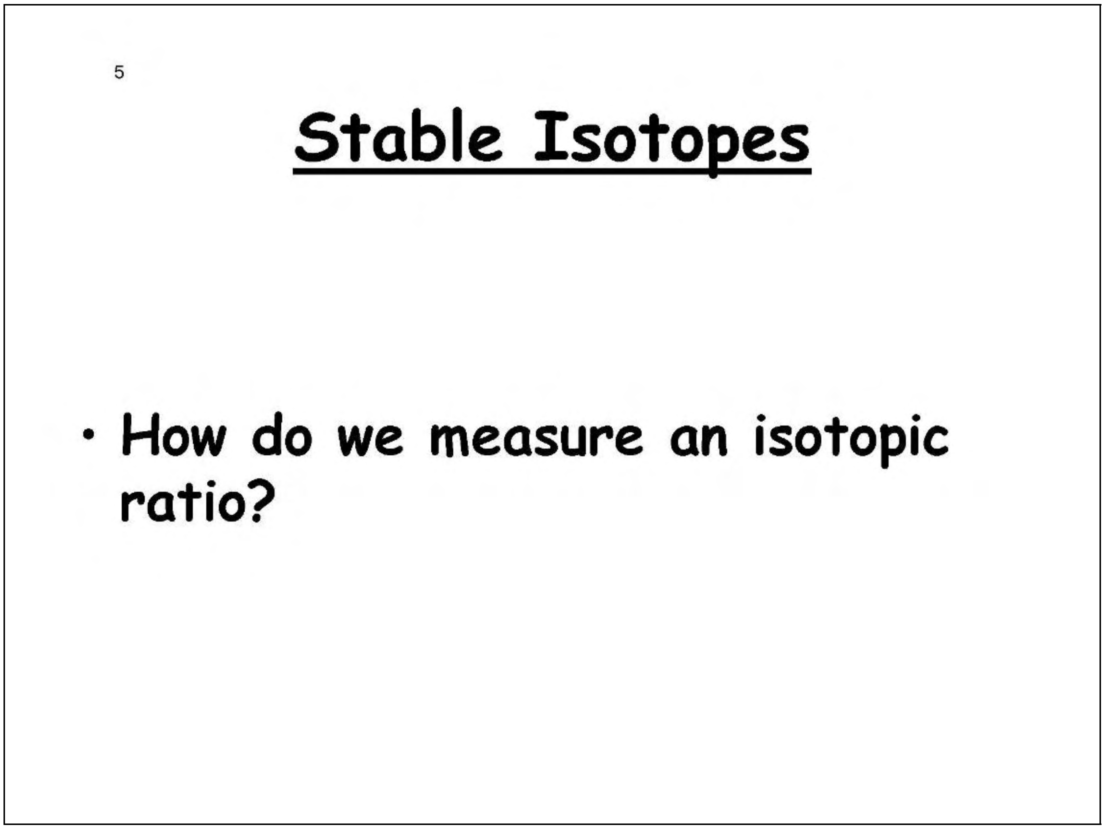
ISOTOPES

- Carbon exists as two stable isotopes, ^{12}C and ^{13}C which differ in the number of neutrons they contain. ^{12}C has 6 electrons, 6 protons and 6 neutrons; ^{13}C has 7 neutrons. ^{1}H has 1 electron and 1 proton and ^{2}H has 1 electron, 1 proton and 1 neutron.



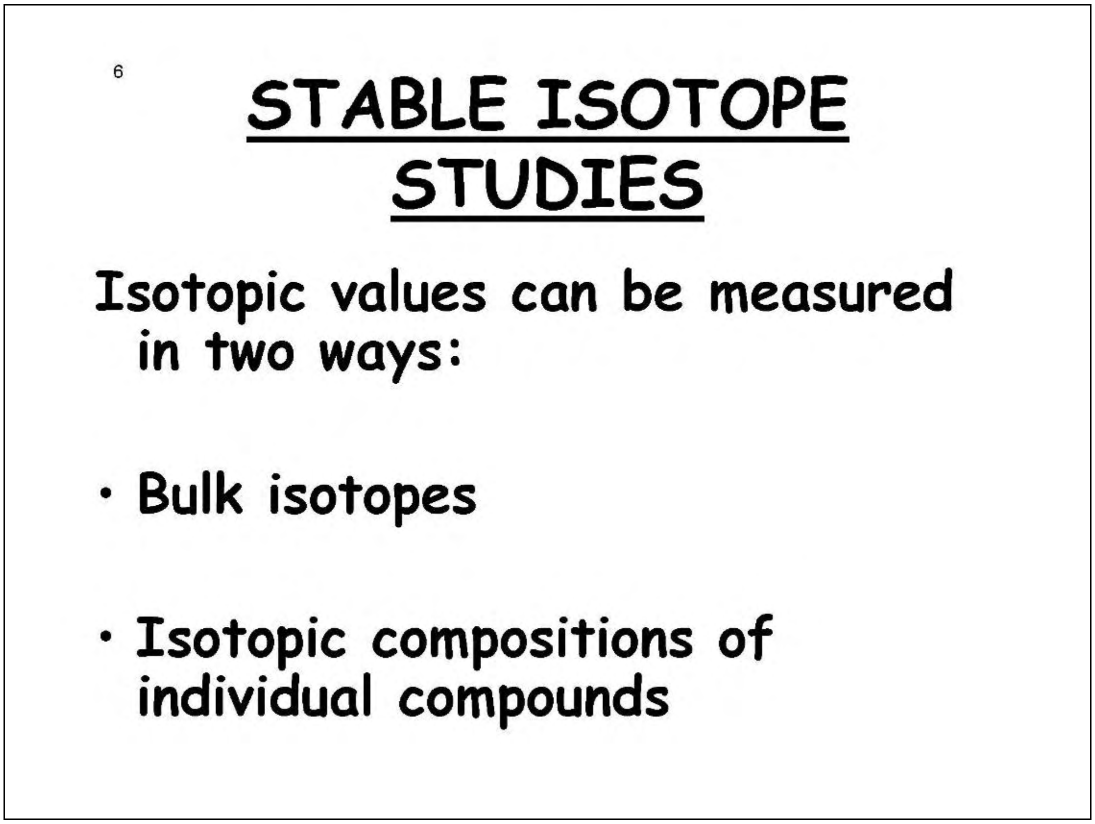
ISOTOPES

- Natural abundance of ^{13}C is about 1%; for ^{2}H the natural abundance is about 0.014%.
- Carbon in fossil fuels is derived from atmospheric CO_2. Hydrogen is primarily derived from H_2O. During photosynthesis, fractionation of the two isotopes will occur with preferential assimilation of the lighter isotopes.



Stable Isotopes

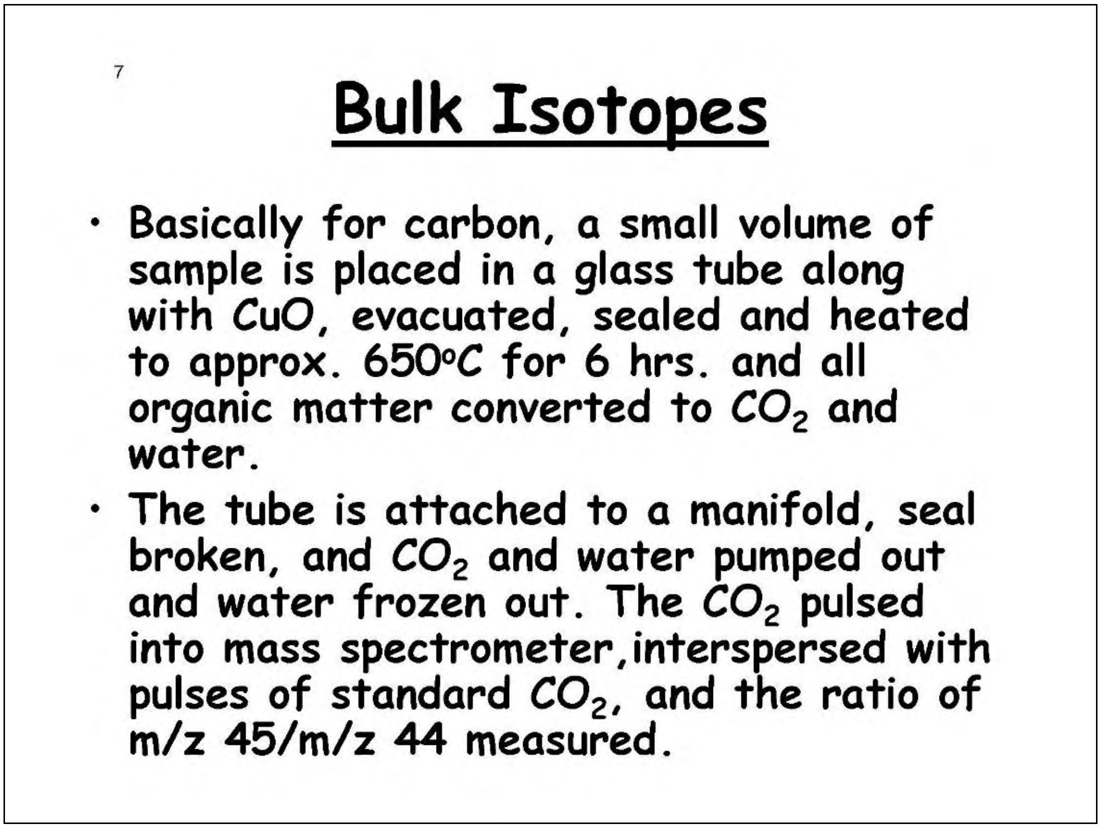
- How do we measure an isotopic ratio?



STABLE ISOTOPE STUDIES

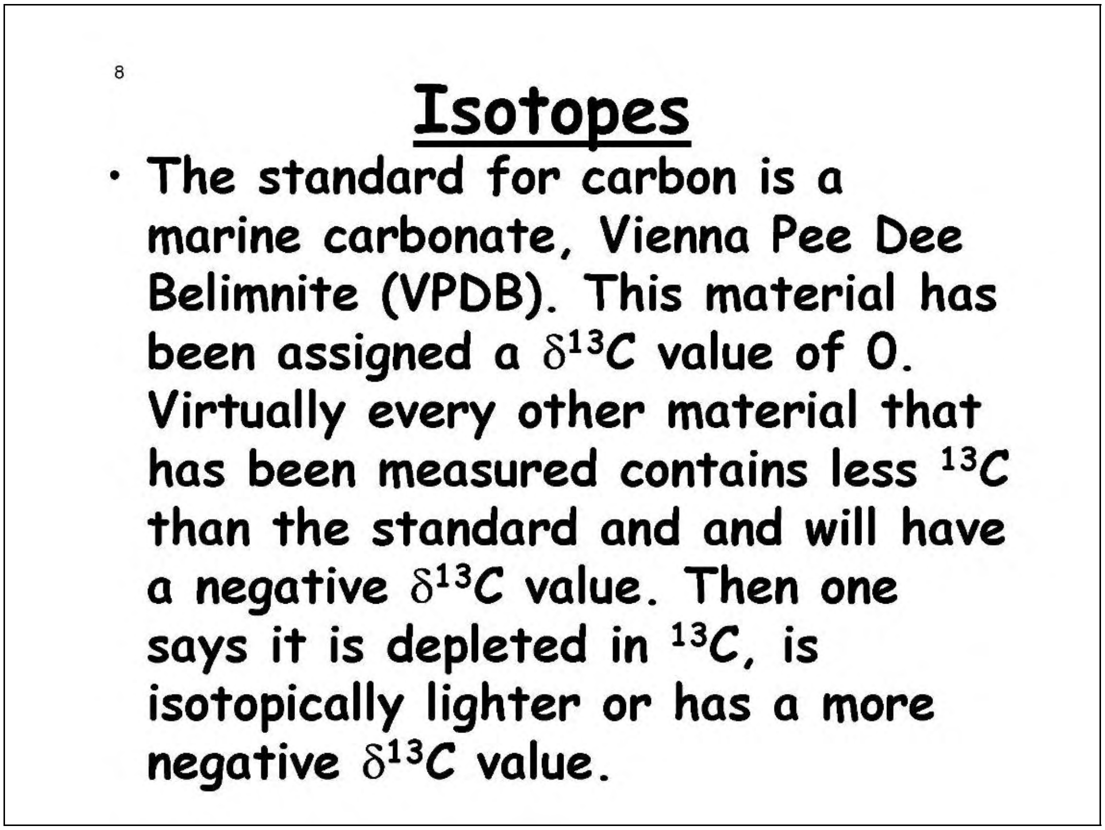
Isotopic values can be measured in two ways:

- Bulk isotopes
- Isotopic compositions of individual compounds



Bulk Isotopes

- Basically for carbon, a small volume of sample is placed in a glass tube along with CuO, evacuated, sealed and heated to approx. 650°C for 6 hrs. and all organic matter converted to CO_2 and water.
- The tube is attached to a manifold, seal broken, and CO_2 and water pumped out and water frozen out. The CO_2 pulsed into mass spectrometer,interspersed with pulses of standard CO_2, and the ratio of m/z 45/m/z 44 measured.



Isotopes

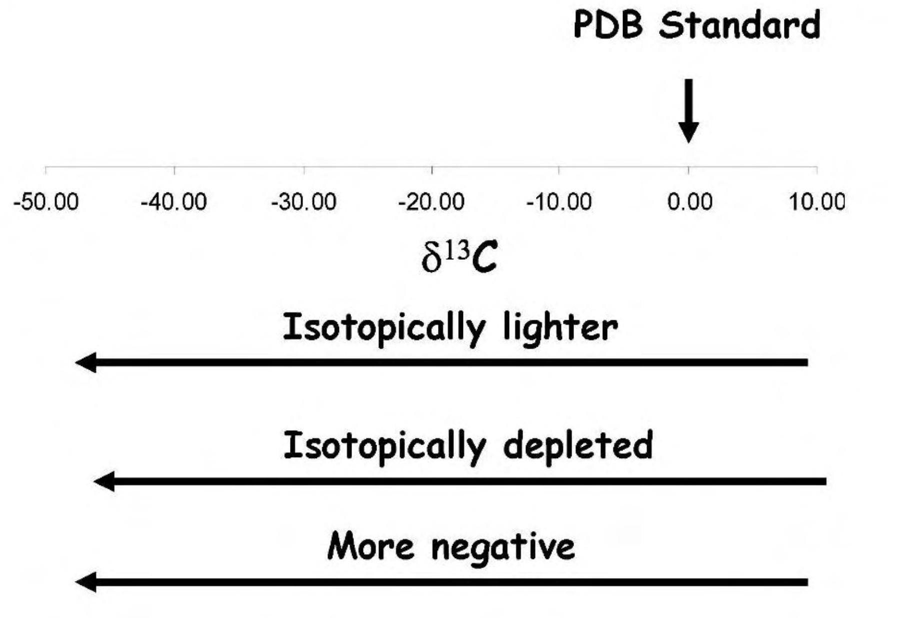
- The standard for carbon is a marine carbonate, Vienna Pee Dee Belimnite (VPDB). This material has been assigned a $\delta^{13}C$ value of 0. Virtually every other material that has been measured contains less ^{13}C than the standard and and will have a negative $\delta^{13}C$ value. Then one says it is depleted in ^{13}C, is isotopically lighter or has a more negative $\delta^{13}C$ value.

Data Output

δ13C notation: $$\delta^{13}\mathrm{C} = \left(\frac{\mathrm{R}_{\mathrm{sample}}}{\mathrm{R}_{\mathrm{standard}}} - 1 \right) \times 1000$$

$R = {}^{13}C/{}^{12}C$

Data Output-Isotope Scale



Isotopically lighter

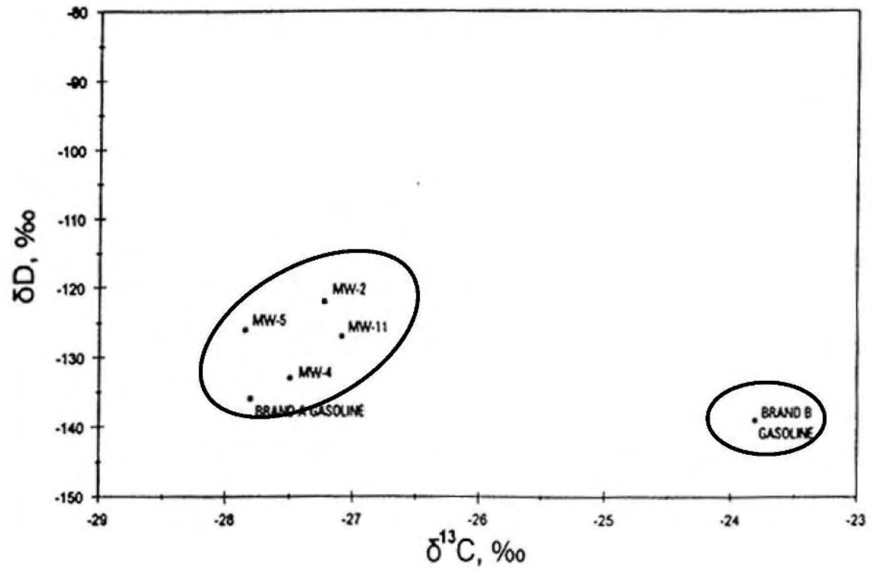
Isotopically depleted

More negative

Bulk Isotopes

- Crude oils from derived from different types of source materials will have different isotopic compositions. For examples Alaskan crudes are typically around –29 per mil whereas Californian crudes derived from Monterey source rocks are around –24 per mil.

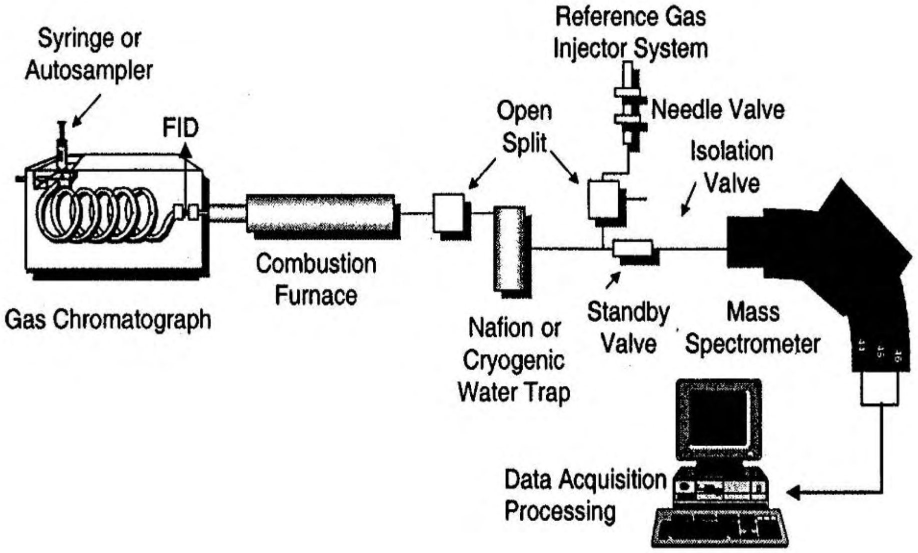
Bulk Isotopes to Differentiate Gasolines



STABLE ISOTOPE STUDIES

- Isotopic compositions of individual compounds

GCIRMS System



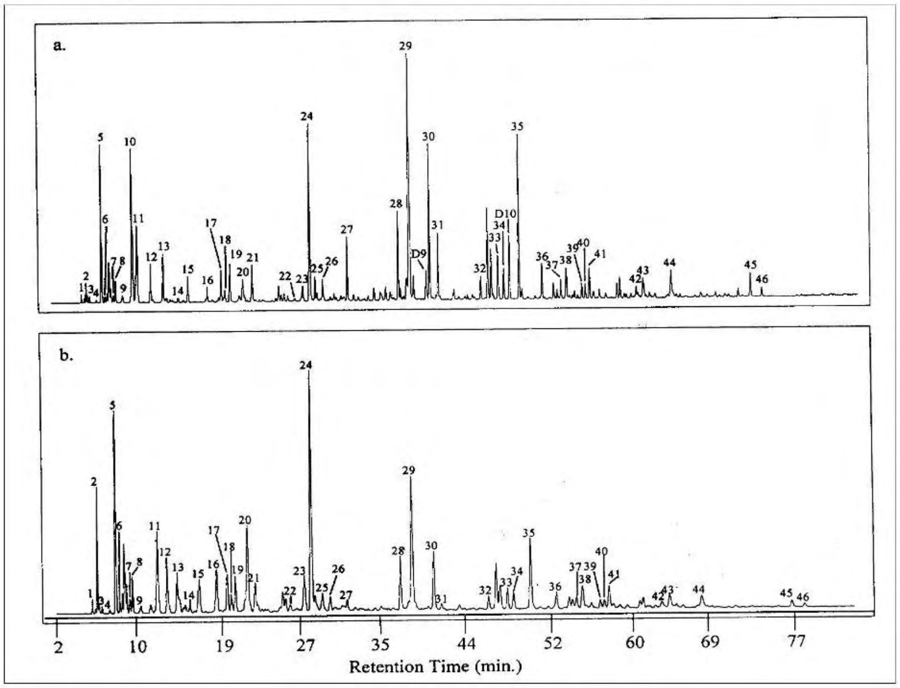
On-Line Determination

- For carbon, combustion interface converts everything to CO_2 and water; water removed CO_2 enters the IRMS system.
- For hydrogen the sample is pyrolysed to produce ^1H and ^2H which enter IRMS, and carbon deposited on the tube
- Important no GC resolution lost during combustion process

Individual Compounds

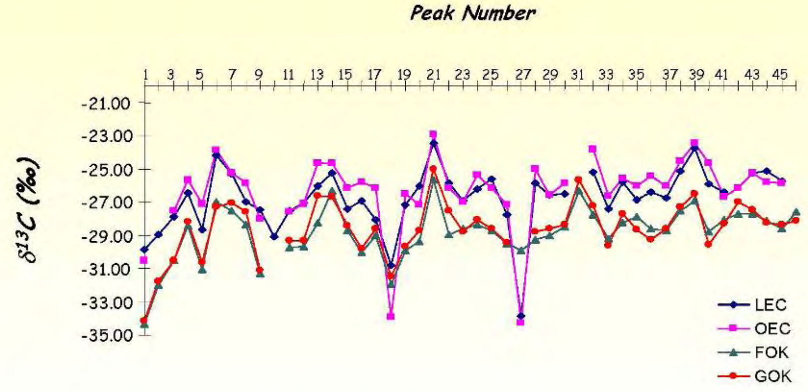
- GCIRMS has been used to determine source and monitor fate of several individual compounds including PCE/TCE, BTEX, MTBE and TBA

Comparison of Gasolines by GCIRMS

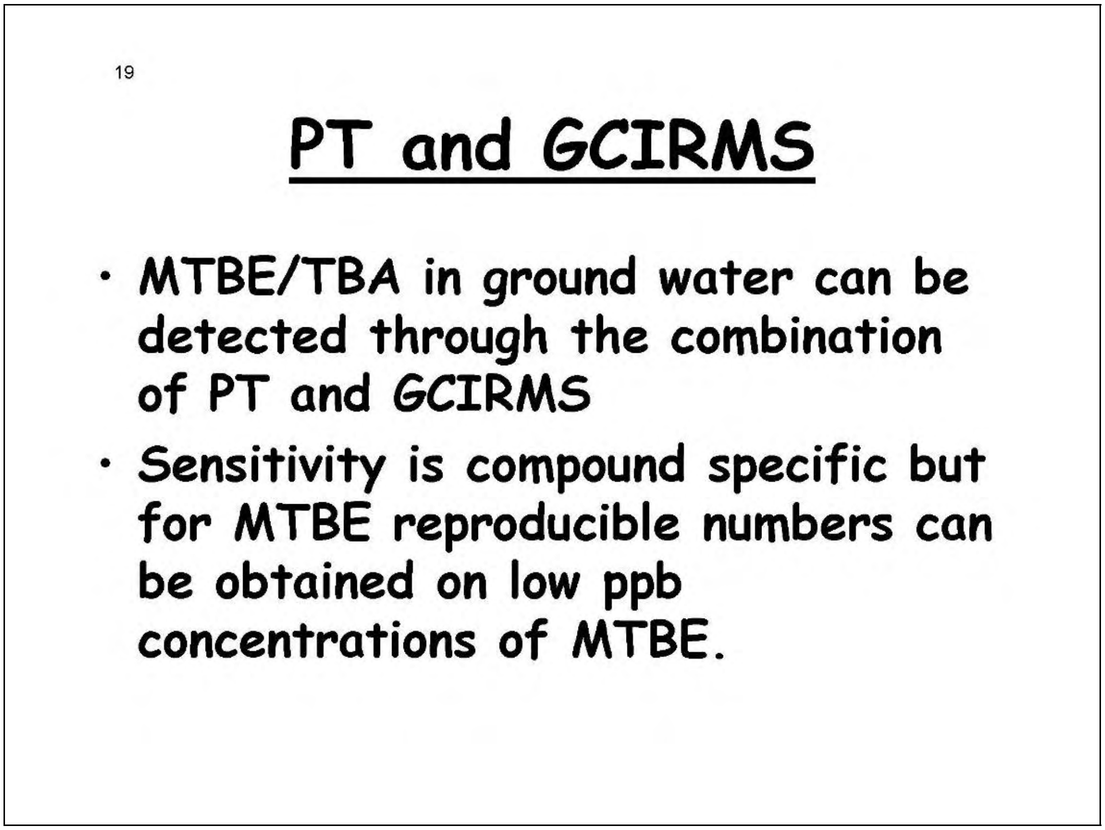


18

Carbon Isotopic Composition of Gasolines from Oklahoma (FOK, GOK) and the East Coast (LEC, OEC)

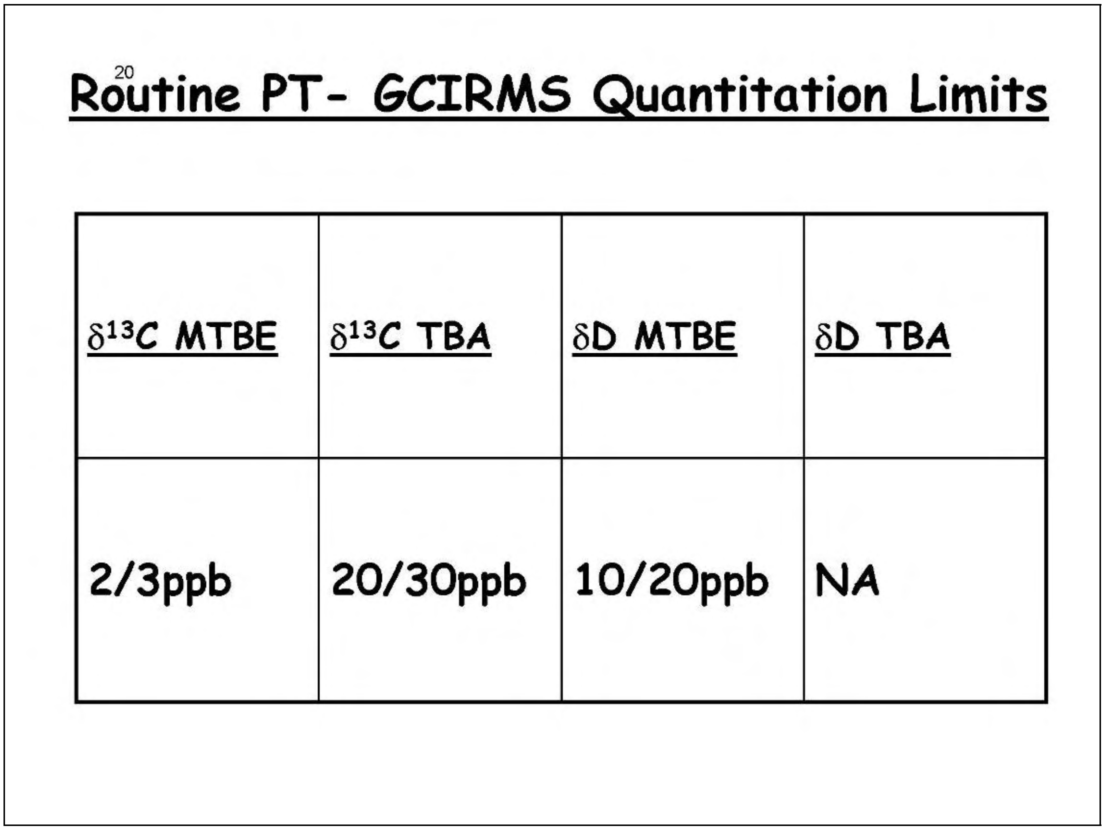


This figure shows the carbon isotopic fingerprint of gasolines sampled from Oklahoma and from the East Coast and demonstrates that these gasolines are significantly different in terms of isotopic composition and can be discriminated from each other on this basis. The peak numbers are identified in the section above.



PT and GCIRMS

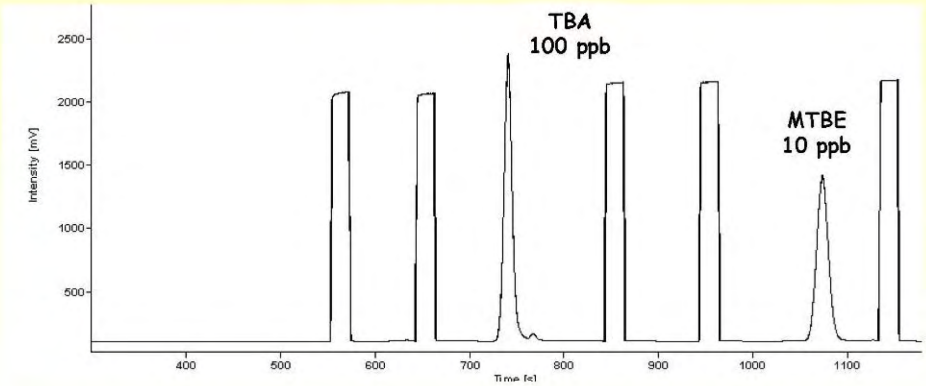
- MTBE/TBA in ground water can be detected through the combination of PT and GCIRMS
- Sensitivity is compound specific but for MTBE reproducible numbers can be obtained on low ppb concentrations of MTBE.



Routine PT- GCIRMS Quantitation Limits

$\delta^{13}C$ MTBE	$\delta^{13}C$ TBA	δD MTBE	δD TBA
2/3ppb	20/30ppb	10/20ppb	NA

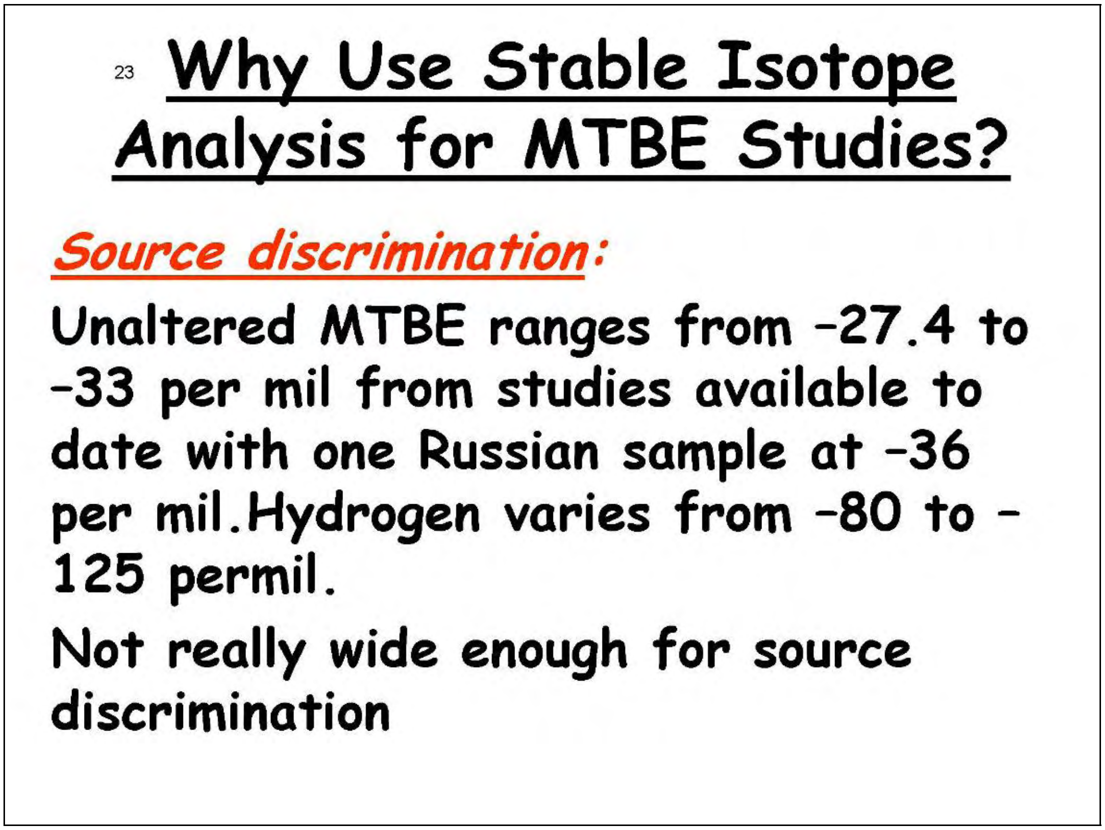
M/z 44 trace of MTBE dissolved in Groundwater (extracted by Purge and Trap)



MTBE is very water soluble, hence in groundwater samples it is often the predominant peak in the chromatogram. In order to characterize MTBE in groundwater samples, a purge and trap system can be interfaced to the GCIRMS system and the carbon isotopic composition of MTBE determined in this manner down to levels of 2-3 PPB.

Why Use Stable Isotope Analysis for MTBE Studies?

Major uses of the isotopes: Source discrimination; Determination of the onset of natural attenuation

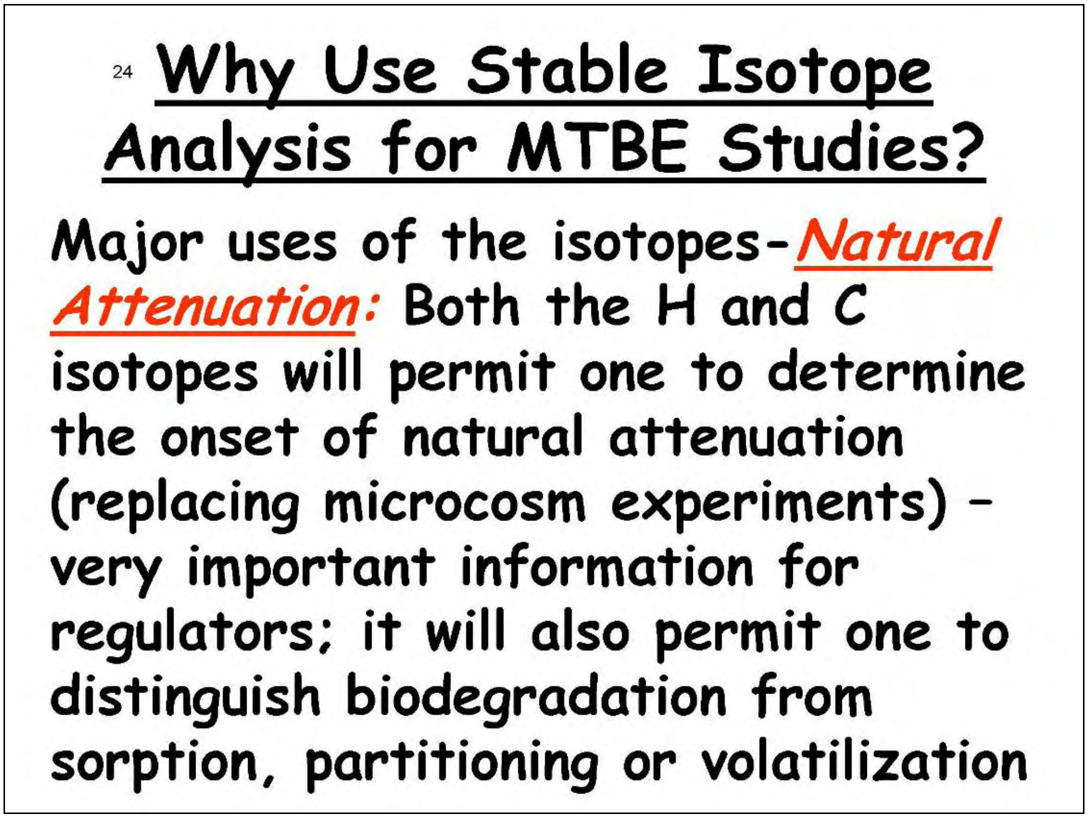


Why Use Stable Isotope Analysis for MTBE Studies?

Source discrimination:

Unaltered MTBE ranges from –27.4 to –33 per mil from studies available to date with one Russian sample at –36 per mil.Hydrogen varies from –80 to –125 permil.

Not really wide enough for source discrimination



Why Use Stable Isotope Analysis for MTBE Studies?

Major uses of the isotopes-*Natural Attenuation*: Both the H and C isotopes will permit one to determine the onset of natural attenuation (replacing microcosm experiments) – very important information for regulators; it will also permit one to distinguish biodegradation from sorption, partitioning or volatilization

Why do the Stable Isotope ratios reflect the onset of *Natural Attenuation?*

It is a consequence of isotopic fractionation and the kinetic isotope effect

---

Isotopic Fractionation

Isotope fractionation is the physical phenomenon which causes changes in the relative abundance of isotopes due to their differences in mass. In the context of the current presentation the most important isotope effect is the kinetic effect.

Kinetic Isotope Effect

- Molecules are comprised primarily of ^{12}C-^{12}C bonds; lesser amounts of ^{12}C-^{13}C bonds and even fewer ^{13}C-^{13}C bonds. The kinetic isotope effect can be thought of as the cleavage of the weaker bonds, ^{12}C-^{12}C, which will ultimately lead to an enrichment of the residual substrate.

Stable Isotopic Fractionation

Rayleigh Model

The relationship between the isotopic composition of a precursor and product can be followed through the use of the Rayleigh equation. This equation establishes the relationship between the isotopic composition of precursor and product based on the fractionation factor and change in concentration of the substrate.

Stable Isotopic Fractionation

Rayleigh Model

The Rayleigh Model in biodegradation studies permits:

1. Improves interpretation of field data and permits one to distinguish between degradation and source fluctuation.
2. Permits quantitative conclusions on rates and extent of elapsed degradation.
3. Provides objective parameter (ε) to compare sites and microcosm experiments

Stable Isotopic Fractionation

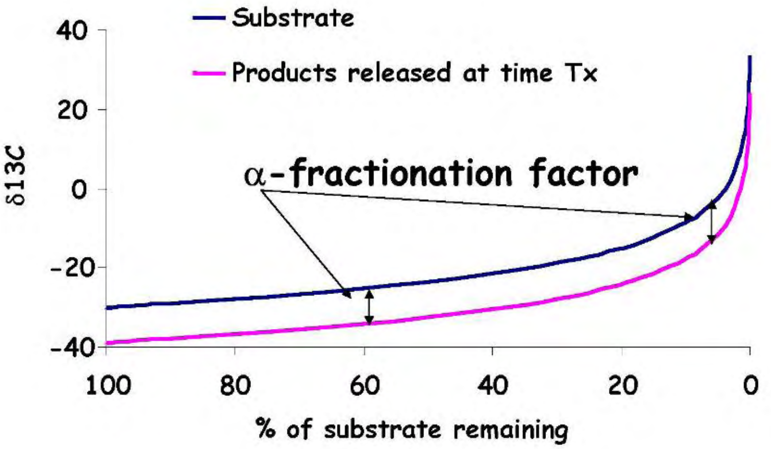
Rayleigh Model

At any time during the progress of a reaction, ratio of $^{13}C/^{12}C$ of remaining substrate and generated reaction product remains constant. This is the fractionation factor α

$$R\ \text{substrate}_t / R\ \text{product}_t = \alpha$$

R_t = $^{13}C/^{12}C$ at specific time "t" during the reaction

Stable Isotopic Fractionation Rayleigh Model



Stable Isotopic Fractionation

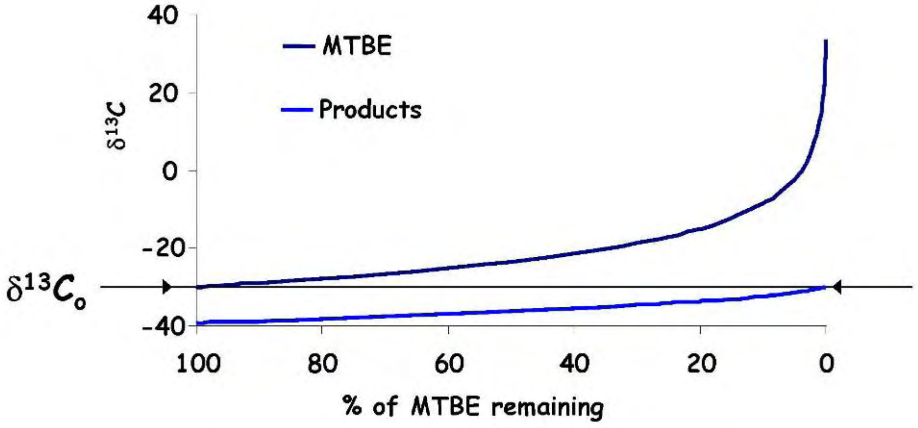
Rayleigh Model

$$\delta^{13}C_t = \varepsilon * \ln F + \delta^{13}C_o$$

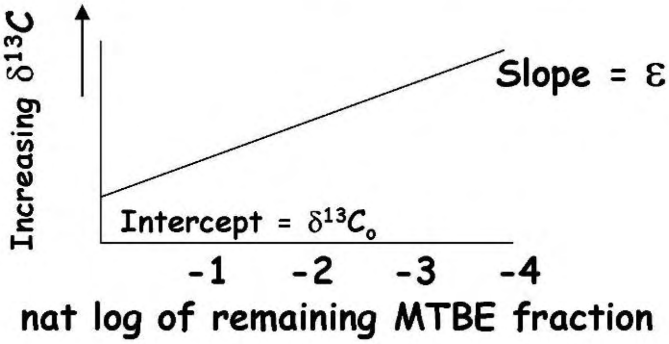
$\delta^{13}C_o$ – initial isotopic composition
$\delta^{13}C_t$ – isotopic composition at time t
F – fraction of MTBE remaining at time t
ε – enrichment factor

The enrichment factor value is very important since it will indicate whether or not similar mechanisms are operational at different sites.

Stable Isotopic Fractionation of MTBE



Stable Isotopic Fractionation Rayleigh Model



MTBE concentration decreases ⟶

$$\delta^{13}C_t = \varepsilon * \ln F + \delta^{13}C_o$$

Why Use Stable Isotope Analysis for MTBE Studies?

Microcosm data provides the ε value for anaerobic vs. aerobic degradation. Subsequent plot of $\delta^{13}C$ v. Residual MTBE concentration provides an indication of the extent of biodegradation at a site v. that from dilution and dispersion

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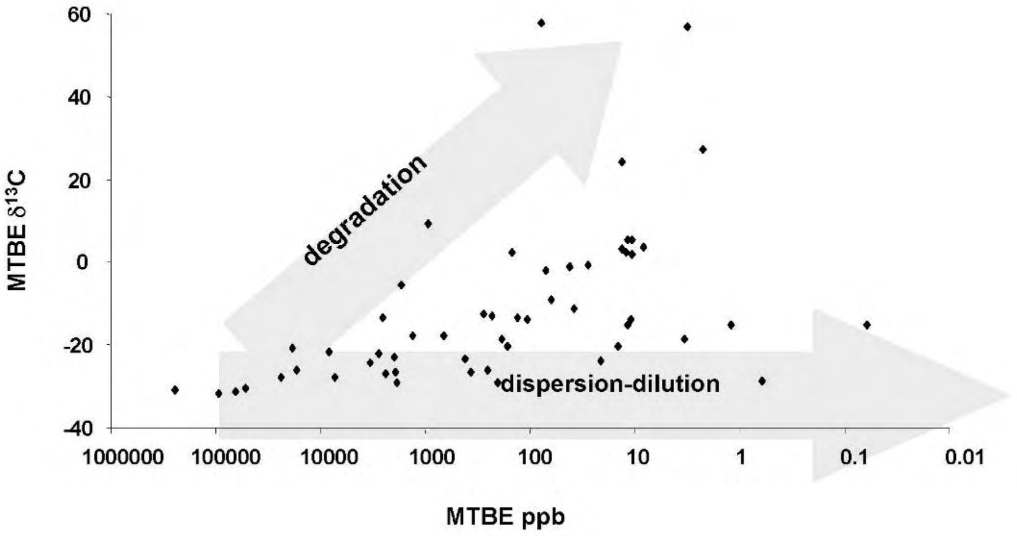
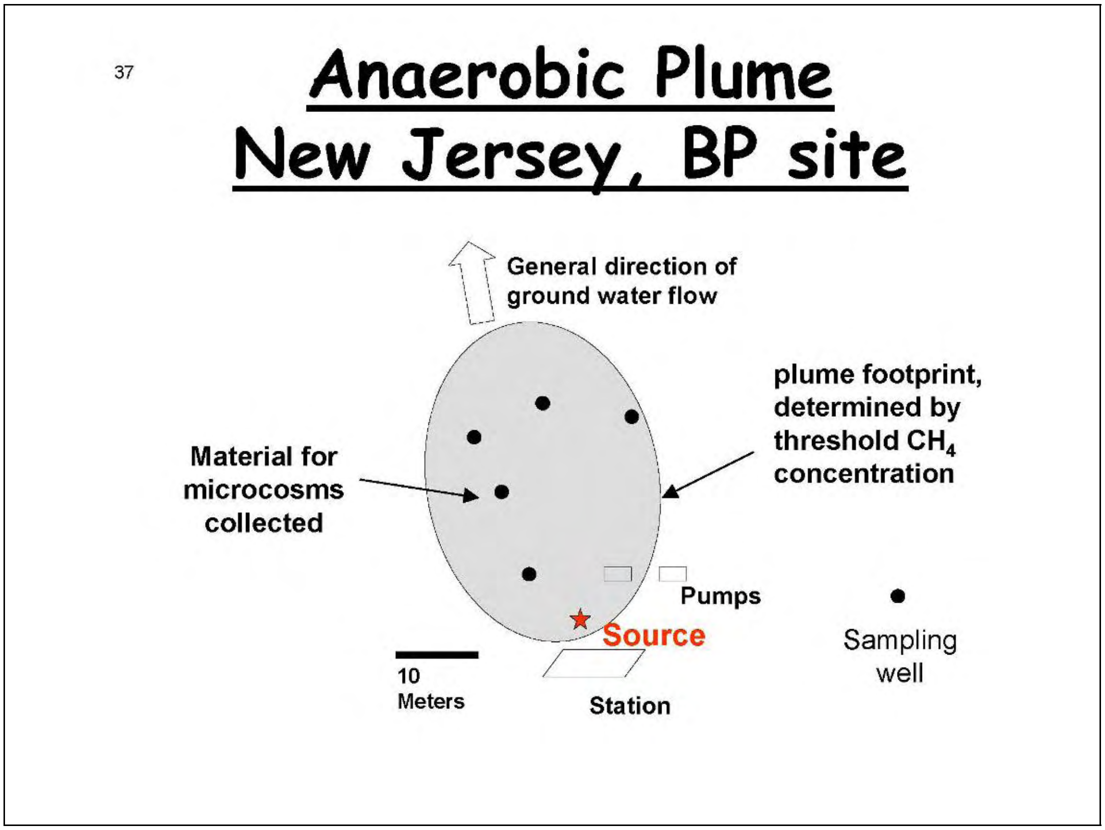
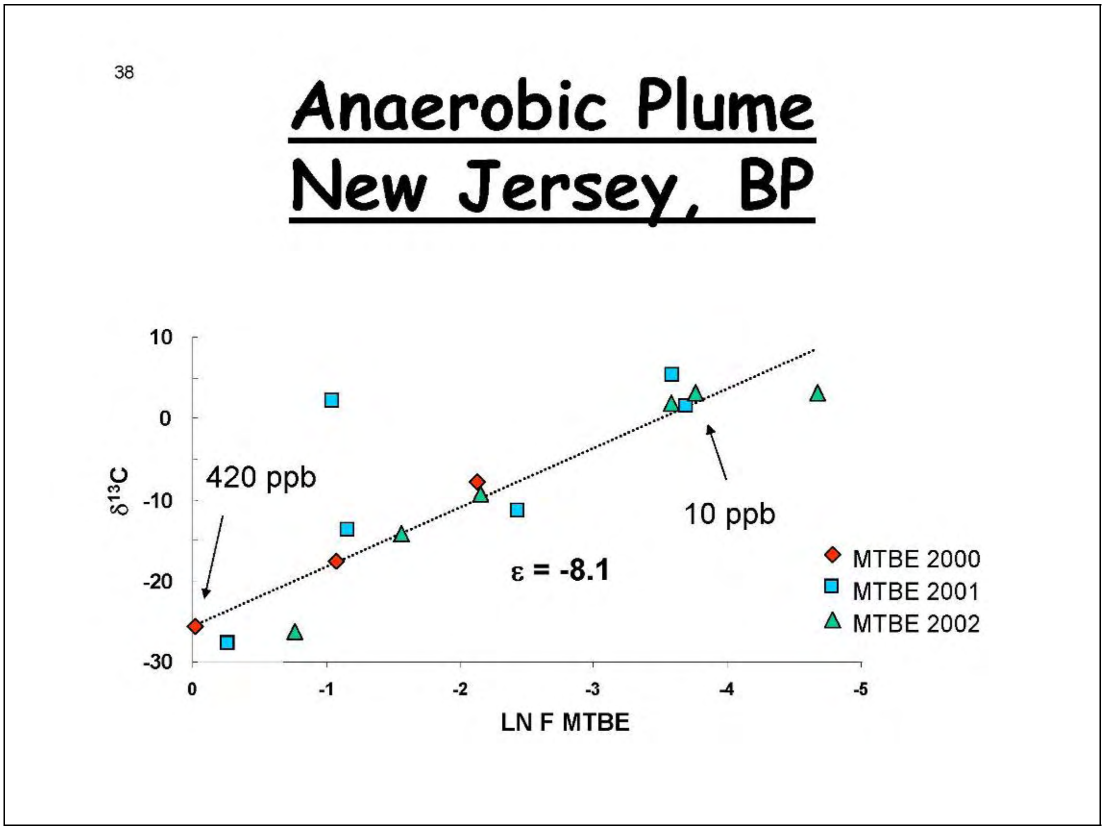
The use of isotopes to differentiate degradation from dispersion and dilution



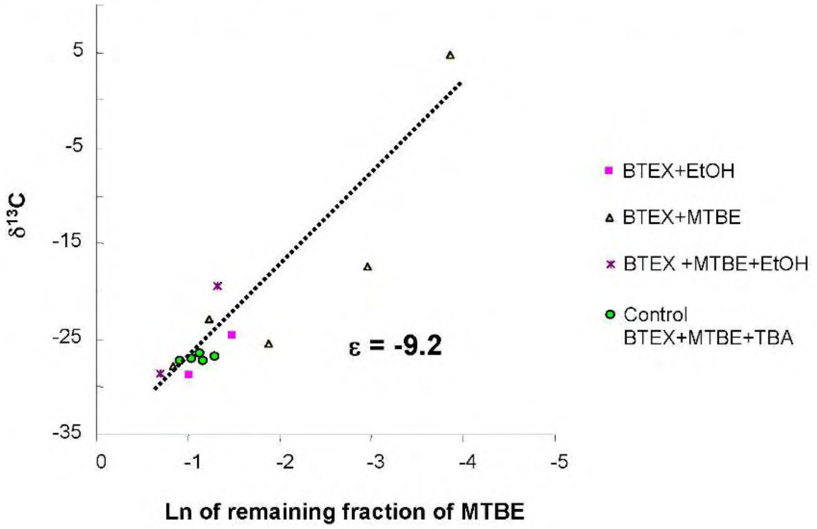


Anaerobic Plume
New Jersey, BP site



Anaerobic Plume
New Jersey, BP

Anaerobic Plume New Jersey, BP – microcosms



SUMMARY

- Stable isotopes provide a powerful tool for monitoring the origin and fate of MTBE and TBA in the environment.
- Stable isotopes can be used to evaluate the onset of natural attenuation and extent of degradation.
- Limits of detection are in the low ppb region and below regulatory action levels.
- The use of isotopes permits one ot discriminate between biodegradation and effects such as dilution and dispersion

Appendix 4. Propagation of Errors Statistical Analysis (Student T-test)

Propagation of Errors Statistical Analysis

4D.1: Introduction

Population parameters can not be fully characterized until sufficient data on the population is collected: therefore, statistical uncertainties must be approximated by using available data (often small, insufficient data sets or potentially similar data drawn from the scientific literature) while employing well-established statistical methods. In this instance, we use the propagation of errors technique (slightly modified) to estimate the uncertainty associated with the stable carbon isotope data. The modified approach incorporates the Student *t*-statistic to illuminate and account for the overall lack of data samples.

In section 3E.2 we will discuss, in some detail, the methods used in determining error propagation. The statistical methods that are utilized in this section are standard statistical techniques; however, we refer the reader to Brandt (1999) for a reference of the methods employed. In section 3E.3, we will consider the pertinent error propagation formula for the stable carbon isotope data. The data in use for this section originated from the USEPA reevaluation of the Chu, et al data (Chu, 2004) as well as the USEPA stable carbon isotope data. The uncertainties determined in this section can safely be assumed to be two-sided (i.e. plus and minus) even if not stated. Finally, section 3E.4 represents a brief discussion of implications to the uncertainties and the applicability of the described techniques to other studies.

4D.2: Error Propagation

Suppose that the population parameters of concern were given by a set of measurable quantities $\vec{x} = (x_1, x_2, ..., x_n)$, in which we had established, by experiment, an estimate of the measurable quantities $\overline{x} = (\overline{x_1}, \overline{x_2}, ..., \overline{x_n})$. If two parameters from the aforementioned set $\overline{x}$ vary together, we would quantify this variation as the covariance of the two variables. Since we have more than 2 parameters -- in general we have n such parameters -- we can define an $n \times n$ symmetric covariance matrix U whose elements are defined by the covariance of two measurements from any two elements from $\overline{x}$, namely:

$$U_{ij} = Cov(\overline{x}_i, \overline{x}_j).$$

This, however, is not the end of the story. If our interest is not in the individual parameters but an analytic function f of the measurable quantities $\vec{x}$, then our goal is to find the covariance matrix of f [1]. Ultimately, the variance -- or how the quantity varies with respect to itself -- of f will serve as the desired statistical uncertainty of f. It is convenient, as well as necessary, to use the Taylor series to obtain a linear approximation. The Taylor series is a way to write an arbitrary function that satisfies certain technical criteria as a polynomial of multiple variables on a certain domain of the function. For this particular case, we are only interested in the linear contribution to the sum, namely:

$$f(\overline{x}) \approx f_0 + \sum_{i=1}^{n} \left. \frac{\partial f}{\partial x_i} \right|_{x_i = \overline{x_i}} \overline{x_i}$$

where f_0 is the first term in the series. Using the following two covariance identities[2]:

$$Cov(aX, bY) = abCov(X, Y)$$
$$Cov(\sum_i X_i, \sum_j Y_j) = \sum_i \sum_j Cov(X_i, Y_j)$$

where in the first equation X and Y are random variables and a and b are real numbers and in the second equation, X_i and Y_i are elements of two sets of random variables (or parameters), we can deduce the form of the

---

[1] For a single function this is a 1 by 1 matrix, however, for multiple functions this will be a non-trivial matrix.

[2] These identities can easily be deduced from the definition of covariance; namely: $Cov(X,Y) = E((X - \mu)(Y - \nu))$, where $E(\bullet)$ is the expectation value (or the expected value of a parameter in a given statistical distribution) of the argument and $E(X) = \mu, E(Y) = \nu$.

covariance matrix of the function f. It follows from the preceding equations that the covariance matrix of f ($V_{ii} = Cov(f(\overline{x}), f(\overline{x})) = Var(f(\overline{x}))$) can be approximated by expanding to linear terms in f, as done earlier:

$$\sigma_f{}^2 = V_{ii} \approx \sum_{i=1}^{n}\sum_{j=1}^{n} \left.\frac{\partial f}{\partial x_i}\right|_{x_i=\overline{x_i}} \left.\frac{\partial f}{\partial x_j}\right|_{x_j=\overline{x_j}} Cov(\overline{x}_i, \overline{x}_j)$$

We should note the first term in the series of f has no bearing on the variance of f. This equation can be restated as:

$$\sigma_f{}^2 = V_{ii} \approx \sum_{i=1}^{n}(\left.\frac{\partial f}{\partial x_i}\right|_{x_i=\overline{x_i}})^2 Var(\overline{x}_i) + \sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} \left.\frac{\partial f}{\partial x_i}\right|_{x_i=\overline{x_i}} \left.\frac{\partial f}{\partial x_j}\right|_{x_j=\overline{x}_j} Cov(\overline{x}_i, \overline{x}_j)\,.$$

The preceding equation represents the most general statement regarding the propagation of error in a function f [3] in terms of the covariance of $\overline{x}$. The formulas in the subsequent section can be derived by employing the prior formula.

4D.3: Statistical Uncertainty

Following the recommendation suggested in the introduction, the total uncertainty should be based on the error propagation of the of the uncertainty of the mean of the differences in $\delta^{13}C \equiv \delta^{13}C_{Downgradient} - \delta^{13}C_{Upgradient}$ and the error in ε, namely,

$$\frac{\Delta(-kt)}{\overline{-kt}} = \frac{\Delta(\ln(C/C_0))}{\overline{\ln(C/C_0)}} = \sqrt{(\frac{\Delta\delta^{13}C}{\overline{\delta^{13}C}})^2 + (\frac{\Delta\varepsilon}{\overline{\varepsilon}})^2 - \frac{2\Delta\delta^{13}C\,\Delta\varepsilon}{\overline{\delta^{13}C\varepsilon}}\rho_{\delta^{13}C\varepsilon}}$$

where the Δ notation represents the error, the over-bar notation represents the mean of the respective parameter and $\rho_{\delta^{13}C\varepsilon}$ is the correlation coefficient. We suggest that $\rho_{\delta^{13}C\varepsilon}$ vanishes, since it is unknown[4] as to whether or not $\delta^{13}C$ and ε are correlated. We assume that the correlation is negligible, and that this approximation is acceptable. The uncertainty in $\delta^{13}C$ should be determined using the Student's *t* statistic;

$$\Delta\delta^{13}C = t_{\alpha(1),3}\, s_{\delta^{13}C}$$

where s is the sample standard deviation, and the t value is one-tailed at 0.10 significance. The sample standard deviation of the $\delta^{13}C$ is determined through a similar propagation of error calculation:

$$s_{\delta^{13}C} = \sqrt{(s_{Cdown})^2 + (s_{Cup})^2 - 2Cov(\delta^{13}C_{down}, \delta^{13}C_{up})}$$

where s_{Cdown} and s_{Cup} are the standard deviations determined by USEPA which implies these quantities assume a value of 0.183. We also are assuming that the Cov quantity in the preceding equation can be neglected in this discussion. The numerical value of $s_{\delta^{13}C}$ can be determined to be 0.25.

Similarly, the uncertainty associated with the ε should be determined using the Student's *t* statistic along with the sample standard deviation, s_ε namely;

$$\Delta\varepsilon = t_{\alpha(1),12}\, s_\varepsilon$$

where the *t* value is the one-tailed at 0.10 significance and the value of s_ε (=.22) was determined from the USEPA revaluation of the Chu, et al (2004) data. The use of the Student's *t* statistic is employed to accurately account for the deficiency arising from the number of samples.

Following the preceding discussion, the uncertainty can be reformulated in the following manner;

---

[3] This expression is exact if f is a linear function.

[4] Without additional data

$$\frac{\Delta(-kt)}{\overline{-kt}} = \frac{\Delta(\ln(C/C_0))}{\overline{\ln(C/C_0)}} = \sqrt{\left(\frac{t_{\alpha(1),3}s_{\delta^{13}C}}{\overline{\delta^{13}C}}\right)^2 + \left(\frac{t_{\alpha(1),12}s_{\varepsilon}}{\bar{\varepsilon}}\right)^2} \ .$$

Let us consider the following average values for $\delta^{13}C$, ε and $\ln(C/C_0)$ namely[5]:

$$\overline{\delta^{13}C} = .30,$$

$$\bar{\varepsilon} = -1.4,$$

$$\overline{\ln(C/C_0)} = -0.27.$$

Utilizing the *t* values from (Zar, 1999), and taking $n = 4$ (although we know in this case $n = 1$) along with the calculated sample standard deviations, we arrive at the following values:

$$s_{\delta^{13}C}t_{.1,3} = .25 * 1.638 = 0.41$$

$$s_{\varepsilon}t_{.1,12} = .22 * 1.356 = 0.30.$$

These values lead to the conclusion that the uncertainty associated with $\ln(C/C_0)$ is:

$$\Delta\ln(C/C_0) = -0.29 \ .$$

4D.4: Discussion

The preceding discussion presented a general procedure to determine the error of propagation as well as a specific example that pertains to the stable carbon isotope data. A particular advantage of this approach is its applicability to a variety of data sets, including the stable hydrogen isotope experiment.

BIBLIOGRAPHY:

Brandt, Siegmund Data analysis: statistical and computational methods for scientists and Engineers 3rd ed. New York Springer, 1999

Zar, Jerrold H. Biostatistical Analysis, 4th ed. New Jersey, Prentice Hall, 1999

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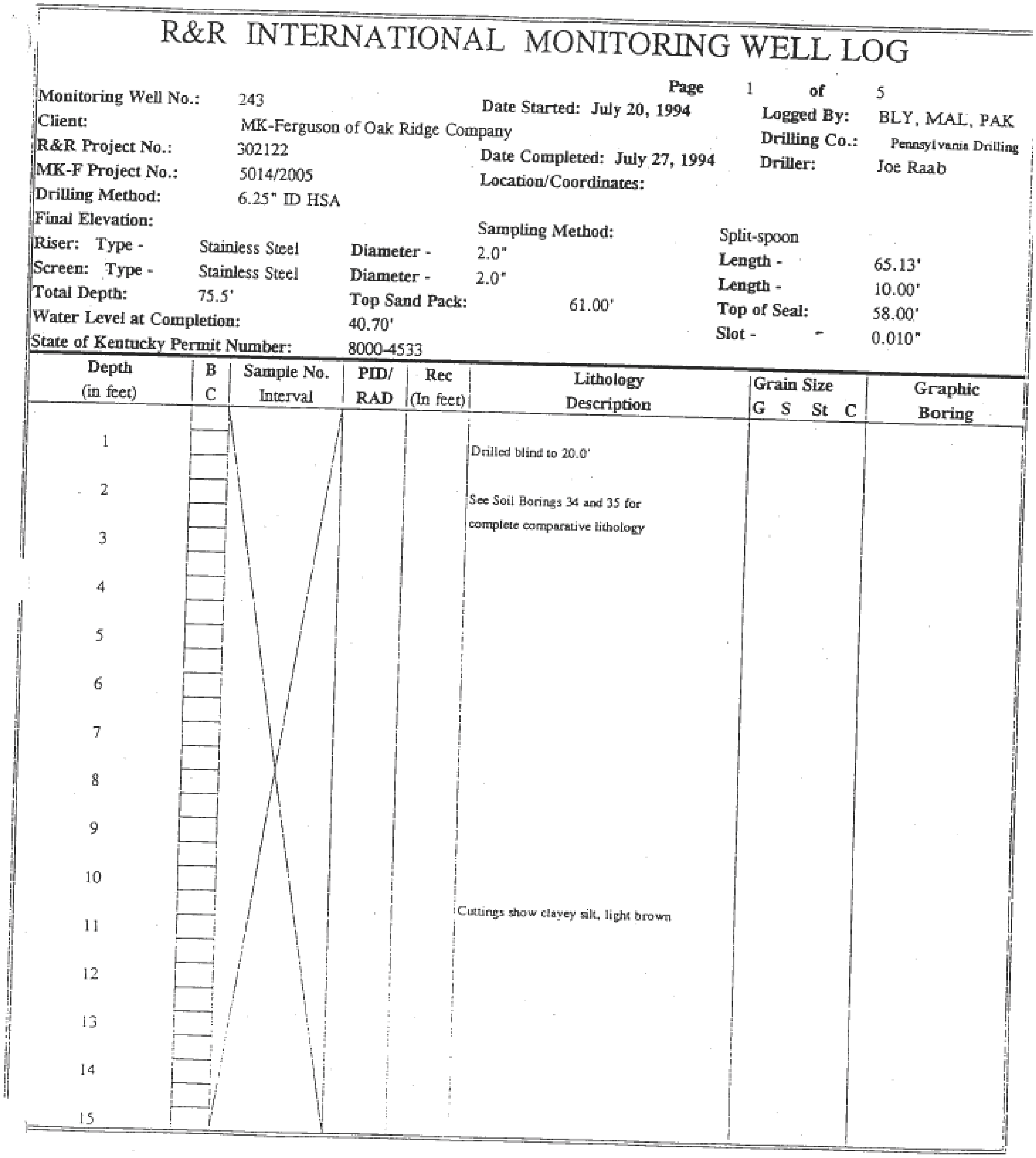
[5] Forgoing units

Appendix 5. Borehole Data

Appendix 5a. Borehole/Well Lithologic Logs (DWGIS)



R&R INTERNATIONAL MONITORING WELL LOG

Page 1 of 5

Monitoring Well No.: 243
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Drilling Method: 6.25" ID HSA
Final Elevation:
Date Started: July 20, 1994
Date Completed: July 27, 1994
Location/Coordinates:
Logged By: BLY, MAL, PAK
Drilling Co.: Pennsylvania Drilling
Driller: Joe Raab
Sampling Method: Split-spoon
Riser: Type - Stainless Steel Diameter - 2.0" Length - 65.13'
Screen: Type - Stainless Steel Diameter - 2.0" Length - 10.00'
Total Depth: 75.5'
Top Sand Pack: 61.00'
Top of Seal: 58.00'
Slot - 0.010"
Water Level at Completion: 40.70'
State of Kentucky Permit Number: 8000-4533

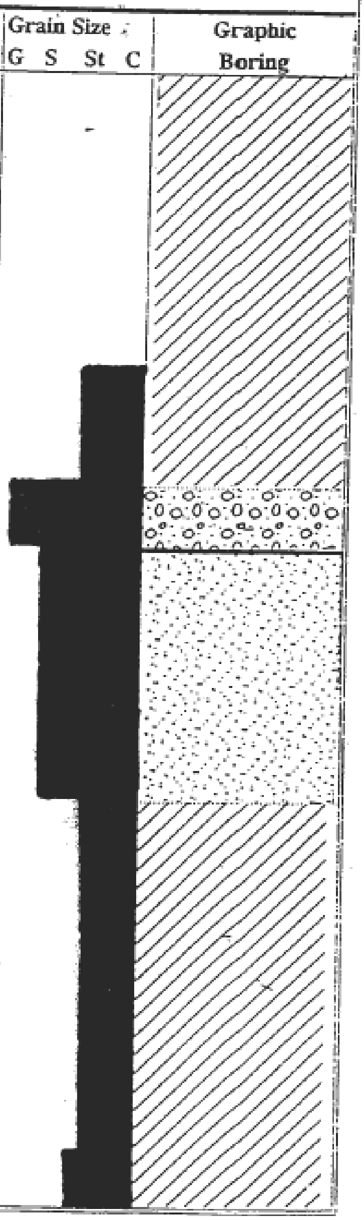
Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
1					Drilled blind to 20.0'		
2					See Soil Borings 34 and 35 for		
3					complete comparative lithology		
4							
5							
6							
7							
8							
9							
10							
11					Cuttings show clayey silt, light brown		
12							
13							
14							
15							

R&R INTERNATIONAL MONITORING WELL LOG

Page 2 of 5

Monitoring Well No.:	243	**Date Started:** July 20, 1994		**Logged By:**	BLY, MAL, PAK
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:** July 27, 1994		**Driller:**	Joe Raab
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description
16					SILT with little clay (10%)
17					
18					
19					
20					CLAY, silty with trace sand seams; mottled gray and yellowish brown (5 Y 5/1 and 7.5 YR 5/8); moist; medium plasticity; soft to stiff
21	1	1	0	1.0'	
	2	(20 - 22)	BKG		
22	10				22.0 - 22.5' GRAVEL (80%) with trace fine to medium sand and clay (10% each); angular to sub-rounded; non-cemented; iron oxidized
23	15	2	0	2.0'	
	25	(22 - 24)	BKG		22.5 - 24.0 SAND (95%) with trace gravel (5%); sub-rounded; well sorted; non-cemented; moist; 7.5 YR 5/8; firm to dense
24	40				
25					
26					
27					
28					
29					
30					
31	4	3	0	2.0'	CLAY (65%), silt (25%), and sand (10%); mottled yellowish gray and brown 5 Y 5/1; and 7.5 YR 5/8; firm to stiff; moist; medium plasticity; fine to medium grained
	8	(30 - 32)	BKG		
32	10				
33	7	4	0	2.0'	clay decreases to 50%, sand increases to 25%



R&R INTERNATIONAL MONITORING WELL LOG

Page 3 of 5

Monitoring Well No.:	243	**Date Started:**	July 20, 1994	**Logged By:**	BLY, MAL, PAK
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:**	July 27, 1994	**Driller:**	Joe Raab
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G	S	St	C	Graphic Boring
	7	(32 - 34)	BKG		silt 25% with trace gravels			■	■	▨
34	7				32.5 - 34.0' sand decreases to 15%; stiff; moist;			■	■	▨
					bottom 0.5' highly plastic			■	■	▨
35	7	5	0	1.6'				■	■	▨
	9	(34 - 36)	BKG					■	■	▨
36	12							■	■	▨
37										▨
38										▨
39										▨
40										▨
41										▨
42										▨
43										▨
44										▨
45										▨
46										▨
47										▨
48										▨
49										▨
50										▨
51	8	6	0	2.0'	CLAY (80%) with trace fine to medium grained sand (10%) and silts (10%)			■	■	▨

R&R INTERNATIONAL MONITORING WELL LOG

Page 4 of 5

Monitoring Well No.:	243	**Date Started:** July 20, 1994		**Logged By:**	BLY, MAL, PAK
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:** July 27, 1994		**Driller:**	Joe Raab
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
	10	(50 - 52)	BKG		CLAY, as above		
52	13				SAND, fine grained; light gray with brown patches; 5 Y 7/6 and 7.5 YR 5/8; well sorted; wet; micaceous; loose; sub-rounded to sub-angular; trace gravel		
		7 (52 - 54)	0 BKG	2.0'			
53	6						
	10						
54	10						
		8 (54 - 56)	0 BKG	2.0'			
55	5						
	5						
56	5						
57							
58							
59							
60							
61							
62							
63							
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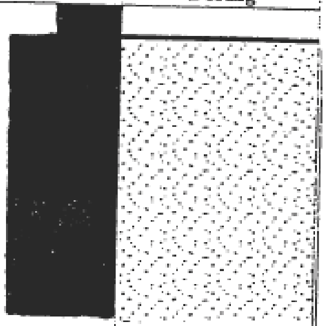

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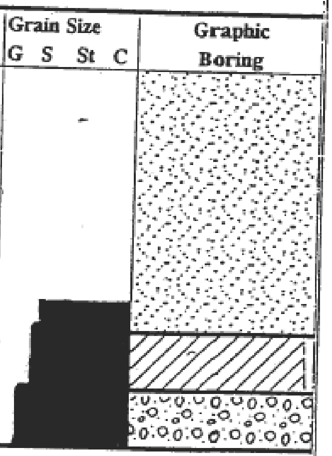
R&R INTERNATIONAL MONITORING WELL LOG

Page 5 of 5

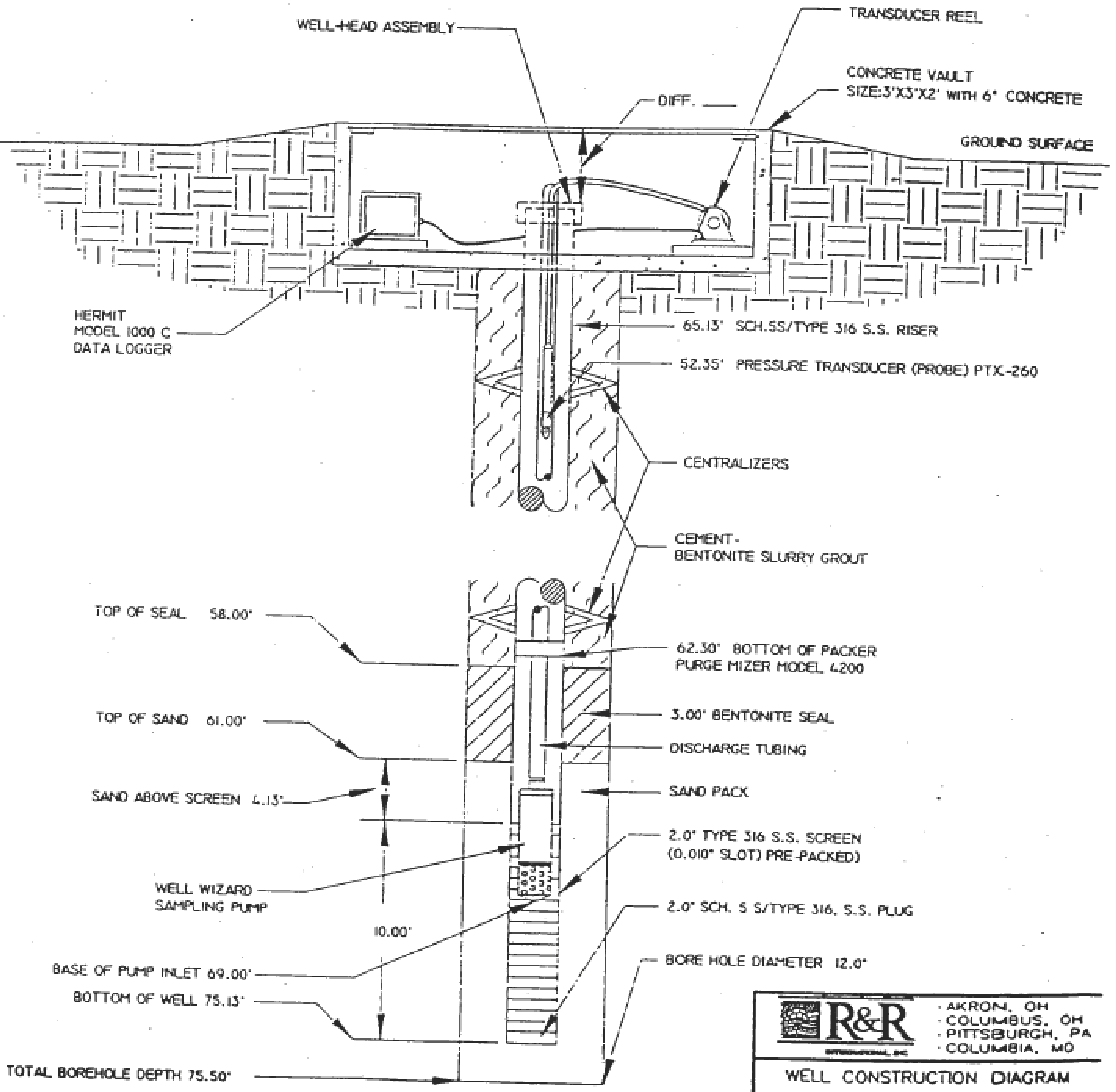
Monitoring Well No.:	243	**Date Started:**	July 20, 1994	**Logged By:**	BLY, MAL, PAK
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:**	July 27, 1994	**Driller:**	Joe Raab
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description
70					
71					
72					
73					SAND, fine-grained, trace silt (5%); brown 10 YR 6/6; sub-rounded; well-sorted; wet
74	10 17	9 (73 - 75)	0 BKG	2.0'	CLAY, with little silt and trace gravel (1%); stiff mottled brown 7.5 YR 4/6 and 10 YR 5/6; mois
75	30				GRAVEL with some sand (20%); round to sub rounded; wet
76					Base of boring at 75.5'
77					
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					

NOTE: Depth of interior well base verified during development; as of 12/15/94 to be 75.13' below T.O.C.



G.S. ELEV. ___
T.O.C. ELEV. ___



LEGEND

NOT TO SCALE

* WELL VAULT AS-BUILT DRAWINGS REFERENCE CSE-59001-001

R&R
INTERNATIONAL, INC

· AKRON, OH
· COLUMBUS, OH
· PITTSBURGH, PA
· COLUMBIA, MO

WELL CONSTRUCTION DIAGRAM

MONITORING WELL NO. MW-243

NORTHWEST PLUME-SOUTH FIELD

PADUCAH GASEOUS DIFFUSION PLANT

S.O.K. PERMIT NO. 8000-4533

R&R INTERNATIONAL MONITORING WELL LOG

Page 1 of 6

Monitoring Well No.: 242
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Drilling Method: 6.25" ID HSA/6.0" OD SSA
Final Elevation:
Riser: Type - Stainless Steel **Diameter -** 2.0" **Length -** 65.10'
Screen: Type - Stainless Steel **Diameter -** 2.0" **Length -** 10.00'
Total Depth: 75.00' (97.30') **Top Sand Pack:** 63.00' **Top of Seal:** 58.00'
Water Level at Completion: 42.40' **Slot -** 0.010"
State of Kentucky Permit Number: 8000-4543

Date Started: August 16, 1994
Date Completed: August 19, 1994
Location/Coordinates:
Sampling Method: Split-spoon
Logged By: LJS
Drilling Co.: Pennsylvania Drilling
Driller: C. Coulter

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
1					Drilled blind to 20.0'		
2					See Soil Borings 30 and 31 for		
3					complete comparative lithology		
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

R&R INTERNATIONAL MONITORING WELL LOG

Page 2 of 6

Monitoring Well No.: 242
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Date Started: August 16, 1994
Date Completed: August 19, 1994
Location/Coordinates:
Logged By: LJS
Drilling Co.: Pennsyl vania Drilling
Driller: C. Coul ter

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
16							
17							
18							
19							
20							
21	12 20	1 (20 - 22)	0 BKG	1.45'	CLAY (70%) with some silt (30%); light brown (10 YR 6/3 - 6/4); damp to moist; very stiff		
22	50/5				GRAVEL (65%) with some fine grained, subrounded sand (25%) and trace silt (10%); gravel is subangular; very dense		
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							

R&R INTERNATIONAL MONITORING WELL LOG

Page 4 of 6

Monitoring Well No.:	242	**Date Started:**	**August 16, 1994**	**Logged By:**	LJS
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:**	**August 19, 1994**	**Driller:**	C. Coulter
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
52							
53							
54							
55							
56	7 8	2 (55 - 57)	0 BKG	2.3'	CLAY (85%) with little fine grained rounded sand (15%); mottled light gray and orangish brown (10 YR 6/1 and 6/8); moist; firm		
57	24						
58					SAND (95%) fine grained, rounded with trace silt (5%); firm (last 0.3')		
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							

R&R INTERNATIONAL MONITORING WELL LOG

Page 5 of 6

Monitoring Well No.:	242	**Date Started:** August 16, 1994		**Logged By:**	LJS
Client:	MK-Ferguson of Oak Ridge Company			**Drilling Co.:**	Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:** August 19, 1994		**Driller:**	C. Coulter
MK-F Project No.:	5014/2005	**Location/Coordinates:**			

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
70							
71							
72							
73							
74							
75							
76	14 14 14	3 (75 - 77)	0 BKG	1.65'	GRAVEL (50%) and SAND (45%) with trace silt (5%); sand is medium grained; gravel is subangular; medium brown (10 YR 6/6); wet firm		
77							
78							
79							
80							
81							
82							
83							
84							
85							
86							
87							

R&R INTERNATIONAL MONITORING WELL LOG

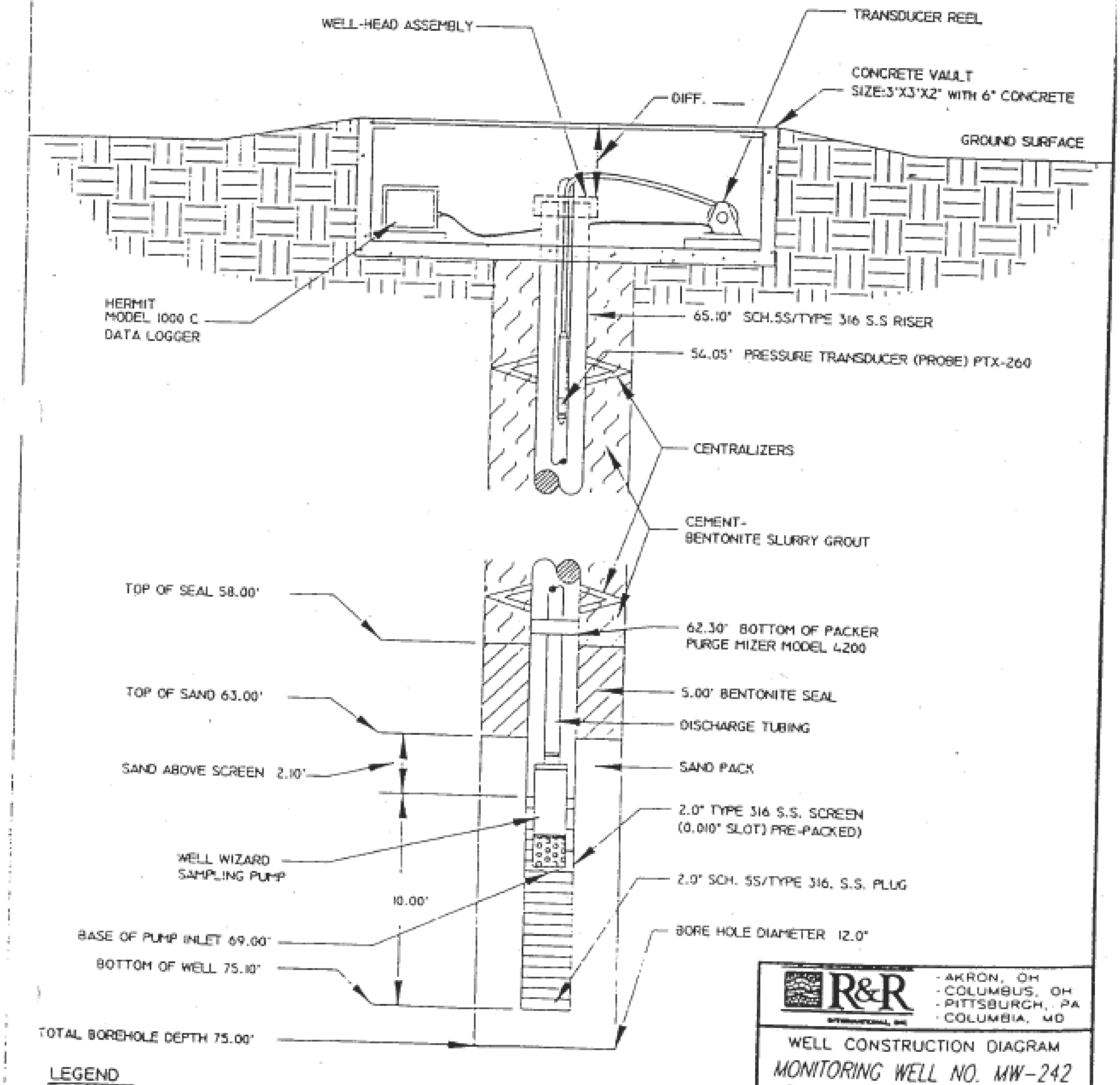
Page 6 of 6

Monitoring Well No.: 242
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Date Started: August 16, 1994
Date Completed: August 19, 1994
Location/Coordinates:
Logged By: LJS
Drilling Co.: Pennsylvania Drilling
Driller: C. Coulter

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
88							
89							
90							
91							
92							
93							
94							
95							
96	12 17	4 (95 - 97)	0 BKG	2.3'	Same as above to 1.4'		
97	21				CLAY (80%) with silt (20%); very stiff		
98					SAND (90%) with trace silt (10%); sand is fine grained; firm; wet		
99					Base of boring at 97.3'		
100							
101							
102							
103							
104							
105							
106							

NOTE: Depth of interior well base verified during development; as of 12/15/94 to be 75.10' below T.O.C.

G.S. ELEV. ___
T.O.C. ELEV. ___

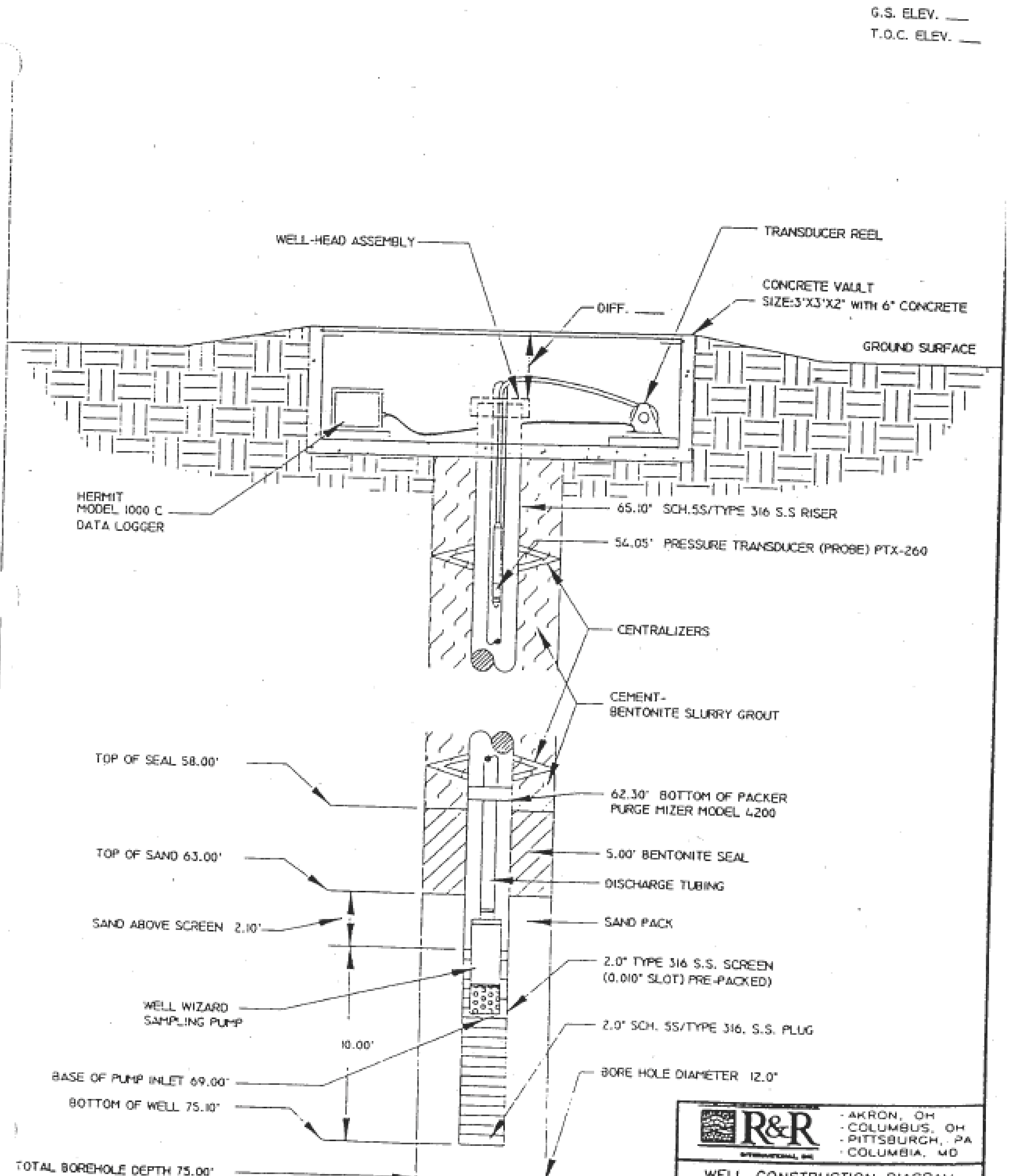


R&R
- AKRON, OH
- COLUMBUS, OH
- PITTSBURGH, PA
- COLUMBIA, MD

WELL CONSTRUCTION DIAGRAM
MONITORING WELL NO. MW-242
NORTHWEST PLUME-SOUTH FIELD
PADUCAH GASEOUS DIFFUSION PLANT
S.O.K. PERMIT NO. 8000-4343

LEGEND

NOT TO SCALE
* WELL VAULT AS-BUILT DRAWINGS REFERENCE C5E-59001-001



LEGEND

NOT TO SCALE

* WELL VAULT AS-BUILT DRAWINGS REFERENCE C5E-59001-001

R&R INTERNATIONAL, INC.
- AKRON, OH
- COLUMBUS, OH
- PITTSBURGH, PA
- COLUMBIA, MD

WELL CONSTRUCTION DIAGRAM
MONITORING WELL NO. MW-242
NORTHWEST PLUME-SOUTH FIELD
PADUCAH GASEOUS DIFFUSION PLANT
S.O.K. PERMIT NO. 8000-4343

R&R INTERNATIONAL MONITORING WELL LOG

Page 1 of 5

Monitoring Well No.: 236
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Drilling Method: 6.25" ID HSA/6.0" OD SSA
Final Elevation:
Riser: Type - Stainless Steel **Diameter -** 2.0" **Length -** 69.50'
Screen: Type - PP Stainless Steel **Diameter -** 2.0" **Length -** 10.00'
Total Depth: 80.00' **Top Sand Pack:** 66.00' **Top of Seal:** 62.00'
Water Level at Completion: 45.16' TOC **Slot -** 0.010"
State of Kentucky Permit Number: 8001-5999

Date Started: Sept. 8, 1994
Date Completed: Sept. 9, 1994
Location/Coordinates:
Sampling Method: Split-spoon

Logged By: PAK
Drilling Co.: Pennsylvania Drilling
Driller: C. Coulter
B. Gollihue

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
1					Drilled blind to 70.0'		
2					See Soil Boring 29 for complete comparative lithology		
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

R&R INTERNATIONAL MONITORING WELL LOG

Page 2 **of** 5

Monitoring Well No.: 236
Client: MK-Ferguson of Oak Ridge Company
R&R Project No.: 302122
MK-F Project No.: 5014/2005
Date Started: Sept. 8, 1994
Date Completed: Sept. 9, 1994
Location/Coordinates:
Logged By: PAK
Drilling Co.: Pennsylvania Drilling
Driller: C. Coulter
B. Gollihue

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
16					Drilled blind to 70.0'		
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							

R&R INTERNATIONAL MONITORING WELL LOG

Page 3 of 5

Monitoring Well No.:	236	**Date Started:** Sept. 8, 1994	**Logged By:** PAK
Client:	MK-Ferguson of Oak Ridge Company		**Drilling Co.:** Pennsylvania Drilling
R&R Project No.:	302122	**Date Completed:** Sept. 9, 1994	**Driller:** C. Coulter B. Gollihue
MK-F Project No.:	5014/2005	**Location/Coordinates:**	

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
34					Drilled blind to 70.0'		
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50							
51							

R&R INTERNATIONAL MONITORING WELL LOG

Page 4 of 5

Monitoring Well No.: 236
Date Started: Sept. 8, 1994
Logged By: PAK
Client: MK-Ferguson of Oak Ridge Company
Drilling Co.: Pennsylvania Drilling
R&R Project No.: 302122
Date Completed: Sept. 9, 1994
Driller: C. Coulter
B. Gollihue
MK-F Project No.: 5014/2005
Location/Coordinates:

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
52					Drilled blind to 70.0'		
53							
54							
55							
56							
57							
58							
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							

R&R INTERNATIONAL MONITORING WELL LOG

Page 5 of 5

Monitoring Well No.: 236

Client: MK-Ferguson of Oak Ridge Company

R&R Project No.: 302122

MK-F Project No.: 5014/2005

Date Started: Sept. 8, 1994

Date Completed: Sept. 9, 1994

Location/Coordinates:

Logged By: PAK

Drilling Co.: Pennsylvania Drilling

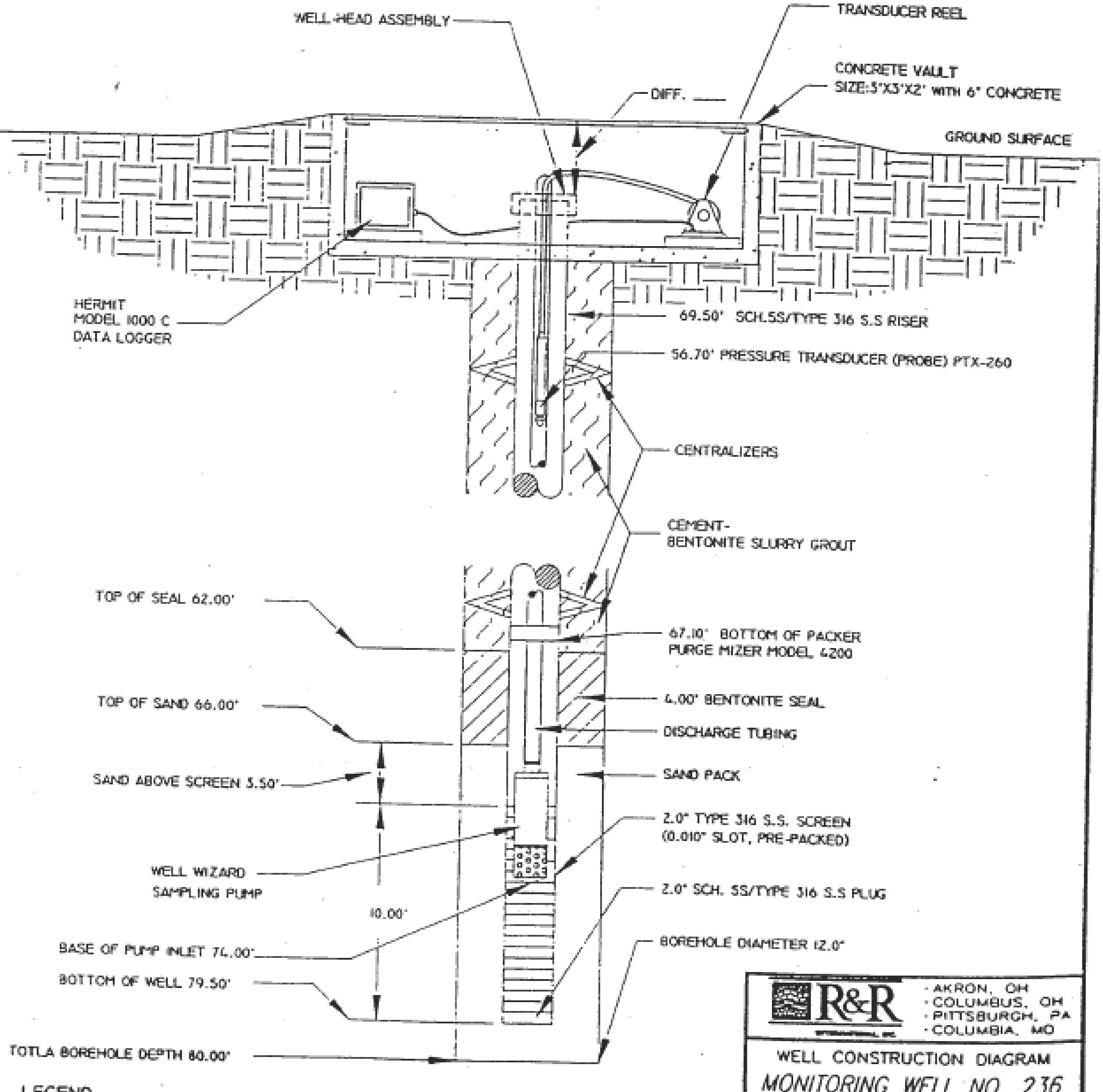
Driller: C. Coulter
B. Gollihue

Depth (in feet)	B C	Sample No. Interval	PID/ RAD	Rec (In feet)	Lithology Description	Grain Size G S St C	Graphic Boring
70					SAND (90%) with trace clay (10%); subangular to subrounded; fine; well-sorted; reddish yellow w/mottled brown; loose; wet; firm		
71	16 14	1 (70 - 72)	0 BKG	2.0'			
72	41				GRAVEL (75%) with some sand (25%); gravel is angular to subrounded; sand is well-sorted; subangular to subrounded; reddish yellow w/ mottled gray (7.5 YR 6/8 and 10 YR 6/1); chert fragments; gravel is poorly sorted		
73							
74							
75							
76							
77							
78							
79							
80							
81							
82							
83							
84							
85							
86							
87							

Base of boring at 80.00'

NOTE: Depth of interior well base verified during development: as of 12/15/94 to be 79.50' below T.O.C.

G.S. ELEV. ___
T.O.C. ELEV. ___



LEGEND

NOT TO SCALE

* WELL VAULT AS-BUILT DRAWINGS REFERENCE CSE-59001-001

R&R
- AKRON, OH
- COLUMBUS, OH
- PITTSBURGH, PA
- COLUMBIA, MO

WELL CONSTRUCTION DIAGRAM

MONITORING WELL NO. 236

NORTHWEST PLUME-NORTH FIELD

PADUCAH GASEOUS DIFFUSION PLANT

S.O.K PERMIT NO. 8001-3999

7/25/95 | [illegible] | [illegible] | [illegible]

PROJECT NUMBER	BORING NUMBER
ORO 30888.FI	MW-168 SHEET 1 OF 3

SOIL BORING LOG

PROJECT PGDP Phase II Site Investigation LOCATION Diesel Spill Area, near Virgina and 10th St.

ELEVATION 2" TOC 377.42 ft. MSL DRILLING CONTRACTOR Brotcke Engineering

DRILLING METHOD AND EQUIPMENT 75 CME, 12" CFA, 7 3/4" OD auger, 5'x 3"ID sampler

WATER LEVELS ______ START 12/20/90 FINISH 01/14/91 LOGGER D Geshwender

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY		DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	0 to 5	5' Continuous	2.1		Top 1.2': Lean Clay (CL); reddish brown, moist, mottling. Bottom 0.9': Lean Clay (CL); gray, moist, stiff.		Background: HNu=0 ppm, RAD=25 cpm PP = pocket penetrometer
5	5 to 10	5' Continuous 13017	4.6		Lean Clay (CL); gray, moderate reddish brown mottling, moist.		HNu=0, RAD=background
10	10 to 15	5' Continuous	5.0		Lean Clay (CL); yellowish brown, reddish brown mottling, moist.		HNu=3 ppm, RAD=background
15	15 to 20	5' Continuous	2.0		Top 1.2': Lean Clay (CL); yellowish brown, mottling, moist. Bottom 0.8': Poorly Graded Gravel (GP); with sand, brown, moist.		HNu=0, RAD=background
20	20 to 25	5' Continuous	3.4		Well Graded Sand (SW); with gravel, reddish brown, wet, sand is coarse grained.		HNu=0, RAD=background
25	25 to 30	5' Continuous 13018	5.0		Top 0.6': Well Graded Sand (SW); with gravel, same as above. Bottom 4.4': Lean Clay (CL); yellowish brown, gray mottling, moist.		HNu=0, RAD=background

PROJECT NUMBER	BORING NUMBER
ORO 30888.FI	MW-168 SHEET 2 OF 3

SOIL BORING LOG

PROJECT PGDP Phase II Site Investigation

LOCATION Diesel Spill Area, near Virgina and 10th St.

ELEVATION 2" TOC 377.42 ft. MSL

DRILLING CONTRACTOR Brotcke Engineering

DRILLING METHOD AND EQUIPMENT 75 CME, 12" CFA, 7 3/4" OD auger, 5'x 3"ID sampler

WATER LEVELS

START 12/20/90

FINISH 01/14/91

LOGGER D Geshwender

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY		DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	30 to 35	5' Continuous 13019	5.0		Top 3.9': Lean Clay (CL); same as above. Bottom 1.1': Clayey Sand (SC); with gravel, moderately yellowish brown, moist.		HNu=0, RAD=background
35	35 to 40	5' Continuous	5.0		Top 1': Clayey Sand with Gravel (SC); same as above except mottling. Bottom 4': Lean Clay (CL); moderately reddish brown, moist.		HNu=couldn't get a reading RAD=background PP = 2.5 Kg/cm2
40	40 to 45	5' Continuous	5.0		Lean Clay with Sand (CL); reddish brown, wet.		HNu=no reading RAD=background PP = 1.5 Kg/cm2
45	45 to 50	5' Continuous	5.0		Lean Clay (CL); reddish brown, moist.		HNu=couldn't get a reading RAD=background PP = 1.8 Kg/cm2
50	50 to 55	5' Continuous	3.7		Clayey Sand (SC); reddish brown, moist.		HNu=0, RAD=background PP = 0.75 Kg/cm2 1.3' of slough
55	55 to 60	5' Continuous	5.0		Lean Clay with Sand (CL); moderate gray with mottling, moist.		HNu=0, RAD=background PP = 0.75 to 1.5 Kg/cm2

PROJECT NUMBER
ORO 30888.FI

BORING NUMBER
MW-168

SHEET 3 OF 3

SOIL BORING LOG

PROJECT PGDP Phase II Site Investigation LOCATION Diesel Spill Area, near Virgina and 10th St.

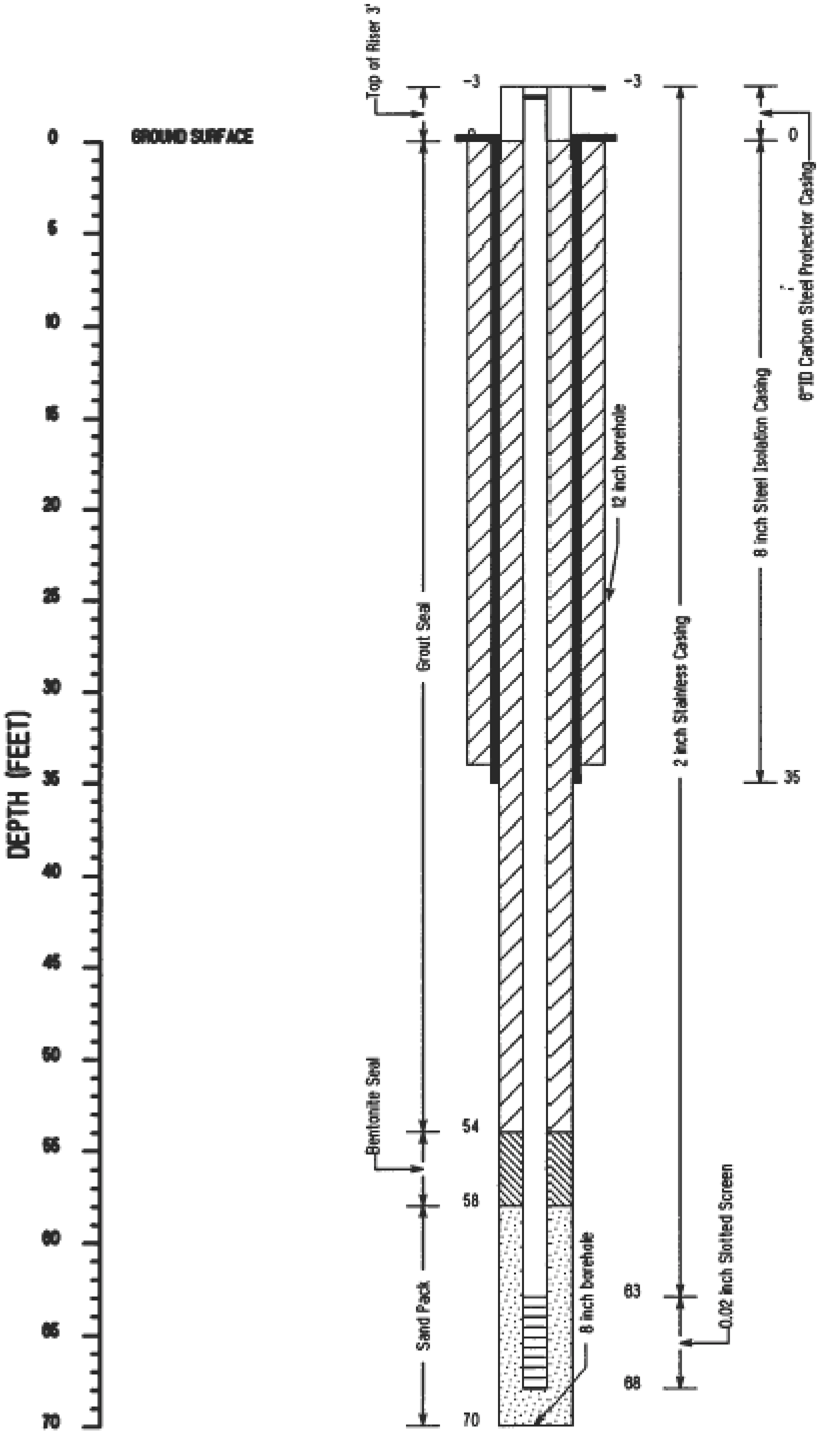
ELEVATION 2" TOC 377.42 ft. MSL DRILLING CONTRACTOR Brotcke Engineering

DRILLING METHOD AND EQUIPMENT 75 CME, 12" CFA, 7 3/4" OD auger, 5'x 3"ID sampler

WATER LEVELS ____ START 12/20/90 FINISH 01/14/91 LOGGER D Geshwender

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY		DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	60 to 65	5' Continuous	1.1		Poorly Graded Sand (SP); with trace gravel, moderate reddish brown, wet ------------?????----------- Well Graded Gravel (GW)		HNu=0, RAD=background Cobble in sampler. Driller thinks he was drilling in gravel.
65	65 to 70	5' Continuous	2.0		Well Graded Gravel (GW); yellowish brown-reddish brown, wet.		HNu=0, RAD=background
70					Total Depth = 70.0 feet		
75							
80							
85							

(See Logbook # 27)



WELL CONSTRUCTION DETAILS
WELL MW-188
ELEVATION: 2" TOC 377.42 ft. MSL

PGDP Phase II Site Investigation
Diesel Spill Area, near Virgina and 10th St.

CH2MHILL

PROJECT NUMBER	BORING NUMBER	
ORO30888.B1	MW194	SHEET 1 OF 2

SOIL BORING LOG

PROJECT PGDP Phase II Site Investigation LOCATION Off Site, Next to Big Bayou Creek
ELEVATION 353.76 NGVD DRILLING CONTRACTOR Brotcke Engineering Co., Inc.
DRILLING METHOD AND EQUIPMENT CME 75 Rig; 7-3/4" OD CME Augers; 3"x5' CME Stainless Steel Sampler
WATER LEVEL AND DATE N/A START 3/7/91 08:00 FINISH 3/8/91 13:15 LOGGER J. Anderson

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
					GRAVEL DRILL PAD	▨	Bkgd: OVA=0 ppm; Rad=40 cpm
	0-5	5' Continuous	3.5	N/A	LEAN CLAY (CL), dark yellow brown (10 YR 4/2), moist; organics and trace gravel present in top 2'	▨	OVA = 0 ppm Rad = 50 cpm Pocket Pen (P.P.) = 0.4-1.7 kg/cm^2
5	5-10	5' Continuous	2.9	N/A	SILT W/SAND (ML), grayish orange (10 YR 7/4), moist	▨ ▥	OVA = 0 ppm Rad = 35 cpm P.P. = 2.5-4.5+ kg/cm^2
10	10-15	5' Continuous	0.5	N/A	POORLY GRADED SAND (SP), moderate yellow brown (10 YR5/4), wet ? —— ? —— ? —— ? —— ? WELL GRADED GRAVEL W/SAND (GW), moderate yellow brown (10 YR 5/4), wet; subrounded gravel	░ ⁘	OVA = 0 ppm Rad = 35 cpm P.P. = N/A (gravel)
15	15-20	5' Continuous	5.0	N/A	FAT CLAY (CH), dark yellow orange (10 YR 6/6), moist; grades leaner and mottles moderately red brown (10 R 4/6) past 19'	▨	OVA = 0 ppm Rad = 60 cpm P.P. = 3.7-4.5+ kg/cm^2
20	20-25	5' Continuous	5.0	N/A	FAT CLAY (CH), moderate red brown (10 R 4/6), mottling light gray (N7), moist	▨	OVA = 0 ppm Rad = 40 cpm P.P. = 3.2-3.5 kg/cm2
25	25-30	5' Continuous	5.0	N/A	LEAN CLAY (CL), light brown (5 YR 5/6), mottling light gray (N7), moist	▨	OVA = 0 ppm Rad = 30 cpm P.P. = 2.0-2.7 kg/cm2
30							

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
ORO30888.B1	MW194	SHEET 2 OF 2

SOIL BORING LOG

PROJECT PGDP Phase II Site Investigation LOCATION Off Site, Next to Big Bayou Creek
ELEVATION 353.76 NGVD DRILLING CONTRACTOR Brotcke Engineering Co., Inc.
DRILLING METHOD AND EQUIPMENT CME 75 Rig; 7-3/4" OD CME Augers; 3"x5' CME Stainless Steel Sampler
WATER LEVEL AND DATE N/A START 3/7/91 08:00 FINISH 3/8/91 13:15 LOGGER J. Anderson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	30-35	5' Continuous	4.7	N/A	LEAN CLAY W/ SAND (CL), light brown (5 YR 5/6), mottled light gray (N7), moist; grades to SANDY LEAN CLAY (CL) past 33'	▨	OVA = 0 ppm Rad = 40 cpm P.P. = 0.2-0.7 kg/cm^2
35	35-40	5' Continuous	3.2	N/A	POORLY GRADED SAND (SP), light brown (5 YR 5/6), wet, fine sand	░	OVA = 0 ppm Rad = 35 cpm P.P. = N/A (sand)
40	40-45	5' Continuous	4.1	N/A	POORLY GRADED SAND (SP), same as above, with CLAYEY SAND pockets from 42-43'	░	OVA = 0 ppm Rad = 50 cpm P.P. = N/A (sand)
45	45-50	5' Continuous	2.2	N/A	WELL GRADED GRAVEL W/SAND (GW), light brown (5 YR 5/6), wet	░ ⁘	OVA = 0 ppm Rad = 35 cpm P.P. = N/A (gravel)
50	50-55	5' Continuous	2.0	N/A	WELL GRADED GRAVEL W/SAND (GW), same as above	⁘	OVA = 0 ppm Rad = 40 cpm P.P. = N/A (gravel)
55					End of Boring		
60							

LOG OF BORING NO. 66
SHEET 1 OF 1

EDGe
Engineering, Design & Geosciences Group, Inc.

MCI Consulting Engineers
Geologic Associates

Project No. 2211710
Project No. 85-375F

SURFACE ELEVATION 368.58
BOTTOM OF HOLE; DEPTH: 63.0
ELEVATION: 305.6
BORING LOCATION: 934.4 N, 7071.8 W
COMPLETION DATE: 8-27-86

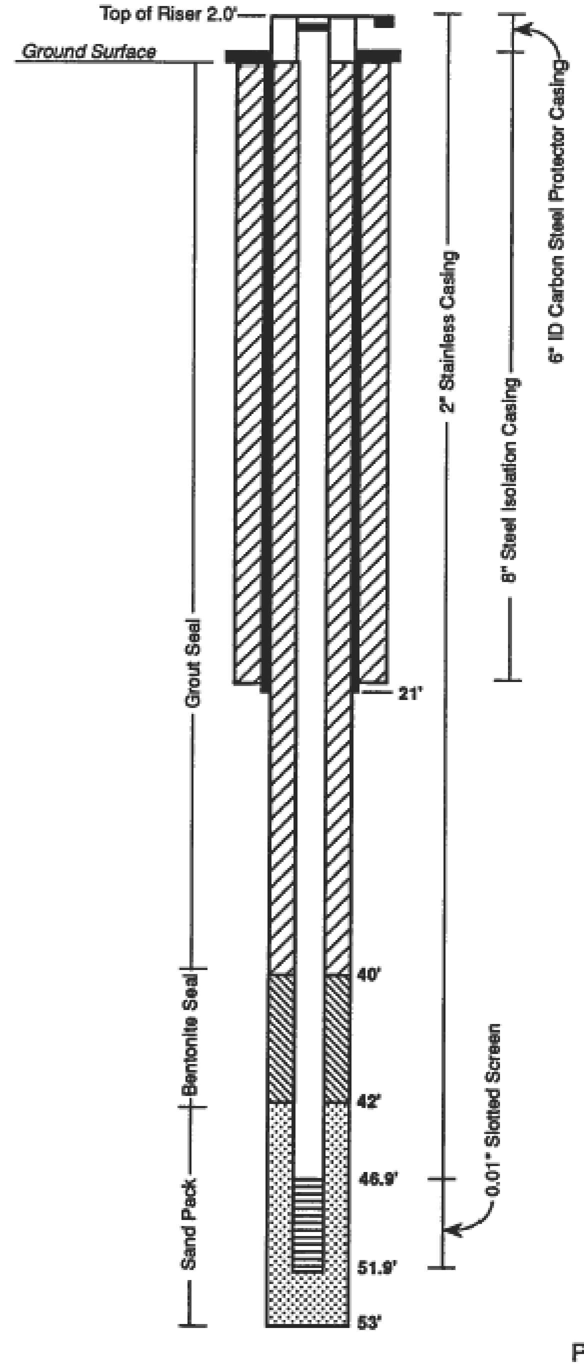
PROJECT:
Martin Marietta Energy Systems
Paducah Gaseous Diffusion Plant, Kentucky
Ground Water Monitoring
Project No. ESO 16380

DRILLER Keith Campbell
HELPER A.L. Clark Staff
DRILL RIG Ingersol Rand TH 60
DRILLED FOR C.M. Johnson
LOGGED BY W.S. Anderson

LITHOLOGY BREAK	SAMPLE NO.	FROM	TO	SAMPLE BLOWS*	DESCRIPTIONS AND REMARKS
18 (1)		0.0	3.0		Clay, very sandy, silty, brown (Fill)
± 18		3.0	15.0		Probably clay, silty, sandy , brown
		15.0 350	18.5		Probably clay, very sandy, silty with occasional cobbles (17.9 - 18.5 ± cobbles)
13.5 (2)	1	18.5	20.0	25-26-32	Sand, coarse and gravel, silty, clayey, brown 66% G, 9% M+C, 25% S ●
		20.0	28.5		Sand, variably coarse to fine, silty, brown
31.5	2	28.5 337	30.0	4-12-18	Sand, fine to very fine, silty, variably clayey, brown 0G, 39% M+C, 61% S ●
		30.0	31.5		Sand, fine to very fine, silty, variably clayey, brown
		31.5	34.0		Probably clay, sandy, silty, brown
		34.0	35.0		Probably sand lense
19.5 (3)		35.0	38.5		Probably clay, sandy, silty, brown
	3	38.5	40.0	5-7-9	0G, 89% M+C, 11% S (45% C) Clay, slightly sandy, slightly silty, light reddish-brown mottled gray ●
		40.0	48.5		Clay, variably sandy, slightly silty, light reddish-brown mottled gray with occasional sand seams (41.0 - 42.0)
	4	48.5	50.0	5-7-10	Clay, variably silty, slightly sandy, light gray 0G, 72% M+C, 28% S, (26% C) ●
51		50.0	51.0 318		Clay, variably silty, slightly sandy, light gray
3 (4)		51.0	54.0 315		Probably sand, very silty
54		54.0	58.5		Probably coarse sand and gravel
[illegible]	5	58.5	59.3	21-50/0.3	Gravel and coarse sand, slightly silty, brown (mechanically crushed during D.S.)
(5)		59.3	63.0		Gravel and coarse sand, slightly silty, brown (Clean out for screen target 60-55)
					Boring terminated at 63.0 feet

* NUMBER OF BLOWS PER 6" INTERVALS. TO DRIVE 1-3-8 I.D., 2" O.D. SPLIT BARREL SAMPLER WITH 140 POUND HAMMER FALLING 30 INCHES (AS PER ASTM D 1586)

● DENOTES GRAIN SIZE ANALYSIS AS PER ASTM D 422-63 (R72)



WELL CONSTRUCTION DETAILS
MW194

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY
PHASE II SITE INVESTIGATION

LOG OF BORING NO. 66
SHEET 1 OF 1

EDGe
Engineering, Design & Geosciences Group, Inc.

MCI Consulting Engineers — Project No. 2211710
Geologic Associates — Project No. 85-375F

SURFACE ELEVATION	368.58
BOTTOM OF HOLE; DEPTH:	63.0
ELEVATION:	305.6
BORING LOCATION:	934.4 N, 7071.8 W
COMPLETION DATE:	8-27-86

PROJECT:
Martin Marietta Energy Systems
Paducah Gaseous Diffusion Plant, Kentucky
Ground Water Monitoring
Project No. ESO 16380

DRILLER	Keith Campbell
HELPER	A.L. Clark Staff
DRILL RIG	Ingersol Rand TH-60
DRILLED FOR	C.M. Johnson
LOGGED BY	W.S. Anderson

LITHOLOGY BREAK	SAMPLE NO.	FROM	TO	SAMPLE BLOWS*	DESCRIPTIONS AND REMARKS
18 (1)		0.0	3.0		Clay, very sandy, silty, brown (Fill)
±18		3.0	15.0		Probably clay, silty, sandy , brown
		15.0 350	18.5		Probably clay, very sandy, silty with occasional cobbles (17.9 - 18.5 ± cobbles)
13.5 (2)	1	18.5	20.0	25-26-32	Sand, coarse and gravel, silty, clayey, brown 66% G, 9% M+C, 25% S ●
		20.0	28.5		Sand, variably coarse to fine, silty, brown
31.5	2	28.5 337	30.0	4-12-18	Sand, fine to very fine, silty, variably clayey, brown 0G, 39% M+C, 61% S ●
		30.0	31.5		Sand, fine to very fine, silty, variably clayey, brown
		31.5	34.0		Probably clay, sandy, silty, brown
		34.0	35.0		Probably sand lense
19.5 (3)		35.0	38.5		Probably clay, sandy, silty, brown
	3	38.5	40.0	5-7-9	0G, 89% M+C, 11% S (45% C) Clay, slightly sandy, slightly silty, light reddish-brown mottled gray ●
		40.0	48.5		Clay, variably sandy, slightly silty, light reddish-brown mottled gray with occasional sand seams (41.0 - 42.0)
	4	48.5	50.0	5-7-10	Clay, variably silty, slightly sandy, light gray 0G, 72% M+C, 28% S, (26% C) ●
51		50.0	51.0 2/3		Clay, variably silty, slightly sandy, light gray
3 (4)		51.0	54.0-315		Probably sand, very silty
54		54.0	58.5		Probably coarse sand and gravel
[illegible]	5	58.5	59.3	21-50/0.3	Gravel and coarse sand, slightly silty, brown (mechanically crushed during D.S.)
(5)		59.3	63.0		Gravel and coarse sand, slightly silty, brown (Clean out for screen target 60-55)
					Boring terminated at 63.0 feet

* NUMBER OF BLOWS PER 6" INTERVALS, TO DRIVE 1-3-8 I.D., 2" O.D. SPLIT BARREL SAMPLER WITH 140 POUND HAMMER FALLING 30 INCHES (AS PER ASTM D 1586)

● DENOTES GRAIN SIZE ANALYSIS AS PER ASTM D 422-63 (R72)

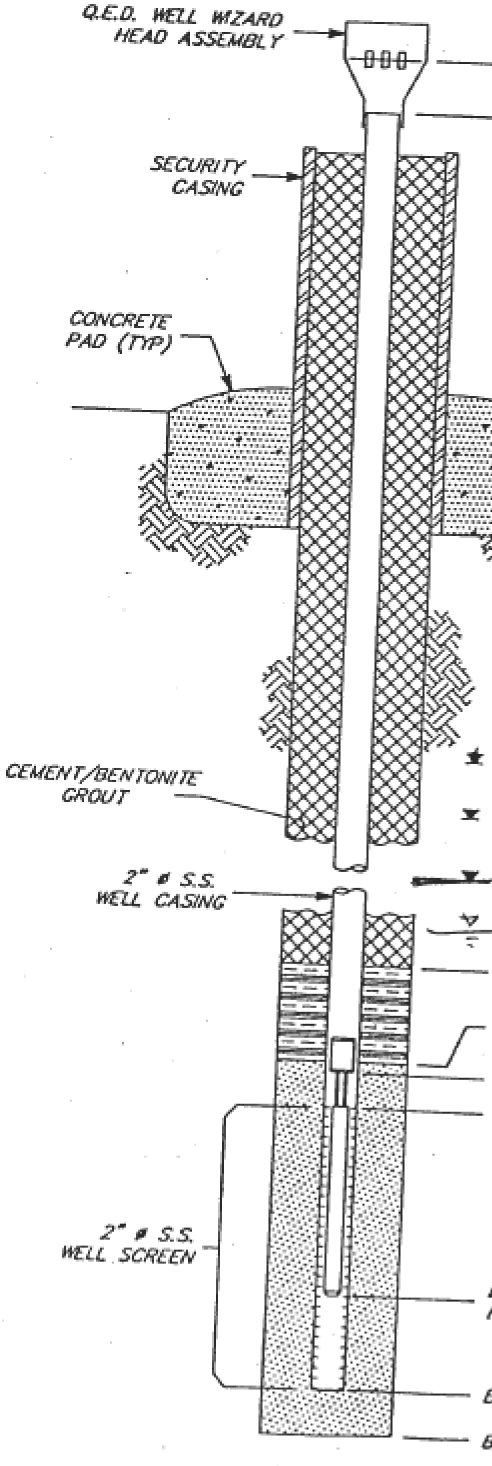
IN VICINITY OF 65,69,65

MONITORING WELL NO. 66

MONITORING WELL COORDINATES 934.4 N / 7071.8 W

INSTALLATION DATE 8-27-86

MARTIN MARIETTA
PADUCAH GDP, KY
PROJECT NO. ESO 16380



	±VERTICAL	ELEVATION
HEAD PLATE	+2.98	371.56
TOP OF S.S. CASING	+2.49	371.07
GROUND SURFACE	0.0	368.58
★ WATER LEVEL @ 1 HR	−39.7	328.9
WATER LEVEL @ 48 HR	−39.4	329.2
WATER LEVEL @ 10:44 AM 10-2-86	−40.72	327.9 5
10/89		322.2
TOP OF BENTONITE PELLETS	−51.0	317.6
TOP OF GRAVEL/SAND PACK	−53.0	315.6
BOTTOM OF PURGE MISER PACKER	−53.7	314.9
TOP OF SCREEN	−55.2	313.4
BOTTOM OF BLADDER PUMP	−58.6	310.0
BOTTOM OF WELL/SCREEN	−60.2	308.4
BOTTOM OF BORING	−64.0	304.6

RGA 59'-63TD (9+TO

Screen TOP 5'

all G w/s

PGDP WAG 22

WELL INSTALLATION DIAGRAM

WELL NO. MW-340

LOGGED BY: John Tillson

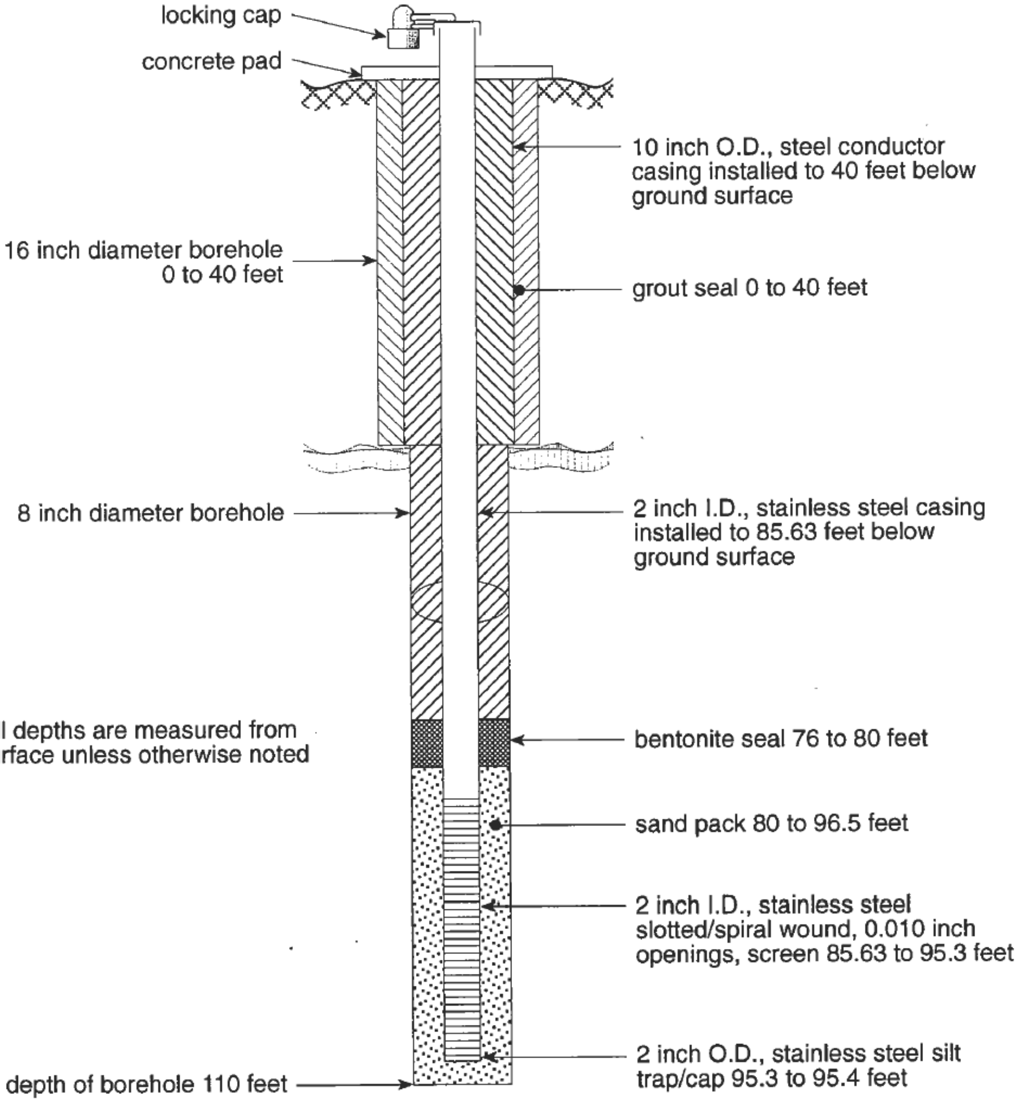
DRILLING COMPANY: Miller Drilling Co., Inc.

DRILLER: Todd Neel

DRILLING DATES

STARTED: 07/09/96

FINISHED: 09/20/96



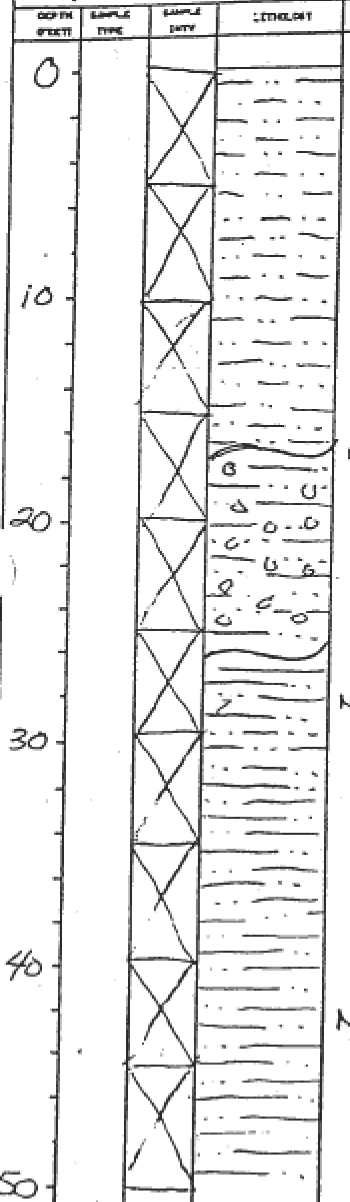
NOTE: All depths are measured from ground surface unless otherwise noted

Not To Scale

Borehole Summary Information

ornl OAK RIDGE NATIONAL LABORATORY

Prepared By: Sm Smith Date: 9-15-94 Page: 1 OF 3
Hole No.: P4 G11 Ground Elevation:
Total Depth: Rig Type: Ingersol Rand Th-[illegible] Location: PGDP
13 ¼ Auger Size: 4 ¾" Sample Type: Cuttings
Project: Phase III Data Verified By: Date:

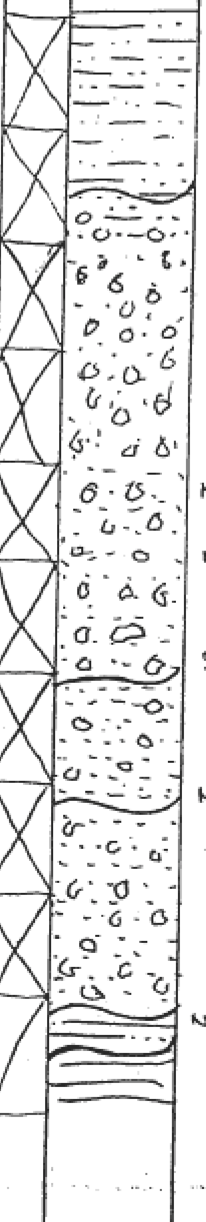


VOC (PPM)	RAD (CPM)	DESCRIPTION
		CL SILTY CLAY: yellow brown (10YR 5/6) mottled with gray (10YR 6/1) soft, occ chert and qtz grains rounded (50% clay)(50% silt)
N/D		
	BKGD	
		CL SILTY CLAY: AA increasing firm, occ fe staining
N/D	BKGD	SM SILTY SAND: yellow brown to brownish yellow (10YR 5/6)(10YR 6/6), medium to coarse grain ([illegible]) sbang, psrt, occ wel cemented, abundant chert gravel, 1/4-1 mm size (40% silt)(50% sand) (10% gravel)
		GC GRAVEL: AA incr gravel (30% silt)(30% sand) (40% gravel)
N/D		~~CL SILT~~ CL SANDY CLAY: yellow brown (10YR 5/6) mottled with gray (10YR 6/1), firm, fe staining, occ sandy stringers (20% sand)(80% clay)
	BKGD	
		CL SILTY ~~SAND~~ CLAY: brownish yellow (10YR 6/6) firm to very firm, fe staining, occ sandy ip, occ black [illegible] (30% silt)(70% clay)
N/D		
	BKGD	CL SANDY CLAY: AA, incr fe staining, firm (30% sand)(70% clay)

Borehole Summary Information

ornl OAK RIDGE NATIONAL LABORATORY

Prepared By: S.M. Smith Date: 9-15-94 Page: 2 of 3
Hole No.: G11 Ground Elevation:
Total Depth: Rig Type: Ingersoll Rand TH60 Location: PGDP
Bit ~~Auger~~ Size: 4 3/4 Sample Type: cuttings
Project: Phase III Data Verified By: Date:

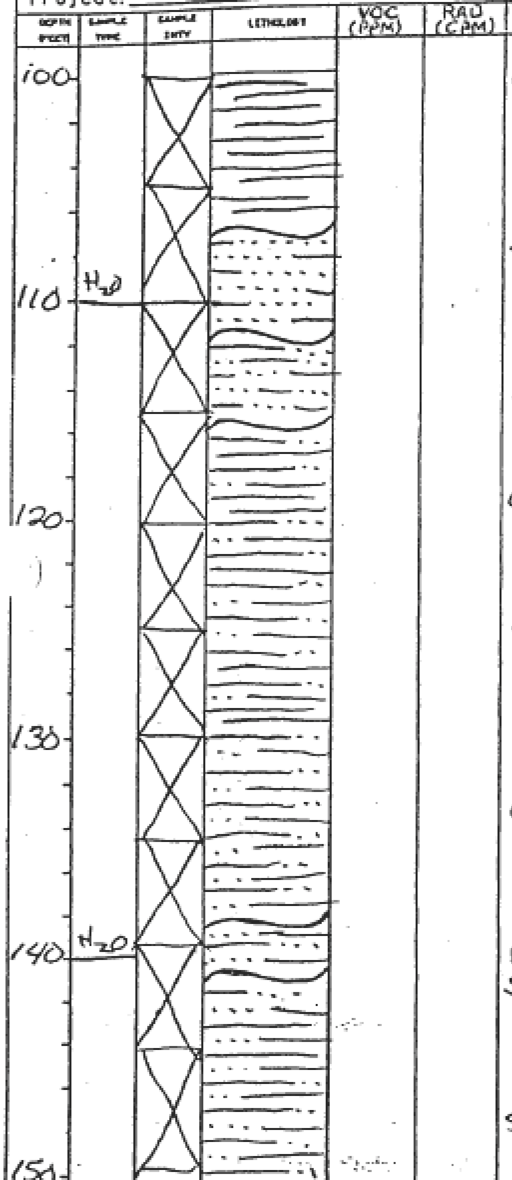


DEPTH (FEET)	SAMPLE TYPE	SAMPLE INTV	LITHOLOGY	VOC (PPM)	RAD (CPM)	DESCRIPTION
50				N/D		CL SANDY CLAY: AA
					BKGD	H2O sample @ 60' sample no# 111010-0774, pumped GM GRAVEL: SANDY GRAVEL: Chert 1/8 - 1 cm clear qtz, medium to coarse grain (mL to cU), sbrd - rd, psrt, pcmt
60	H2O			N/D		
					BKGD	GW GRAVEL: clean gravel, decr sand, strong brown (7.5YR 5/6) to reddish yellow (7.5YR 6/8), chert, angular, 1/4 - 2cm, occ 5mm size (95% gravel) (5% sand)
70	H2O			N/D		H2O sample @ 70' sample no# 111010-0775 pumped
				1	BKGD	GM GRAVEL: SANDY GRAVEL, Chert 3 - 1/8 cm, coarse [illegible] xln ip, angular with fe inclusions, well graded sand, medium to coarse grain (mU to cU) sbrd to rd, well graded (80% gravel)(20% sand)
80	H2O			9.0		H2O sample @ 80' sample no# 111010-0777 pumped SP SAND: ~~gravelly~~ gravelly sand clear - frost - brownish yellow (10YR 6/6) well graded, very coarse to coarse grain (vcL to cL) sbrd - occ rd, unconsolidated, gravel to 3cm (70% sand)(30% gravel)
				N/D		
					BKGD	GM GRAVEL: AA
90						
	H2O			N/D		TOP PORTER CREEK @ 96' H2O sample @ 95' sample no# 111010-0778 pumped CL SANDY CLAY: yellowish brown (10YR 5/8) firm, mottled w/ gray (10YR 5/1) nodules, sandy ip, (80% clay)(20% sand) fe staining
100						

Borehole Summary Information

ornl OAK RIDGE NATIONAL LABORATORY

Prepared By: ______ Date: ______ Page: __ OF __
Hole No.: ______ Ground Elevation: ______
Total Depth: ______ Rig Type: ______ Location: ______
Auger Size: ______ Sample Type: ______
Project: ______ Data Verified By: ______ Date: ______



DESCRIPTION

CH CLAY: very dark grey (10YR 3/1) very firm, fat, micaceous

SM SILTY SAND: yellow (10YR 7/8) poorly graded, vfine to fine grain (vfU to fU) sbang to sbround, very silty to clayey mtrx, (60% sand) (40% silt) wet

H_2O sample @ 110' sample no. 110101-0779

SC CLAYEY SAND: light yellowish brown (2.5Y 6/4) soft, grading to sandy clay (50% clay) (50% silty sand)

CL SANDY CLAY: dark gray (10YR 4/1) firm to very firm, w/clear vfU sandy inclusions, very micaceous

CL SILTY CLAY: dark gray (10YR 4/1) firm to moderately firm, very micaceous, w/clear qtz grains, vfine grain vfL

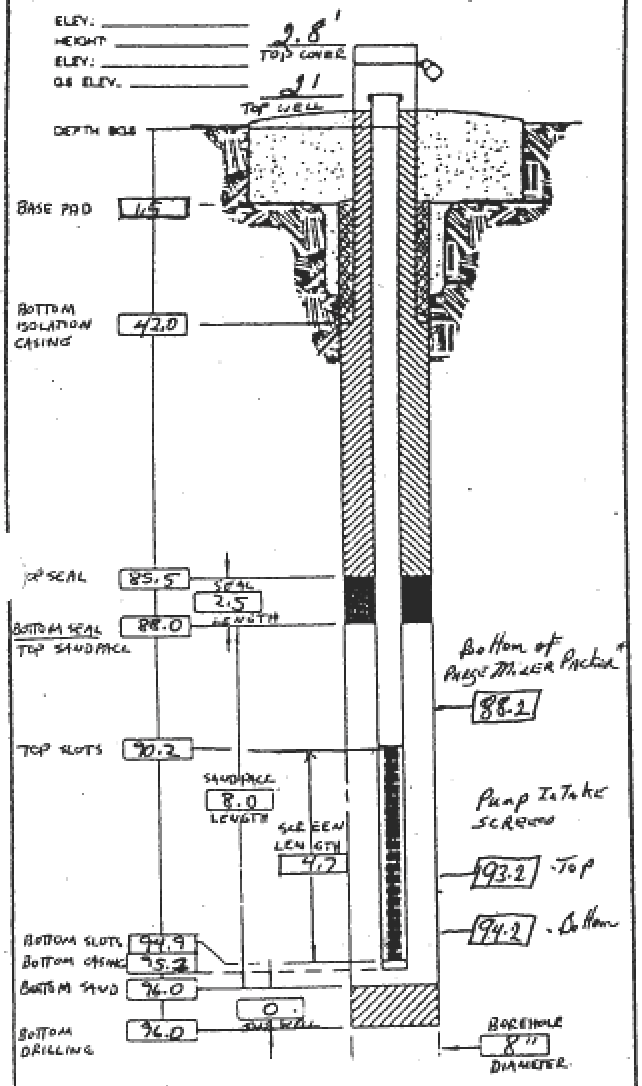
CL SILTY CLAY: aa incr very dark gray (~~10YR~~ (7.5YR 3/0)'

H_2O Sample @ 140' sample no. 110101-0780

SM SANDY SILT: light gray (10YR 6/1) soft; occasional black minerals, very micaceous, wet, grading to clayey (70% silt) (20% sand) (10% clay)

SM SANDY SILT: aa incr silty clay, very micaceous grading to sandy clay, light gray to gray (10YR 6/1) to (10YR 5/1)

WELL NO.: MW-262
INSTALLATION: Paducah Gaseous Diffusion Plant
PROJECT NO.: 2012-5509
CLIENT / PROJECT: MMES / Groundwater Phase IV
SITE: NE Plume
CONTRACTOR: M K Ferguson
DRILL CONTRACTOR: Geotek
TART DATE: 1-17-95 (9:30 M)
END DATE: (M)
WELL COORD.:



PROTECTIVE CSG
MATERIAL / TYPE Steel
DIAMETER 12 inch
DEPTH BGS 1.5 ft WEEP HOLE [✓ Y] / N

QUARD POSTS ([✓ Y] / N)
NO. 4 TYPE "Steel. 6 inch

SURFACE PAD
COMPOSITION AND SIZE Concrete 5'X 5'X 1½"

RISER PIPE
TYPE Stainless Steel
DIAMETER 2 inch
TOTAL LENGTH (TOC TO TOB)
VENTILATED CAP ([✓ Y] / N) Well Wizard Cap

GROUT
COMPOSITION & PROPORTIONS Aquaguard
GROUT TYPE Bentonite
WEIGHT (LBS / GAL) 10.2
% SOLIDS 30%
TREMIED (Y / N) Y
INTERVAL BGS 0-85.5

CENTRALIZERS (Y / [✓ N])
DEPTH(S)

SEAL
TYPE Bentonite ⅜" coated pellets
SOURCE Pel-plug
SETUP / HYDRATION TIME >8 hr VOL FLUID ADDED /
TREMIED ([✓ Y] / N) Y

FILTER PACK
GRADUATION DESIGNATION 9942
GRAIN SIZE 20/40
TYPE Qtz Sand
AMT. USED 100 lb
TREMIED (Y / N) Y
SOURCE Morie Sand
GR. SIZE DIST

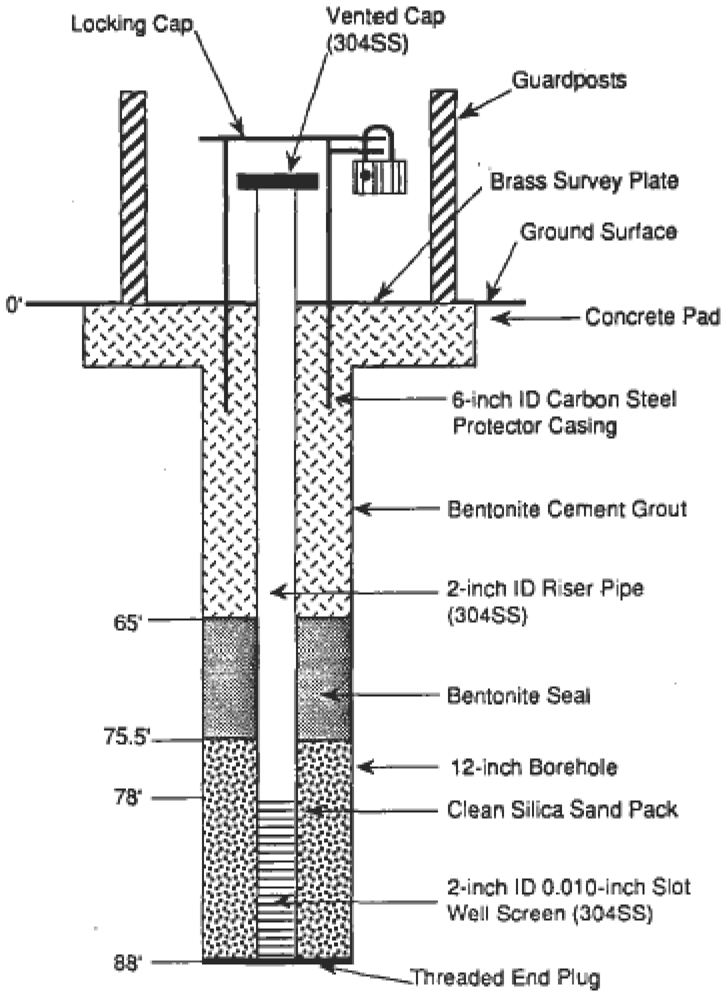
SCREEN
TYPE Wirewound (Johnson)
DIAMETER 2 inch
LENGTH 4.7 ft
SLOT SIZE AND TYPE 10
INTERVAL BGS 90.2-94.9 ft.

ISOLATION CASING ([✓ Y] / N)
TYPE Steel
DIAMETER 10"
TOTAL LENGTH 42.0'

SUMP ([✓ Y] / N)
INTERVAL BGS 94.9-95.2 ft.
BOTTOM CAP [✓ Y] / N

BACKFILL PLUG
MATERIAL None
SETUP / HYDRATION TIME /
TREMIED (Y / N)

Well 125
Well without
Isolation Casing



Well 125 Construction Details
Paducah GDP, Kentucky

CH2M HILL

Appendix 5b. Borehole/Well Completion Data

Well Number	**Year Completed**	**Well Location, Plant Coordinates**		**Within NW Plume**	**RGA Horizon**	**Top Approximate Screen Interval, (ft bgs)**	**Bottom Approximate Screen Interval, (ft bgs)**	**Ground Surface Elevation (ft msl)**	**Top Screen Interval, (ft msl)**	**Bottom Screen Interval, (ft msl)**
		X	Y							
66	1986	-6872.62	978.57	Yes	**URGA**	55.2	60.2	368.6	**313.4**	**308.4**
168	1991	-4822.5	-924.8	Yes	**URGA**	63	68	374.5	**311.5**	**306.5**
194	1991	-10177.5	1865.6	No	**URGA**	41.9	46.9	353.5	**311.6**	**306.6**
197	1991	-6162.5	2863.1	No	**URGA**	58	63	366	**308**	**303**
185	1991	-6601.9	952.9	Yes	**MRGA**	68	73	371.5	**303.5**	**298.5**
381	2002	-4890.7	7746.4	Yes	**MRGA**	65.8	75.8	369.3	**303.5**	**293.5**
242	1995	-7083.28	1678.98	Yes	**MRGA**	65.1	75.1	369.21	**304.11**	**294.11**
243	1995	-7382	1681.4	Yes	**MRGA**	65.1	75.1	367.4	**302.3**	**292.3**
236	1995	-5087.79	7919.99	Yes	**LRGA**	69.5	79.5	368.89	**299.39**	**289.39**
262	1995	-5378.46	86.98	Yes	**LRGA**	90.2	94.9	372.2	**282**	**277.3**
340	1996	-6165.4	665.5	Yes	**LRGA**	85.6	95.3	370	**284.4**	**274.7**
125	1990	-5662.81	6139.28	Yes	**LRGA**	78	88	372.67	**294.67**	**284.67**

Table A5b.1. Well construction and screened interval data for EAP & SCI wells.

Appendix 6. Biofouling Evaluation Activities Analytical Proposal (TRFLP)

Microbiological Sampling of Groundwater Monitoring Wells at the Paducah Gaseous Diffusion Plant (PGDP) -- Considerations and Options to Resolve Technical Issues

Hope Lee (North Wind, Inc.) and Brian Looney (Savannah River National Laboratory)

Introduction

Representatives of the Paducah Gaseous Diffusion Plant (PGDP), regulatory agencies, universities, industry and the Department of Energy are collaborating to investigate the potential for attenuation of tricholoroethene (TCE) in the aerobic groundwater underlying that site. This work builds on previous site data and specifically focuses on collecting the geochemical and microbiological information needed to assess the role of aerobic cometabolism in biological degradation of TCE. Typical of such studies, this effort primarily utilizes groundwater samples collected from monitoring wells located throughout the contaminant plume. This type of sampling represents a practical compromise. Groundwater monitoring wells provide broad access and samples of subsurface materials for a reasonable cost, but they sample only those organisms that are in the water phase and may not provide complete information on the relatively large fraction of the organisms that are attached to the aquifer matrix – the organisms associated with the solid phase can only be effectively collected by drilling and coring (a process that introduces its own set of uncertainties). Recent research has suggested that alternative monitoring well based methods such as colonizing samplers and push pull tests may provide data to supplement microbial measurement in water samples. Nonetheless, groundwater samples are the standard and such samples represent the only reasonable large scale method to collect replicable samples. Factors that impact microbial data collected from groundwater samples (e.g., biofilms, construction materials, pump systems, etc.) have been the subject of significant research. Notably, biofilms have been documented in the monitoring wells at PGDP and the potential impacts of the local microbial population and well cleaning histories on the current study are worthy of consideration.

Problem Statement

Biofilms ("Biofouling") in wells in the Northwest contaminant plume at Paducah has called into question the representativeness of the groundwater samples that were used in enzyme activity probe assessment. If samples that were analyzed for aerobic degradation capability are not qualified as representing the potential and activity of the bulk groundwater system, then there are concerns that the data will not (a) be applicable to determining a rate of attenuation, or (b) likely be used as a technical tool in the evaluation of other groundwater plumes at the site (one of the primary purposes of the demonstration).

In order to ensure that the biological assessments, mainly the enzyme activity probes, are not compromised by any questions relating to the influence or contribution of biofouling populations present in most, if not all, of the sampled monitoring wells, a *yet to be determined* evaluation needs to be undertaken. The accepted evaluation needs to effectively and conclusively determine if the groundwater sampled in May-June 2007 represented Northwest (NW) formation groundwater OR if those samples were a mixture of indigenous formation and biofilm populations resulting from the lack of rehabilitation of wells in the NW monitoring wells.

Background

It is worth noting that the biofilm populations present in any biofouled well *are* the result of indigenous microorganisms attaching to surfaces present in the well whether as a result of materials present in the well (screens) or the stagnant conditions present in open borehole type wells. While it is certainly worth establishing if groundwater sampled following low-flow procedures (for this assessment as well as other monitoring efforts for standard geochemistry and VOC analysis) represents the typical abundances and or total biomass present in natural groundwater, the populations present in the biofilms represent the metabolic functions present in the aquifer.

One other consideration that has not been taken into account, is that it is often expected that there are microsites and potential biofilms naturally occurring in the aquifer; anaerobic bugs do exist at most sites (so do aerobic), however the prevalence of anaerobic or aerobic, even specific functional groups of organisms is not the same over space and time, in the aquifer. Organisms are most typically opportunistic and shifts in populations are seen over time with variances in the availability of oxygen or other electron acceptors; microbial techniques minimize the visualization of the ever-changing population structure of communities because they typically only consider one moment in time and space. This comment is particularly important in the context for the choice of wells; the desire to choose wells along a flow path is important for geochemistry but also for getting a better handle on the sampling for metabolic function over the lateral extent of the plume.

Proposed Solutions/Evaluation

1. Rehabilitate all of the wells and resample at some undetermined time point in the future
2. Rehabilitate two of the wells (66 and 340) and resample at some undetermined time point in the future
3. Evaluate the microbial community diversity within the different wells; use the samples already collected

It is our understanding that one of the proposed actions in response to the above stated problem would be to rehab wells 66 and 340. However the other sampled wells that have been cleaned in the past three years have been done at irregular schedules. Therefore, to clean two wells and expect that the sampling following would be similar to wells that were cleaned two years ago or eight months ago, is not substantiated in the literature. In fact, there are few studies that have determined the (a) impact of cleaning on indigenous microbial communities or (b) time it takes for a biofilm to “reform” in a well. Unless there is an option to clean all of the sampled wells, over a relatively short timeframe, with sampling of all of the wells within a designated timeframe (e.g. 3 months), questions will continue to rise regarding the relevance and validity of the data sets generated (both this study as well as historical geochemistry and VOC concentration trends, etc.)

An alternative action would be to further examine the microbial communities present in samples that have already been collected in order to place the data in context. The proposed work would involve analyzing the DNA of collected samples using a technique called Terminal Restriction Fragment Length Polymorphism or TRFLP. TRFLP is a DNA (can also be RNA targeted) fingerprinting technique that provides a broad look at the diversity of the Bacterial and/or Archaeal communities in a sample (Marsh et al., 1999; 2000; Dunbar et al., 2000; 2001; Osborn et al., 2000; Blackwood et al., 2003). TRFLP is a relatively straight-forward technique that relies on the presence of the 16S rDNA gene, which has been shown to be present in all known organisms (Woese, 1975). Most typically, the technique involves (1) PCR amplification of DNA from a sample using fluorescently labeled primers, followed by a (2) restriction enzyme digest that cuts the DNA fragments into pieces, and finally (3) a run through a DNA sequencer to determine the length (bp) and abundance (fluorescence) of each of the fluorescent fragments produced from steps one and two (Figure 1). Ideally, an individual organism would provide a single fragment from the analysis; however it has been shown that this is not the case and individual organisms can produce multiple fragments. Additionally, more than one organism could theoretically produce the same size fragment. However, the fingerprint resulting from a TRFLP analysis has been shown to be a powerful technique for identifying differences in population structure and determining the overall diversity of a population, and can easily be compared across temporal or spatial scales (few examples: Dunbar et al., 2000; Osborn et al., 2000; Scala and Kerkhof, 2000; Mummey and Stahl, 2003).

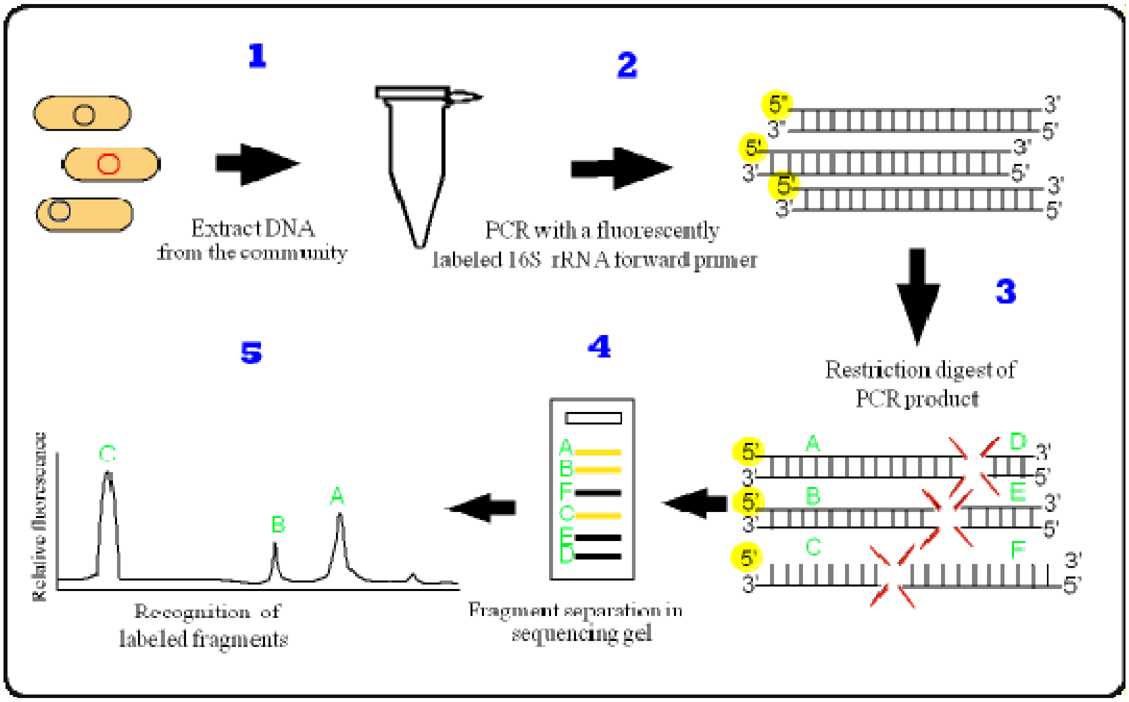


Figure 1. TRFLP schematic, copied with permission from the Center for Microbial Ecology, Michigan State University.

For the particular concern at PGDP, TRFLP is proposed as a simple approach to identify the contribution of biofilm (i.e. biofouling) communities to the total microbial makeup of the groundwater samples collected for enzyme probe analysis. Theoretically, biofilm populations and/or wells with biofouling issues should have microbial communities that look more similar to one another than to the aquifer communities. It is assumed that in a “thriving” biofilm population, there are both anaerobic and aerobic microorganisms present. Microbial populations on the surface of biofilms are in constant contact with the groundwater and are therefore predominated by aerobic metabolisms; underlying populations are sustained, down through the thickness of the biofilm, through the use of microbial exudates from neighboring populations, as electron acceptors (i.e. anaerobic). Thus anaerobic organisms that could not otherwise survive in aerobic, oligotrophic groundwater (no electron donor availability) can thrive in stagnant biofilm communities that have the potential to biofoul monitoring wells. Additionally, biofilm communities, while some fraction may represent the indigenous community, are specialized in that they provide the opportunity not only for anaerobic growth but also for depressed communities, the opportunity to build biomass. As such, these communities are typically dominated by (a) anaerobic organisms and (b) opportunistic organisms that have taken advantage of the sessile, eutrophic environment created by biofilm populations.

By comparing TRFLP patterns in all twelve wells sampled, the following scenario would be expected if the biofilm populations present in wells in the NW plume represented a significant component of the biomass sampled:

(1) Community profiles will not differ based on TCE concentrations, i.e. high TCE concentration wells will not look similar to one another and significantly different from communities outside the plume
(2) Community profiles will not differ based on availability of oxygen, methane, or other biogeochemical parameter
(3) Community profiles of the wells that were cleaned in the same time frame should look more similar to one another than those that were cleaned more recently or never
(4) All of the profiles should have similarities that “outweigh” the differences, i.e. if biofilm is present in all, should show similarities (e.g. anaerobic contribution)

References

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Appendix 7. First Order degradation rate calculation from the Southwest Plume Investigation.

Location	Distance	Measured TCE	Normalized TCE	Best Fit	Lower 95% CL	Upper 95% CL	Ln Normalized TCE	Total Cl	Ln (Best Fit)	Ln (LCL)	Ln (UCL)
MW248	4,170	13,000	13,000	13,618	10,590	17,513	9.4727	65417	9.519E+00	9.268E+00	9.771E+00
MW250	4,545	11,000	11,973	12,556	9,691	16,268	9.3904	60099	9.438E+00	9.179E+00	9.697E+00
MW243	4,592	13,000	13,691	12,429	9,584	16,118	9.5245	62117	9.428E+00	9.168E+00	9.688E+00
MW241	10,892	1,400	3,187	3,178	2,162	4,672	8.0668	28733	8.064E+00	7.679E+00	8.449E+00
MW238	11,051	1,500	3,084	3,071	2,083	4,528	8.0340	31814	8.030E+00	7.641E+00	8.418E+00
MW236	11,479	1,400	2,772	2,799	1,882	4,162	7.9273	33033	7.937E+00	7.540E+00	8.334E+00

GW Flow Rate (ft/d)	Contam Transport Rate	TCE Deg. Rate Coefficient (year^{-1})	TCE Half-Life (yrs)
1	0.91	**0.0719**	**9.6**
3	2.72	**0.2149**	**3.2**

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9978
R Square	0.9956
Adjusted R Square	0.9946
Standard Error	0.058926278
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.173384776	3.17338478	913.9126952	7.13149E-06
Residual	4	0.013889225	0.00347231		
Total	5	3.187274001			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.42179761	0.060732881	171.60058	6.91796E-09	10.25317575	10.59041947
X Variable 1	-2.165E-04	7.16026E-06	-30.230989	7.13149E-06	-2.363E-04	-1.966E-04
Rate (1 ft/d)	**0.0719**				**0.0785**	**0.0653**
Rate (3/ft/d)	**0.2149**				**0.2346**	**0.1952**
Half-life (1 ft/d)	**9.6**				**8.8**	**10.6**
Half-life (3 ft/d)	**3.2**				**3.0**	**3.6**

Appendix 8. NGWA - PGDP First Order Rate Constant Estimation Method and Results Presentation

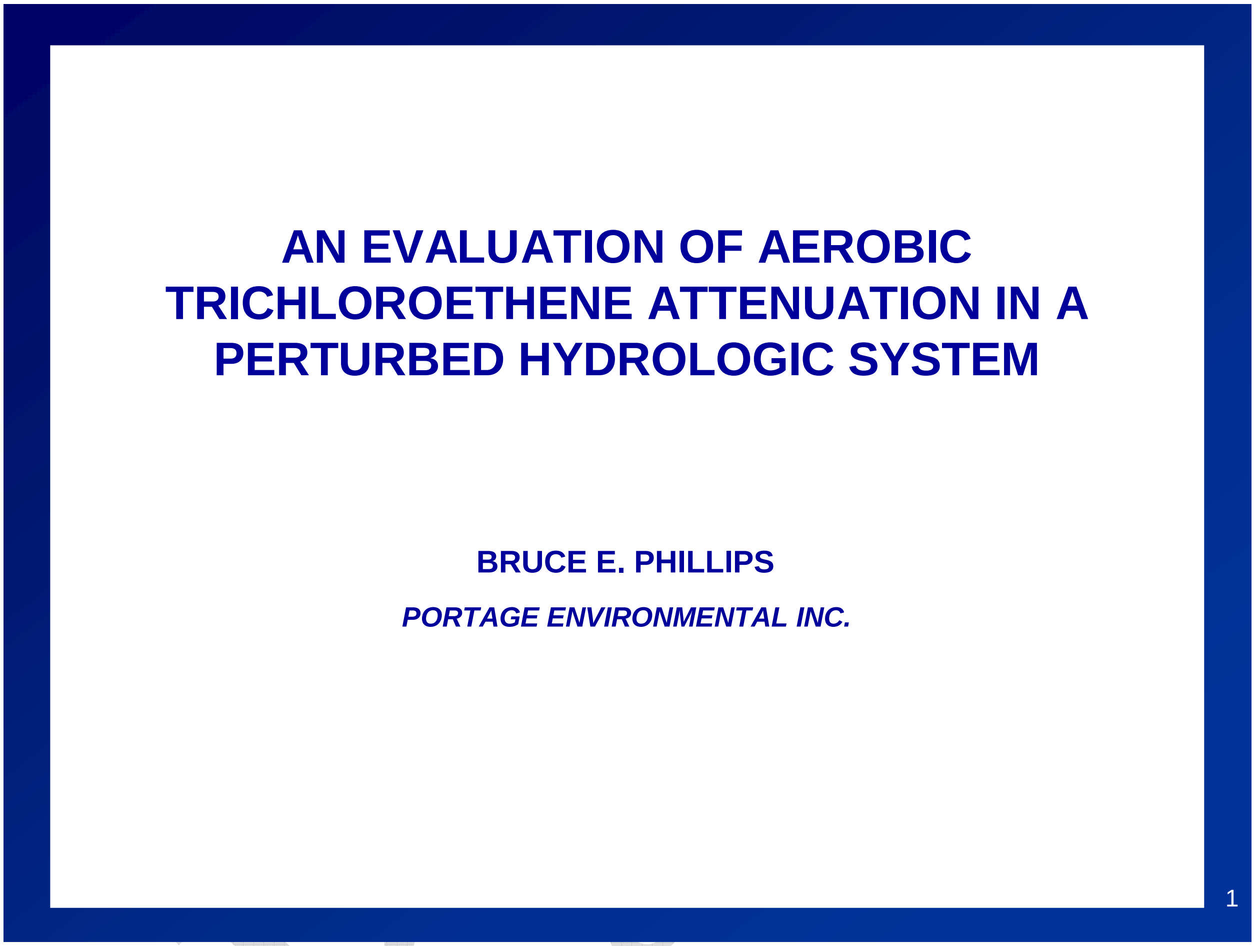
An Evaluation of Aerobic Trichloroethene Attenuation in a Perturbed Hydrologic System

Bruce E. Phillips, Portage Environmental Inc.

Aerobic natural attenuation of trichloroethene (TCE) is being evaluated on a groundwater contaminant plume at the Paducah Gaseous Diffusion Plant. The hydrologic system is considered perturbed due to ongoing remedial actions (pump and treat operations) over the past twelve years. However, the plume remains relatively stable. First-order rate estimation methods were used to calculate attenuation rates after monitoring well data were statistically evaluated to determine which locations near extraction wells could be used for the analyses. The method used to determine an attenuation rate was a “tracer corrected” approach using a co-contaminant [technetium-99 (^{99}Tc)] that would distinguish dispersion and degradation processes. Since the hydrologic system was perturbed, the ratio of TCE to ^{99}Tc for each sampling event was used in the evaluation (actual concentrations of either TCE or ^{99}Tc near extraction wells were less than in the surrounding plume but the ratios remained similar). The degradation half-life for TCE was calculated to range between 16.5 and 6.1 years for average groundwater flow rates between 550 and 910 feet/year, respectively. Ongoing analytical work is being conducted at the site to determine if the observed TCE attenuation is due to aerobic cometabolism, or if some other process (e.g., sorption) is attenuating TCE at greater rates than the ^{99}Tc.

(Presented as a poster session March 31 and April 1, 2008 at the National Groundwater Association Groundwater Summit 2008 in Memphis, TN. The abstract above was submitted October 26, 2007 and accepted on January 11, 2008.)

SLIDE 1



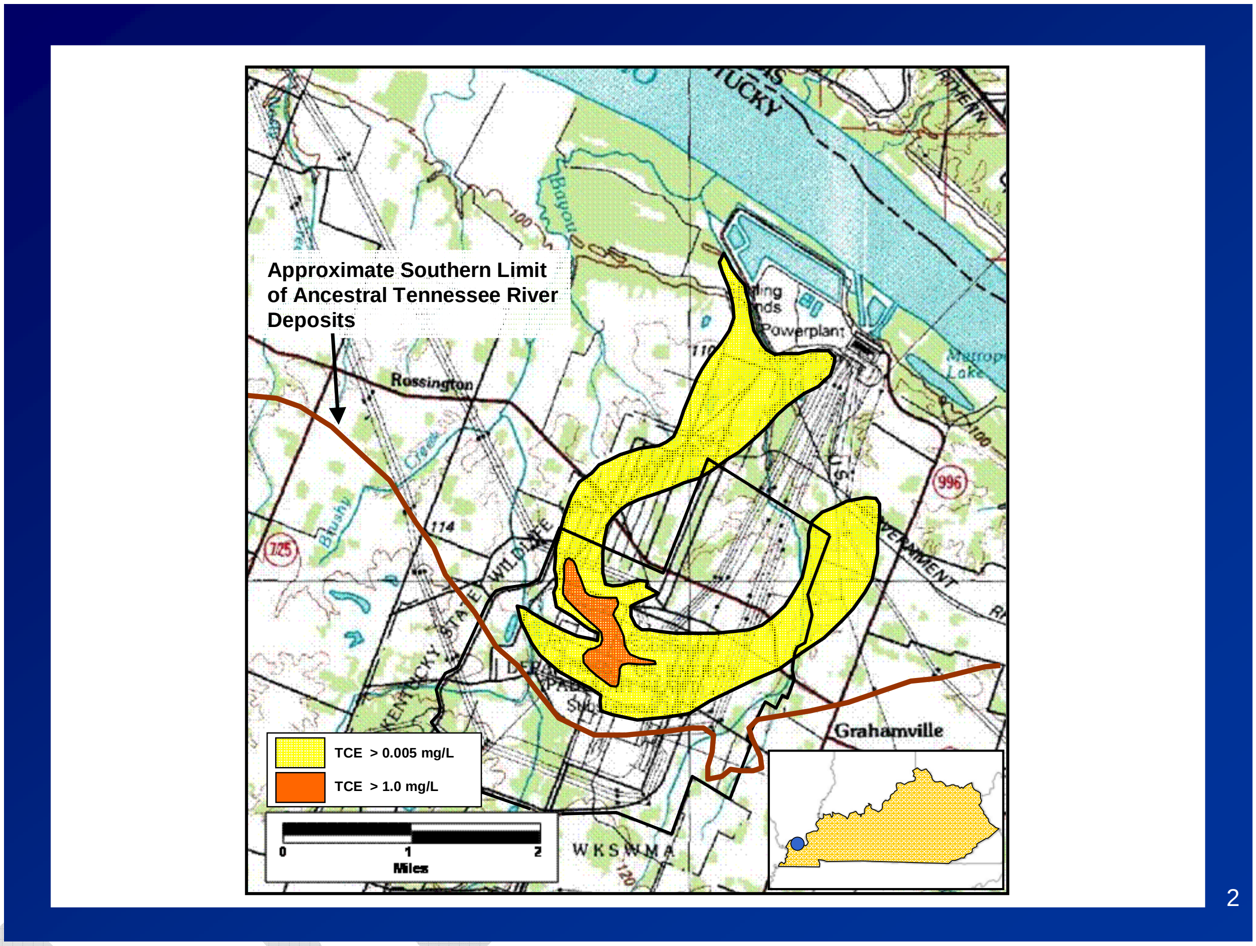
AN EVALUATION OF AEROBIC TRICHLOROETHENE ATTENUATION IN A PERTURBED HYDROLOGIC SYSTEM

BRUCE E. PHILLIPS

PORTAGE ENVIRONMENTAL INC.

Slide 2

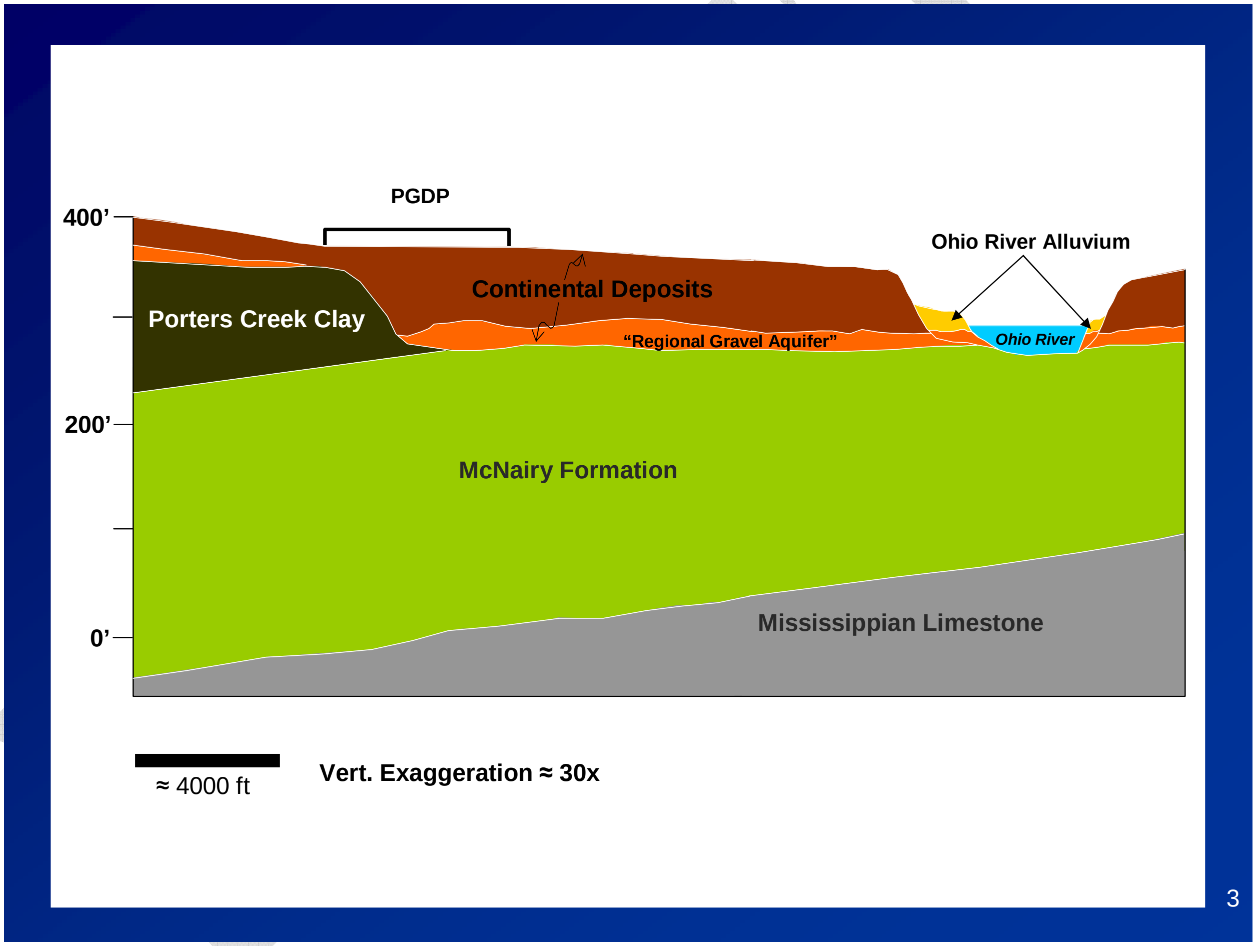
The Paducah Gaseous Diffusion Plant (PGDP), a facility owned by the U.S. Department of Energy (DOE), is located in western Kentucky approximately 3.5 miles southwest of the Ohio River. Off-site groundwater contamination associated with the PGDP was first discovered in 1988 as a result of residential well sampling north of the facility. The PGDP is the source of three groundwater contaminant plumes in the Regional Gravel Aquifer (RGA) which is the shallow aquifer underlying the plant. These plumes are defined by an organic contaminant, trichloroethene (TCE) and a radionuclide, technetium (^{99}Tc).



SLIDE 3

The shallow groundwater flow system at the PGDP is developed in sediments filling a buried valley of the ancestral Tennessee River (which previously flowed near the present course of the Ohio River). The valley fill sediments consist of a basal sand-and-gravel unit averaging 35 ft thick referred to as the “Regional Gravel Aquifer.” The long-term average groundwater flow velocity for the Northwest (NW) Plume is 550 to 910 ft/yr (1.5 to 2.5 ft/d) (determined considering the length of the plume in 1990 when initially characterized versus the expected time of contaminant release). The RGA underlies approximately 50 to 60 ft of clayey-silt that comprises the upper portion of the valley fill sequence. Groundwater flow in the upper sequence is predominantly downward and acts to recharge the RGA. Groundwater flow in the RGA is towards the Ohio River.

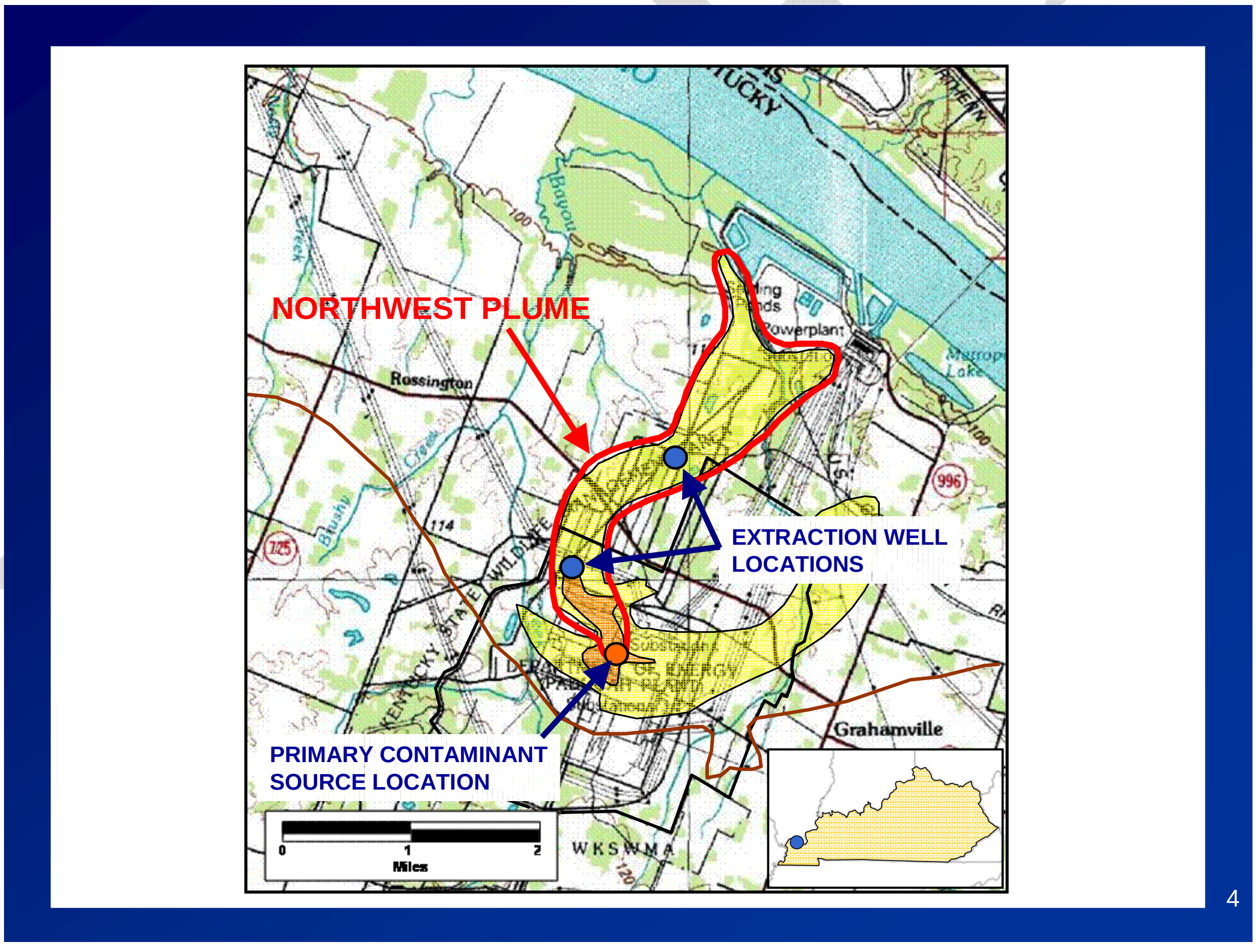
The RGA is dominantly an aerobic aquifer with dissolved oxygen levels ranging from 2 to 8 mg/L. The fraction of organic carbon in the aquifer is low at 0.02%.



SLIDE 4

The NW Plume is the best characterized of the PGDP contaminant plumes. Observations of dissolved TCE and ^{99}Tc levels within the NW Plume indicate that TCE attenuates faster over distance than ^{99}Tc. TCE attenuation is being evaluated on a nearly 3.8 mile long, aerobic plume to provide a rate coefficient for fate and transport modeling. This degradation rate coefficient is estimated using a modified method from EPA's technical protocol (EPA 1998; Sorenson 2000).

The primary source of both the TCE and ^{99}Tc is located near the C-400 Cleaning Building. The TCE source, a DNAPL source, has been estimated at up to 100,000 gallons (380,000 liters) distributed in pools and ganglia to a depth of approximately 95 feet. The NW Plume extends from the C-400 Cleaning Building, located near the center of the industrial complex, to near the Ohio River, a distance of approximately 3.8 miles. DOE installed a two-well-field "partial" hydraulic containment system to mitigate the migration of the core of the plume. The system includes one well field near the point where the plume exits the industrial complex and another well field located near the downgradient limit of the plume core defined by TCE concentrations greater than 1 mg/L. Each well field contains two extraction wells pumping approximately 50 gpm (273,000 L/d) each. Site data indicate the C-400 sources of TCE and ^{99}Tc are not being rapidly depleted and the NW Plume was approximately stable prior to startup of the extraction wells in late 1995.



NORTHWEST PLUME

EXTRACTION WELL LOCATIONS

PRIMARY CONTAMINANT SOURCE LOCATION

SLIDE 5

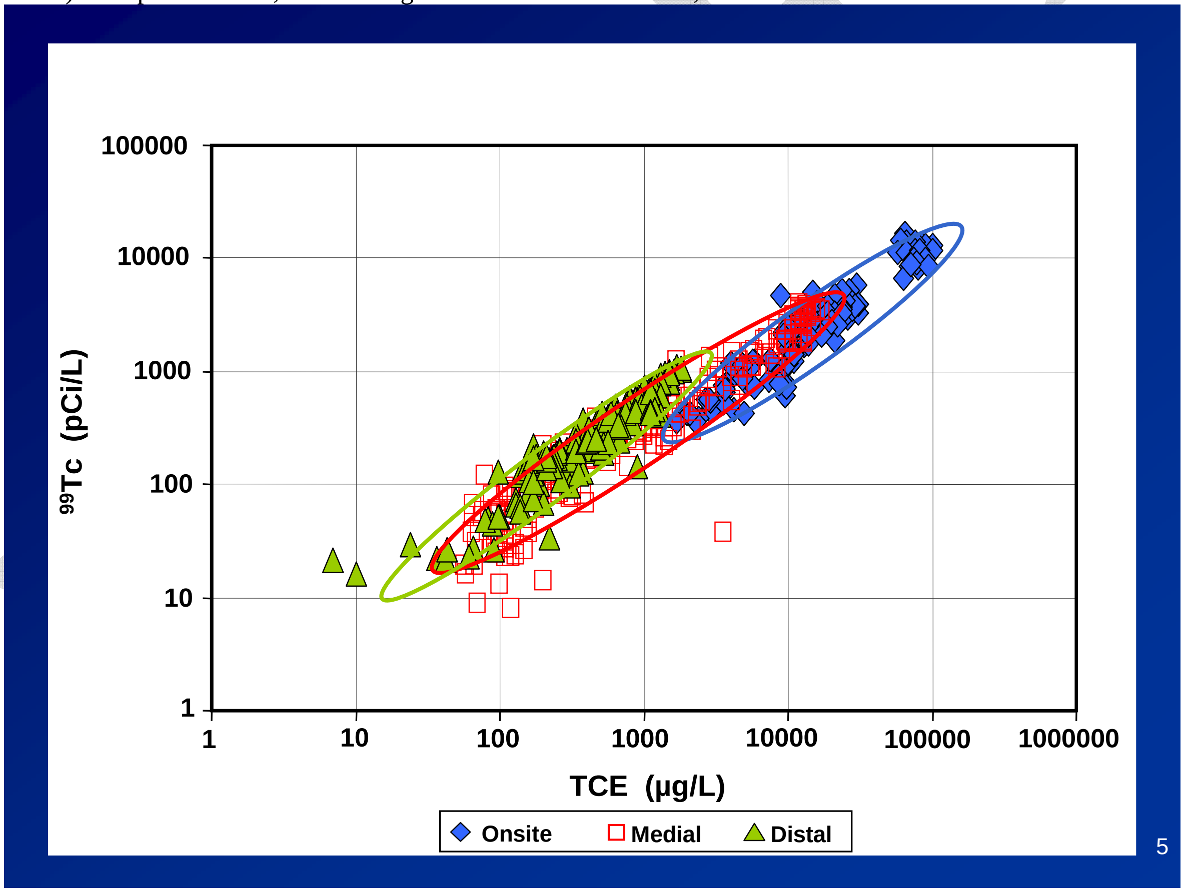
^{99}Tc is a co-contaminant with TCE in the NW Plume. Previous investigations at the site have described the strong correlation (correlation coefficient of 0.96) of TCE concentrations and ^{99}Tc activities within the plume (DOE 1995). ^{99}Tc degrades to ^{99}Ru by beta and gamma decay with a half-life of 212,000 years. In aerobic settings like the RGA, ^{99}Tc is in the form of the pertechnetate anion that is readily mobile. Previous studies of ^{99}Tc transport in the RGA have shown that ^{99}Tc migrates as a dissolved species and does not form colloids. A log-log plot of ^{99}Tc versus TCE in the NW Plume illustrates the strong correlation between the two contaminants and suggests a slight loss of TCE in moving from the source to distal sampling locations.

^{99}Tc meets the three requirements of a tracer for analyzing first-order attenuation rate coefficients:

1) Both TCE and ^{99}Tc sources are located near the C-400 Cleaning Building and exhibit a single co-mingled plume migrating to the northwest of C-400.

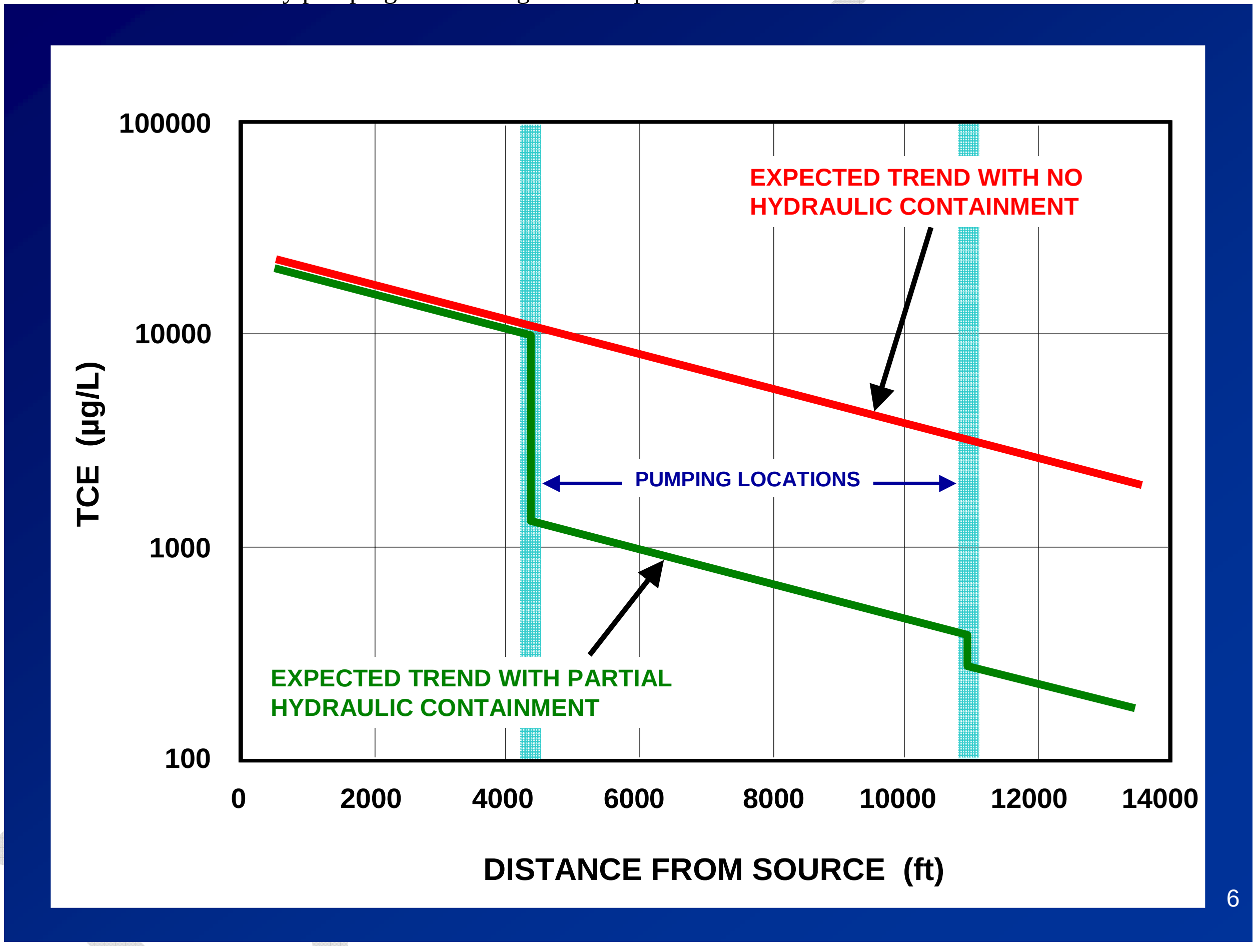
2) ^{99}Tc does not degrade within the aquifer relative to the potential age of the sources (maximum age of source is 55 years relative to the half-life of 212,000 years).

3) Sorption of ^{99}Tc, relative to groundwater flow and TCE, is well understood.



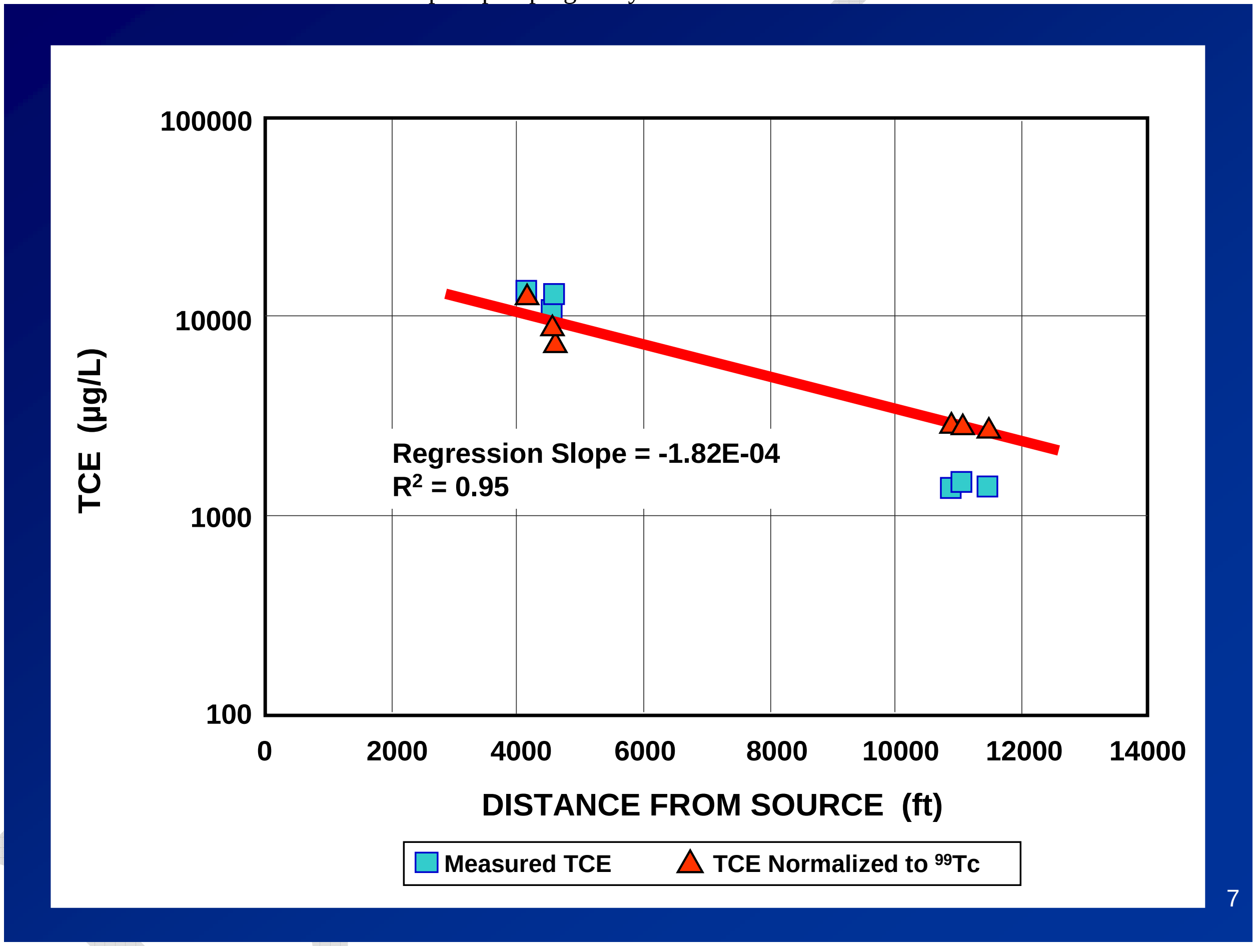
SLIDE 6

In a perturbed system with ongoing groundwater pumping, the linear regression of contaminant concentrations alone may lead to an overestimate of the attenuation rate. Contaminant concentrations in monitoring wells near the extraction field and downgradient are significantly influenced by the remedial action. However, if the regression is performed on the natural logarithm of the ratio of contaminant to tracer, based on the modified method of Sorenson (2000), the analysis should still be valid. Monitoring well data for ten wells located near the extraction fields were evaluated using statistical t-tests to determine if the pre-pumping and post-pumping means of the ratios of contaminant to tracer were similar (with 95% level of confidence). Based on this initial analysis, four monitoring wells were rejected. It is assumed that these four wells were affected by pumping and no longer in flowpaths indicative of the NW Plume core.



SLIDE 7

Previous estimates of TCE degradation at Paducah used a limited data set. The previous analysis used data from only one month prior to initiation of the remedial action (six sampling locations in two general areas) to arrive at a range in TCE half-life from 3.2 to 11.3 years (this corresponded to a range in groundwater flow rate from 1 to 3 years). The previous study normalized downgradient TCE concentrations using both ^{99}Tc and total chloride. While the methodology used was applied correctly, the result was essentially relying on the linear regression between two groupings of data points. The reason for using a limited data set was that the hydraulic containment system initiated in late 1995 had caused changes in monitoring well concentrations near the extraction wells and other wells along the NW Plume core did not exist at the time. A more robust data set could be used if post-pumping analyses could be considered.



SLIDES 8 / 9 / 10

Analyses (TCE and ^{99}Tc) from eleven monitoring wells, as well as two creek seeps, located along the core of the NW Plume and sampled between 1995 and 2005 comprise the data set for derivation of the TCE attenuation rate coefficient. Although the monitoring wells only partially penetrate the RGA, the observed contaminant levels are representative of the core of the plume. A good measure of the average contaminant level in the core is the contaminant levels in the extraction wells which are fully penetrating. This expanded data set includes over 450 pairs of analyses of TCE and ^{99}Tc compared to the previous study which only used six pairs of contaminant/tracer analyses.

Using methods in EPA's technical protocol (EPA 1998), the presence of a nonreactive co-contaminant such as ^{99}Tc may be used as a tracer to evaluate the rate of degradation of TCE within a dissolved-phase plume, using ^{99}Tc to normalize the downgradient TCE concentrations. This method relies on the assumption that first-order kinetics can be used to model degradation and differences between actual and normalized levels in the downgradient locations are attributable to degradation and volatilization (independent of dilution and dispersion if the co-contaminant or tracer behaves in a simlar manner during groundwater transport). Sorenson (2000) modified the equation in the EPA technical protocol such that when the natural logarithm of the ratio of contaminant concentration to tracer concentration is plotted against the distance along a flow path, the slope of the line is equal to the first-order degradation rate coefficient divided by the groundwater velocity. This is shown by the following equation:

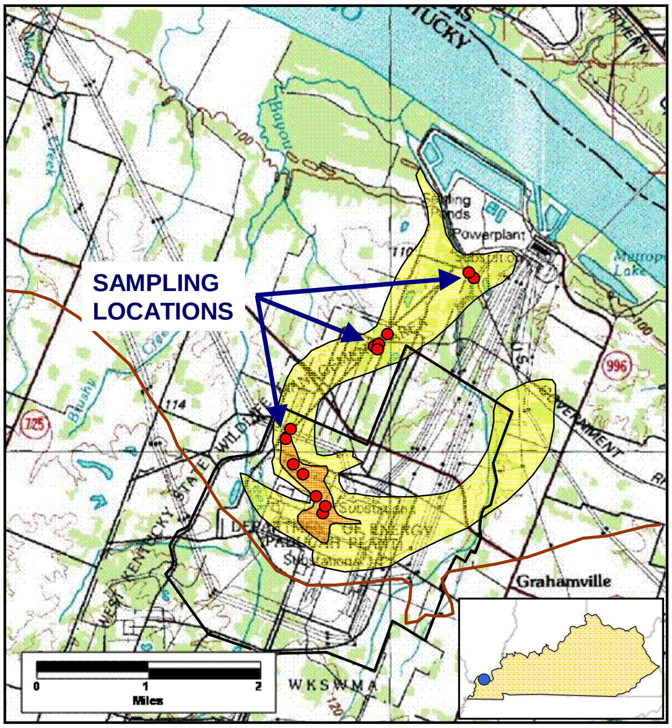
$\ln(C^*_x) = (k/v)x + \ln(C^*_A)$ where:

C^*_x is the ratio of the contaminant concentration at point x to the tracer concentration at point x;
C^*_A is the concentration ratio at the upgradient reference point or source;
k is the first-order degradation rate coefficient;
v is the contaminant transport velocity; and,
x is the distance from the source to the downgradient sampling location along the flowpath.

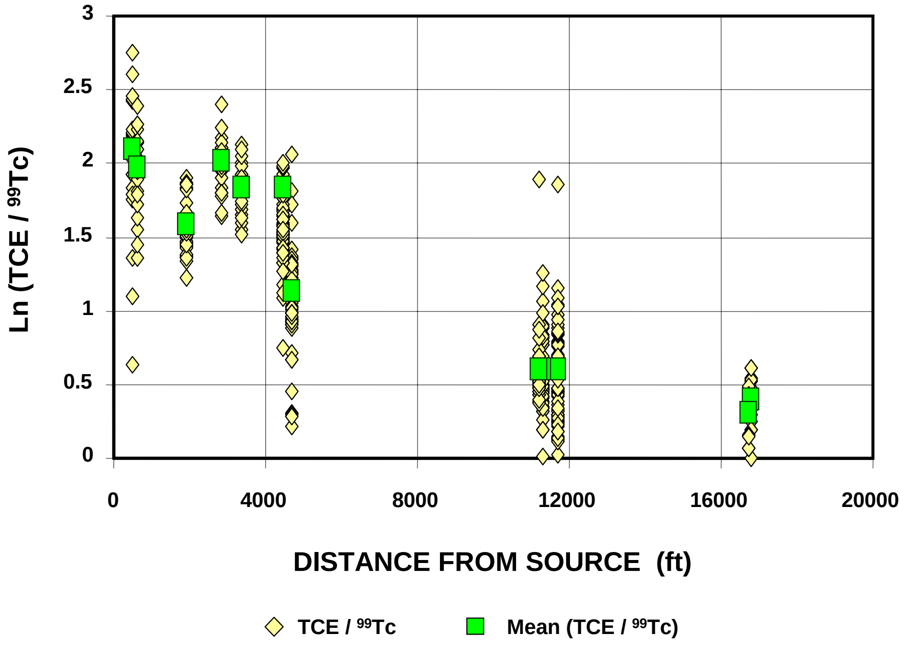
As implied by the above equation, attenuation of one compound relative to another can be evaluated by plotting the ratios of the two compounds at sampling locations as a function of downgradient distance.

Sampling Location	Distance from Source (ft)
MW342	480
MW343	630
MW262	1,905
MW261	2,850
MW339	3,360
MW248	4,460
MW243	4,700
MW241	11,150
MW240	11,200
MW238	11,300
MW235/MW381	11,700
LBC-Seep6	16,720
LBC-Seep5	16,800

Blue = URGA screen **Green = LRGA screen** **Red = MRGA screen**



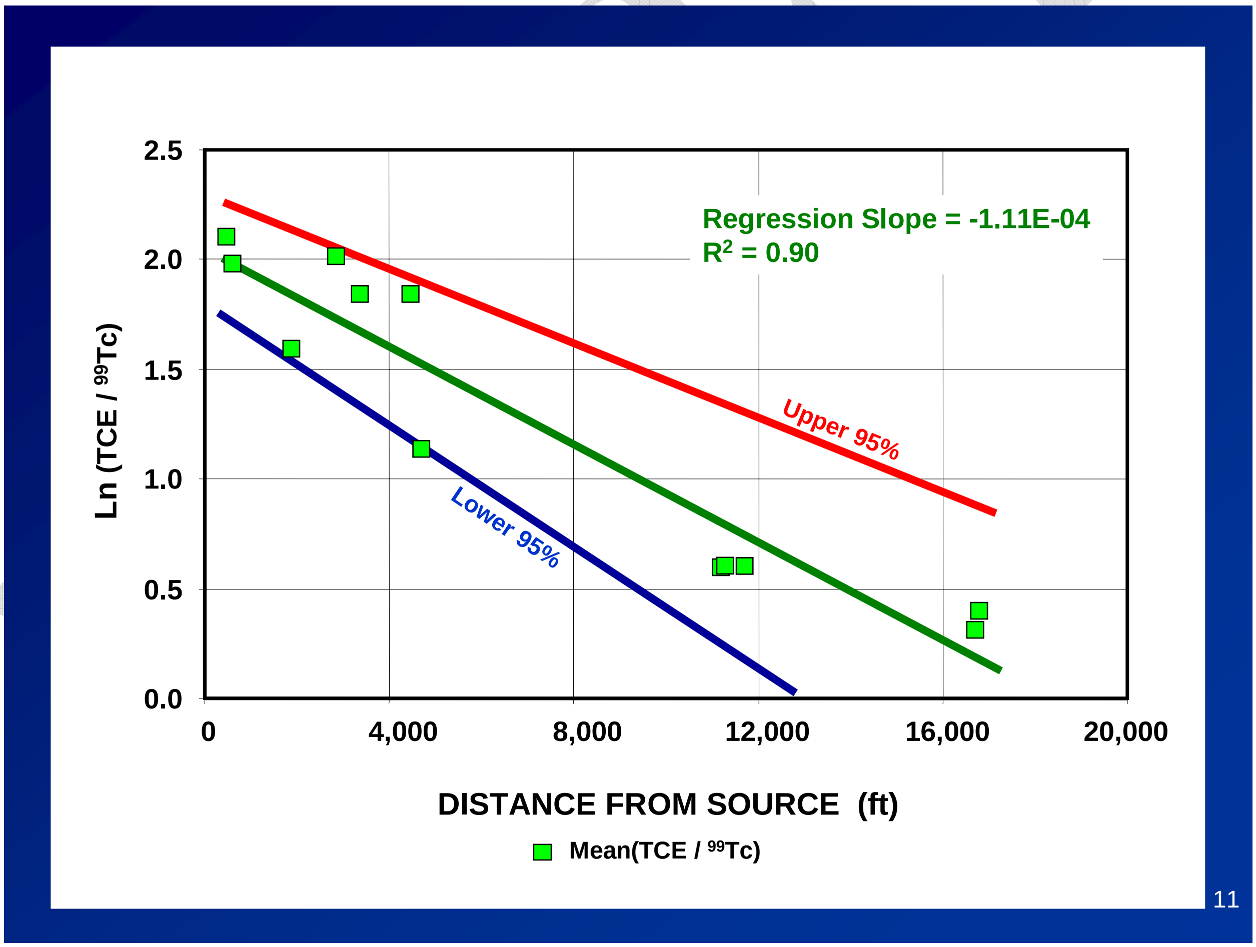
SAMPLING LOCATIONS



3
2.5
2
1.5
1
0.5
0
Ln (TCE / 99Tc)
0
4000
8000
12000
16000
20000
DISTANCE FROM SOURCE (ft)
TCE / 99Tc
Mean (TCE / 99Tc)

SLIDE 11

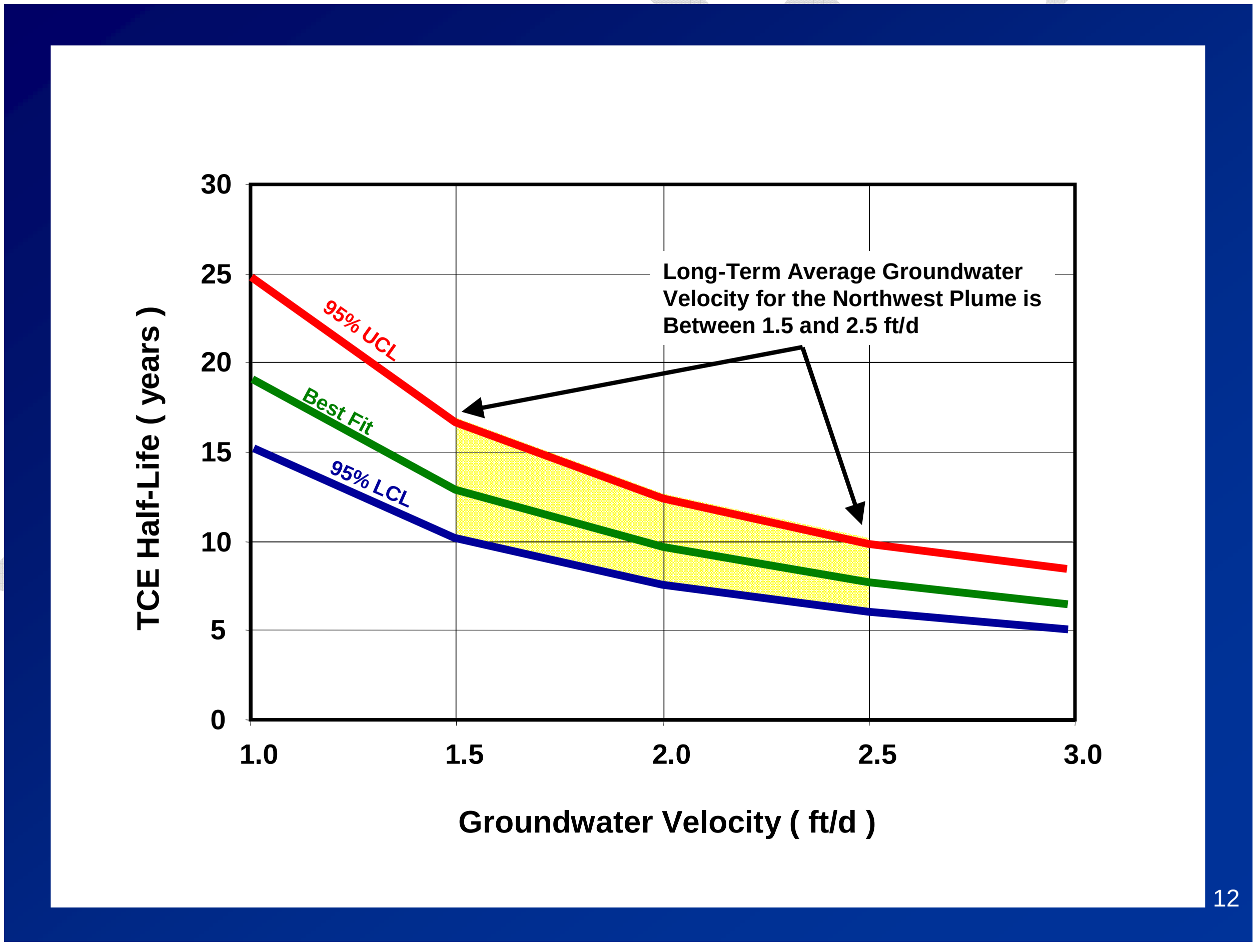
Rather than perform the linear regression on individual data points, the mean of the contaminant/tracer ratio at each sampling location was plotted against the distance from the source for the current evaluation. While some scatter is apparent in the data, as would be expected in a heterogeneous hydrologic setting, the first-order linear regression appears reasonable. The upper and lower 95% confidence intervals were also calculated with commercial software to provide a range of values that might be used in probabilistic modeling.



SLIDE 12

This analysis, using ^{99}Tc as a conservative tracer, yields a TCE degradation rate coefficient of 0.042 year^{-1} to 0.114 year^{-1} for groundwater flow rates of 550 to 910 feet/year, respectively. Groundwater velocity is probably the most critical hydrogeological parameter in first-order rate estimates so bounding values were used rather than a specific value. These degradation rate coefficients correspond to a TCE half-life ranging from 6.1 to 16.5 years.

Volatilization of TCE in the RGA is not considered significant because the RGA is a semi-confined aquifer, with the upper surface of the aquifer at a depth of approximately 50 to 60 feet along most of the transport length (until reaching Little Bayou Creek where springs are found). Recent sensitivity analyses have determined that the distribution coefficient (K_d) of ^{99}Tc ranges from 0.0 to 0.1 L/kg meaning it would be only slightly retarded, if any, during migration. Likewise, the same study determined the distribution coefficient of TCE at the site ranges from 0.01 to 0.1 L/kg suggesting that TCE is also only slightly retarded relative to groundwater flow. Therefore, sorption was considered only briefly due to the absence of organic material in the aquifer (also, it is assumed that clay particles are not significant in the aquifer as evidenced by the high hydraulic conductivity and flow velocity).



Long-Term Average Groundwater Velocity for the Northwest Plume is Between 1.5 and 2.5 ft/d

DISCUSSION SUMMARY SLIDES (to be pulled from text below)

EPA's technical protocol (EPA 1998) reviewed literature documenting TCE degradation rate constants and found that most rates clustered between 0.3 and 3.0 year^{-1} (equal to TCE half-life range of 2.3 to 0.2 years). This literature review primarily reflected studies of anaerobic degradation which occurs at a greater rate than aerobic co metabolism.

Idaho National Engineering and Environmental Laboratory (INEEL) has documented the occurrence of aerobic degradation through co metabolism at their site. The calculated TCE half-life for INEEL ranged from 13 to 21 years. In co metabolism, TCE is not a source of energy for the microbes, but it is degraded by the enzymes that the microbes generate to catalyze oxidation of other organic material (which may be naturally occurring or a groundwater co-contaminant).

The downgradient decrease of TCE levels relative to ^{99}Tc in the core of the NW Plume provides a means for derivation of a site-specific TCE degradation rate coefficient for the dissolved-phase TCE contamination in the RGA. The use of tracer-corrected TCE concentrations, specifically using the contaminant to tracer ration, following a statistical screening of wells affected by ongoing groundwater extraction operations, allowed the quantification of aerobic degradation independent of dispersion because the ^{99}Tc is also subject to dispersion.

The rate of degradation in this aerobic setting is much slower, by more than an order of magnitude, relative to anaerobic dechlorination. The range of the TCE degradation rate coefficient, 0.042 year^{-1} to 0.114 year^{-1} (equivalent to a TCE half-life range of 16.5 to 6.1 years, respectively) is calculated over the range in average groundwater flow rate within the NW Plume, which is estimated to vary from 550 to 910 ft/year.

The possibility of an aerobic degradation mechanism (such as co metabolism) is considered. During co metabolism, TCE does not act as a source of energy for the microbes, but it is transformed by enzymes that catalyze oxidation of other organic substrates. Recent laboratory studies using PGDP groundwater have revealed the presence of bacteria (methanotrophs, etc.) capable of co metabolically transforming TCE. The substrate, which may include naturally occurring humic acids in groundwater, has not yet been identified.

SLIDE 15

DOE (United States Department of Energy) 1993a. *Record of Decision for Interim Remedial Action of the Northwest Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/06-1143&D4, U.S. Department of Energy, Paducah, KY, July.

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Sorrenson, K.S., Jr., L.N. Peterson, R.L. Ely, and R.E. Hinchee 2000. *An Evaluation of Aerobic Trichloroethene Attenuation Using First-Order Rate Estimation*, Appendix E of the “Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B” (DOE/ID-10718), Idaho National Engineering and Environmental Laboratory, March 27.