



# THE MEMPHIS DEPOT TENNESSEE

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## ADMINISTRATIVE RECORD COVER SHEET

AR File Number 854

# Memphis Depot Dunn Field

## Zero Valent Iron Permeable Reactive Barrier Implementation Study Work Plan



April 2006 (Final)



**CH2MHILL**



**U.S. Army Engineering  
and Support Center, Huntsville**

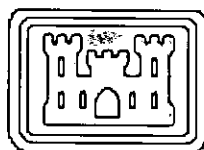
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**Defense Distribution Center (Memphis)  
Dunn Field**

# **Zero-Valent Iron Permeable Reactive Barrier Implementation Study Work Plan**

**Final  
April 2006**

**PREPARED FOR**



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April 17, 2006

MEMORANDUM FOR: TURPIN BALLARD (USEPA – Region 4) AND EVAN  
SPANN (TDEC)

SUBJECT: Final Zero Valent Iron (ZVI) Permeable Reactive Barrier (PRB)  
Implementation Study Workplan Dunn Field Defense Depot  
Memphis, Tennessee

The Final Dunn Field Zero Valent Iron (ZVI) Permeable Reactive Barrier (PRB) Implementation Study Workplan is hereby submitted. This document is part of the Dunn Field Off-Depot Groundwater Remedial Design (RD) and describes the procedures to be used during the installation of a PRB using jet grouting or "jetting" techniques.

For more information, please contact David D. Nelson, Project Manager for CH2M HILL at (770) 604-9182, x394.

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Attachment on CD ROM:

Zero Valent Iron (ZVI) Permeable Reactive Barrier (PRB) Implementation Study  
Workplan, Final

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# Acronyms and Abbreviations

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AFB	Air Force Base
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BCT	BRAC Cleanup Team
bgs	Below Ground Surface
BRAC	Base Realignment and Closure
CEHNC	U.S. Army Engineering and Support Center, Huntsville, Alabama
CF	Chloroform
cm/sec	Centimeters per Second
CT	Carbon Tetrachloride
CVOC	Chlorinated Volatile Organic Compound
ft <sup>3</sup>	Cubic Feet
DCE	Dichloroethene
DLA	Defense Logistics Agency
DO	Dissolved Oxygen
DPT	Direct-Push Technology
DQO	Data Quality Objective
DRC	Depot Redevelopment Corporation
EB	Equipment Blank
ECD	Electron Capture Detector
EDMS	Environmental Data Management System
EISOPQAM	Environmental Investigation Standard Operating Procedures and Quality Assurance Manual
EPA	Environmental Protection Agency
ETI	EnviroMetal Technologies, Inc.
FID	Flame Ionization Detector
FB	Field Blank
ft/d	Feet per Day
ft/min	Foot per Minute
FTL	Field Team Leader
gpm	Gallons per Minute
GPS	Global Positioning System
HASP	Health and Safety Plan
HBI	Hayward Baker Inc.
IDW	Investigative-Derived Waste
kg	Kilogram
lb/ft <sup>3</sup>	Pounds per Cubic Foot
lb/gal	Pounds per Gallon
mg/L	Milligrams per Liter
MIP	Membrane Interface Probe
MLGW	Memphis Light, Gas and Water
MS/MSD	Matrix Spike/Matrix Spike Duplicate



MW	Monitoring Well
NTU	Nephelometric Turbidity Unit
ORP	Oxidation Reduction Potential
OVA	Organic Vapor Analyzer
PCA	Tetrachloroethane
PCE	Tetrachloroethene
PPE	Personal Protective Equipment
PRB	Permeable Reactive Barrier
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RA	Remedial Action
RAB	Restoration Advisory Board
RD	Remedial Design
RDI	Remedial Design Investigation
RG	Remedial Goal
RI	Remediation Investigation
rpm	Revolutions per Minute
SVOC	Semivolatile Organic Compounds
TB	Trip Blank
TCA	Trichloroethane
TCE	Trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TM	Technical Memorandum
TSDF	Transportation/Storage/Disposal Facility
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
ZVI	Zero-Valent Iron
UIC	Underground Injection Control
USGS	United States Geological Survey
µg/L	Micrograms per Liter
yd <sup>3</sup>	Cubic Yard

## 1.0 Introduction

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As part of the Remedial Design (RD) effort for Dunn Field of the former Defense Distribution Center (Memphis) (hereafter referred to as the Memphis Depot), a pilot-scale zero-valent iron (ZVI) permeable reactive barrier (PRB) will be installed west of Dunn Field (also referred to as Off-Depot) using the jet grouting or "jetting" technique to evaluate its implementability and cost-effectiveness for the full-scale Off-Depot Remedial Action (RA). Specifically, this work will include installing a 55-foot long, 8-foot high ZVI PRB from approximately 70 to 78 feet below ground surface (bgs), advancing confirmatory soil borings, and installing four additional monitoring wells (MWs) in support of the Off-Depot Groundwater RD.

The primary objective for the activities described in this work plan is to determine if the jetting technique is a viable, cost-effective method for installation of a ZVI PRB. Hydraulic fracturing is currently the only commercially available method to construct ZVI PRBs below 60 feet bgs. However, the long-term reliability of this method has been difficult to verify. In addition, because there has been only minimal competition for the hydraulic fracturing method for constructing deep PRBs, the costs have not decreased despite the installation of several PRBs.

If the jetted approach is found to be both technically feasible and cost-effective, implementation study results will be used to develop full-scale design parameters. The study will focus on the implementability of the jetted ZVI PRB, with some limited long-term groundwater monitoring. Key implementation study criteria will include:

- Installation time and scalable costs
- PRB permeability and its short- and long-term impact on groundwater flow patterns
- Overall jetting logistics and waste management effort
- Iron wastage rate
- Short- and long-term effect on groundwater chlorinated volatile organic compound (CVOC) concentrations

In addition, to consolidate work planning efforts, the following tasks will be conducted to complete the Source Areas Remedial Design Investigation (RDI):

- Installation of three MWs to delineate further the CVOC groundwater plumes and provide additional monitoring locations for the full-scale groundwater remedy (see Section 3.2).
- Collection of soil samples using direct-push technology (DPT) methods to refine further the limits of soil contaminated with CVOCs down to a depth of approximately 30 feet (within the loess deposits only) (see Section 3.5).

This work plan has been developed by CH2M HILL for the U.S. Army Engineering and Support Center, Huntsville, Alabama (CEHNC) and the Defense Logistics Agency (DLA). Once approved by the Memphis Depot Base Realignment and Closure (BRAC) Cleanup Team (BCT), which consists of personnel from DLA, the U.S. Environmental Protection Agency

(EPA), and the State of Tennessee Department of Environment and Conservation (TDEC), the activities described herein will be implemented by CH2M HILL and its subcontractors.

The data collected during the ZVI PRB Implementation Study effort will be documented within a technical memorandum (TM) that will be part of the Off-Depot Groundwater RD. The TM will include, as a minimum:

- Description of the investigation procedures
- Description of the PRB installation procedures
- Field measurement methods and data collected
- Summary of field and laboratory analytical data presented in graphs, tables, and/or figures
- Variances to work plan procedures
- Assessment of jetting as a viable PRB installation technique
- Data quality and validation report

The data collected as part of the supplemental Source Areas RDI will be presented in the Source Areas RD.

This work plan is organized into the following sections:

- **Section 1 Introduction** includes a discussion of the work plan structure, objectives, and organization.
- **Section 2 Background Information** presents information on the operational history and current status of Dunn Field.
- **Section 3 ZVI PRB Installation Activities** describes the activities and procedures required to install the pilot-scale ZVI PRB.
- **Section 4 Sampling and Analysis** describes how field sampling, waste characterization, and sampling and analysis activities will be conducted in support of the ZVI PRB Implementation Study.
- **Section 5 Data Management, Analysis, and Interpretation** describes procedures for recording observations and raw data in the field or laboratory and procedures that will be used to analyze and interpret data from the ZVI PRB Implementation Study.
- **Section 6 Health and Safety and Community Relations** briefly reviews the health and safety aspects that are in accordance with the approved CH2M HILL Memphis Depot Health and Safety Plan, as well as community relations activities performed in conjunction with the ZVI PRB Implementation Study.
- **Section 7 Reporting** describes preparation of the TM documenting the results of the ZVI PRB Implementation Study.
- **Section 8 Schedule** indicates the planned starting and ending dates for the tasks outlined in the work plan.
- **Section 9 References** lists all documents cited in this work plan.

## 2.0 Background Information

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This section presents information on the hydrogeologic setting and the current status of Dunn Field as related to the RD process. A thorough description of the operational and regulatory history of Dunn Field is provided in the *Dunn Field Remedial Investigation Report* (CH2M HILL, 2002a), *Dunn Field Five-Year Review* (CH2M HILL, 2003a), and the *Dunn Field Feasibility Study* (CH2M HILL, 2003b).

### 2.1 Hydrogeologic Setting

#### 2.1.1 Geology

The impacted vadose zone at Dunn Field consists of two distinct geological units: a shallow, relatively low-permeability loess, and the deep, relatively high-permeability alluvium (fluvial sands). The loess, a semi-cohesive eolian deposit composed of silt, silty clay, silty fine sand, and mixtures thereof, extends from the ground surface to a depth of about 30 feet bgs. To the west of Dunn Field, the loess deposits are approximately 20 feet thick. Underlying the loess are the fluvial deposits, which generally include two layers as shown on Figures 2-1A and B.

The upper 10 feet of the fluvial deposits represents a transition zone between the silt-dominated loess and sand and gravel of the fluvial aquifer. Underneath the western boundary of Dunn Field, the lower portion of the fluvial deposits, which is comprised of sand, sandy gravel, and gravelly sand, is about 40 feet thick. The sand is generally bright orange to dark red and ranges from poorly-graded to well-graded, fine- to coarse-grained, and very well-sorted to poorly sorted quartz grains. The unit transitions downward into poorly graded, tan to brownish yellow sandy gravel, with chert being the primary gravel constituent. The gravel ranges from small pebbles (1/2 inch) up to small cobbles (average diameter of 4 inches). Interbedded within the sand and gravel are clay lenses that range from thin laminations to layers up to 1-foot thick.

As shown on Figure 2-1A, a clay unit of variable thickness is present at the bottom of the fluvial aquifer as this formation transitions to the Jackson Formation/Upper Claiborne Group. According to logs from soil borings collected along the path of the proposed PRB, the unit is an orange, stiff to dense, silty clay with gray mottling that ranges from 5 to 8 feet in thickness. The unit directly overlies the gray, stiff, dense, silty clay of the Jackson Formation/Upper Claiborne Group. The two clay layers are distinguished by their different colors and the presence of slightly less silt in the clay of the Jackson Formation (ranging from 20 to 25 percent). Table 2-1 presents the depth information for the clay unit at the bottom of the fluvial aquifer as found in MWs (i.e., MW-161 and MW-163) and soil borings (i.e., SB-1 through SB-4) adjacent to the study area.

Additional site and regional geology details are presented in the *Dunn Field Remedial Investigation Report* (CH2M HILL, 2002a).

### 2.1.2 Hydrogeology

The uppermost aquifer at Dunn Field occurs in saturated sand and gravel in the lower portion of the fluvial deposits. This fluvial aquifer is the target of this study. Recharge to the fluvial aquifer is primarily from the infiltration of rainfall. Discharge from the fluvial aquifer is toward underlying units in hydraulic communication with the fluvial deposits.

The base of the fluvial aquifer is the transitional clay unit atop the Jackson Formation/Upper Claiborne Group. The saturated thickness of the fluvial aquifer is variable across Dunn Field and is controlled by the configuration of the transitional and basal clay layers. Maximum saturated thickness ranges between 10 and 30 feet above the clay. In November 2005, the average depth to water in the study area was approximately 75 feet bgs, with an average saturated thickness of 4.7 feet. Locally, the groundwater in the fluvial aquifer flows in a western direction, which is also the direction of the local dip of the underlying clay.

Aquifer tests conducted at Dunn Field suggest that the hydraulic conductivity of the Off-Depot fluvial aquifer generally varies as a function of saturated thickness (Table 2-2). The geometric mean of the Off-Depot slug test-derived hydraulic conductivities,  $1.2 \times 10^{-2}$  centimeters per second (cm/sec) (33.9 feet/day [ft/d]), is comparable to previously reported values for Dunn Field ( $7.7 \times 10^{-3}$  cm/sec) (CH2M HILL, 2002a). However, using the MWs with saturated thicknesses less than 12 feet that are also near the proposed pilot study area, the geometric mean of the slug test-derived hydraulic conductivities is  $2.5 \times 10^{-2}$  cm/sec (70.8 ft/d). In comparison, the mean hydraulic conductivity for the MWs in the deeper portion of the fluvial aquifer was estimated to be  $3.4 \times 10^{-3}$  cm/sec (9.6 ft/d).

### Groundwater Modeling

The groundwater flow model, MODFLOW-96, was selected to develop the groundwater flow model for the study area. MODFLOW is a well-accepted, 3-D, cell-centered, saturated groundwater flow model developed by the United States Geological Survey (USGS). MODPATH, a 3-D particle tracking model, was used to assess the pathlines of groundwater through the aquifer. This model was also developed by the USGS. The Groundwater Vistas software interface (Version 3.5), developed by Environmental Simulations, Inc., was used as the pre-and post-processor for MODFLOW and MODPATH.

After the March 2005 potentiometric surface was replicated in the groundwater flow model (MACTEC, 2005a), various formation and iron/sand hydraulic conductivity values were used to evaluate the groundwater flow path following system installation (summarized in Table 2-3); the ZVI layout is presented in Section 3<sup>1</sup>. One assumption for the modeling effort is that the selected sand will not decrease the permeability of the reactive media; therefore, the model assumed the hydraulic conductivity of the iron alone for the reactive media. The model also accounts for differences in material porosity (formation was assumed to be 0.3; the iron, 0.45). As shown in Appendix A, despite similar hydraulic conductivities, the MODPATH results indicate that the groundwater should flow through the iron/sand columns.

<sup>1</sup> As of the writing of this document, the hydraulic conductivity of the iron/sand mixture is unknown since the mixtures have not been completed. However, a sample of the proposed iron/sand blend is to be submitted to a geotechnical laboratory before the mobilization date for constant head (ASTM D2434) or falling head (ASTM D5084) permeability testing. In addition, samples of the aquifer material will be submitted for grain size analysis. The results of these tests will be submitted under separate cover.

Additional site hydrogeology details are presented in the *Dunn Field Remedial Investigation Report* (CH2M HILL, 2002a).

**TABLE 2-3**

Groundwater Model Input Summary

*Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

Pair	K (ft/d)		Comment <sup>1</sup>
	Formation	Iron/sand column	
1	30	150	<ul style="list-style-type: none"> <li>Geometric mean for the Off-Depot formation</li> <li>K for 100% Connelly 1167 iron</li> </ul>
2	30	200	<ul style="list-style-type: none"> <li>Geometric mean for the Off-Depot formation</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>
3	70	150	<ul style="list-style-type: none"> <li>Geometric mean for the thin aquifer present in the study area</li> <li>K for 100% Connelly 1167 iron</li> </ul>
4	70	200	<ul style="list-style-type: none"> <li>Geometric mean for the thin aquifer present in the study area</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>
5	130	150	<ul style="list-style-type: none"> <li>Geometric mean for wells nearest to ZVI PRB (MW-144 and MW-161)</li> <li>K for 100% Connelly 1167 iron</li> </ul>
6	130	200	<ul style="list-style-type: none"> <li>Geometric mean for wells nearest to ZVI PRB (MW-144 and MW-161)</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>

<sup>1</sup>An assumption has been made that the selected sand will not decrease the permeability of the reactive media; therefore, the model assumed the hydraulic conductivity of the iron alone for the reactive media.

## 2.2 Nature and Extent of Groundwater Contamination

The nature and extent of contamination in groundwater underlying Dunn Field is based on chemical analyses of groundwater samples collected since January 1996. Groundwater samples have been analyzed for explosives, herbicides, metals (total), pesticides, polychlorinated biphenyls, semivolatile organic compounds (SVOCs), and CVOCs. CVOCs, SVOCs, and total metals were the most frequently detected analytical constituents in groundwater samples. The most recent groundwater sampling data for the study area are presented in Table 2-4.

As shown on Figure 2-2, there are three major CVOC plumes in the groundwater underlying Dunn Field that mix and intermingle: a northern plume, a western-northwestern plume, and a western-southwestern plume. All of the plumes have on-site and Off-Depot components. The CVOCs that have consistently been detected in groundwater during sampling events include 1,1,2,2-tetrachloroethane (PCA), carbon tetrachloride (CT), 1,1,2-trichloroethane (TCA), chloroform (CF), tetrachloroethene (PCE), *cis*- and *trans*-1,2-dichloroethene (DCE), total 1,1-DCE, and trichloroethene (TCE).

TCE and 1,1,2,2-PCA concentration trends for MWs located upgradient (i.e., MW-77 and MW-161) and downgradient (MW-144 and MW-163) of the study area are presented on Figures 2-3A and 2-3B. TCE and 1,1,2,2-PCA concentrations appear to be gradually

decreasing with time and distance, except at MW-77. Because it is closer to the Source Areas than the other MWs, the TCE and 1,1,2,2-PCA concentration patterns at MW-77 may be the result of the ZVI injection pilot study conducted in fall 2003. Overall, CVOC concentrations in the MW-73 area were reduced by more than 90 percent for more than a year. Due to advection, the Source Area CVOC plume reduction resulted in the 1,1,2,2-PCA concentration reduction at MW-77 (85 percent reduction from April 2005 to June 2005). As the CVOC concentrations rebounded in the treatability study area, the CVOC concentrations at MW-77 also responded (1,1,2,2-PCA increased to 14 milligrams per liter [mg/L] by November 2005). These data suggest that permanent source area mass removal will result in significant plume CVOC concentration decreases within a relatively short timeframe; therefore, the full-scale ZVI PRB design is highly sensitive to the performance of the Source Areas remedy.

## 2.3 Current Status of Dunn Field

The Dunn Field Remedial Investigation (RI) and RD have been completed in several stages and have included the following activities, which are used as a basis for this study:

- **RI.** The 1996 to 2001 RI included soil, soil gas, and long-term groundwater sampling, in addition to aquifer testing (CH2M HILL, 2002a).
- **Off-Depot Design-Related Investigation.** This investigation was conducted from June through December 2004 by MACTEC to evaluate site hydrogeology and contaminant concentrations in the area of MW-54, so that appropriate Off-Depot RAs could be designed and implemented. The objective of the Off-Depot Design-Related Investigation was expanded to identify the area(s) to be included in the early implementation of the RA, to provide baseline groundwater data for comparison to post-injection monitoring results, and to assess the hydrogeology downgradient of the area treated with ZVI (MACTEC, 2005a).
- **Dunn Field RDI.** This investigation included the installation of on-site and Off-Depot MWs, membrane interface probe (MIP) and DPT points, and soil borings in support of the Source Area RD, the Off-Depot groundwater model for the Off-Depot Groundwater RD, and the design and final placement of the Off-Depot ZVI PRB. The investigation was conducted in October and November 2005; however, limited additional data will be collected as part of this work plan to complete the RDI.

Based on the various investigation findings, the following response actions have already been conducted in, or affect, the Off-Depot area of Dunn Field:

- **Interim Groundwater Remedial Action.** A groundwater extraction system consisting of 11 recovery wells was installed along the western Dunn Field boundary and began operation in November 1998. The objectives of the hydraulic containment system are to: (1) prevent further contaminant plume migration and (2) reduce contaminant mass in groundwater.
- **Early Implementation of Selected Remedy.** Based on the results of groundwater sampling conducted from June through October 2004, ZVI was injected into the fluvial aquifer to address the concentrations of CVOCs at the leading edge of the high-

concentration portion of the plume (within the 500-microgram-per-liter [ $\mu\text{g/L}$ ] isopleth for total CVOs). The targeted area was 800 to 1,000 feet downgradient (west) of Dunn Field (MACTEC, 2005b).

Finally, in support of the overall Dunn Field RD, one field-scale treatability study relevant to the ZVI PRB Implementation Study has been conducted. The ZVI treatability study (CH2M HILL, 2004b), which included pressurized pneumatic injection of ZVI powder into the saturated zone (fluvial aquifer) at Dunn Field, was conducted from October 29 to November 14, 2003, to collect site-specific data to design the full-scale Source Area groundwater remedy. The results of the study indicate that ZVI is an effective treatment technology for the groundwater contaminants located under Dunn Field.

Ongoing Dunn Field design and development activities include the following:

- Design of the Source Area subsurface soil and groundwater RAs
- Development of the Off-Depot groundwater model
- Design of the Off-Depot Groundwater RA

## 2.4 ZVI PRB Implementation Study Justification

Depending on depth, ZVI PRBs are typically installed using the following construction methods:

Depth (ft)	Method
0 to 20	Excavation with or without side wall support (e.g., trench boxes, biodegradable slurry)
15 to 35	Excavation with sidewall support
	One-pass trenchers
30 to 60	Excavation with sidewall support (biodegradable slurry)
	Hydraulic fracturing
>60 feet	Hydraulic fracturing

### Hydraulic Fracturing

As indicated above, hydraulic fracturing is currently the only commercially available method to construct ZVI PRBs below 60 feet bgs. These PRBs are constructed from a series of wells installed along the PRB alignment. According to the vendor (GeoSierra), a controlled vertical fracture is initiated in each well at the required azimuth orientation and depth. Iron filings are injected into the wells in a highly viscous cross-linked proprietary hydroxypropyl guar biodegradable gel to form a continuous PRB. This installation method is purported to achieve a uniform distribution of iron up to 9 inches thick through the targeted zone.

PRB geometry is monitored in real time by active resistivity to ensure that the barrier is constructed as designed. In addition, hydraulic pulse interference tests can be conducted before and after placement of the PRB to verify that the PRB does not reduce the permeability of the formation. Vertical hydrofracturing has been used to complete at least 9 iron PRBs up to 117 feet bgs and 1,200 feet in length.



## Jet Grouting

Jet grouting may be a viable, cost-effective alternative to hydraulic fracturing for the ZVI PRB installation at Dunn Field. Jet grouting is a ground modification technique that employs high-velocity, high-energy jets to remove and/or mix soils in situ with cement-based grout or other engineered media to stabilize soft soils. This process has been used to create ZVI PRBs at F.E. Warren Air Force Base (AFB), Travis AFB, and the DuPont facility in Kinston, North Carolina. The ZVI PRB at Travis AFB was created with overlapping columns; the Warren AFB and Kinston ZVI PRBs were created with a series of shallow panels (comparable to the hydrofracturing approach). In general, the ZVI was applied in a biodegradable guar-based drilling fluid that rapidly broke down after implementation, leaving a mixture of native soils and ZVI.

Based on conversations with Glenn Anderson (Travis AFB), John Wright (Warren AFB), and Richard Landis (DuPont), one of the biggest influences on jetted PRB effectiveness is aquifer heterogeneity. At both AFBs, the PRBs were installed in aquifers with multiple and divergent lithologic layers. As a result, the transmissive layers that were dominating contaminant flow may have been blended with low-permeability layers to create a low-permeability wall. Potentiometric and analytical data indicated that neither PRB met remediation goals. The pilot-scale Warren AFB ZVI PRB had mixed success, with reductions in TCE concentrations over a 9-month period ranging between 36 percent and 91 percent<sup>2</sup>.

In comparison, the Kinston PRB has effectively controlled CVOC migration, allowing the facility to shut down its expensive groundwater recovery system. The aquifer at Kinston is shallower and more homogeneous than those at the other jetted sites. In addition, the use of panels (as opposed to columns) at Kinston may also have been a factor in its long-term effectiveness.

As detailed in Section 3, Hayward Baker Inc. (HBI) has modified their jetting strategy to better control jetted ZVI PRB permeability and significantly minimize the iron wastage rate. Rather than mixing the iron into the formation materials as previously done, HBI intends to erode and then remove most of the native sediments from the column geometry. A guar/water slurry will be injected as the formation materials are eroded to support the column structure before it is replaced with the iron/sand mix. The formation fines will be either expelled during the erosion process or, since they will tend to be suspended in the guar slurry, displaced during the addition of the iron/sand mix via tremie methods. The coarser native materials will be removed like the fines or may settle to the bottom of the eroded column before the iron/sand mix is added. This technique modification, coupled with the relatively homogeneous nature of the fluvial aquifer, suggests that this approach is a viable alternative for the Dunn Field ZVI PRB.

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<sup>2</sup> Communication with Mike Duschene, ETI (February 28, 2006).

## 3.0 Implementation Activities

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This section describes the activities and procedures required to implement the Off-Depot ZVI PRB Implementation Study and complete the Dunn Field RDI.

### 3.1.1 Preliminary Activities

Preliminary study activities associated with the implementation of the ZVI PRB Implementation Study include:

- Submission of application for MW installation<sup>3</sup> and notice of intent to inject ZVI following the State of Tennessee underground injection control (UIC)<sup>4</sup> permit guidance. Only the substantive requirements of the applicable regulations will be followed during the study effort.
- Survey of ZVI PRB alignment.
- Installation of a gate along the western perimeter fence of Dunn Field, possibly at the corner of Menager Avenue and Kyle Street, and associated temporary road construction, as necessary.
- Coordination with the City of Memphis, Memphis Light, Gas and Water (MLGW), and Memphis Depot personnel on the location of utilities in the area.
- Designation of areas for temporary storage of equipment, construction materials, and waste management.
- Site-specific security and safety concerns.

### 3.1.2 Logistics

Required equipment, supplies, and personnel will be mobilized after approval of this work plan and the Site-Specific Health and Safety Plan (HASP). The Site-Specific HASP must be reviewed and approved by CEHNC before the project begins.

A site coordination meeting will be held after the final work plan has been approved and before mobilization of the field effort. Participation may include personnel from DLA, EPA, TDEC, CEHNC, CH2M HILL, the Depot Redevelopment Corporation (DRC), and subcontractors. The meeting will include discussions of Depot regulations, data quality objectives (DQOs), field procedures, and field schedules, as well as a review of the Site-Specific HASP.

### 3.1.3 Land Surveying

Available maps describing the location of the proposed MWs, DPT points (Figure 3-1), and pilot-scale ZVI PRB (Figure 3-2) will be provided to Allen & Hoshall, Inc., a professional land surveyor registered in the State of Tennessee. The surveyor will translate this

<sup>3</sup> <http://www.shelbycountyttn.gov> > Government > County Services > Health Services > Environmental Health > Air Pollution Information. The application will be submitted by the drilling subcontractor.

<sup>4</sup> <http://tennessee.gov/environment/permits/injetwel.php>

information and stake the proposed MW and DPT locations and the PRB alignment based on provided northing and easting coordinates. The stakes or pin flags will be positioned at a sufficient height to be visible to persons mowing the grass.

Post-installation soil confirmation sampling locations will be clearly marked in the field with stakes or pin flags so that their positions can be surveyed at the completion of the study.

### 3.1.4 Utility Locating

CH2M HILL field personnel will have utilities located adjacent to and within the area of the proposed ZVI PRB alignment and MW and on-site DPT soil sampling locations at least 2 weeks prior to commencement of the activity. Utilities will be marked by a professional utilities locating service prior to the start of construction. The proposed MW and DPT locations and ZVI PRB layout are depicted on Figures 3-1 and 3-2, respectively, but final locations will be based on the utility locations and conditions encountered in the field.

## 3.2 Monitoring Well Installation

Additional on-site and Off-Depot MWs are proposed to provide further plume delineation and additional monitoring locations for full-scale implementation and to monitor the pilot-scale ZVI PRB. The proposed wells are discussed below.

### Dunn Field (RDI)

As shown on Figure 3-1 and summarized below, three MWs have been installed on Dunn Field to delineate further the CVOC groundwater plumes and provide additional monitoring locations for the groundwater remedy.

Well Number	Proposed Location	Purpose
MW-172	East of MW-173	Delineate the eastern extent of the CVOC plume
MW-187	East of the inaccessible area near Treatment Area 3	Assess whether there is a groundwater impact due to the loess contamination discovered during the primary phase of the RDI
MW-188	South of MW-131 and east of MW-177	Further delineate the CVOC plume in Treatment Area 2

### Off-Depot (PRB Monitoring)

As shown on Figure 3-2 and summarized below, eight Off-Depot MWs will be installed to monitor the effectiveness of the pilot-scale ZVI PRB.

Well Number	Proposed Location	Purpose
MW-189	10 feet upgradient of the pilot-scale ZVI PRB; in-line with MW-161 and MW-144	Assess upgradient CVOC concentrations and groundwater geochemistry
MW-190	10 feet upgradient of the pilot-scale ZVI PRB	
MW-191	10 feet downgradient of the pilot-scale ZVI PRB; in-line with MW-161 and MW-144	Assess downgradient CVOC concentrations and groundwater geochemistry
MW-192	10 feet downgradient of the pilot-scale ZVI PRB; other side of the ZVI PRB from MW-191 in the direction of groundwater flow	

Well Number	Proposed Location	Purpose
MW-193	30 feet downgradient of the pilot-scale ZVI PRB; other side of the ZVI PRB from MW-191 in the direction of groundwater flow	Assess downgradient CVOC concentrations and groundwater geochemistry
MW-194	Installed within the ZVI PRB after the confirmation soil cores have been collected	Assess CVOC concentrations and groundwater geochemistry within the ZVI PRB
MW-195		
MW-196		

All of the new MWs will consist of 2-inch diameter polyvinyl chloride (PVC) and will range from 80 to 110 feet bgs. All MWs will be installed using rotasonic drilling methods as conducted by ProSonic Corporation of Aiken, South Carolina.

Continuous soil sampling will be conducted at each of the well locations using the rotasonic soil coring system. The sampling interval will not be greater than 10 feet. Each location targeted for the fluvial aquifer will be drilled 10 feet into the underlying clay unit for verification. The sampling technique must provide samples that are representative of the interval sampled and that are relatively undisturbed. For the study area only, select soil cores from below the water table will be archived for future reference. For other areas, select soil cores from below the water table may be archived for future reference at the discretion of the field team leader (FTL).

### 3.2.1 Well Installation

The well casing and screen will be constructed within the rotasonic drill casing (minimum 6¼-inch inner diameter) as the casing is withdrawn from the boring. The annular space will be filled with well material consisting of the filter pack, bentonite seal, and grout as the rotasonic casing is withdrawn from the borehole. The depth of placement of the screen and well material will be as directed by the FTL.

#### Well Casing and Screen

Well casings will be new, unused, decontaminated, 2-inch inside diameter schedule 40 PVC pipe with internal flush-joined threaded joints that conform to American Society for Testing and Materials (ASTM) Standard F-480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System). The 10- to 20-foot screens will be factory-slotted to 0.010 inch. A threaded PVC cap or point will be placed at the bottom of the screen.

#### Filter Pack

Filter Seal No. 2 or equivalent will be used as the filter pack, which will extend from the bottom of the hole to at least 5 feet above the top of the well screen. The filter pack will be installed with a bottom-discharge tremie pipe. The tremie pipe will be lifted from the bottom of the hole at the same rate as the filter pack is set. The contractor will record the volume of the filter pack emplaced in the well. With the approval of the FTL, potable water may be used to emplace the filter pack so long as no contaminants are introduced.

#### Bentonite Seal

Following filter pack placement, a 2- to 5-foot-thick bentonite seal will be placed above the filter pack. The 100 percent sodium bentonite seal will consist of 1/4-inch or 3/8-inch diameter dry bentonite pellets or chips. The bentonite seal will be installed by gravity

methods. The bentonite seal will be allowed to hydrate for a minimum of 4 hours prior to the placement of the cement grout.

### **Cement Grout**

Cement grout will be placed in the annular space above the bentonite seal to ground surface. The grout will be pumped through a side-discharge tremie pipe with the downhole end of the pipe at the top of the bentonite seal. As the grout is forced through the pipe and upward through the borehole, the tremie pipe will be lifted (as sections of the tremie pipe are removed at the surface) while keeping the downhole end below the surface of the grout. The greatest lift thickness per event will be no more than 60 feet. Grouting events will be separated by a minimum of 12 hours. The grout seal will be Type II Portland cement or American Petroleum Institute (API) Class A cement with no more than 4 percent bentonite. The grout will be mixed in the following proportions: 94 pounds of neat cement, not more than 4 pounds of 100 percent sodium bentonite powder, and not more than 8 gallons of potable water. The grout will have a mixed minimum specific density of 9.4 pounds per gallon (lb/gal) or the manufacturer's recommended density. A mud balance will be used to ensure that the density of the mixture conforms to the manufacturer's standards. Before the wells are completed, the boreholes will be topped off with grout to approximately 1 to 2 feet bgs.

### **3.2.2 Well Completion**

All MWs will be completed with flush-mount wellhead protection pads and properly developed. For those wells on Dunn Field, four bollards will be placed at each corner of the pad. The 3-inch diameter, galvanized steel bollards will be recessed approximately 2 feet into the ground, fully set in concrete, and painted with high-visibility yellow paint. The inner annulus of the pipe will be filled with grout.

The top-of-casing and wellhead protection pad will be surveyed for each new MW and added to the existing Memphis Depot horizontal and vertical coordinate system. After the new MWs are installed, a site-wide groundwater level gauging event will take place across Dunn Field that will also include existing MWs. Depth-to-water data will be used to develop a potentiometric surface map for use in the Off-Depot Groundwater RD.

### **3.2.3 Well Development**

The wells will be developed with a surge block in conjunction with a pump and/or bailers. No air, detergents, soaps, acids, bleaches, or additives will be used during well development. Well development will be initiated no sooner than 24 hours following grout placement.

Development will start once the pump or other water-removal device is set within the water in the well and will continue until clear, sand-free formation water is produced from the well and until pH, conductivity, turbidity, and temperature measurements have stabilized. Stabilization is defined as the point at which the pH is within  $\pm 0.1$ , the conductivity is + or - 3 percent, and the turbidity remains less than 10 nephelometric turbidity units (NTUs) for at least 30 minutes. The FTL will determine when development is complete. Water from development will be contained and disposed of in accordance with Section 3.8.

### 3.3 Baseline Groundwater Sampling

After each new MW is installed and developed, CH2M HILL will collect baseline groundwater samples from the three new Dunn Field MWs (MW-172, MW-187, and MW-188) to complete the RDI, five new Off-Depot MWs (MW-189 to MW-193), and seven existing Off-Depot MWs (MW-54, MW-77, MW-144, MW-150, MW-161, MW-162, and MW-163). Well purging and sampling procedures for the baseline event (and subsequent monitoring events for the implementation study area) are included in Section 4. Analytical results from this sampling event will be used to provide up-to-date CVOC concentration and geochemical data for the fluvial aquifer in the study area.

The samples will be analyzed for VOCs by Kemron Environmental of Marietta, Ohio. All samples will be shipped from the site for laboratory analysis via overnight courier. All data will be validated by a CH2M HILL chemist. A data quality evaluation report describing the sampling results will be attached to the TM.

### 3.4 Slug Testing

CH2M HILL will conduct single-well aquifer tests (slug tests) in the following MWs in the ZVI PRB study area:

- **Existing:** MW-76, -77, -144, -157, -161, -162, -163, -164, and -184
- **New:** MW-189 to MW-196

Slug testing will be done prior and subsequent to ZVI PRB installation to assess whether the installation caused any change to local permeability of the fluvial aquifer; the MWs installed in the ZVI PRB (MW-194 to MW-196) will be only slug tested after installation. Results of the slug tests will be included in tabular form in the TM describing pilot test results.

### 3.5 On-site Soil Sampling

To complete the RDI, 25 discrete soil samples will be collected using a standard DPT. As shown on Figure 3-1 and summarized in Table 3-1, the soil sampling locations were selected to complete the delineation of the areas with CVOC concentrations (particularly 1,1,2,2-PCA) that are above the established Dunn Field RGs. The vertical sampling interval was selected based on the maximum MIP response at each targeted sampling location.

### 3.6 ZVI PRB Installation

As discussed in Section 2, the Dunn Field ZVI PRB will be installed using a procedure developed from previous jetted PRB efforts (namely Travis and Warren AFBs). HBI will use the following two-phase process:

- **Phase I** — The geometry of the PRB will be created using HBI's conventional jet grouting methodologies with a water and biodegradable guar drilling fluid.

**TABLE 3-1**  
Proposed Soil Sampling Summary  
Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan

Treatment Area	Coordinates		Depth (feet bgs)	Rationale
	North	East		
1	2400	1120	21-22	Complete delineation of impacted loess around MW-10.
	2440	1120	14-15	
3	1400	1280	12-13 and 27-28	Tighten delineation around inaccessible tree and debris area, particularly to the north and south.
	1400	1330		
	1440	1260		
	1440	1330		
	1480	1260		
	1480	1330		
4	1000	1160	21-22	Complete delineation of impacted area.
	1000	1200	26-27	
	1040	1160	17-18	
	1040	1280	16-17	
	1080	1120	7-8	
	1080	1280	16-17	
	1120	1280	12-13	
	1160	1160	11-12	
	1160	1200	12-13	
	1160	1240	12-13	
	1160	1280	12-13	

- Phase II** — The iron will be mixed with sand and placed down the hole via a tremie pipe; the enzyme required for breaking the guar slurry will also be added during this phase. Because of its higher specific gravity, the sand and iron mix will displace the guar/ water/soil mix within the jetted geometry. If gravity addition results in incomplete slurry displacement or the tremie pipe plugs due to the angular shape of the iron particles, the iron/sand will be pumped under low pressures into the column via tremie pipe. If that is not effective, the column, which would then contain iron/sand and the guar/ water/soil slurry, would be rapidly re-jetted to distribute the iron/sand throughout the eroded column. This would result in some iron loss, which would be considered during the final assessment of the technology.

### 3.6.1 ZVI PRB Location and Equipment Layout

As shown on Figure 3-2, the ZVI PRB will be installed west of Rozzelle Street between MW-144 and MW-161 on an undeveloped parcel beneath the MLGW power line corridor. The power lines are about 50 feet above ground surface. As presented in Appendix B, equipment brought on-site during the ZVI PRB Implementation Study will include the following:

- Rotary drill rig (Bauer BG-15 or similar)
- Double system jet pump (Gardner Denver D-2000 extended duty triplex pump or similar)
- Vacuum truck
- Various tanks, pumps, and ancillary equipment

It is anticipated that standard tractor trailers and removable goose neck trailers will be used to mobilize the equipment to the site. All of the drilling and jetting equipment will be staged near the study area. During the mobilization and set-up process, HBI will make the necessary electrical connections/wiring of equipment, connection of hoses/plumbing, run high-pressure hoses, and calibrate scales. With City of Memphis, MLGW, and/or Memphis Depot permission, certain areas may be temporarily blocked off to move equipment or to create an exclusion zone during the jetting process.

### 3.6.2 Jetting Process

The preliminary ZVI PRB layout is shown on Figure 3-3. Based on discussions with HBI and a bench-scale treatability study conducted for the Memphis Depot by EnviroMetal Technologies, Inc. (ETI) (Appendix C), the jetted ZVI PRB will have the following characteristics:

- **Length:** approximately 55 feet
- **Height:** 8 feet (extending from approximately 70 to 78 feet bgs)<sup>5</sup>
- **Width:** 6-foot diameter columns; 12 feet total (2 rows of offset columns). Based on the ETI conceptual design, a 100 percent iron PRB would be 1.2 feet thick. The proposed PRB configuration/width is defined by the installation method.
- **Column volume:** 226 cubic feet (ft<sup>3</sup>) or 8.3 cubic yards (yd<sup>3</sup>)
- **Iron mass:** 4 tons per column; 68 tons total. Based on the ETI conceptual design, 47 tons of iron would be required to construct a 1.2-foot thick, 55-foot long, 8-foot tall PRB with iron at 180 pounds per cubic foot (lb/ft<sup>3</sup>). However, because the overlapping column approach is being used for this application, additional iron is required to meet the minimum ETI specification of 20 percent iron by volume for each of the 17 columns.
- **Sand volume:** 6.6 yd<sup>3</sup> per column; 113 yd<sup>3</sup> total.

The installation process will include reactive media preparation, testing, establishment of the pilot-scale PRB layout, and completion of Phases I and II.

#### Reactive Media

The reactive media, consisting of sand and ZVI, will be delivered to the site and staged separately. Because it has a higher hydraulic conductivity, CC-1004 (-8+50 mesh) will be used in the PRB implementation study instead of CC-1167 (-18+84 mesh), which was used in the bench-scale treatability test. Both are manufactured by CONNELLY-GPM, INC. The

<sup>5</sup> Reactive media height is based on the *Report of Offsite Design-Related Investigation Dunn Field* (MACTEC, 2005), soil boring logs from the October 2005 RDI along the proposed ZVI PRB alignment, and groundwater levels measured in October and November 2005.



specified material will be delivered to the site in 3,000-pound bulk bags that have an estimated dry bulk density of 150 lb/ft<sup>3</sup>. The in-place estimated hydraulic conductivity of the ZVI is approximately  $7.3 \times 10^{-2}$  cm/sec, and the surface area of the ZVI is estimated to vary from 0.8 to 1.5 square meters per gram. The sand in the reactive material mix will be clean, washed, and screened sand and will conform to a gradation that will not result in loss of permeability when mixed with the ZVI.

### **Reactive Media Preparation**

Sand and ZVI will be blended on a volumetric basis using one or more ready-mix concrete trucks that will arrive at the site with a load of pre-weighed sand. At the site, the ZVI will be placed into the ready-mix truck(s) using a forklift and small conveyor. The ZVI and the dry weight of the sand will be used to proportion the backfill. The weight tickets on the bagged iron will be used to ensure proper weight of the ZVI in the mix.

The ZVI and sand will be mixed thoroughly into a homogenous blend. The samples will be visually observed by CH2M HILL and HBI to assess the iron content of the mix. The uniformity of the mixture will also be assessed with a magnetic separation test (Appendix D). If the specified iron-to-sand ratio is less than 20 percent, then additional iron will be added; if the mix exceeds 24 percent, then the blending procedure will be evaluated and revised as necessary. The quantity of reactive media stored overnight will be minimized.

As discussed below, if biopolymer is used to deliver the iron and sand into the excavated column, a mixing tank with a paddle mixer and bottom discharge (or similar) would be used to mix the iron, sand, and biopolymer. A positive displacement pump would then be used to transfer the slurry through the tremie pipe into the column. An enzyme breaker would also be added to the slurry to promote degradation of the biopolymer.

### **Test Columns**

After mobilization to Dunn Field, HBI will complete one or two full-depth test columns near the study area to verify column geometry and mix design workability. These columns will be installed with the same techniques that will be used for the production columns. The quality and distribution of the in-place reactive media will be assessed after the 55-foot long PRB is established.

The vast majority of HBI experience with this technology has been for geotechnical applications where creating the design geometry is critical. Two methods that HBI has used in the past include: (1) excavating the column to reveal its final geometry, and (2) using PVC pipes installed at multiple radial intervals that vibrate or sound when the jet has reached their location. Although this application is a variation of HBI's conventional jet grouting method and needs to be tested, their experience, particularly in similar lithology, indicates that they will be able to reliably generate the design geometry. HBI's initial testing program will focus on volume to assess geometry as follows:

1. The height of the column will be defined by the interval that is eroded: 8 feet.
2. HBI experience indicates that they are able to erode the formation to form a column; therefore, the assumption is that the cross-sectional area of the erosion is a circle.

3. The specific gravity of the guar/water/soil slurry will be adjusted to maintain the shape of the column using conventional geotechnical assumptions. The cylinder-shaped cavity should be maintained until the reactive media is added just after the erosion process.
4. Assuming that the guar slurry can be effectively displaced by either of the reactive media application methods discussed below, the volume of the cavity will be verified by the amount of reactive media tremied into the column and the volume of slurry displaced during the process.
5. Given the volume of slurry, the height of the column, and HBI's experience with column generation during jetting, the diameter can be calculated.

Since the jetted column does not extend to the ground surface, roof collapse is possible. The tremie pipe will be used to measure the elevation of the column bottom after the jetting process has been completed. Jetting process modifications would be made in the field if the difference between the design and the post-jetting column depth is significantly different (that is, more than 1 foot).

### **ZVI PRB Installation**

After the testing phase is complete, HBI will commence with the production columns. Each column will be completed in two phases, as described below.

**Phase I – Column Geometry.** HBI will use a guar/water slurry to create the column geometry. The guar and water solution will be hydrated in a 20,000-gallon tank. It is anticipated that the guar and water will be combined at the rate of approximately 30 to 40 pounds of powdered guar for every 1,000 gallons of water. Soda ash and biostat will be added as needed to prevent the premature breakdown of the biopolymer and potential collapse of the column. After the guar and water are hydrated, the guar slurry will be transferred via centrifugal pump to a high-pressure, extended-duty triplex pump. Used as the drilling fluid, the slurry will be injected under low pressures and flow rates as the drill rods are advanced to the design depth. It is anticipated that the pressure and flow rate will be approximately 1,500 pounds per square inch (psi) and 25 gallons per minute (gpm), respectively.

The verticality of the drill rods will be verified using the process commonly used by environmental well drillers. The verticality of the drill rig will be checked after the mast is raised to full height and throughout the drilling process. The weight of the drill string and the cutting tool to be used during this procedure will minimize variance from vertical. After the drill rod has reached the design depth, the pressure, flow rate, and other jetting parameters will be as follows:

- Pressure = 6,800 psi
- Flow rate = 80 gpm
- Rotation = 10-12 revolutions per minute (rpm)
- Retraction = 1 foot per minute (ft/min)

To establish column geometry, the drill rods will be turned at a constant rate and then the pressure will be increased until design parameters are achieved. A two-phase internal rod system will be used to independently supply drilling fluid and air to two concentric nozzles.

The drilling fluid will be used to erode and remove the soil. Air, delivered by a compressor at approximately 80 psi, will shroud the drilling fluid and increase erosion efficiency.

Erosion will be initiated at an average depth of 78.5 feet bgs (approximately 6 inches into the clay) with high-velocity injection of cutting and replacement fluids. This process will continue with consistent, uniform rotation and lifting to create column geometry, while expelling eroded spoil out of the top of the borehole annulus. The reactive zone is anticipated to be 8 feet extending from the top of the confining clay layer to at least 1 to 2 feet above the groundwater table. The drill rod will be lowered to the bottom of the column again so that it can be re-jetted to loosen the soil and decrease the specific gravity of the column. After the column has been created, the drilling tools will be removed and relocated to the next hole. The biopolymer slurry will temporarily support the excavated column.

**Phase II - Tremie pipe placement.** The 20 percent iron and 80 percent sand mix (by volume) will be placed using one of the two methods described in the testing phase.

1. The dry sand and iron mixture will be placed under gravity using a tremie pipe with a funnel. The enzyme breaker will also be added during this process.
2. Alternatively, if the sand and iron mix does not flow into the targeted zone by gravity, guar slurry will be added to the sand and iron mix before it is pumped into the column under pressure.

The bottom of the tremie pipe must be maintained close to the backfilled material to minimize the drop of the iron-sand through the biopolymer and the potential for segregation. The volume of guar/water/soil material that is displaced from the column will be compared to the theoretical volume of the column. The displaced material will be collected with a vacuum truck and then transferred to a lined roll-off box for temporary storage. If the correlation is low (less than 90 percent), HBI will briefly re-jet the column to stir the zone and ensure that the iron is evenly distributed. If the columns are larger than the design, then the jetting parameters (that is, pressure, flow rate, rotation, and retraction) will be adjusted to create the correct column volume. Otherwise, additional reactive media (iron and sand) will be required to complete the ZVI PRB.

### 3.6.3 Monitoring During Jetting

The HBI drill rig has an electronic sensor board that measures and displays the drilling tool rotational rate (in rpm) and extraction rate (in ft/min). The drill rig operator will also use a stopwatch to monitor the extraction rate for this application. In addition, the pump operator will monitor the pressure generated by the double pump system. The pressure component is critical to the effectiveness of the cutting and extraction process so that the desired column geometry is created.

Guar slurry consistency and injection flow rate will also be monitored during the jetting process. Careful monitoring of the consistency will help ensure that the guar slurry does not break down prematurely. The guar slurry injection and extraction flow rate must also be monitored to gauge cutting and reactive media emplacement effectiveness.

For health and safety purposes, the area surrounding the boreholes and the work area perimeter will be monitored with a flame ionization detector (FID) with readout levels of parts per million. A consistent, 30-second, 1-part-per-million measurement will result in a

change of personal protective equipment (PPE) from standard Level D to Level C. Additional health and safety aspects of this project are described in the Site-Specific HASP.

### **3.6.4 Jetting Borehole Abandonment**

Each jetting boring will be abandoned by first placing a coarse-grained, clean sand in the borehole from the bottom to approximately 50 feet bgs. A 2- to 5-foot thick bentonite seal will be placed on top of the sand. Cement grout will be placed in the annular space above the bentonite seal to ground surface. The grout will be pumped through a side-discharge tremie pipe with the downhole end of the pipe at the top of the bentonite seal. As the grout is forced through the pipe and upward through the borehole, the tremie pipe will be lifted (as sections of the tremie pipe are removed at the surface) while keeping the downhole end below the surface of the grout. The greatest lift thickness per event will be no more than 60 feet. The grout seal will be Type II Portland cement or API Class A cement with no more than 4 percent bentonite. The grout will be mixed in the following proportions: 94 pounds of neat cement, not more than 4 pounds of 100 percent sodium bentonite powder, and not more than 8 gallons of potable water. The grout will have a mixed minimum specific density of 9.4 lb/gal or the manufacturer's recommended density.

### **3.6.5 Site Cleanup and Restoration**

Upon completion of the implementation study, the site will be cleaned up to pre-construction conditions. All equipment will be transported offsite; waste will be managed in accordance with Section 3.8. The site will be regraded and revegetated as necessary.

### **3.6.6 Communication**

During the field effort, CH2M HILL will be responsible for site management and communications among team members. CH2M HILL anticipates that there will be one primary Site Manager and up to two other CH2M HILL personnel on-site during the field activities. HBI may have up to eight personnel at the site performing various functions during the field effort. Access to HBI personnel will be restricted during the field effort to avoid miscommunication of instructions. Communications among the team members will be via cell phones and hand-held radios. Typically, cell phones operate satisfactorily in the study area. In some cases, hand signals will be used for the pump operator due to noise levels.

CH2M HILL also anticipates that several observers from other organizations will be on location during the field effort. Team members will communicate with the observers in person or via cell phone. The site will have designated work and observer zones and will be marked accordingly. The health and safety aspects of the field work are described in the Site-Specific HASP, which will be submitted as a separate document for review by CEHNC.

## **3.7 Confirmation Sampling**

### **3.7.1 Soil Borings**

After the ZVI PRB has been installed, ProSonic will mobilize to the site and advance soil borings through the PRB to assess the distribution of the ZVI. At least five borings will be installed vertically through the PRB in multiple columns and a range of radial distances to

assess iron distribution. The iron should cause a distinctive black coloration that should be visually observable in soil cores. Once oxidized, the powder turns to reddish brown, which may also be detected if the natural soil color is a lighter color. For these borings, select soil cores will be archived for future reference and testing. Sampling procedures are provided in Section 4.3.3.

### **Borehole Abandonment**

Each soil boring will be abandoned by first placing a coarse-grained, clean sand in the borehole from the bottom to approximately 50 feet bgs. A 2- to 5-foot thick bentonite seal will be placed on top of the sand. Cement grout will be placed in the annular space above the bentonite seal to ground surface. The grout will be pumped through a side-discharge tremie pipe with the downhole end of the pipe at the top of the bentonite seal. As the grout is forced through the pipe and upward through the borehole, the tremie pipe will be lifted (as sections of the tremie pipe are removed at the surface) while keeping the downhole end below the surface of the grout. The greatest lift thickness per event will be no more than 60 feet. The grout seal will be Type II Portland cement or API Class A cement with no more than 4 percent bentonite. The grout will be mixed in the following proportions: 94 pounds of neat cement, not more than 4 pounds of 100 percent sodium bentonite powder, and not more than 8 gallons of potable water. The grout will have a mixed minimum specific density of 9.4 lb/gal or the manufacturer's recommended density.

### **3.7.2 Groundwater Sampling**

Groundwater sampling will be performed following the installation of the new MWs; samples will be collected from eight new (Figure 3-2) and seven existing MWs (MW-54, MW-77, MW-144, MW-157, MW-161, MW-150 and MW-163). Groundwater samples will be collected during a baseline event (Section 3.3) and six monthly confirmatory sampling events.

The new downgradient MWs will be positioned so that the impact of the pilot-scale ZVI PRB on groundwater CVOC concentrations can be observed within the first month or two of monitoring. As shown on Figure 3-2, new and existing MWs will be located about 5 to 10, 20, and 40 feet downgradient of the pilot-scale ZVI PRB. Given the nearly instantaneous iron corrosion and CVOC dechlorination kinetics and relatively rapid groundwater flow rate (1.1 ft/day), groundwater downgradient of the pilot-scale ZVI PRB should be impacted within the desired timeframe. Although CVOC concentrations below laboratory detection limits downgradient of the PRB are not likely to be observed within a month, statistically significant decreases are anticipated. It is anticipated that the results from the first month or two of groundwater monitoring, as well as the soil boring findings, will provide the evidence required to evaluate the viability of the technology for full-scale application.

## **3.8 Waste Management**

Waste generated during installation of the PRB will be managed by HBI and CH2M HILL as part of the field effort. All solid and liquid waste generated during the ZVI PRB installation and additional groundwater and soil investigation will be managed and stored in a proper manner. The jetting spoils will be collected directly from the top of the borehole with vacuum equipment and then transferred to lined roll-off boxes for temporary storage. The

solids will be retained in the 30-yd<sup>3</sup> roll-off containers for characterization and eventual transportation. Water in the roll-off boxes will be characterized and either transferred to the IRA discharge line or discharged to the ground surface in the study area.

Residual drilling fluids, development water, and wastewater from equipment decontamination produced during the jetting and drilling operations will be containerized by HBI, ProSonic, and the DPT subcontractor in 55-gallon drums (or in fractionation tanks as needed) approved by the U.S. Department of Transportation. The drums will be permanently marked with a weatherproof label provided by the FTL, signifying the date, site number, and MW/soil boring number.

All soil cuttings from the MW installation, soil borings, and DPT sampling will be placed in the roll-off boxes (or other appropriate approved containers) located in a central staging area on Dunn Field. The soil cuttings may be temporarily staged at the work location prior to placement in the central roll-off boxes. Soil, wastewater, and sediment generated from equipment and personnel decontamination activities will also be stored at the site prior to removal from Dunn Field.

As described in Section 4, representative samples of the investigative-derived waste (IDW) will be collected for chemical characterization by CH2M HILL for disposal. Once analytical results of the IDW are available, CH2M HILL will be responsible for management of all IDW in accordance with federal, state, and local regulations. The IDW will be removed from the site within 60 days following the receipt of the analytical results. During past investigation activities at Dunn Field, liquid IDW was disposed of in the City of Memphis sewer system after a temporary permit had been obtained from the City of Memphis Public Works Department. The permit provided an explanation that the water contained concentrations of contaminants similar to those of the effluent from the operating Dunn Field groundwater extraction system, which discharges into the City's sewer system.

Non-investigative waste, such as litter and household garbage, will be collected on an as-needed basis to maintain the site in a clean and orderly manner. This waste will be containerized and transported to the designated sanitary landfill or collection bin. Acceptable containers will be sealed containers or plastic garbage bags.

## **3.9 Decontamination**

### **3.9.1 Personnel Decontamination**

On-site activities will require decontamination of personnel exiting the work area, especially in cases where a release of contaminants has been detected. Decontamination procedures are defined in Section 4 of the November 2001, EPA Science and Ecosystem Services Division *Environmental Investigation Standard Operating Procedures and Quality Assurance Manual* (EISOPQAM, EPA, November 2001). All PPE will be contained in drums and disposed of separately in accordance with Section 3.8.

### **3.9.2 Equipment Decontamination**

All downhole drilling and other equipment will be decontaminated according to procedures presented in Appendix B of EISOPQAM (EPA, November 2001).

Decontamination of the drilling/jetting rig and associated equipment, pipes, bits, and tools that are considered downhole equipment will be completed before drilling and jetting begins and at the completion of the PRB installation. This process will consist of the following:

- Perform high-pressure, low-volume steam-cleaning.
- Wash and scrub with non-phosphate detergent (Liquinox®) and potable water any areas contaminated by grease, oil, fuels, or dirt.
- Rinse with potable water.
- Air dry to the extent practical.

Decontamination of the DPT rig, drill rig, rotasonic drilling equipment, pipes, bits, tools, and all downhole equipment will be conducted between each soil sampling location and MW installation. Decontamination of development equipment will be performed between each well developed and will consist of the following steps:

1. Perform high-pressure, low-volume steam-cleaning.
2. Wash and scrub with non-phosphate detergent (Liquinox®) and potable water.
3. Rinse with potable water.
4. Rinse with deionized (or analyte-free) water.
5. Air dry to the extent practical.
6. Where practical, wrap equipment in plastic sheeting or aluminum foil.

Decontamination activities will be conducted on a concrete or asphalt decontamination pad on Dunn Field. A minimum 3-foot high splashguard will be constructed around three sides of the decontamination pad using plywood and plastic sheeting. All wash and decontamination water will be managed in accordance with Section 3.8.

### 3.10 Health and Safety

A Site-Specific HASP will be developed and submitted to CEHNC for review and approval prior to mobilization. Issues pertinent to the jetting process and the groundwater and soil investigation will be discussed in the Site-Specific HASP. These issues may include, but not be limited to, the following:

- **ZVI PRB Installation: Jetting.** The installation of the ZVI PRB will require the use of a rotary drill rig, high-pressure hoses, centrifugal pumps, and a high-pressure pump. The use of this equipment has inherent hazards, including rotating mechanical equipment, potential hazardous atmospheres, noise, and the potential for slips, trips, and falls, as well as high injection pressures (greater than 6,000 psi) during the jetting process.
- **MW Installation: Drilling.** The installation of wells at Dunn Field will require the use of rotasonic equipped drill rigs. The use of this equipment has inherent hazards, including rotating mechanical equipment, potential hazardous atmospheres, noise, and the potential for slips, trips, and falls.
- **Soil Sampling.** Soil from the loess deposits may contain levels of VOCs hazardous to personnel exposed to the vapors. Screening with field equipment will be necessary to keep the hazards below action levels.

- **Groundwater Sampling: Use of Pumping Equipment.** The use of equipment to obtain samples includes air-operated bladder-type pumps, electrical generators, tubing, diffusion bags, and portable direct-reading instruments. The work will require effort around potentially hazardous environments and will require controls on ambient air hazards.

### 3.11 Site Security/Erosion Control

Access controls (i.e., orange safety fencing) and erosion control measures will be maintained around all jetting, drilling, stockpiles, or other areas disturbed by operations. Designated work and observation zones will be maintained during the field effort. Open holes will be barricaded with orange safety fence. All work areas will be kept clean and neat. Gates along the fence to the study area and Dunn Field will be secured at night with padlocks.



## 4.0 Sampling and Analysis

Sampling and analysis procedures associated with the activities required for the ZVI PRB Implementation Study and completion of the Dunn Field RDI are outlined below. This section includes information regarding locations, frequency, and analyses for soil and groundwater to be collected during the investigation, as well as analyses required for disposal characterization for IDW.

### 4.1 Data Quality Objectives

The quality control (QC) objectives of the ZVI PRB Implementation Study are to provide accurate, precise, and complete data to effectively assess jetting as a ZVI PRB installation method at Dunn Field. The primary evaluation will be based on the results of the soil samples, which will be used to assess the iron distribution. Analyses will also be performed on the slurry used to emplace the ZVI and the sediment returned to the surface during the jetting process. Groundwater levels and samples will also be collected to assess ZVI PRB performance. The DQOs detailed in Table 4-1 are established to achieve the objectives outlined in Section 1.

### 4.2 Groundwater Sampling

Groundwater sampling will be performed following the installation of the new Dunn Field and Off-Depot MWs; samples will be collected from 11 new Dunn Field and Off-Depot MWs (Figures 3-1 and 3-2) and 7 existing Off-Depot MWs. As summarized below, groundwater samples will be collected during a baseline event and six confirmatory sampling events.

Location	No.	Baseline	Monthly ZVI PRB Effectiveness Monitoring
New Dunn Field	3	MW-172, MW-187, and MW-188	None
Existing Dunn Field	0	None	None
New Off-Depot	8	MW-189 to MW-193	MW-189 to MW-193
New Off-Depot (in wall)	3	None	MW-194 to MW-196
Existing Off-Depot	7	MW-54, MW-77, MW-144, MW-150, MW-161, MW-162, and MW-163	MW-54, MW-77, MW-144, MW-150, MW-161, MW-162, and MW-163

In addition to CVOC analysis, groundwater samples will be analyzed for the field parameters summarized in Table 4-2. Groundwater sampling and sampling equipment decontamination will be performed in accordance with this work plan, *Remedial Action Sampling and Analysis Plan* (MACTEC, 2004c), the EPA Region 4 Science and Ecosystems Services Division *EISOPQAM*, dated November 2001, and the U.S. Army Corps of Engineers (USACE) Engineer Manual 200-1-3, dated February 2001.

**TABLE 4-1****Data Quality Objectives***Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

<b>Objective</b>	<b>Data Quality Level</b>	<b>Qualitative DQO</b>	<b>Quantitative DQO</b>
Conduct land survey of ZVI PRB alignment, and sampling and MW locations	Screening (initial) and definitive (post-study and RDI)	Conduct initial land survey to position ZVI PRB, and select soil boring and MW locations. Post-investigation survey will be conducted to establish coordinates of additional or revised sampling locations.	Use a professional land surveyor to conduct a survey and provide specific geographical coordinates in a northing and easting format.
Update CVOC distribution in loess deposits soil	Definitive (Level III) (soil samples)	Develop profile of CVOC distribution within loess deposits soil.	Collect and analyze soil samples for target compound list (TCL) VOCs (Method 5035/8260B) in offsite laboratory based on previously measured MIP response.
Update CVOC distribution in groundwater; monitor downgradient total organic carbon	Definitive (Level III) (groundwater samples)	Collect groundwater samples to revise groundwater CVOC plume maps. Finalize Source Area groundwater remedial strategy based on results.  Establish baseline groundwater concentration before pilot-scale ZVI PRB is installed  Monitor effectiveness of ZVI PRB and the breakdown and flushing of the biopolymer from the PRB over time.	Install additional MWs and collect groundwater samples. MWs will also be sampled before, during, and after pilot- and full-scale groundwater remedy is implemented. Analyze groundwater samples by SW-846 Method 8260B.
Measure iron concentration in iron/sand mix	Screening (visual observation and on-site testing)	Measure iron content to estimate mass flux of iron placed into the fluvial aquifer during the jetting process	Magnetic separation tests will be used to measure iron content.
Measure iron concentration in return slurry	Screening (visual observation and on-site testing) and definitive (Level III)	Measure iron content to estimate mass flux of iron returned to the surface during the tremie process.	Samples will be analyzed for total metals according to EPA SW846 6010B; on-site magnetic separation tests will also be used to measure iron content.
Measure iron concentration in jetting spoils	Screening (visual observation and on-site testing) and definitive (Level III)	Measure iron content in spoils to estimate iron wastage rate.	Samples will be analyzed for total metals according to EPA SW846 6010B; on-site magnetic separation tests will also be used to measure iron content.
Measure iron content in soil cores	Screening (visual observation and on-site testing) and definitive (Level III)	Measure iron concentrations in soil cores to assess in place ZVI PRB and effectiveness of jetting method.	Collect and analyze five soil cores advanced through the ZVI PRB at a range of radial distances. Samples will be analyzed for total metals according to EPA SW846 6010B; on-site magnetic separation tests will also be used to measure iron content.

**TABLE 4-1**  
Data Quality Objectives  
*Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

Objective	Data Quality Level	Qualitative DQO	Quantitative DQO
Assess hydraulic conductivity of fluvial aquifer	Definitive	Evaluate hydraulic conductivity of the fluvial aquifer prior and subsequent to installation of PRB.	Measure changes in water levels after input and removal of slug using pressure probe and analyze data with accepted software.
Assess potentiometric surface over time	Screening (water level measurements)	Evaluate whether ZVI PRB has impacted natural groundwater flow patterns.	Measure water levels at MWs up-, side-, and down-gradient of the ZVI PRB before, during, and after implementation (30, 60, and 90 days post-jetting).
Waste characterization	Definitive (Level III)	Develop profile for disposing of solid and aqueous waste.	Collect water and soil samples and analyze according to EPA SW methods.

**TABLE 4-2**  
Groundwater Monitoring Parameter Summary  
*Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

Parameter	Laboratory Method
<b>CVOC – Laboratory</b>	
Volatile Organics	Fixed Based Laboratory – SW846 Method 8260B
Total organic carbon (PRB monitoring only)	Fixed Based Laboratory – EPA Method 415.1
<b>Geochemical Parameters – Field</b>	
Color	Field/Visual
Visible particulate	Field/Visual
Turbidity	Field Direct Reading Instrument – YSI 6820 Multimeter
Dissolved oxygen (DO)	Field Direct Reading Instrument – YSI 6820 Multimeter
Oxidation Reduction Potential (ORP)	Field Direct Reading Instrument – YSI 6820 Multimeter
pH	Field Direct Reading Instrument – YSI 6820 Multimeter
Temperature	Field Direct Reading Instrument – YSI 6820 Multimeter

Groundwater levels will be measured in MWs prior to and during each sampling event. Water levels will be measured using an electronic sensor with tape graduated in 0.01-foot increments. Measurements will be recorded as depth to water from the mark on the top of the well casing. Well number, date and time of measurement, and depth to water will be recorded in the field logbook.

Before sampling, each well will be purged using a low-flow bladder pump to minimize both agitation of the groundwater and sample turbidity. The methods discussed below are consistent with Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures (EPA, 1996). The intent of those procedures is to remove stagnant water from the well and introduce fresh groundwater into the well at a rate that does not produce significant

drawdown of the water level in the well being sampled. This procedure reduces both the time required to purge the wells and the quantity of water removed (IDW).

The field team will keep the pumping rate as low as possible, taking care not to lower the water level in the well. The anticipated pumping rate is 0.15 to 0.25 gpm so that water levels do not decline more than 1.2 inches (0.1 foot). Water level measurements will be recorded concurrently with the water quality parameter measurements. Field measurements of DO, ORP, turbidity, pH, temperature, and specific conductance will be recorded at the beginning of the procedure and at 5-minute intervals during purging. The water quality parameters will be measured using an airtight flow-through cell. Measurement data will be recorded in the field logbook. Purging will continue until field measurements have stabilized.

Stabilization is defined as the point at which the pH is within  $\pm 0.1$ , the conductivity is + or - 3 percent, and the turbidity remains less than 10 nephelometric turbidity units (NTUs) for at least 30 minutes. The FTL will determine when development is complete. The above parameters will be documented and the wells will then be sampled using the same low-flow pump rate.

Samples will be collected from MWs using the low-flow bladder pump and Teflon®-lined tubing once the field parameters have stabilized. Headspace in the VOC sample container must be minimized by filling the sample vial until a positive meniscus is present.

Containers will be quickly and adequately sealed; container rims and threads will be clean before tightening lids. Unless otherwise specified, Teflon®-lined screw lids will be used to seal the vial. Sample containers will be properly labeled and will be immediately cooled to  $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$ , and this temperature will be maintained through delivery to the laboratory until the samples are analyzed. New tubing will be used and the pump decontaminated for each well.

## 4.3 Soil Sampling

### 4.3.1 Soil Core Sampling

During the drilling of each boring for the MWs, soil cores will be collected in continuous sampling mode from land surface to completion depth. The core samples will be collected in plastic tube bags placed at the end of the core barrel subsequent to drilling each 10- to 20-foot length. The core samples will be cut open and examined for geologic characteristics immediately upon return to the surface.

Lithologic descriptions of unconsolidated materials encountered in the boreholes will be presented in accordance with the 1990 ASTM D-2488-90, *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure). Descriptive information to be recorded in the field will include:

- Identification of the predominant particles size and range of particle sizes
- Percent of gravel, sand, fines, or all three
- Description of grading and sorting of coarse particles
- Particle angularity and shape
- Maximum particle size or dimension

Plasticity of fines description includes:

- Color using Munsell Color System
- Moisture (dry, wet, or moist)
- Consistency of fine-grained soils
- Structure of consolidated materials
- Cementation (weak, moderate, or strong)

Identification by the Unified Soil Classification System (USCS) group symbol will be used. Additional information to be recorded is: depth to the water table, caving or sloughing of the borehole, changes in drilling rate, depths of laboratory sample collection, presence of organic materials, presence of fractures or voids in consolidated materials, and other noteworthy observations or conditions, such as the locations of geologic boundaries.

Headspace field screening (see the field screening Standard Operating Procedure in TM SA.01 – *Data Collection Plan for Long-Term Operational Areas, Main Installation, Memphis Depot*) will be conducted over each core using an organic vapor analyzer (OVA)/FID until the last core is removed from the boring. No samples will be collected for laboratory analysis. At the discretion of the field geologist, select soil cores may be archived for future reference.

#### 4.3.2 DPT Sampling

Twenty-five discrete soil samples will be collected using a standard DPT rig. These samples will be delivered by CH2M HILL to an offsite laboratory where they will be analyzed for CVOCs (SW-846 Method 8260B).

#### 4.3.3 ZVI PRB Confirmation Sampling

After the ZVI PRB has been installed, five borings will be installed vertically through the PRB in multiple columns and a range of radial distances to assess iron distribution. Soil and core samples will be collected beginning at approximately 65 feet bgs. The continuous core samples will be 4 inches in diameter and will be brought to the surface as intact as possible for an iron content assessment by the FTL (visual and magnetic separation test) and submittal to the laboratory for total iron analysis according to EPA SW846 6010B. The soil core will be analyzed as follows:

1. Vertically split the entire core (~8 feet of core where the sand/iron column is present), saving one half for archiving.
2. Divide the remaining half of the core into eight 1-foot sections from top to bottom. Each section will be about 2 kilograms (kg).
3. Randomly select four of the sections for the magnetic separation test (Appendix D). Conduct test and record results.
4. Randomly select one of the sections for total iron analysis according to EPA SW846 6010B.

Where possible, a conductivity probe will be advanced to identify soil conductivity changes due to the presence of highly conductive ZVI.

## 4.4 Reactive Media, Return Slurry, and Jetting Spoils Sampling

As discussed in Section 3.6.2, at least one **reactive media sample** from each mix batch (for example, once per cement mixer) will be visually observed by the FTL and HBI and analyzed with the magnetic separation test (Appendix D) to assess the iron content of the mix.

For each column, one sample of the **return slurry** will be collected and analyzed for total metals according to EPA SW846 6010B. Samples will be shipped via FedEx™ from the site to Kemron Environmental of Marietta, Ohio, for laboratory analysis. If possible, the samples will also be analyzed on-site using the magnetic separation test (Appendix D) to assess iron content.

All **jetting spoils** will be transferred to a central staging area on Dunn Field. Water decanted from the jetting spoils container will be managed in accordance with Section 4.5.3. The sediment will be sampled for iron content and final disposal purposes according to methods and analyses required by the accepting transportation/storage/disposal facility (TSDF). Two samples will be collected per container (lined basin or roll-off box). Once the soil analytical data have been obtained, the sediment will be removed from Dunn Field within 60 days. The data will also be used to estimate the quantity of wasted iron.

## 4.5 Investigation-Derived Waste

Representative samples of the IDW will be collected for chemical characterization needed for offsite disposal. IDW samples will be analyzed for the list of parameters described in Table 4-3.

### 4.5.1 Decontamination Sediment

Sediment will be removed from the decontamination area and placed in drums. Sediment samples will be collected from the drums and analyzed for the same parameters as soil samples to assess final disposition of IDW materials.

### 4.5.2 Soil

Soil cuttings generated from the investigation will be placed in drums or other appropriate storage devices and stored at the site. The soil will be sampled for final disposal purposes according to methods and analyses required by the accepting TSDF. Once the soil analytical data have been obtained, the soil will be removed from Dunn Field within 60 days. Previous IDW soil samples from the ZVI treatability study area were analyzed by toxicity characteristic leaching procedure (TCLP) methods and were found to be non-hazardous. The soil did not require special procedures for transportation and disposal.

### 4.5.3 Water

Water derived from decontamination activities will be collected and containerized. Water samples will be collected from the drums and analyzed for CVOCs, SVOCs, metals, pH, reactivity, corrosivity, flammability, and explosivity. Results will be used to determine final disposition of the water.

#### **4.5.4 Personnel IDW**

IDW from personnel, including Tyvek<sup>®</sup> or Saranex<sup>®</sup> coveralls, nitrile gloves, rubber booties, duct tape, and spent jars from field screening, will be placed into separate drums for waste collection purposes. Analytical results from the soil samples will help determine whether there is a need to sample the IDW and, if so, what analyses should be performed. Two IDW samples are estimated for this effort.

## 5.0 Data Management, Analysis, and Interpretation

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### 5.1 Data Description

Information generated from the ZVI PRB Implementation Study and completion of the Dunn Field RDI will include land survey, hydrogeologic, and geochemical data:

- Land survey data will be derived from the process of selecting the soil sampling locations (DPT and conventional soil borings locations), new MWs, and ZVI PRB alignment. Soil confirmation sampling locations will be clearly marked in the field with stakes or pin flags so that their positions can be identified using a global positioning system (GPS) or conventional land survey (Allen & Hoshall, Inc.) when the investigation is complete.
- Hydrogeologic data will be derived from the collection and analyses of water level measurements, slug testing, and soil and groundwater samples.
- Geochemical information from this study will be derived from groundwater sampling results (CVOC analysis), soil and sediment sampling results (CVOCs or total metals), and field geochemistry. These data are critical for the completion of the Source Areas and Off-Depot Groundwater RDs (for example, placement of the Source Area ZVI injection locations and orientation of the full-scale Off-Depot ZVI PRB).

### 5.2 Data Management

Data management for the ZVI PRB Implementation Study and completion of the RDI will match the requirements of the DQOs presented in Section 4.1. Much of the field data will be obtained through the efforts of field screening, which includes the use of direct-reading instruments and the laboratory analysis of samples. The information presented in this section is considered supplemental to the *Remedial Action Sampling and Analysis Plan* (MACTEC, 2004c) for the Memphis Depot activities.

#### 5.2.1 Sample Numbering System

During sampling events conducted for the Dunn Field RDI, nomenclature will be used to distinguish between categories of sampling events, sampling locations, and, where appropriate, depth of sample collection. Sample numbering protocol as shown in Table 5-1 will be used.



**TABLE 5-1**  
**Sample Numbering Summary**  
*Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

Sampling Event	Type of Sample(s) and Location	Sample Number Description	Example Sample Number
Groundwater sampling for VOCs and geochemistry	Groundwater on-site and Off-Depot	Sampling location and depth to pump. Note: for samples collected with a diffusion bag (optional), sample numbers will reflect depth of diffusion bag sampler located in each well.	MW-73_75 If [diffusion bags are used: MW-73_75-78
Soil sampling	RDI confirmation sample	Sample numbers reflect treatment area (1-4), grid location (see Figure 3-1 and Table 3-1), and discrete sample depth.	TA4_N1080_E1120_16-18
	ZVI PRB confirmation sample	Samples will reflect location and depth of sample collection.	SB01_100-110
Iron/sand mix sampling	Iron/sand sample	Samples will reflect date.	IS01_030606
Return slurry sampling	Return slurry sample collect during the tremie process	Samples will reflect column number and date.	RS01_1_030606
Jetting spoils sampling	Sediment sample collected from the storage container	Samples will reflect date.	JS01_030606

**Note:** For duplicate soil samples, a double blind sample number will be used for the duplicate sample. Matrix spike/matrix spike duplicates will be denoted with an "MS/MSD" at the end of the sample number. Equipment, field, and trip blanks will be designated with "EB", "FB", and "TB", respectively.

### 5.2.2 Soil and Water Sample Labels

All soil and water samples obtained at the site will be placed in an appropriate sample container, as identified in Table 4-3, for shipment to the laboratory. Each sample container will be identified with a separate identification label. Labeling will be done in indelible/waterproof ink. Errors will be crossed out with a single line, dated, and initialed. Each securely affixed label will include the following information:

- Project identification
- Sample identification
- Sampler's name or initials
- Preservatives added
- Date of collection
- Time of collection
- Required analytical method numbers

### 5.2.3 Field Screening Data Management

Field screening efforts will include ambient air screening around MWs and soil borings with an OVA/FID and screening of groundwater during purging procedures with portable direct-reading instruments, which will be calibrated in accordance with the *Remedial Action Sampling and Analysis Plan* (MACTEC, 2004c). Data that will be recorded with each measurement include the following:

- Date and time
- Elapsed time since test began, as necessary
- Location of measurement/location where the sample was collected, as necessary
- Instrument measurement

Each measurement will be handwritten into a bound field logbook and, after the entire test has been completed, the data will be transferred into an electronic file for use within the Dunn Field ZVI PRB Implementation Study TM.

Other field notes to be collected during the ZVI PRB Implementation Study and written in the field logbook include: weather information, personnel present during on-site activities, subcontractor names and activities, notes on the proximity of the activities to established features within Dunn Field, and all other pertinent information that may impact data analysis. This information will be included in the ZVI PRB Implementation Study TM, as necessary.

### 5.2.4 Analytical Laboratory Data Management

Multiple samples will be submitted to an analytical laboratory for CVOC and total metals analyses and reporting. During collection of groundwater and soil samples, the date, time, location of sample collection, and the sample number will be recorded in the field logbook. This information will be transferred, as required, to the chain-of-custody documents. Copies of the chain-of-custody documents will be kept at the site until the study is complete and will then be transferred to the site files for record-keeping.

After the analytical data have been received from the laboratory, the data will be stored electronically, summarized, and reproduced for the Dunn Field ZVI PRB Implementation Study TM. Prior to this, however, the data will be reviewed by a project chemist for quality assurance (QA). If there are any differences between the chemist's and the laboratory's review of the data, a letter report will be issued describing the differences and any potential to affect the results from the study. Data will be delivered according to Environmental Data Management System (EDMS) Version 4.11 or higher. Information on EDMS is available at the following Web site: [http://www.aee.faa.gov/emissions/edms/edms\\_Updates/Updates.htm](http://www.aee.faa.gov/emissions/edms/edms_Updates/Updates.htm)

## 5.3 Data Analysis and Interpretation

The data collected during the ZVI PRB Implementation Study will be tabulated and graphed to assess CVOC spatial trends. All data and the resulting interpretation will be presented and described within the Dunn Field ZVI PRB Implementation Study TM and relevant RD documents. The data will be used as a basis for the design of the Dunn Field groundwater and soil remedies.

## 6.0 Community Relations

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The Memphis Depot has an active community involvement program that monitors events that occur at the Memphis Depot site, especially for Dunn Field. This study will occur with the knowledge of members of the community, many of whom live just beyond the perimeter of Dunn Field.

Prior to initiation of field activities, fact sheets describing the investigation and duration of the fieldwork will be distributed to community members in the area adjacent to Dunn Field. The findings from the study, once finalized, will also be presented to the Restoration Advisory Board (RAB) members.

## 7.0 Reports

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A ZVI PRB Implementation Study TM will provide the necessary documentation of the completed study. CH2M HILL plans to complete the TM according to the schedule presented in Section 8. The TM will include, but not be limited to, the following:

- Description of the study procedures and ZVI PRB implementation process
- Field measurement methods and data collected
- Summary of field and laboratory analytical data presented in graphs, tables, and/or figures
- Variances to field procedures
- Overall impact on the Off-Depot RD

The TM, which will be reviewed by the Memphis Depot BCT, will include recommendations for possible full-scale application and additional investigations that may be required to implement the evaluated technology. The TM will also contain a separate section that covers data quality and validation. At a minimum, the following information will be included in this section:

- Assessment of measurement data precision, accuracy, and completeness
- Laboratory and performance audit results
- Potential QA problems and corrective actions implemented
- Copies of pertinent documentation, such as memos and reports

The TM will be submitted to the BCT for review and comment. The final TM will be presented within the Source Area and/or Off-Depot Groundwater RD documents.

## 8.0 Schedule

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The schedule of activities associated with this project, such as the completion of the work plan, the proposed fieldwork, and the preparation of the final TM, is presented as Figure 8-1. CH2M HILL estimates that 50 days will be required from implementation of the field effort to completion of the PRB, including mobilization and site setup, through completion of the soil core sampling. The TM will be produced following the analysis of the field, groundwater, and soil core data. Groundwater monitoring will continue for another 4 months; the resulting analytical data will be included in the Off-Depot RD.

## 9.0 References

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## Tables

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**TABLE 2-1**

Summary of Depth Information for Soil Borings Along the Proposed PRB

*Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan*

<b>Boring Number</b>	<b>Depth to Top of Clay in Fluvial Deposits (ft bgs)</b>	<b>Depth to Top of Clay in Jackson Fm/Upper Claiborne Fm (ft bgs)</b>	<b>Total Depth of Boring (ft bgs)</b>
SB-1	71	76	96
SB-2	74	82	86
SB-3	77	84	86
SB-4	79	86	96
MW-144	76	N.D.	86
MW-161*	80.5	N.D.	86
MW-163	76	84	86

\* Top of clay in the Jackson Formation/Upper Claiborne Unit was not defined in this boring.

ft bgs = feet below ground surface

N.D. = not determined

TABLE 2-2

Summary of Off-Depot Slug Test Results  
Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan

Well ID	Penetration <sup>1</sup>	Well Screen within the saturated zone (L, ft) <sup>2</sup>	Saturated Thickness (D, ft) <sup>3</sup>	K (cm/s)	K (ft/day)	GW Velocity (ft/d)
MW-31	Fully	10.2	10.18	3.5E-02	97.8	
MW-44	Partially	10.0	20.26	4.2E-03	12.0	
MW-54	Partially	15.0	17.26	4.0E-03	11.4	
MW-76	Fully	9.6	9.63	7.8E-03	22.1	
MW-79 (Test1)	Partially	20.0	32.36	3.7E-03	10.3	
MW-79 (Test2)	Partially	20.0	32.36	1.1E-03	3.2	
MW-144*	Fully	20.0	2.71	4.3E-02	121.9	
MW-145 (Test1)	Partially	20.0	38.72	2.7E-03	7.5	
MW-145 (Test2)	Partially	20.0	38.72	5.2E-03	14.6	
MW-147	Fully	8.9	8.85	4.4E-02	123.9	
MW-148	Fully	11.5	11.49	1.9E-02	54.7	
MW-149	Partially	20.0	30.93	5.3E-03	14.9	
MW-150	Fully	10.6	10.60	4.5E-02	127.6	
MW-161 (Test 1)*	Fully	20.0	4.92	4.4E-02	124.7	
MW-161 (Test 2)*	Fully	20.0	4.92	5.1E-02	144.6	
MW-162*	Fully	20.0	5.13	5.6E-02	158.7	
MW-163*	Fully	20.0	3.32	1.4E-02	40.0	
MW-164*	Fully	20.0	2.96	1.4E-02	39.7	
MW-184*	Fully	10.0	3.29	5.4E-03	15.3	
Geometric Mean (Overall)				1.2E-02	33.9	2.0
Geometric Mean (Saturated thickness < 12 feet)				2.5E-02	70.8	4.2
Geometric Mean (Saturated thickness > 17 feet)				3.4E-03	9.6	0.6
Minimum				1.1E-03	3.2	0.2
Maximum				5.6E-02	158.7	9.4
Iron				7.0E-02	198.4	

**Notes:**

1. Fully penetrating means the entire aquifer thickness was screened and partially penetrating means only part of the saturated aquifer was screened.
2. Well screen within the saturated zone is always less or equal saturated aquifer thickness ( $L \leq D$ ).
3. Saturated Aquifer Thickness = groundwater elevation - clay elevation

— Pressure heads was measured using a MiniTroll Pro, manufactured by In-Situ Inc., during the slug tests.

— AquiferTest software (developed by Waterloo Hydrogeologic, Inc.) and Bouwer & Rice method was used to determine the hydraulic conductivity in each test well. Note that the effective radius was used if the stagnant water level was below the top of the screen:  $r_{eff} = \sqrt{r^2 \cdot (1-n) + n \cdot R^2}$ ;  $r$  piezometer radius;  $n$  porosity; and  $R$  bore hole radius.

— Results based on slug out tests

— Hydraulic gradient (0.0178 ft/ft in PRB study area) based on March 2005 potentiometric surface and  $n = 0.3$  were used for groundwater velocity calculations.

\*Data collected in March 2006; other data collected in August 2004.

TABLE 2-4  
Groundwater Sampling Analytical Results for the ZVI PRB Study Area, November 2005  
Memphis Depot Dunn Field ZVI PRB Implementation Study Work Plan

Well	Sample Date	Sample Interval (ft BTOCI)	Ferrous Iron (mg/L)	Total Iron (mg/L)	Dissolved Oxygen (mg/L)	pH	Conductivity (micromhos/cm)	Temperature (°C)	ORP (mV)	Turbidity (NTU)	PCr	TCE	cis-1,2-DCE	trans-1,2-DCE	VC	1,1-DCE	1,1-DCA	1,2-DCA	1,1,2,2-PCA	1,1,1-TCA	1,1,2-TCA	Cr	Ct	Mg	Total VOCs <sup>1</sup>	Arsenic	Alkalinity	Calcium	Nitrate/Nitrite	Magnesium	Manganese	Selenium		
EPA Primary Drinking Water Standards Maximum Contaminant Limits: Dunn Field ROD (March 2004) Groundwater Remediation Goals:																																		
MW-54	18-Nov-2005	89.5									2.5	5	70	100	3	77340	NA	NA	5	NA	200	5	5	80	NA			0.01	NA	NA	10/1	NA	0.05	0.05
MW-70	19-Nov-2005	82.8									4.42	478	25.4	4.81	<1.0	<1.0	<1.0	<1.0	853	<1.0	3.44	1.3	1.46	<1.0	1,372									
		88.8									16.9	2,420	63.4	15.8	<10.0	<10.0	<10.0	<10.0	2,990	<10.0	6.65J	<10.0	11.6B	<10.0	5,548									
MW-76	17-Nov-2005	88.2									4.84	1,620	70.5	13.8	29.5	1.07	<1.0	0.506J	2,200	<1.0	13.1	<1.0	2.12B	1.31	3,954									
MW-77	16-Nov-2005	84.9									1.14	5,166	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.1									
MW-144	14-Nov-2005	74.4									21.1	5,300	107	15.5	<1.0	<1.0	<1.0	1.39	14,000	<1.0	18.7	0.961J	2.58	1.85	19,468									
MW-150	16-Nov-2005	75	0.06	0.11	1.97	6.1	0.289	16.7	207	0.0	10.2J	2,280	54.3	<20.0	<20.0	<20.0	<20.0	<20.0	4,970	<20.0	14.1J	<20.0	<20.0	<20.0	7,304	<0.0100	95.2	17.9	0.36	9.97	0.00449 J	<0.0500		
	19-Nov-2005	82.2									2.47	639	32.7	5.78	<1.0	<1.0	<1.0	<1.0	284	<1.0	11.3	<1.0	1,36B	1.67	1,047									
	19-Nov-2005	92.7									10.6	1,700	64.3	16.7	<10.0	<10.0	<10.0	<10.0	3,080	<10.0	16.3	<10.0	<10.0	<10.0	4,868									
MW-157	17-Nov-2005	73.3									1.49	117	9.35	1.3	<1.0	<1.0	<1.0	<1.0	2.22	<1.0	<1.0	4.56	8.18	<1.0	144									
MW-160	18-Nov-2005	80.8									14.7	161	30.8	12.2	<1.0	<1.0	<1.0	<1.0	13.4	<1.0	<1.0	1.01	2.26	<1.0	235									
MW-161	14-Nov-2005	79.9									7.68J	1,590	43	<20.0	<20.0	<20.0	<20.0	<20.0	2,600	<20.0	7.58J	<20.0	<20.0	<20.0	4,313									
	16-Nov-2005	80	0.00	0.19	0.93	6.3	0.303	16.1	165	5.6																	<0.0100	115	20.4	0.486	11.3	0.00476 J	<0.0500	
MW-162	14-Nov-2005	83.7									3.43	72.9	2.91	<1.0	<1.0	<1.0	<1.0	<1.0	10.2	<1.0	<1.0	<1.0	0.463J	<1.0	69		<0.0100	86.2	18.5	3.42	9.86	.00579 J	<0.0500	
	16-Nov-2005	83	-	1.20	2.53	6.0	0.260	16.1	249	6.8																	<0.0100	86.2	18.5	3.42	9.86	.00579 J	<0.0500	
MW-163	17-Nov-2005	74.9									4.3	1,300	24	2.68	<1.0	<1.0	<1.0	<1.0	2,080	<1.0	4.95	0.882J	0.88J	1.97	3,418		<0.0100	86.2	18.5	3.42	9.86	.00579 J	<0.0500	
MW-164	14-Nov-2005	72.6									0.576J	75.5	8.05	0.599J	<1.0	<1.0	<1.0	<1.0	2.14	<1.0	<1.0	5.44	8.44	<1.0	100		<0.0100	76.1	19.2	3.8	8.99	0.172	<0.0500	
	16-Nov-2005	73	0.06	0.75	3.49	6.0	0.276	12.5	109	9.4																	<0.0100	76.1	19.2	3.8	8.99	0.172	<0.0500	
MW-184	18-Nov-2005	67	0.08	0.50	1.11	6.1	0.420	16.2	124	2.0	0.695J	12.6	1.43	0.331J	<1.0	<1.0	<1.0	<1.0	1.74	<1.0	<1.0	8.08	32.6	<1.0	56	<0.0100	160	26	0.541	11	0.138	<0.0500		

Note: Italicized sample intervals indicate groundwater samples collected by diffusion bag samplers.

All other groundwater samples were collected using low-flow techniques

\*Insufficient quantity out of Total Iron Reagent - Unable to quantify

\*\*Bailed MW-08: No parameters available

Note: all VOCs are reported in ug/L

< BL: not detected above reporting limit of #

not sampled

<sup>1</sup>Total VOCs are the sum of all the detected VOCs without qualifiers, not just the sum of the ones presented in this table

B = Analyte detected in the associated Method Blank

J = Semiquantitative result (out of instrument calibration range)

J = The analyte was positively identified, but the quantitation was below the reporting limit

Metals and other geochemical parameters are in mg/L

TABLE 4-3  
Sampling and Analysis Summary  
Memphis Depot Dredge Field ZVI PRB Implementation Study Work Plan

Sample Task	Sample Point	Matrix	Sampling Frequency	Approx. Sample No	Sampling Method	Sampling Equipment	TAT	DOO Level/Data Package Requirement	Required Analysis	Analytical Methods	Holding Time	Sample Preservation	Containers
Groundwater Sampling Baseline Sampling Event	7 existing and 8 new monitoring wells	Water	Once	15 plus 2 dup (10%) and 1 MS/MSD (5%)	Grab, Low flow technique	Flow-thru cell, bladder pump, Teflon-lined tubing	14 days	DOO Level III	TCL Volatiles	8260B	14 days	HCl pH<2, Cool to 4°C	(2) 40 mL vial
	Equipment Rinseate Blank		1 per 10 samples (10%)	2	Prepared in Field	Analyte-free water, SS funnel							
	Trip Blank		1 per cooler containing volatile samples	2	Prepared by Lab	N/A							
PRB Effectiveness Monitoring	7 existing, 5 new Off-Depot, and 3 new in-wall monitoring wells	Water	6 monthly events	15 plus 2 dup (10%) and 1 MS/MSD (5%) per event	Grab, Low flow technique	Flow-thru cell, bladder pump, Teflon-lined tubing	14 days	DOO Level III	TCL Volatiles	8260B	14 days	HCl pH<2, Cool to 4°C	(2) 40 mL vial
	Equipment Rinseate Blank		1 per 10 samples (10%)	2	Prepared in Field	Analyte-free water, SS funnel							
	Trip Blank		1 per cooler containing volatile samples	2	Prepared by Lab	N/A							
Soil Sampling MIP Confirmation Sampling	Treatment areas in conjunction with MIP investigation	Soil	24 locations to complete RD1	24 plus 2 dup (10%) and 1 MS/MSD (5%)	Grab	DPT, SS spoon	24 to 72 hrs	DOO Level III	TCL Volatiles	5035/8260B	14 days	Cool to 4°C	(2) 40 mL vials
	Iron/sand mix before application	Soil	Minimum once per batch (truck)	Approximately 20	Grab	see Appendix C	n/a	Screening	Magnetic separation	n/a	n/a	n/a	n/a
	Post-installation soil borings through ZVI PRB	Soil	5 borings	Approximately 20	Grab	see Appendix C	n/a	Screening	Magnetic separation	n/a	n/a	n/a	n/a
Sediment Sampling Return slurry	Lined basin or roll-off boxes	Sediment	Once per column	17	Grab	SS Spoons, SS Bowl	14 days	DOO Level III	TAL Metals	6010/6020	14 days	Cool to 4°C	(1) 8 oz glass
		Sediment	Two samples per container	2 samples (minimum)	Grab	SS Spoons, SS Bowl	14 days	DOO Level III	TAL Metals	6010/6020	14 days	Cool to 4°C	(1) 8 oz glass
IDW Disposal Characterization Sampling Disposal to POTW	Well development, purge water, decon fluids, and surface water (as necessary)	Water	One Representative Sample to comply with the Memphis Depot Industrial Discharge Agreement with the City of Memphis	One	Grab	Drum thief or dip jar	14 days	DOO Level III	TCL Volatiles TAL Metals	8260B 6010B/7470A	14 days 6 months, Hg = 28 days	HCl pH<2, Cool to 4°C HNO <sub>3</sub> pH<2, Cool to 4°C	(3) 40 mL vial (1) 500 mL HDPE
									TCL Semivolatiles	8270C	7 day extr; 40 day analysis	Cool to 4°C	(1) Amber Litter Glass Jar
									TCLP Volatiles	1311/8260B	14 day TCLP extr; 14 day analysis	Cool to 4°C	(1) 4 oz glass
Soil	Soil cuttings, decon residuals	Soil	One sample per roll-off box	Variable	Composite comprising 5 aliquots (except for VOCs, which is a grab)	SS Auger, SS Spoons, SS Bowl	14 days	DOO Level III	TCLP Semivolatiles	1311/8270C	14 day TCLP extr; 7 day extr; 40 day analysis	Cool to 4°C	(2) 8 oz glass
									TCLP Pesticides	1311/8081A	14 day TCLP extr; 7 day extr; 40 day analysis		
									TCLP Herbicides	1311/8151A	14 day TCLP extr; 7 day extr; 40 day analysis		
									TCLP Metals	1311/8610B, 7470A	6 month TCLP extr; 6 month analysis, Hg 28 day TCLP extr; 28 day analysis	Cool to 4°C	(2) 8 oz glass
									Ignitability	1030	ASAP		
									Corrosivity	8045A	ASAP		
									Reactivity	Chapter 7.3	ASAP		

Notes:

1 - Wells will be purged with QED or equivalent low-flow device. Samples will be collected using Teflon tubing and pump.

TAT = Turnaround time

VOCs = Volatile organic compounds

SVOCS = Semi-volatile organic compounds

C = degrees Celsius

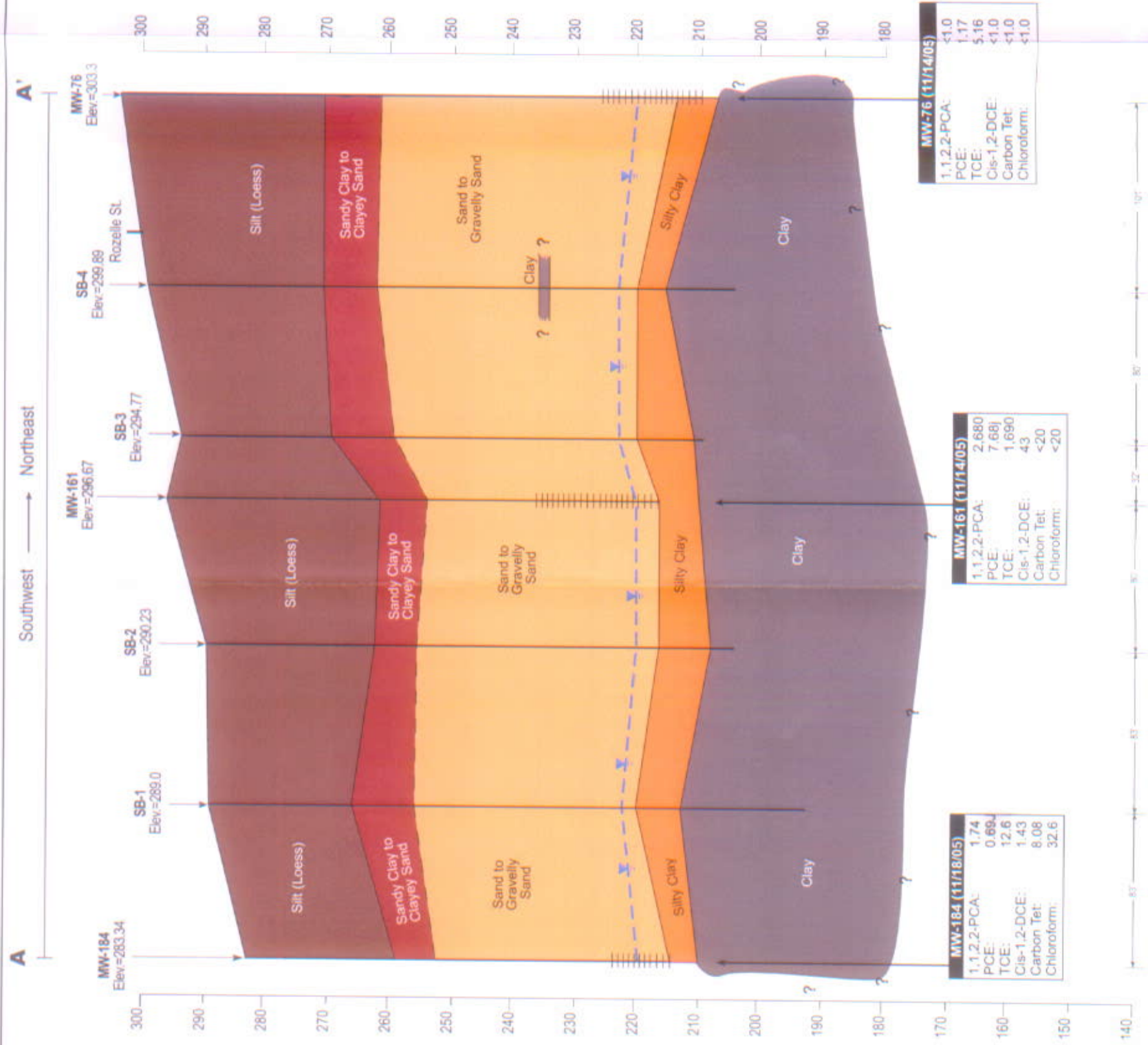
ml = milliliter

NA - Not Applicable

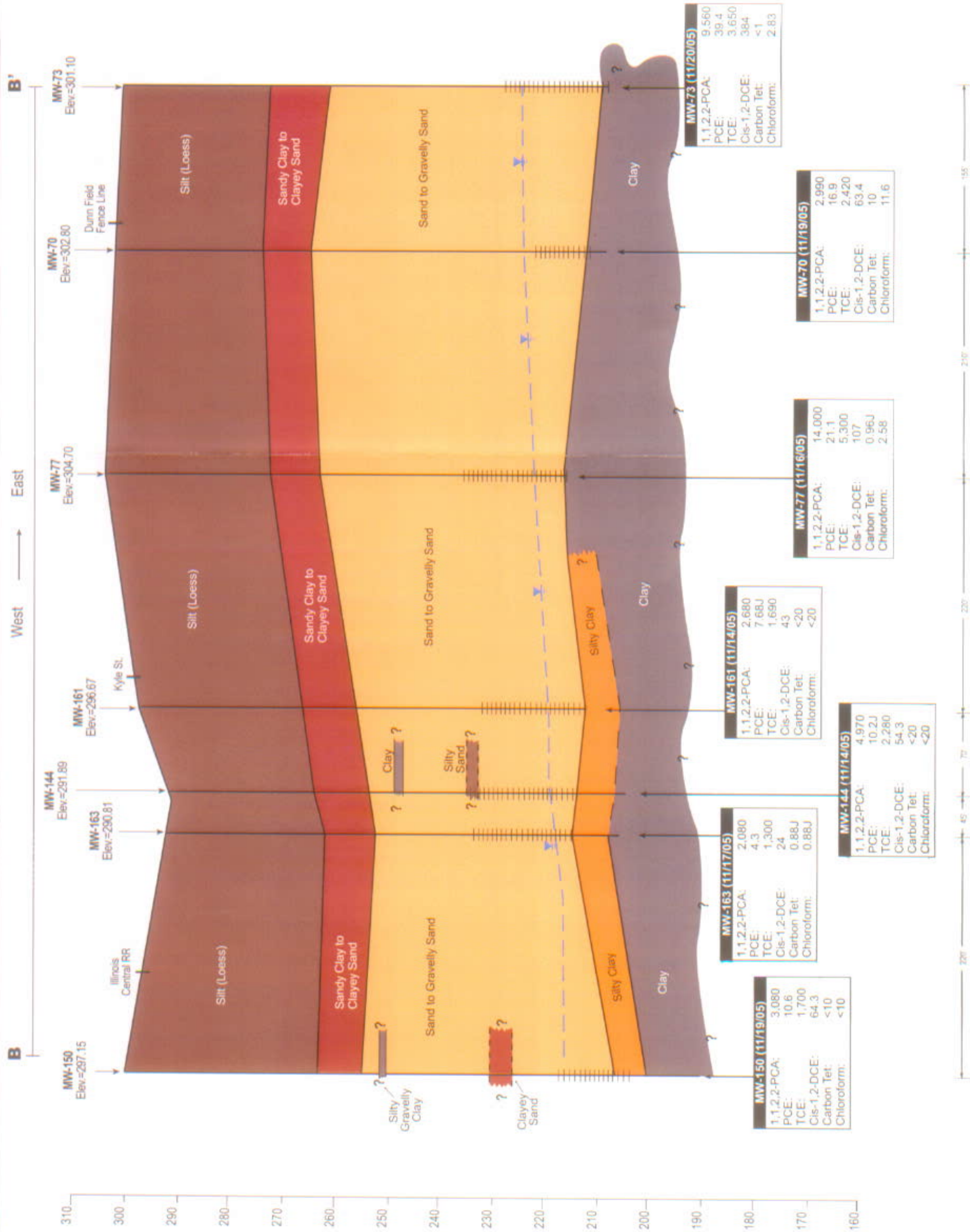
## Figures

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**FIGURE 2-1A**  
Lithologic Cross-Section Perpendicular  
to Suspected Contaminant Flow Path  
ZVI PRB Implementation Study  
Memphis Depot, Dunn Field



**FIGURE 2-1B**  
Lithologic Cross-Section Along  
Average Groundwater Flow Path  
ZVI PRB Implementation Study  
Memphis Depot, Dunn Field

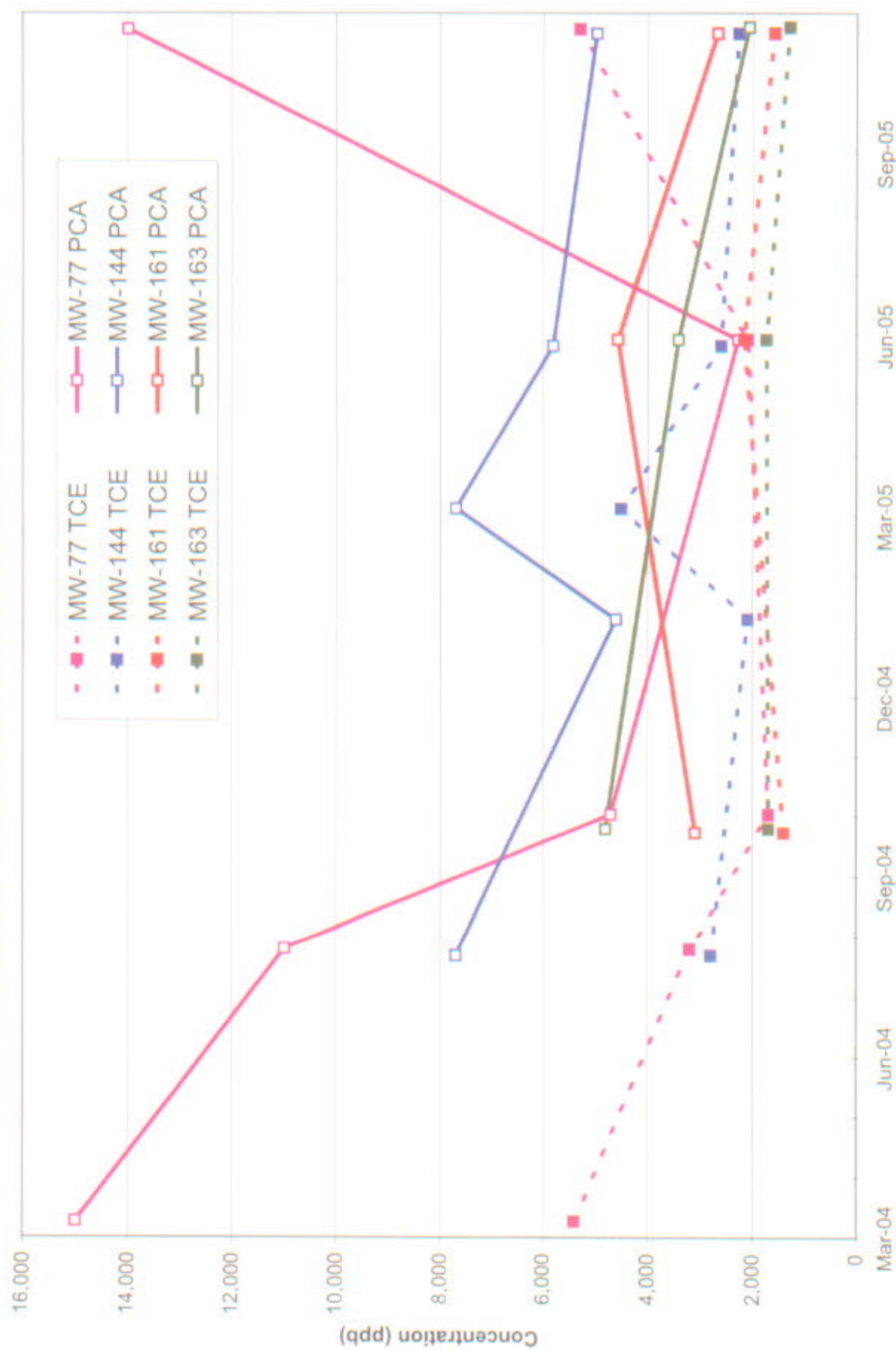




**FIGURE 2-2**  
Total Groundwater Chlorinated Volatile Organic  
Compound (CVOC) Concentrations  
November 2005  
Memphis Depot Dunn Field Remedial Design Inc.

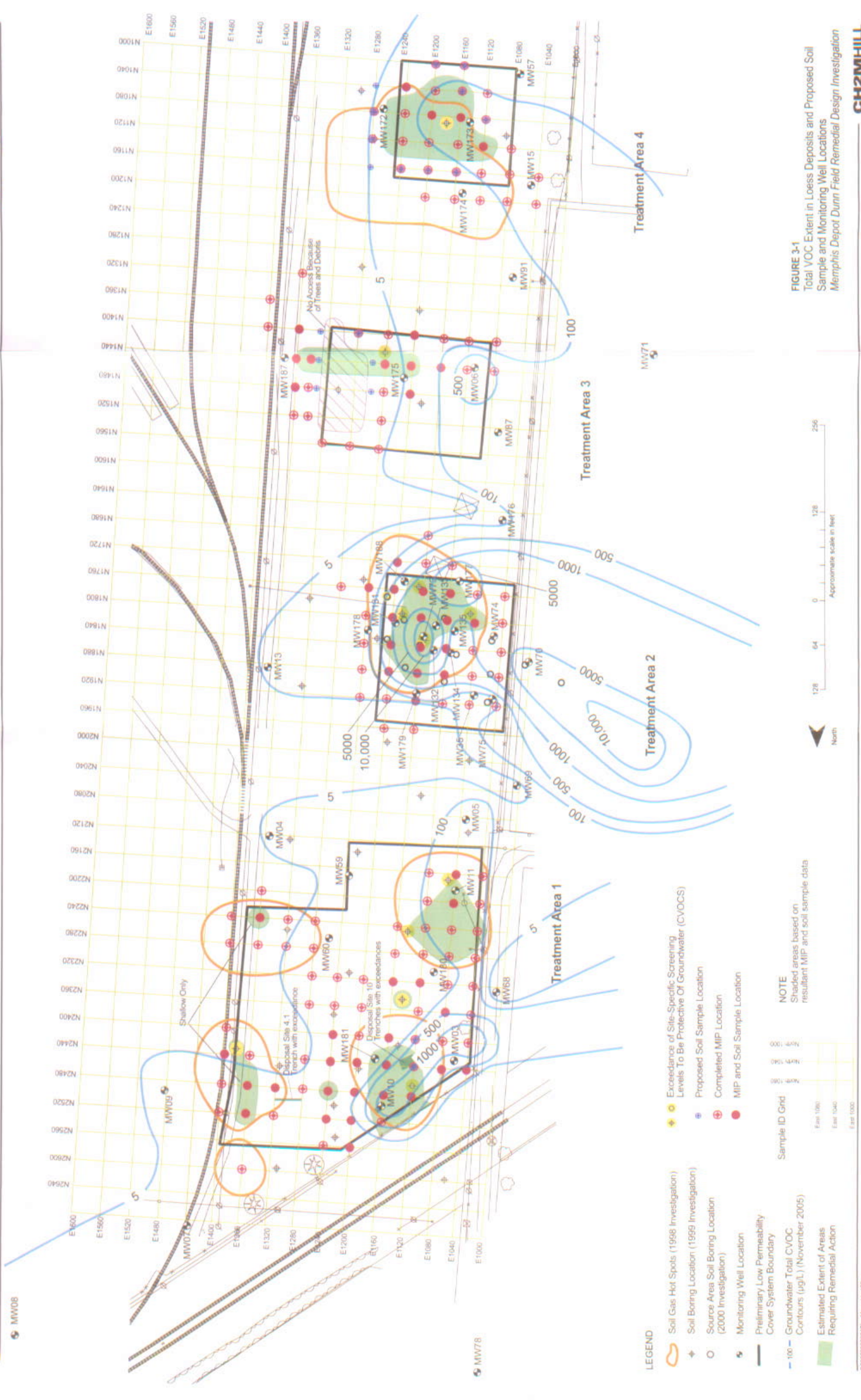


Figure 2-3A  
Groundwater CVOC Concentrations at ZVI PRB Study Area



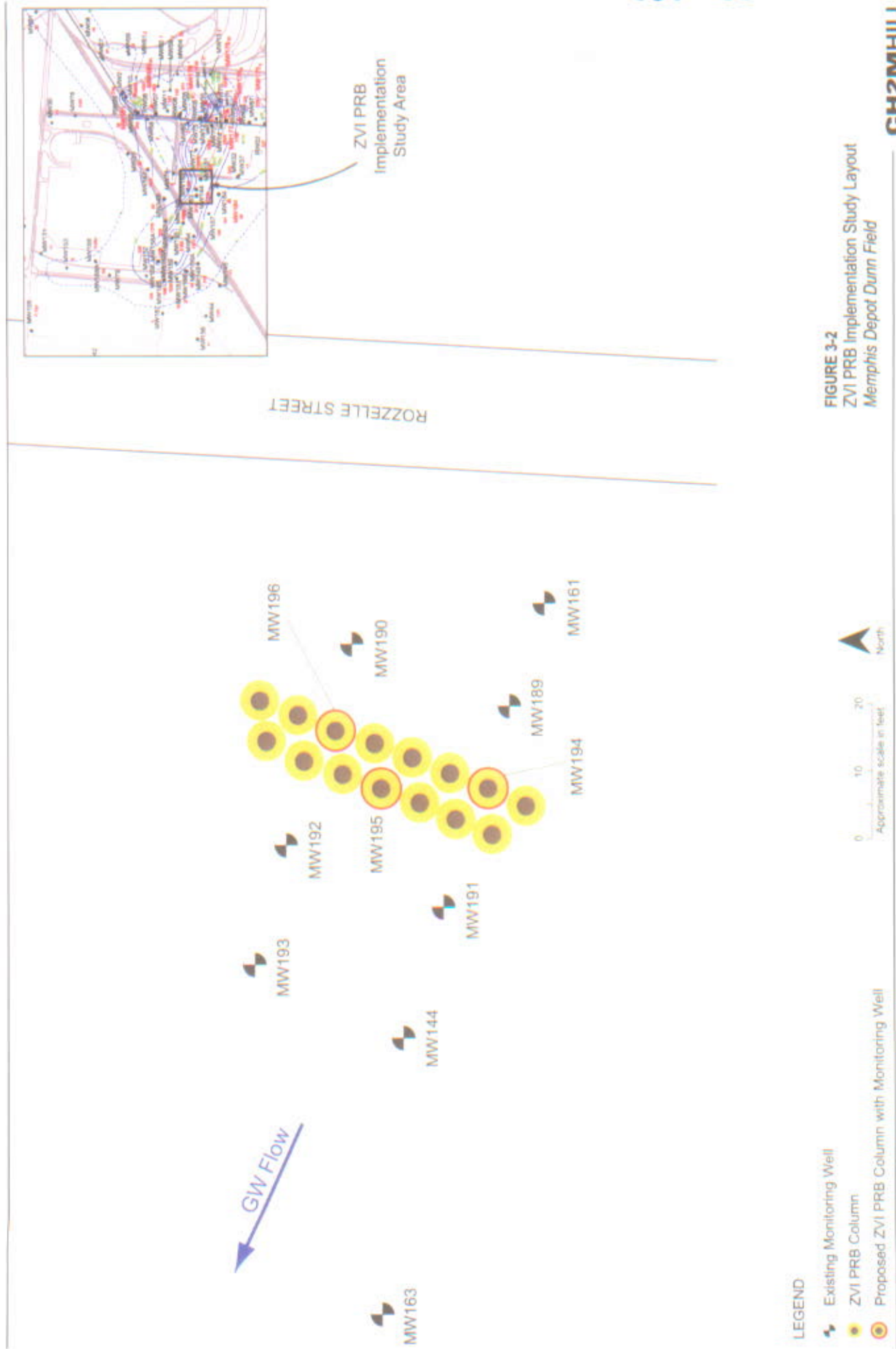






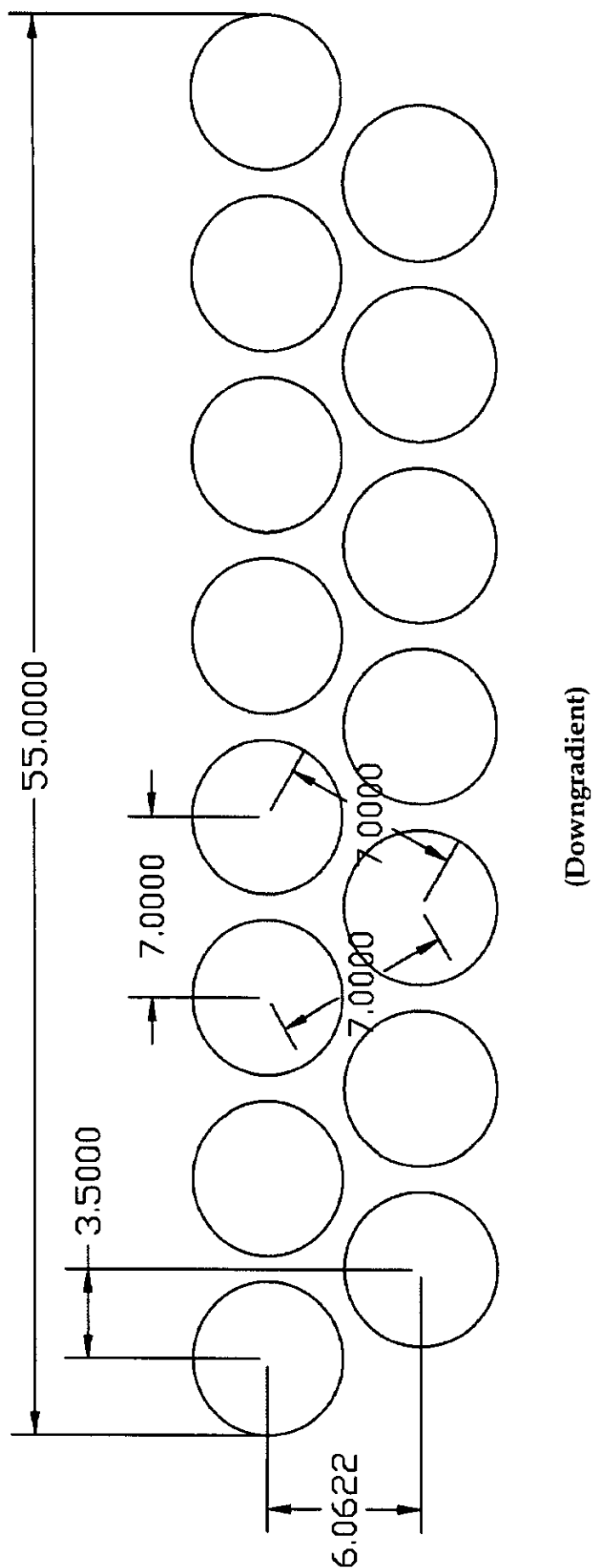
**FIGURE 3-1**  
Total VOC Extent in Loess Deposits and Proposed Soil  
Sample and Monitoring Well Locations  
Memphis Depot Dunn Field Remedial Design Investigation





**FIGURE 3-2**  
ZVI PRB Implementation Study Layout  
*Memphis Depot Dunn Field*

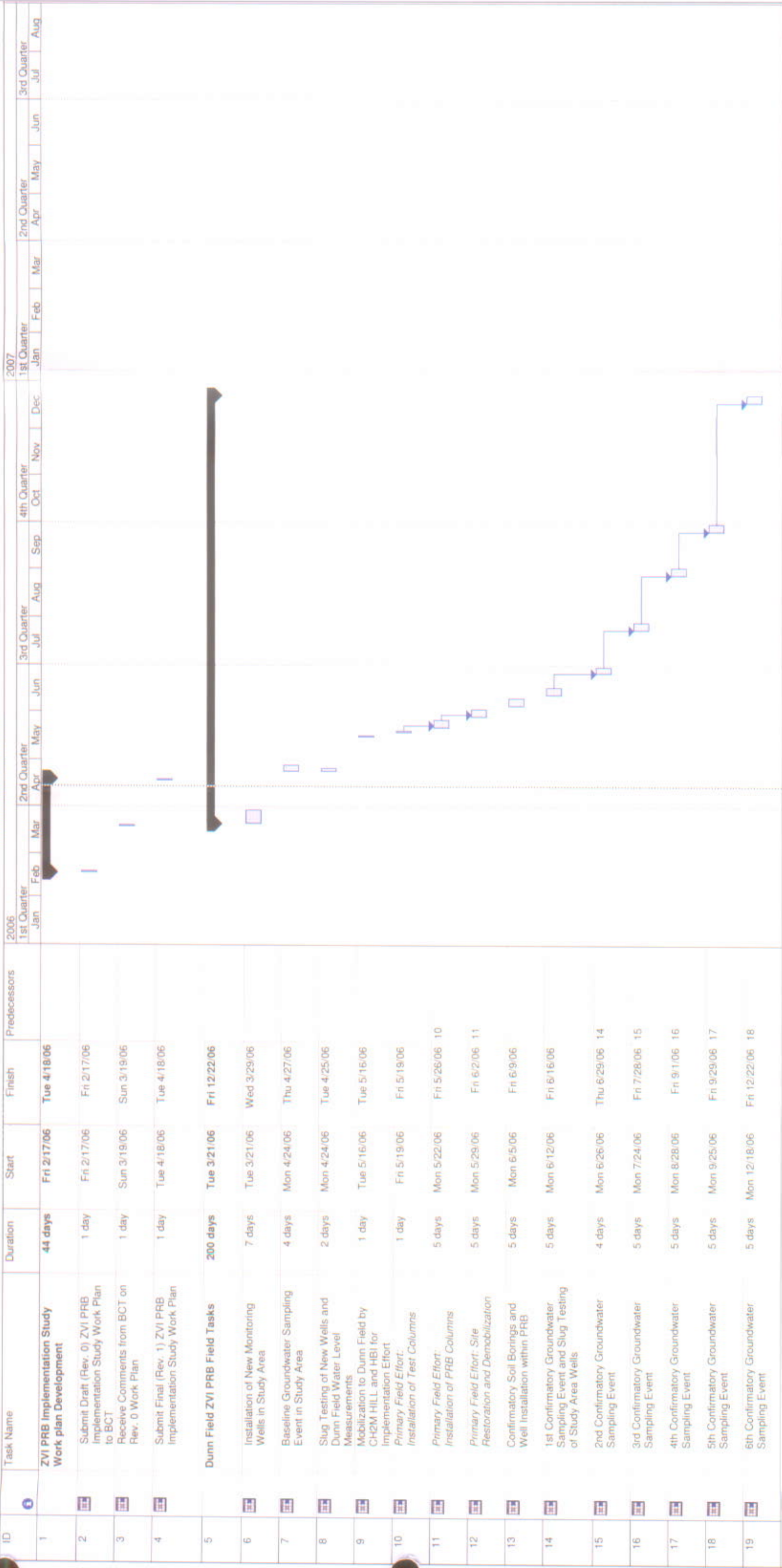
(Upgradient)



Note: Dimensions in feet.

**FIGURE 3-3**  
Proposed ZVI PRB Column Layout  
*Memphis Depot Dunn Field*

Figure 8-1  
Schedule of Activities for the Off Depot Groundwater RD and ZVI PRB Implementation Study  
Memphis Depot Dunn Field



Project: Memphis Depot Dunn Field ZVI PRB Implementation Study Workplan  
Date: Thursday, February 9, 2006

Task Split

Progress Milestone

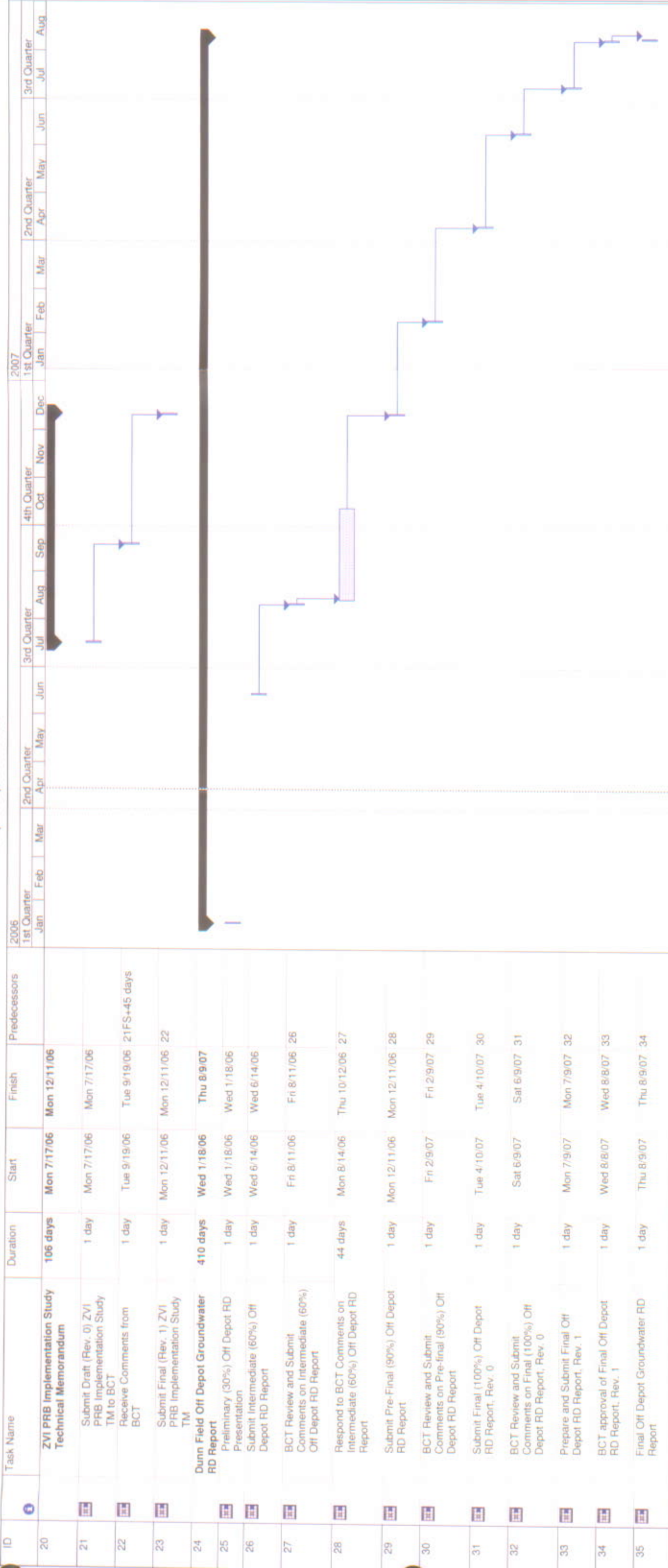
Summary Project Summary

External Tasks External Milestone

Deadline



**Figure 8-1**  
**Schedule of Activities for the Off Depot Groundwater RD and ZVI PRB Implementation Study**  
*Memphis Depot Dunn Field*



# Groundwater Modeling Results

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### Groundwater Modeling

The groundwater flow model, MODFLOW-96, was selected to develop the groundwater flow model for the study area. MODFLOW is a well-accepted, 3-D, cell-centered, saturated groundwater flow model developed by the United States Geological Survey (USGS). MODPATH, a 3-D particle tracking model, was used to assess the pathlines of groundwater through the aquifer. This model was also developed by the USGS. The Groundwater Vistas software interface (Version 3.5), developed by Environmental Simulations, Inc., was used as the pre-and post-processor for MODFLOW and MODPATH.

After the March 2005 potentiometric surface was replicated in the groundwater flow model (MACTEC, 2005a), various formation and iron/sand hydraulic conductivity values were used to evaluate the groundwater flow path following system installation (summarized in Table A-1); the alternating column ZVI layout is illustrated on the model outputs.

**TABLE A-1**  
Groundwater Model Input Summary  
*Memphis Depot Dunn Field*

Pair	K (ft/d)		Comment <sup>1</sup>
	Formation	Iron/sand column	
1	30	150	<ul style="list-style-type: none"> <li>Geometric mean for the Off-Depot formation</li> <li>K for 100% Connelly 1167 iron</li> </ul>
2	30	200	<ul style="list-style-type: none"> <li>Geometric mean for the Off-Depot formation</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>
3	70	150	<ul style="list-style-type: none"> <li>Geometric mean for the thin aquifer present in the study area</li> <li>K for 100% Connelly 1167 iron</li> </ul>
4	70	200	<ul style="list-style-type: none"> <li>Geometric mean for the thin aquifer present in the study area</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>
5	130	150	<ul style="list-style-type: none"> <li>Geometric mean for wells nearest to ZVI PRB (MW-144 and MW-161)</li> <li>K for 100% Connelly 1167 iron</li> </ul>
6	130	200	<ul style="list-style-type: none"> <li>Geometric mean for wells nearest to ZVI PRB (MW-144 and MW-161)</li> <li>K for 100% Connelly 1004 iron (slightly coarser)</li> </ul>

<sup>1</sup>As of the writing of this document, the hydraulic conductivity of the iron/sand mixture is unknown since the mixtures have not been completed. However, a sample of the proposed iron/sand blend is to be submitted to a geotechnical laboratory before the mobilization date for constant head (ASTM D2434) or falling head (ASTM D5084) permeability testing. Until then, an assumption has been made that the selected sand will not decrease the permeability of the reactive media; therefore, the model assumed the hydraulic conductivity of the iron alone for the reactive media.

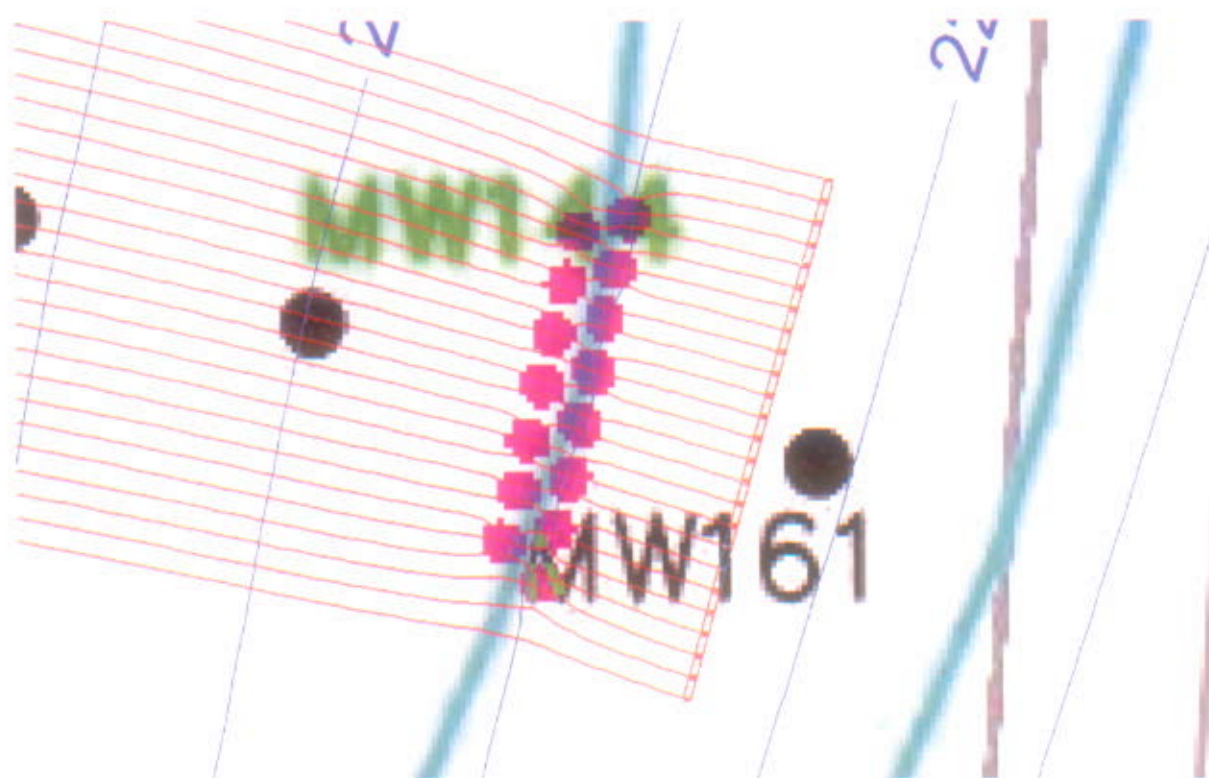
One assumption for the modeling effort is that the selected sand will not decrease the permeability of the reactive media; therefore, the model assumed the hydraulic conductivity of the iron alone for the reactive media. The model also accounts for differences in material porosity (formation was assumed to be 0.3; the iron, 0.45).

Each of the six model outputs shown below have the following elements:

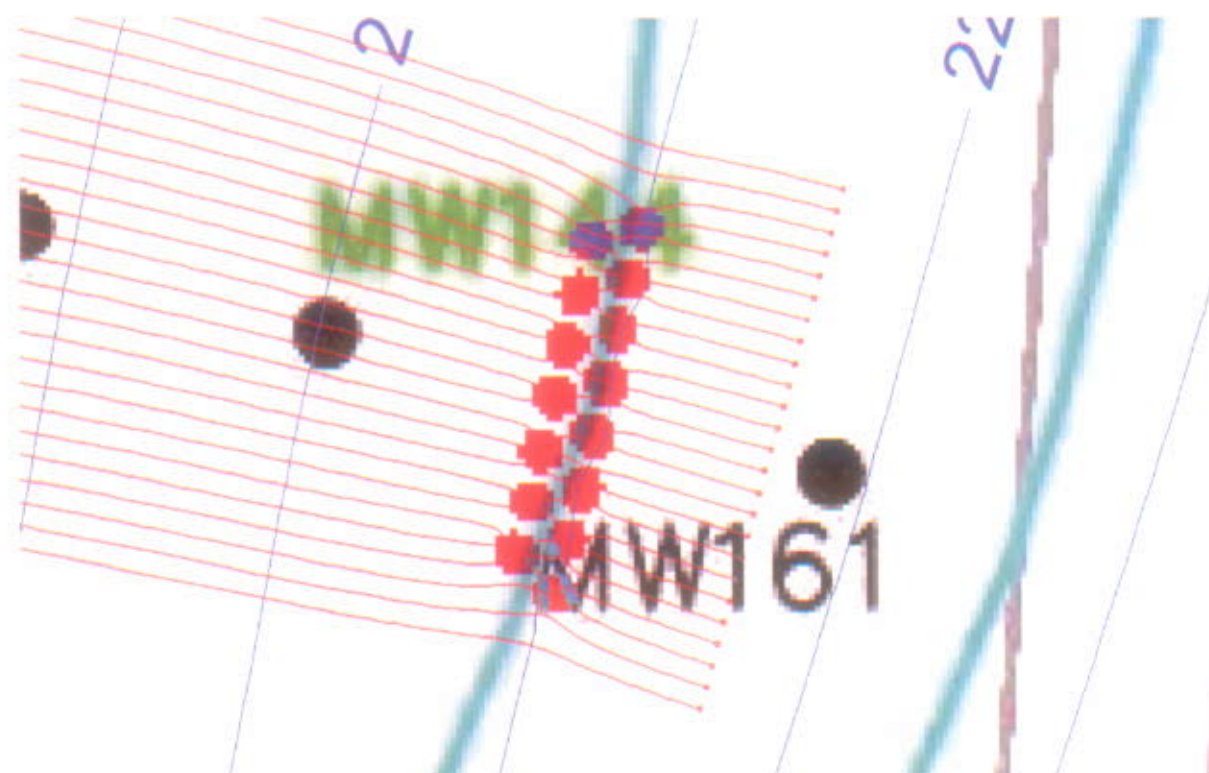
Description	Element	Comment
Pink or red circles	Iron/sand columns	
Red lines	Groundwater path lines	Flow from right (east) to left (west)
Black circles	Existing monitoring wells	
Thin blue lines	March 2005 potentiometric surface	
Thick blue lines	Groundwater model potentiometric surface	Used to match field conditions
Gray lines	Rozzelle street	

### Results

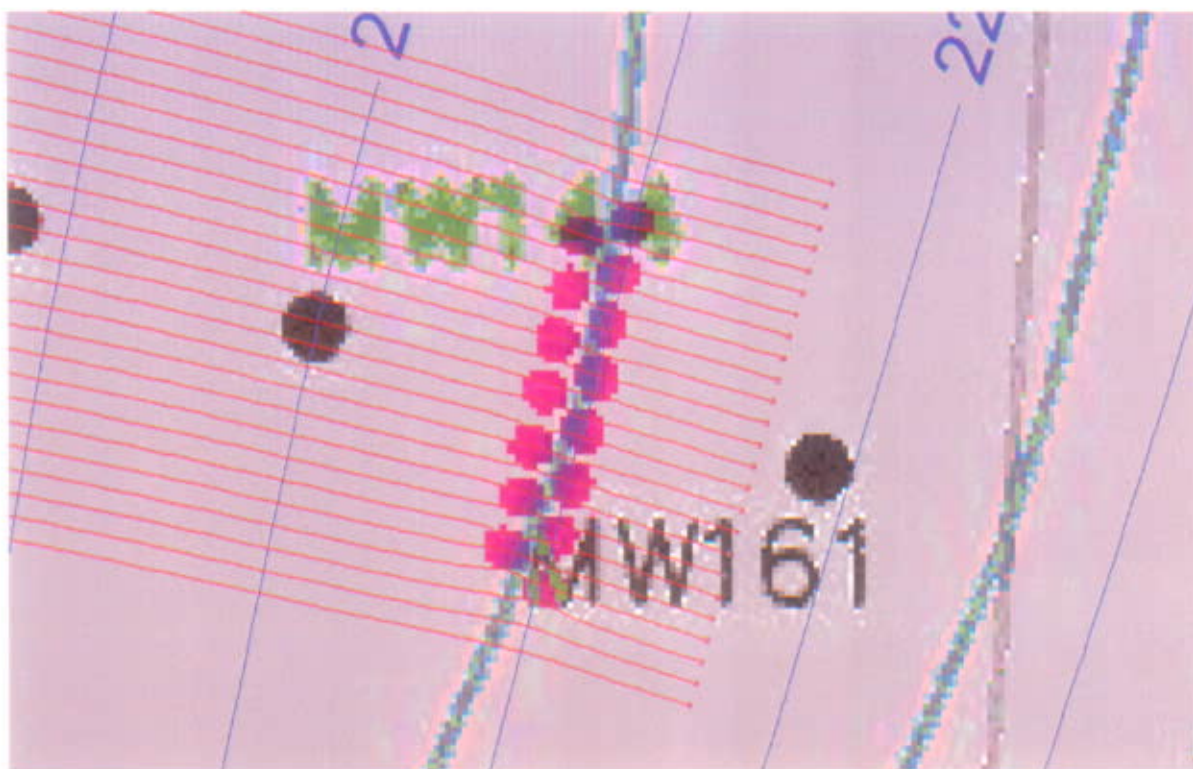
Despite similar hydraulic conductivities (formation vs. iron/sand columns), the MODPATH results indicate that the groundwater should flow through the iron/sand columns. The groundwater passes through the iron/sand columns such that the required treatment times are achieved.



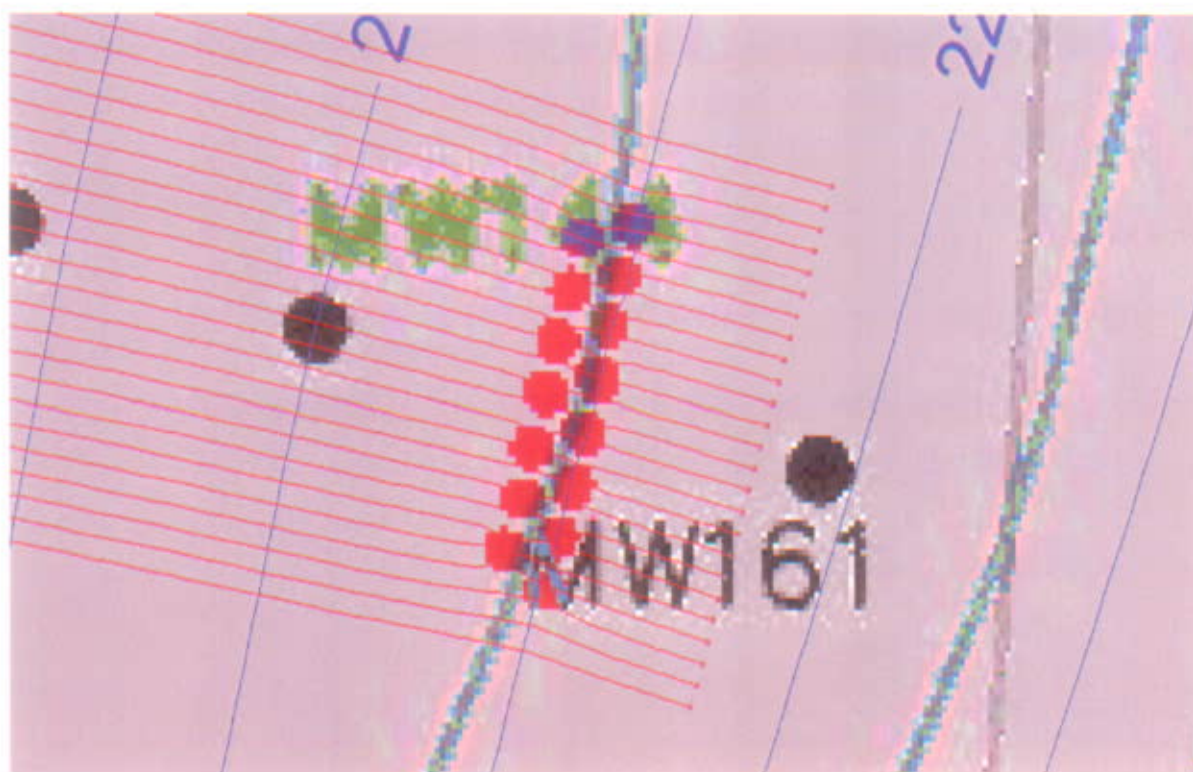
**Scenario 1:** Formation K: 30 ft/d; Iron/sand K: 150 ft/d



**Scenario 2:** Formation K: 30 ft/d; Iron/sand K: 200 ft/d

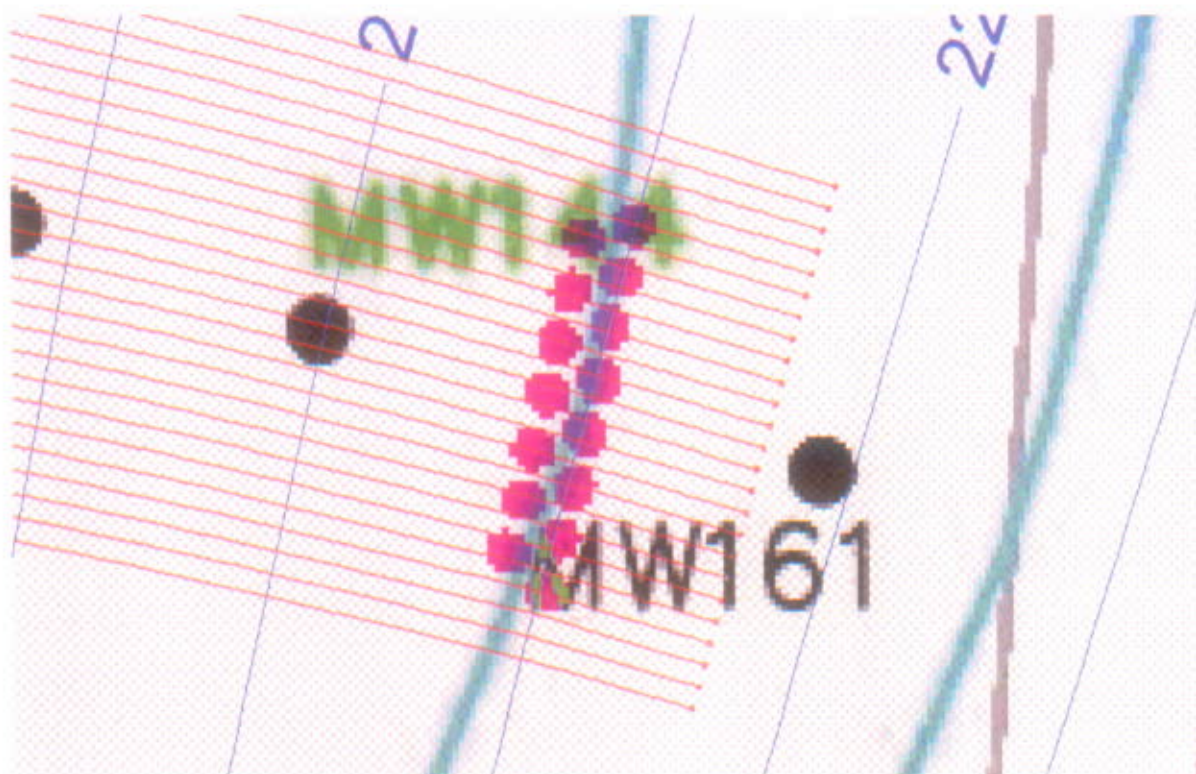


Scenario 3: Formation K: 70 ft/d; Iron/sand K: 150 ft/d

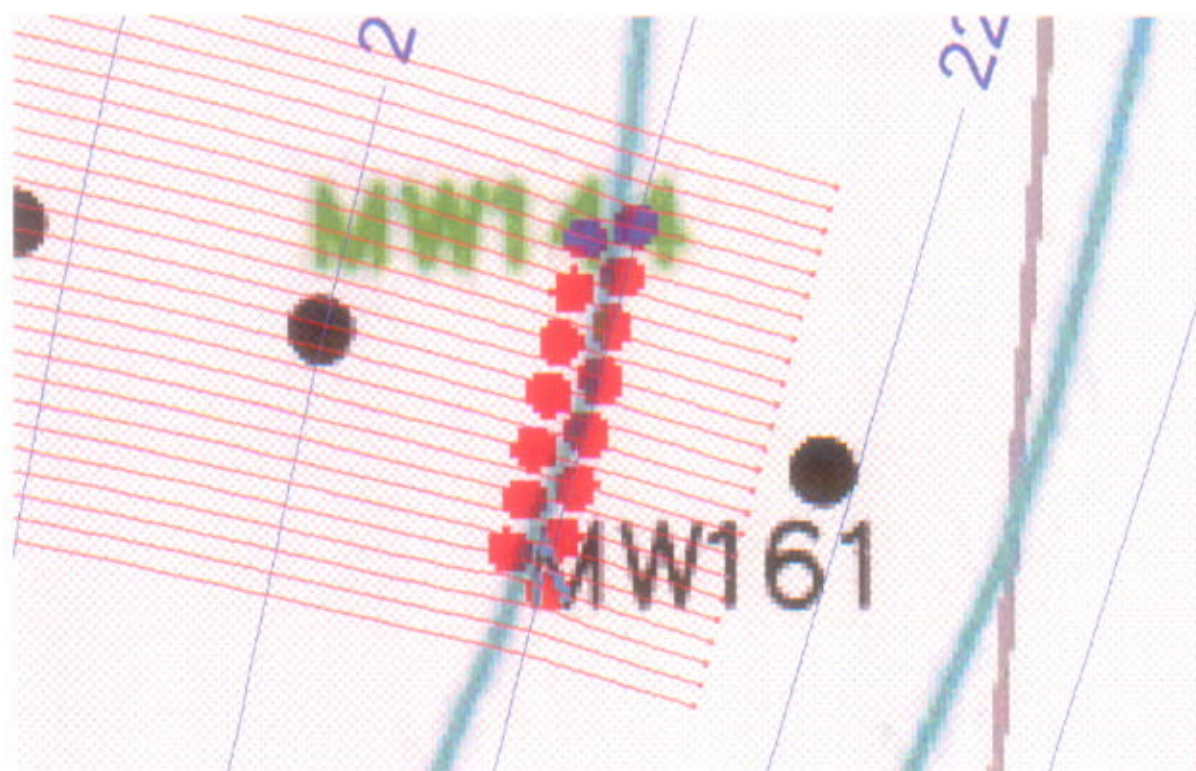


Scenario 4: Formation K: 70 ft/d; Iron/sand K: 200 ft/d





Scenario 5: Formation K: 130 ft/d; Iron/sand K: 150 ft/d



Scenario 6: Formation K: 130 ft/d; Iron/sand K: 200 ft/d

## **Proposed Drilling Equipment (HBI)**

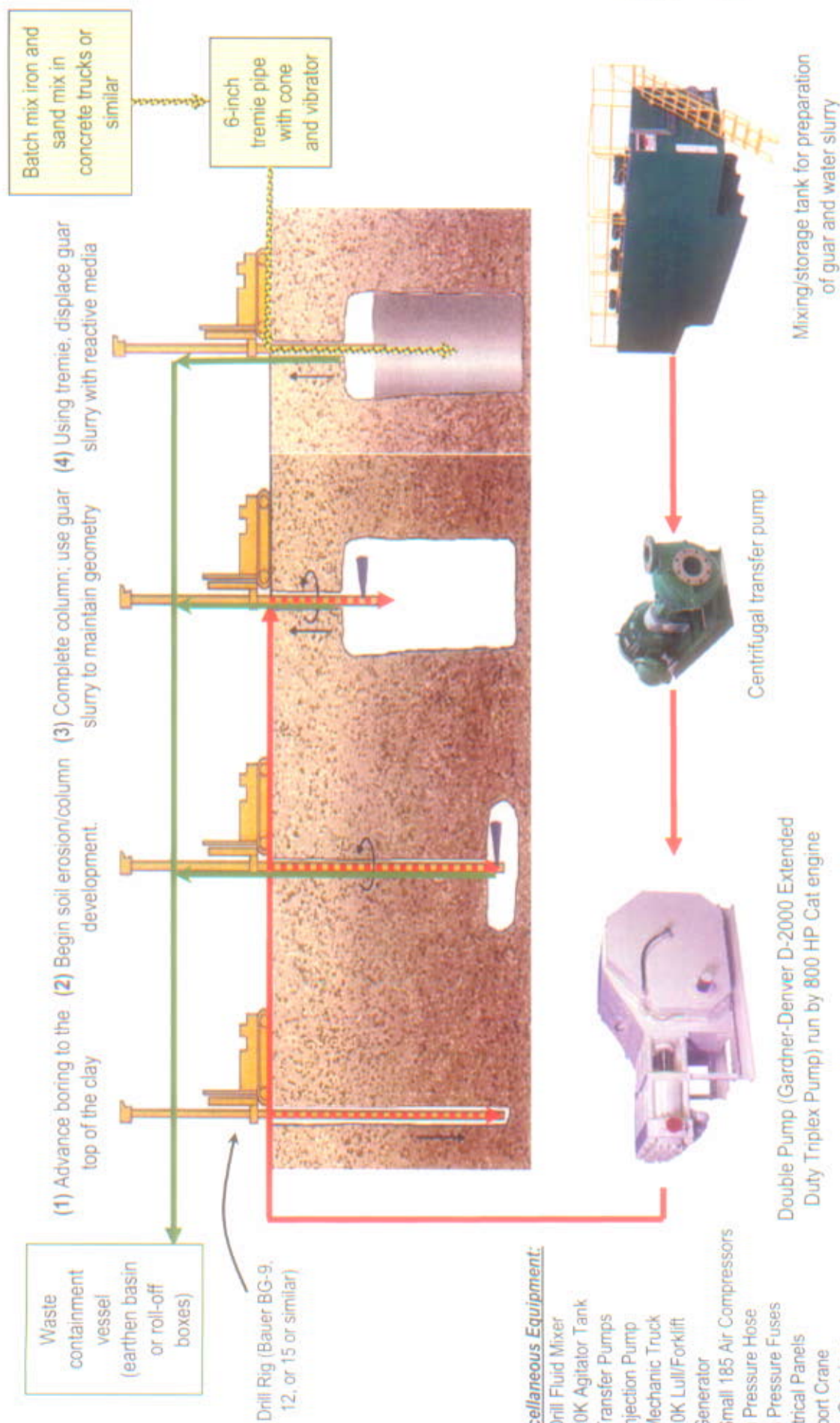
---

## Appendix B

### Schematic of ZVI PRB Installation Equipment Setup and Process Flow

#### ZVI PRB Implementation Study

#### Memphis Depot Dunn Field



#### Miscellaneous Equipment:

- (1) Drill Fluid Mixer
- (1) 20K Agitator Tank
- (2) Transfer Pumps
- (1) Injection Pump
- (1) Mechanic Truck
- (1) 10K Lull/Forklift
- (1) Generator
- (2) Small 185 Air Compressors
- High Pressure Hose
- High Pressure Fuses
- Electrical Panels
- Support Crane
- Parts Container
- Jet Grout Container





BG - 15 Pictures





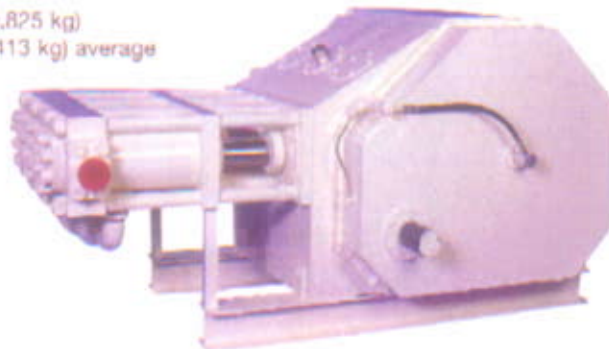
Photograph of Double Pump



## D-2000 Extended Duty Pump

### Specifications:

Maximum Input:	1000 BHP (746 kW)
Maximum RPM:	250
No. of Plungers:	3
Stroke Length:	8" (203 mm)
Plunger Load:	90,000 lbs. (40,825 kg)
Pump Weight:	12,000 lbs. (5,413 kg) average
Gear Ratio:	6.353:1



Unit shown with in-line fluid end.

### D-2000 Performance Ratings

Plunger Diameter	Displacement per Revolution	Displacement at Pump RPM - Extended Duty Application															
		100				150				200				250			
In.	mm.	Gal/Rev.	Liter/Rev.	GPM	LPM	PSI	kg/sq. cm	GPM	LPM	PSI	kg/sq. cm	GPM	LPM	PSI	kg/sq. cm	GPM	LPM
Steel and Stainless Steel In-line Fluid Ends																	
2.5	64	0.510	1.930	51	189	18244	1290	78	289	18244	1290	102	388	15121	1084	127	453
3	76	0.734	2.779	73	278	12739	896	110	417	12739	896	147	556	10508	739	194	695
3.5	89	0.969	3.787	100	378	9359	658	150	567	9359	658	200	756	7720	543	250	946
4	102	1.308	4.940	130	494	7168	504	196	741	7168	504	261	988	5911	416	326	1236
4.5	114	1.652	6.252	165	625	5662	398	248	938	5662	398	330	1250	4670	328	413	1564
5	127	2.038	7.718	204	772	4586	322	305	1158	4586	322	408	1544	3783	268	510	1931
Forged Steel CWS or Valve Over Valve Fluid Ends																	
3.75	95	1.147	4.341	115	434	8153	573	172	651	8153	573	229	866	6725	473	267	1028
4	102	1.308	4.940	130	494	7168	504	196	741	7168	504	261	988	5911	416	326	1236
4.5	114	1.652	6.252	165	625	5662	398	248	938	5662	398	330	1250	4670	328	413	1564
5	127	2.038	7.718	204	772	4586	322	305	1158	4586	322	408	1544	3783	268	510	1931
5.5	140	2.467	9.319	247	934	3790	268	370	1401	3790	268	493	1868	3126	220	617	2336
5.75	146	2.697	10.207	270	1021	3408	244	404	1521	3408	244	509	2041	2980	201	674	2500
6	152	2.936	11.114	294	1111	3195	224	440	1667	3195	224	567	2223	2827	185	734	2780
6.5	165	3.446	13.044	345	1304	2714	191	517	1957	2714	191	689	2608	2536	157	862	3263
6.75	171	3.716	14.066	372	1407	2516	177	587	2110	2516	177	743	2813	2376	146	929	3618
Input Power:		800				900				1000				1000			
		447				671				746				746			

Notes: - Gear ratio 6.353:1. Maximum fluid load 90,000 lbs. Ratings are based on 90% mechanical efficiency and 100% volumetric efficiency. Exact applications to be approved by Gardner Denver Engineering.

## Pump Information

**Bench-Scale Treatability Report in Support of a  
Granular Iron Permeable Reactive Barrier  
Installation at Dunn Field (ETI, 2005)**

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**Bench-Scale Treatability Report in Support of a Granular  
Iron Permeable Reactive Barrier Installation at Dunn Field,  
Memphis Army Depot, Memphis, TN**

Prepared For:

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ETI Reference: 31925.10

Final Report  
January 2005

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## 1.0 INTRODUCTION AND BACKGROUND

This bench-scale treatability report was prepared for CH2M Hill to support the design of a granular iron permeable reactive barrier (PRB) for treatment of dissolved chlorinated volatile organic compounds (VOCs), present in groundwater at Dunn Field, Memphis Army Depot, Memphis, TN (the "site"). This report presents the results and data interpretation of a column treatability study conducted at the Institute for Groundwater Research, University of Waterloo (UW), Waterloo, Ontario, Canada, under contract to EnviroMetal Technologies Inc. (ETI).

### 1.1 Background Information on the EnviroMetal Process

As a consequence of the significant limitations of pump-and-treat systems, *in-situ* PRBs have been identified as an alternative groundwater remediation technology (Gillham, 1996; O'Hannesin and Gillham, 1998). The concept involves the construction of a permeable wall or barrier, containing appropriate reactive materials, across the path of a contaminant plume. As the contaminated groundwater passes through the wall, the contaminants are removed through chemical or physical processes. Various configurations of *in-situ* treatment systems have been evaluated, based on site-specific conditions. Advantages of *in-situ* PRBs include:

- low maintenance costs;
- no operating costs;
- long-term passive treatment;
- absence of waste materials requiring treatment or disposal;
- absence of invasive surface structures and equipment; and
- conservation of groundwater resources.

Several types of materials have been suggested for use in PRBs. The most advanced stage of application has been achieved with systems using granular iron to degrade chlorinated organic compounds. Under highly reducing conditions and in the presence of metallic surfaces, certain dissolved chlorinated organic compounds in groundwater degrade to non-toxic products such as ethene, ethane and chloride (Gillham and O'Hannesin, 1994). The process is abiotic reductive dehalogenation, with the metal serving to lower the solution redox potential (Eh) and as the electron source in the reaction. Using granular iron as the reactive metal, reaction half-lives (the time required to degrade one half of the original contaminant mass) are commonly several orders of magnitude lower than those measured under natural conditions.



The technology is particularly attractive for the remediation of contaminated groundwater because of the high rates of degradation, the granular iron is relatively inexpensive, the process requires no external energy supply and because most compounds are degraded with production of few, if any, hazardous (chlorinated) organic by-products.

To date, granular iron PRBs have been installed at over 125 sites in the United States, Canada, Europe, Japan and Australia. These PRBs have been installed at Superfund sites; as part of brownfield site redevelopment; at various active manufacturing, DOE and dry cleaning facilities; and landfills. A total of 28 PRBs have been installed at DoD facilities throughout the United States. With 16 full-scale systems, in addition to 12 pilot-scale systems, which have been installed at earlier stages of the technology to provide "proof of concept" and over the past years to demonstrate effective construction methods. The earliest commercial applications in California and Belfast, Ireland have been in operation for the past 10 years.

## 1.2 Approach to Technology Implementation at the Site

A granular iron PRB has been proposed as an *in-situ* treatment alternative to degrade VOCs in groundwater at the site. When viewed in the context of previous successful applications, the site appears quite amenable to treatment using this technology:

- i) the primary VOCs present, 1,1,2,2-tetrachloroethane (1122TeCA), carbon tetrachloride (CT), chloroform (TCM), tetrachloroethene (PCE), trichloroethene (TCE) and cis 1,2-dichloroethene (cDCE) have been successfully treated at other sites; and
- ii) the main inorganic chemistry of the plume appears to pose no significant impediments to technology application.

Based on the information provided to ETI by CH2M Hill, at the proposed PRB location with a water table of about 80 ft below ground surface (bgs), the VOC plume ranges from about 8 to 16 ft in saturated thickness ranging from a depth of 80 to 100 ft bgs. The estimated groundwater velocity at the proposed PRB location is variable with a groundwater velocity range of about 0.55 to 1.1 ft/day.

Several design parameters need to be addressed and quantified in order to apply the granular iron technology in the field, and to determine its cost-competitiveness with other treatment

technologies. This bench-scale test was initiated to provide design parameters (VOC degradation rates) for the anticipated maximum concentrations entering the PRB. Specifically, the following factors need to be investigated to facilitate field implementation of a treatment system at the site:

- i) The degradation rates of chlorinated VOCs present in site groundwater using a commercial granular iron source. Degradation rates determined using site groundwater allow refinement of the degradation rates and resulting residence time. This residence time within the iron treatment zone will provide the time for the VOCs to achieve concentrations below the regulatory limits.
- ii) The production and subsequent degradation rates of chlorinated compounds produced from the VOCs originally present in the site groundwater (e.g., dichloroethene (DCE) isomers and vinyl chloride (VC) from TCE and 1122TeCA). These can also affect the dimensions of the treatment system.
- iii) The volume of iron material required. This volume is based on the concentrations of VOCs present in groundwater entering the treatment zone and potential breakdown products, degradation rates and groundwater flow velocity.
- iv) The effects of the process on the inorganic chemistry of the groundwater, in particular, the potential for mineral precipitation. Mineral precipitates could affect the long-term operations and maintenance (O&M) requirements of the treatment system.

### **1.3 Bench-Scale Test Report Organization**

The remainder of this report is organized as follows:

- Section 2.0 presents the detailed objectives and methods for the bench-scale test.
- Section 3.0 presents the organic and inorganic results from the bench-scale test.
- Section 4.0 discusses the calculated residence time required to meet the target levels, and provide a preliminary conceptual design for the treatment system.
- Section 5.0 summarizes the results.

## 2.0 BENCH-SCALE TEST OBJECTIVES AND METHODS

### 2.1 Bench-Scale Test Objectives

The primary objective of the bench-scale test was to provide the data necessary to determine the residence time for the dimensions of the granular iron system to remediate the VOCs present in the plume, and their chlorinated breakdown products, to below their regulatory criteria. Samples collected during the laboratory column test were used to evaluate the following specific objectives:

- determine degradation rates of VOCs in site groundwater using granular iron;
- characterization of chlorinated breakdown products, and evaluation of the rates of degradation of these products;
- changes in inorganic geochemistry as a result of the pH and Eh changes, including possible mineral precipitation.

### 2.2 Bench-Scale Test Methods

The bench-scale testing included two columns using groundwater collected from two separate locations, MW-54 and MW-77. The columns contained 100 % granular iron obtained from Connelly GPM of Chicago, IL (CC-1167, -18 to +84 US Standard Mesh size). The grain size distribution curve for this iron source is shown in Appendix A. The specific surface area of the granular iron was  $1.5 \text{ m}^2/\text{g}$  determined by the BET method (Brunauer et al., 1938) on a Micromeretic Gemini 2375 surface analyzer. A hydraulic conductivity value of  $3.3 \times 10^{-2} \text{ cm/sec}$  (94 ft/day) was obtained for this granular iron sample using a falling head permeameter test.

The column was constructed of Plexiglas™ with a length of 1.6 ft (50 cm) and an internal diameter of 1.5 in (3.8 cm) (Figures 1 and 2). Seven sampling ports were positioned along the length at distances of 0.08, 0.16, 0.33, 0.50, 0.66, 1.0, and 1.3 ft (2.5, 5, 10, 15, 20, 30, and 40 cm) from the inlet end. The column also allowed for the collection of samples from the influent (0 ft, 0 cm) and effluent lines (1.6 ft, 50 cm). Each sampling port consisted of a nylon Swagelok fitting (0.063 in, 0.16 cm) tapped into the side of the column, with a syringe

needle (16G) secured by the fitting. Glass wool was placed in the needle to exclude the iron particles. The sampling ports allowed samples to be collected along the central axis of the column. Each sample port was fitted with a Luer-Lok™ fitting, such that a glass syringe could be attached to the port to collect a sample. When not in operation the ports were sealed by Luer-Lok™ plugs.

To assure a homogeneous mixture, aliquots of iron were packed vertically in lift sections within the column. Values of bulk density, porosity, and pore volume (PV) were determined by weight (Table 1). The column experiment was performed at a site groundwater temperature of 18°C (64°F). An Ismatec™ IPN pump was used to feed the site water from a collapsible Teflon® bag to the influent end of the column. The pump tubing consisted of Viton®, and all the other tubing was Teflon® [0.125 in (0.32 cm) OD × 0.063 in (0.16 cm) ID]. Flow velocities of about 1.2 ft/day (36 cm/day) for MW-54 and 0.86 ft/day (26 cm/day) for MW-77 were selected in consultation with CH2M Hill to be in the range of the site groundwater velocity and to complete the tests within a reasonable time.

### 2.2.1 Groundwater Shipment and Storage

Groundwater was collected by CH2M Hill from monitoring well MW-54 and MW-77 at the site and shipped to UW in 4 L amber glass sample bottles with no headspace. Samples from the site were analyzed immediately upon arrival for select VOCs, using the methods described in this section.

The major VOCs detected in the water collected from MW-54 was TCM at a concentration of about 8 µg/L; 1,1,2-trichloroethane (112TCA) at a concentration of about 5 µg/L; 1122TeCA concentration of about 470 µg/L; TCE at a concentration of about 1,000 µg/L; cDCE concentration of about 30 µg/L and trans 1,2-dichloroethene (tDCE) of 7 µg/L. Laboratory grade CT and TCM chemicals were used to increase the CT and TCM concentrations in the site water influent reservoir to about 50 and 250 µg/L, respectively, which was considered to be more representative of anticipated design concentrations along the line of the proposed iron PRB.

The site water sample from MW-77 had a TCM concentration of about 5 µg/L; 112TCA concentration of about 10 µg/L; 1122TeCA of about 8,700 µg/L; PCE concentration of 20 µg/L; TCE concentration of 3,600 µg/L; cDCE concentration of about 130 µg/L and a

tDCE concentration of about 20 µg/L. Laboratory grade 1122TeCA chemical was used to increase the 1122TeCA concentration in the site water influent reservoir to about 15,000 µg/L, which was considered to be more representative of anticipated design concentrations along the line of the proposed iron PRB.

The column tests were conducted at 18°C (64°F) which is the anticipated groundwater temperature at the site. The site water was stored at 4°C (39°F) until required at which time it was siphoned from the field sample bottles into a collapsible Teflon<sup>®</sup> bag. Due to the holding capacity of this influent reservoir, as noted in Appendix C by reservoir number [RN], the influent reservoir was filled three times [a-c] for both MW-45 and MW-77 over the course of the test.

### 2.2.2 Sampling and Analysis

The columns were sampled every 3 to 10 PVs until steady state concentration profiles were achieved. In the bench-scale test, steady state is defined as the time when VOC concentrations versus distance profiles do not change significantly between sampling events. After removing the stagnant water from the sampling needle, 2.0 to 4.0 mL samples were collected from the sampling ports using glass on glass syringes, transferred to glass sample bottles, and analyzed immediately (no holding time). Samples for organic analyses, nitrate, sulphate, chloride, Eh and pH measurements were collected from each port as well as from the influent solution and the effluent overflow bottles. Samples for inorganic analyses were obtained from the influent solution and the effluent overflow bottles towards the end of the test as steady state conditions were approached.

Additional organic samples were sent to an independent laboratory chosen by CH2M Hill (Appendix B) to verify the organic influent and effluent results obtained from the UW laboratory.

## 2.3 Analytical Methods

### 2.3.1 Organic Analyses

The less volatile halogenated organic such as TCE, 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA), PCE, 1,1,1-trichloroethane (1,1,1-TCA), 1,1,2-TCA, CT and TCM were extracted from the water sample within the glass sample bottle using pentane with an internal standard of 1,2-dibromoethane, at a water to pentane ratio of 2.0 to 2.0 mL. The sample bottles were placed on a rotary shaker for 10 minutes to allow equilibration between the water and the pentane phases, then the pentane phase was transferred to an autosampler bottle. Using a Hewlett Packard 7673 autosampler, a 1.0  $\mu$ L aliquot of pentane with internal standard was automatically injected directly into a Hewlett Packard 5890 Series II gas chromatograph (GC). The chromatograph was equipped with a  $\text{Ni}^{63}$  electron capture detector (ECD) and DB-624 megabore capillary column (30 m x 0.538 mm ID, film thickness 3  $\mu$ m). The GC had an initial temperature of 50°C, with a temperature time program of 15°C/minute reaching a final temperature of 150°C. The detector temperature was 300°C. The carrier gas was helium and makeup gas was 5% methane and 95% argon, with a flow rate of 30 mL/min.

For the more volatile compounds such as the DCE isomers, VC, dichloromethane (DCM), 1,1-dichloroethane (1,1-DCA) and 1,2-dichloroethane (1,2-DCA), 4.0 mL samples were collected in glass on glass syringes and placed in 10 mL Teflon<sup>®</sup> faced septa crimp cap vials, creating a headspace with a ratio of 6.0 mL headspace to 4.0 mL aqueous sample. The samples were placed on a rotary shaker for 15 minutes to allow equilibration between the water and gas phase. Using a Hewlett Packard 7694 headspace auto sampler, a 1 mL stainless steel sample loop injected the samples directly onto a Hewlett Packard 5890 Series II GC.

For the DCE isomers and VC, the chromatograph was equipped with a HNU photoionization detector (PID) with a bulb ionization potential of 10.2 eV. The GC was fitted with a fused silica capillary NSW-PLOT column (15 m x 0.53 mm ID). The samples were placed in the analyzer oven for 2 minutes at 75°C, and subsequently injected onto the GC. The temperature program was 160°C for 5.5 minutes, then increased at 20 °C/min to 200°C and held for 5.5 minutes. The injector and detector temperatures were 100°C and 120°C, respectively. The carrier gas was helium with a flow rate of 5.5 mL/min. Data was collected with a Pentium 166 computer using HP-Chemstation Version 5.04.

For DCM, 11DCA and 12DCA, the GC was equipped with a Ni<sup>63</sup> ECD detector with a J&W DB-624 (30 m x 0.53 mm). The GC has an initial temperature of 50°C, with a temperature program of 10°C/min, reaching a final temperature of 130°C and then is held at 130°C for 0.5 minutes. The detector is set for 300°C and then injector temperature is 200°C. The carrier gas is helium with a flow rate of 7 mL/min.

Method detection limits (MDL) were determined for each compound as the minimum concentration of a substance that can be identified, measured and reported with 99% confidence that the analyte concentration is greater than zero. The MDLs were determined from analysis of samples from a solution matrix containing the analytes of interest. Although MDLs are reported, these values are not subtracted from any reported VOC concentrations (Appendix C). The reason for this is that it indicates that the organic concentrations are approaching or advancing within the column, and is helpful when determining degradation rates. Detection limits for all compounds, as given in Table 2, were determined using the EPA procedure for MDL (US EPA, 1982).

### 2.3.2 Inorganic Analyses

Eh was determined using a combination Ag/AgCl reference electrode with a platinum button and a Markson™ Model 90 meter. The electrode was standardized with ZoBell™. Millivolt (mV) readings were converted to Eh, using the electrode reading and the standard potential of the Ag/AgCl electrode at a given temperature. The pH measurements were made using a combination pH/reference electrode and a Markson™ Model 90 meter, standardized with the pH buffer 7 and the appropriate buffer of either 4 or 10. A 2.0 mL sample was collected with a glass on glass syringe and analyzed immediately for Eh and then pH.

For nitrate, sulphate and chloride analyses, a 2.0 mL sample was collected and added to a 5 mL autosampler plastic vial. The samples were then placed on a Dionex AS-40 autosampler. A 25 µL sample was then injected onto a Dionex ion chromatograph (ICS-2000) equipped with an ion-eluent generator and conductivity detector. A Dionex IonPac AS18 column (4 x 250 mm) was used. The mobile phase used was 30 mM KOH at a flow rate of 1.2 mL/min. The data were collected with a Dell P4-3GHz computer using Dionex chromeleon 6.5 software.

Over the course of the test, two water samples were collected from the influent and two from each effluent, and sent to Philip Analytical Services, Mississauga, Ontario for cation and



anion analyses. Cation analyses, included As, Fe, Na, Mg, Ca, Cr, Cu, K, Mn, Si, etc. were performed using inductively coupled plasma (ICP). The anion samples were unfiltered and acidified to a pH of 2 with nitric acid. Anion analyses, including Cl, NO<sub>3</sub> and SO<sub>4</sub>, were performed using ion chromatography. Alkalinity, ammonia (as N), total organic carbon (TOC) and dissolved organic carbon (DOC) analyses are determined by colorimetry. Detection limits for the inorganic parameters are included in Table 2.

### **3.0 BENCH-SCALE TEST RESULTS**

#### **3.1 Interlaboratory Comparison**

An independent laboratory, Kemron Environmental Services (Kemron), was selected by CH2M Hill to verify UW organic analyses from three influent samples [0 PV, 43.7 PVs (MW-54) and 33.3 PVs (MW-77)] and a column effluent sample from each of the site waters [43.7 PV (MW-54) and 33.3 PV (MW-77); Appendix B]. As shown on Tables 3 and 4, a good comparison was observed between the two laboratories with the exception of MW-54 CT and TCM analyses from the influent sample (0 PV). It appears that the Kemron data was 2 to 4 times the concentration that was determined by UW. These samples were collected from the influent reservoir and were sampled just after the influent concentration of CT and TCM were increased to reflect more representative concentrations for the MW-54 site water. Since the other organic compounds have a similar concentration, the difference in CT and TCM appears to be incomplete mixing of the influent reservoir within the refrigerator prior to sending samples to Kemron. When compared later at 43.7 PVs, the CT and TCM for both the Kemron and UW have similar concentrations.

#### **3.2 Degradation of Volatile Organic Compounds**

Samples for measurement of VOC concentrations along the length of the column were taken approximately every 3 to 10 PVs (Appendix C). Using the distance for each sampling port and flow velocity, the residence time was calculated for each port. The results obtained when steady state conditions were reached are plotted as VOC concentration (µg/L) versus residence time within the column (hrs). Although some fluctuations in the influent concentrations occurred, this did not affect interpretation of the observed results, as the influent concentration for each profile was used to determine the degradation rates for that particular profile.

#### MW-54

The final steady-state concentration profiles for the columns are shown in Figures 3 to 5. At a flow velocity of about 1.2 ft/day (36 cm/day), one PV corresponds to a residence time of about 33 hrs. A total of 49 PVs of water were passed through the column. The CT and TCM concentrations decreased from influent concentrations of 55 and 502 µg/L to non-detectable values within a residence time of 1.6 hrs and 10 hrs, respectively (Figure 3). Due to the dechlorination of CT and TCM, approximately 50 µg/L of DCM was detected along the column, as anticipated since DCM does not degrade in the presence of granular iron (Figure 3). The 1122TeCA concentration decreased from an influent concentration of 496 µg/L to non-detectable values within a residence time of about 7 hrs along the column (Figure 4). TCE concentration decreased from an influent concentration of 788 µg/L to non-detectable values within a residence time of 6.6 hrs along the column (Figure 4). Due to the dechlorination of 1122TeCA and TCE, the cDCE concentration increased from an influent concentration of 41 µg/L to a peak concentration of 56 µg/L at a residence time of 3.2 hrs and then declined to non-detectable values within a residence time of 20 hrs along the column (Figure 5). The tDCE concentration followed the same trend as cDCE, due to the dechlorination of mainly 1122TeCA, and increased from an influent concentration of 5.6 to 26 µg/L at a residence time of 3.2 hrs and declined to non-detectable values within a residence time of 10 hrs along the column (Figure 5). There were sporadic and trace levels of 1,1-dichloroethene (11DCE) and VC found within the column and PCE was only detected in the influent at 3.0 µg/L (Appendix C). There were no detectable concentrations of 111TCA, 112TCA, 11DCA and 12DCA (Appendix C).

#### MW-77

The final steady-state concentration profiles for the columns are shown in Figures 6 to 8. At a flow velocity of about 0.86 ft/day (26 cm/day), one PV corresponds to a residence time of about 46 hrs. A total of 44 PVs of water were passed through the column. The 1122TeCA concentration declined from an influent concentration of 22,145 µg/L to non-detectable values within a residence time of about 14 hrs along the column (Figure 6). TCE concentrations declined from an influent concentration of 3,176 µg/L to non-detectable values within a residence time of about 18 hrs along the column (Figure 7). Due to the dechlorination of 1122TeCA and TCE, the cDCE concentration increased from an influent concentration of 177 to 3,685 µg/L at a residence time of 4.5 hrs and then declined to non-detectable values within a residence time of about 37 hrs along the column (Figure 7). The tDCE and 112TCA

concentrations followed the same trend as cDCE with an increase in the concentration due to the dechlorination of 1122TeCA. The tDCE concentration was 21 µg/L in the influent and increased to 1,434 µg/L at a residence time of about 2 hrs and then declined to non-detectable values within a residence time of about 18 hrs (Figure 7). For 112TCA, the influent concentration was 11 µg/L and increased to 66 µg/L at a residence time of 2 hrs followed by a decline in concentration to non-detectable values at a residence time of 14 hrs along the column (Figure 8). The PCE concentration of 48 µg/L in the influent declined to non-detectable values within a residence time of about 9 hrs along the column (Figure 8). The concentration of VC increased from non-detectable values in the influent to 106 µg/L at a residence time of 9 hrs followed by a decline in concentration to non-detectable values at a residence time of about 28 hrs along the column (Figure 8). Trace amounts of 11DCE, 12DCA and DCM were observed in the column. CT was only detected in the influent at 6 µg/L (Appendix C). There were no detectable concentrations of 111TCA, 11DCA and TCM.

### 3.3 Determination of VOC Degradation Parameters

The VOC degradation trends observed in groundwater in contact with granular iron are typically described using first-order kinetics:

$$C = C_o e^{-kt} \quad (1)$$

or

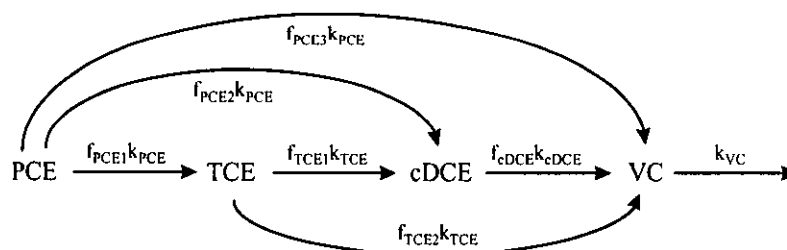
$$\ln\left(\frac{C}{C_o}\right) = -kt \quad (2)$$

where: C = VOC concentration in solution at time t,  
 $C_o$  = VOC concentration of the influent solution,  
 k = first-order rate constant, and  
 t = time.

The time at which the initial concentration declines by one-half, ( $C/C_o = 0.5$ ), is the half-life.

ETI has developed a first-order kinetic model to simulate the degradation of VOCs with granular iron. In the model, potential breakdown products are concurrently produced and degraded as described by first-order kinetic equations. The model is an expression of the chemistry that is observed in the solution phase. For example, for the chlorinated ethenes (PCE, TCE, cDCE and VC) the production of chlorinated acetylene via a  $\beta$ -elimination pathway is considered to be the dominant degradation pathway (Eykholt, 1998; Arnold and Roberts, 1999). However, since chlorinated acetylenes are unstable, short-lived, intermediates that are rapidly reduced to ethene (Roberts et al., 1996; Sivavec et al., 1997), these compounds are not typically detected in the solution phase and are therefore not explicitly contained in the degradation model. Arnold et al. (2002) showed that  $\beta$ -elimination is also the major dechlorination pathway of 1122TeCA with granular iron, resulting in formation of 12DCE isomers as well as small amounts of TCE formed via the dehydrochlorination pathway.

The equations contained in the model were developed by ETI to describe the first-order kinetic degradation process occurring in a granular iron groundwater treatment zone. For example, PCE, TCE, cDCE and VC the model takes the form:



where:  $f$  = mole fraction (or percent molar conversions)

$k$  = first-order rate constant

In order to determine the VOC concentrations at a given time the following first-order equations are used:

$$\frac{dPCE}{dt} = -k_{PCE}PCE \quad (3)$$

$$\frac{dTCE}{dt} = f_{PCE1}k_{PCE}PCE - k_{TCE}TCE \quad (4)$$

$$\frac{dcDCE}{dt} = f_{PCE2}k_{PCE}PCE + f_{TCE1}k_{TCE}TCE - k_{cDCE}cDCE \quad (5)$$

$$\frac{dVC}{dt} = f_{PCE3}k_{PCE}PCE + f_{TCE2}k_{TCE}TCE + f_{cDCE}k_{cDCE}cDCE - k_{VC}VC \quad (6)$$

These equations were adapted for the computer program Scientist<sup>®</sup> for Windows<sup>®</sup> Version 2.0 (1995). The Scientist<sup>®</sup> program can be used to fit the first-order equations to experimental data using the least squares best-fit method. Least squares fitting is performed using a modified Powell algorithm to find a local minimum of the sum of squared deviations between observed data and model calculations. The degradation rate and molar conversion are determined for each compound sequentially starting with the most chlorinated compound.

The results from the model include half-lives and molar conversions for all VOCs selected and statistical fit data including coefficient of determination ( $r^2$ ) values. The  $r^2$  values indicate how well the degradation model represents the experimental data. The half-lives determined for the VOC profiles are shown in Table 5. Also shown are the corresponding  $r^2$  values.

For MW-54, the degradation model provided relatively good fits to the CT, TCM, 1122TeCA, TCE, cDCE and tDCE concentration profiles, with  $r^2$  values greater than 0.85. Steady state half-life values at groundwater temperature of 18°C (64°F) were 0.3 hrs for CT, 1.1 hrs for TCM, 1.5 hrs for 1122TeCA, 2 hrs for TCE, 2.4 hrs for cDCE and 1.2 hrs for tDCE for MW-54 (Table 3 and Appendix C). For MW-77, the degradation model provided relatively good fits for 1122TeCA, 112TCA, PCE, TCE, cDCE, tDCE, and VC, with  $r^2$  values greater than 0.94. Steady state half-life values at groundwater temperature of 18°C (64°F) were 1.3 hrs for 1122TeCA, 2.5 hrs for 112TCA, 2.9 hrs for PCE, 2.7 hrs for TCE, 4.1 hrs for cDCE, 2.5 hrs for tDCE and 2.4 hrs for VC (Table 5 and Appendix C). Based on the half-lives determined from previous bench-scale testing with the same iron source at 25°C and corrected for 18°C, the half-lives determined in the bench-scale test were in the range of previously determined values.

The obtained half-life values for cDCE and tDCE were about 2 times higher in the MW-77, compared to the values in the MW-55 column. ETI notes that degradation behavior of lower chlorinated compound, like DCE isomers are controlled by two parameters; degradation half-life and the conversion rate from higher chlorinated compounds, in this case 1122TeCA and TCE. Figures 9 and 10 summarize the molar conversions determined using the degradation model for MW-54 and MW-77. For example, cDCE half-life in MW-54 is lower but the molar conversion from 1122TeCA to cDCE is higher (2.4 hrs, 66%), while MW-77 is the opposite (4.1hr, 49%)

The calculated half-lives and molar conversions are used to develop residence time estimates for a field-scale PRB in Section 4.1.

### 3.4 Inorganic Results

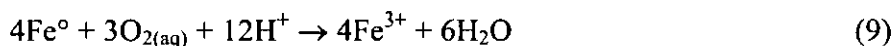
Similar to other subsurface environments, the composition of groundwater flowing through a granular iron PRB will undergo acid-base reactions, mineral precipitation/dissolution, oxidation/reduction reactions and mixing. These changes may lead to significant changes in aqueous inorganic chemistry, and the potential precipitation of a variety of mineral phases.

Two influent and effluent samples were collected from both columns as steady state approached. Changes in inorganic chemical constituents observed in the influent and effluent groundwater are summarized in Table 6. Appendix D contains the inorganic analytical data and the nitrate, chloride and sulphate profiles are shown in Appendix C. No change in concentration was observed arsenic, iron, sodium, sulphate, potassium and dissolved organic carbon (DOC) for MW-77 and chloride for MW-54. A slight decrease in concentration was observed for barium and strontium while a slight increase was observed for boron, molybdenum, zinc and DOC (MW-54). The chloride concentration increased in MW-77 due to the dechlorination process, an average mass balance of 92% as obtained. The column chloride profiles reflect similar concentrations.

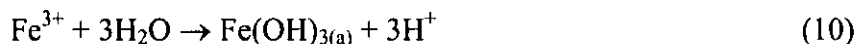
When iron is exposed to water, several reactions occur as a result of iron corrosion:



This iron corrosion drives the geochemical changes that occur as groundwater flows through the PRB. When groundwater first contacts the granular iron, dissolved oxygen corrodes the iron:



Hematite ( $\text{Fe}_2\text{O}_3$ ) is the stable iron oxide that would occur in the upgradient zone of an iron PRB. However, the initial precipitate would probably be the amorphous iron hydroxide [ $\text{Fe}(\text{OH})_{3(\text{a})}$ ] rather than the well-crystallized hematite (Drever, 1997):



After complete depletion of dissolved oxygen, the water corrosion of iron dominates to produce hydrogen and hydroxide resulting in an increase in pH and decline in Eh:



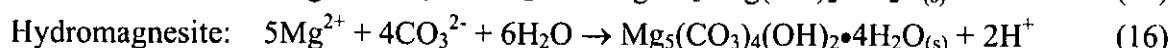
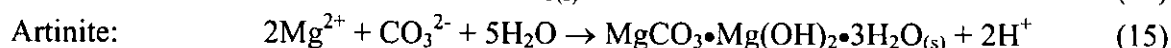
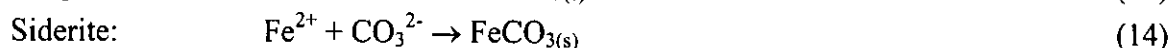
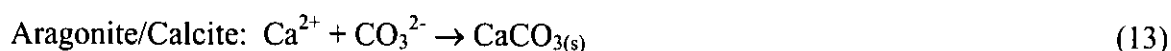
Figure 11 shows the Eh and pH profiles observed at steady state for both columns. The redox potential declined to reducing conditions as shown by the decline for MW-54 in Eh from an initial value of about +274 mV to a minimum value of about -353 mV and +330 mV to a minimum value of about -366 mV for MW-77 within the columns (Figure 11; Appendix C). Values of pH increased from 6.8 in the influent of the column to a maximum value of 9.5 for MW-54 and from 7.3 in the influent of the column to a maximum value of 9.5 for MW-77 within the columns (Figure 11; Appendix C). These trends are typically observed.

The hydrogen produced in Equation 11 can be stored within the iron grains, dissolved in the groundwater, exsolve into a gas and/or be consumed by biological organisms. Tests conducted with granular irons typically used in PRBs have resulted in water corrosion rates on the order of 0.1 to 1 mmol/kg Fe/day (Reardon, 1995 and ETI, unpublished data). The water corrosion rate depends on the iron type, dissolved inorganic species and temperature. Reardon (1995) found that corrosion rate increased by the presence of anions in the order of  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$  and Deng et al. (1998) found that hydrogen production was inhibited by  $\text{PO}_4^{3-} > \text{BO}_3^{3-} > \text{H}_2\text{SiO}_4$ . Reardon also notes that iron corrosion has been found to be constant over a pH range of 4 to 10. Recent test results indicate that corrosion rate declines significantly with decreasing temperature in the range of 2 to 30 °C, however, the scale of this temperature dependence is still under investigation (ETI, unpublished data).

As pH increases due to water corrosion, bicarbonate ( $\text{HCO}_3^-$ ) in solution converts to carbonate ( $\text{CO}_3^{2-}$ ) to buffer some of the pH increase:



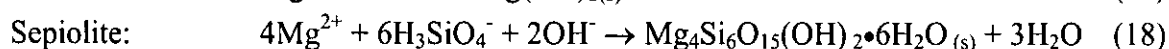
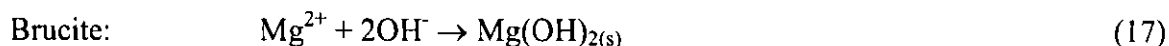
The carbonate may then combine with cations ( $\text{Ca}^{2+}$ ,  $\text{Fe}^{2+}$ , and  $\text{Mg}^{2+}$ ) in solution to form mineral precipitates:





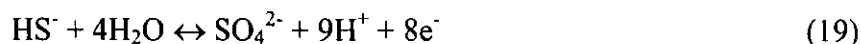
In analyses of iron obtained from previous laboratory studies and field sites, siderite as well as both calcite and aragonite, which are forms of calcium carbonate, have been identified. An average calcium concentration decreased from 17 mg/L in the influent to an average of 10 mg/L in the column effluent for MW-54 and 20 mg/L in the influent to an average of 12 mg/L in the column effluent for MW-77. Corresponding decreases in alkalinity from about 65 mg/L to about an average of 31 mg/L for MW-54 and 102 mg/L to about 21 mg/L for MW-77 was observed in the columns. Declines in calcium and alkalinity concentrations indicate formation of calcium carbonate minerals (see above). In analyses of iron obtained from previous laboratory studies and field sites, siderite as well as both calcite and aragonite, which are forms of calcium carbonate, have been identified.

Concentration of magnesium declined from 8.3 and 11 mg/L for MW-54 and MW-77 in the influent to about 0.07 and 0.12 mg/L, respectively, as groundwater flowed through the granular iron columns. Magnesium is known to substitute for calcium and iron in the structure of calcium and iron carbonates, resulting in a higher likelihood of forming solid mineral solutions ( $\text{CaMg}(\text{CO}_3)_2$  or  $\text{FeMg}(\text{CO}_3)_2$ ) rather than pure phases. Magnesium may also precipitate as magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ) known as brucite and/or magnesium silicate ( $\text{Mg}_4\text{Si}_6\text{O}_{15}(\text{OH})_2 \cdot 6\text{H}_2\text{O}$ ) known as sepiolite:



The concentration of silicon declined from about 17 mg/L in both columns to less than 1 mg/L in the columns. Silica may have been precipitating as amorphous silicate, sepiolite (Eq. 18) and/or adsorbing onto iron hydroxides.

The concentration of sulphate remained the same at 17 mg/L in MW-54 and about 26 mg/L in MW-77. The column profiles also reflect these concentrations. At high Eh, the stable form of sulphur is sulphate ( $\text{SO}_4^{2-}$ ), while at very low Eh sulphide ( $\text{H}_2\text{S}$  or  $\text{HS}^-$ ) is the stable form with  $\text{HS}^-$  being predominant at pH greater than 7:



Given the low solubility of iron sulphide ( $\text{FeS}$ ), the hydrogen sulphide produced precipitates out of solution.



Over time, iron sulphides transform into pyrite ( $\text{FeS}_2$ ) and/or marcasite, a polymorph of pyrite. Sulphate reduction maybe mediated by biological activity and a reduction in sulphate is typically not observed in bench-scale column tests. However, declines in sulphate concentrations have been observed at a number of field sites as groundwater passes through the iron treatment zones. Sass et al. (2001) found evidence for the formation of marcasite in cores from two PRB field sites.

Figure 12 shows a decline of the low influent nitrate concentrations of 4.0 mg/L for both MW-54 and MW-77 to detectable concentrations at the first sampling port (1.6 hr for MW-54; 2.2 hr for MW-77) followed by non-detectable concentrations. It is apparent that nitrate at these concentrations did not adversely affect the degradation process. This same trend is observed for other waters with similar nitrate concentrations.

These inorganic changes are similar to those observed in other column PRB studies. The implication of these data to field scale PRB application is discussed in Section 4.4.

## 4.0 FIELD-SCALE TREATMENT SYSTEM DESIGN CONSIDERATIONS

### 4.1 Required Residence Time

Degradation rates (Table 5) and molar conversions (Figures 9 and 10) determined based on the column test results and concentrations from MW-54 and MW-77 were input into the first-order degradation model to determine possible residence time requirements in a field-scale system. The Scientist<sup>®</sup> program described in Section 3.2 may also be used to simulate the change in VOC concentrations over time using the first-order kinetic equations. In simulation mode, the model calculates the VOC concentrations over time, from which the time required for the VOCs to degrade to their regulatory criteria can be determined. The residence time calculation is shown conceptually in Figure 13.

These column tests were conducted at the anticipated field groundwater temperature of 18°C (64°F). If it is assumed that the groundwater temperature will not fall substantially below 18°C (64°F), it is reasonable to use the generated laboratory half-lives.

Based on data provided by CH2M Hill, we have evaluated two PRB locations (near well MW-54 and MW-77), assuming two alternative influent concentration scenarios at each location (Tables 7 and 8). Applying those scenarios, the residence times required to achieve the target risk levels in an iron PRB near MW-54 ranges from 24 hrs (1.0 days) to 26 hrs (1.1 days) (Table 7 and Figures 14 and 15). For a PRB near MW-77, the required residence time ranges from 27 hrs (1.1 days) to 29 hrs (1.2 days) (Table 8 and Figures 16 and 17).

### 4.2 Conceptual System Design

Based on information from CH2M Hill, the proposed PRBs be installed to a depth of up to 100 ft below ground surface (bgs). The anticipated iron saturated depths are 16 ft near MW-54 and 8 ft near MW-77. Based on the reported groundwater flow velocities of 0.55 and 1.1 ft/day near MW-54 and MW-77, respectively, and the required residence times, the iron zone thickness range from 0.55 to 0.61 ft for MW-54 and 1.2 to 1.3 ft for MW-77 (Tables 7 and 8).

The total volume of iron can be calculated as follows:

Volume of Iron = length of treatment zone × saturated depth × flow-through thickness

Assuming a bulk density for iron of  $0.090 \text{ ton/ft}^3$  and a PRB length of 1,070 ft, about 847 to 940 tons of granular iron (18/84 US Standard Mesh) may be needed to construct the proposed PRB near well MW-54 (Table 9). For a 410 ft long PRB near well MW-77, 354 to 384 tons of iron would be needed (Table 9).

A suitable construction method to achieve the depth of 100 ft is vertical hydrofracturing. Thin vertical treatment zones can be installed using this method which uses a specialized tool to orient the vertical fracture and initiate the fracture process. The tool is placed to the desired depth through a borehole and the interval for fracturing isolated by packers. A finer grained iron is suspended in a biodegradable slurry and pumped under low pressure (a few hundred psi) into the formation. The fracturing fluid causes the soil to separate creating an iron treatment zone a few inches in width with a controlled vertical thickness. Several fractures propagated from boreholes located along the line of installation coalesce to create a continuous PRB (i.e. a thin vertical plane of iron). Parallel vertical planes can be installed to increase the flow-through thickness of the granular iron system. GeoSierra is the contractor who is using this installation technique and costs should be obtained directly from GeoSierra (Grant Hocking 678-514-3300, [www.geosierra.com](http://www.geosierra.com)).

#### 4.3 Iron Consumption

As discussed in Section 3.3, there are many processes such as water corrosion, VOC degradation, dissolved oxygen reduction, sulphate and methane reduction that may consume the iron. These processes are not independent of one another and also depend on site conditions such as groundwater flow velocity, inorganic aqueous concentrations, VOC concentrations, biological activity and temperature. All of these factors make it difficult to gauge with exact certainty the time required to consume the iron in a PRB.

If water corrosion were to remain constant over time at a typical rate of  $0.3 \text{ mmol/kg Fe/day}$ , the iron is predicted to last several decades. However, Reardon (1995) and Gillham et al. (2001) noted declining hydrogen production over time at room temperature. This decline in corrosion rate was likely due to mineral precipitate formation on the surface of the iron over long periods of time. Sorel et al. (2000; 2001) found that the groundwater pH at the first commercial PRB in Sunnyvale, CA continues to increase from a value of 7.5 in the upgradient aquifer to a value of about 11 in the PRB and that dissolved hydrogen concentrations approach solubility. Clearly, water corrosion is still occurring at significant rates at this site after 10 years.

Other factors such as desaturation of the iron and oxidation by atmospheric oxygen would also affect the lifetime of the iron. Although there is some uncertainty in the conditions that may exist decades in the future, it seems reasonable to expect the iron in the PRB to last for many decades.

#### 4.4 Possible Effect of Precipitation on Field-Scale Performance

Concern has been expressed regarding the potential for inorganic precipitates to reduce the activity of the iron and/or to reduce the permeability through pore clogging. Field experience to date indicates, that at most sites, carbonate precipitates represent the largest volume of precipitates.

Gillham et al. (2001) documented the migration of mineral precipitates through a bench-scale column of granular iron in a long-term test and verified what various research groups had visually observed. This means that it would take even longer for complete porosity loss to occur as the precipitation front moves through the PRB. In fact, in long-term column tests by Gillham et al. (2001), Eykholt (1999) and Sass (2001) indicated that complete porosity loss did not occur, even in cases where the precipitate had migrated through the entire column (i.e. effluent aqueous inorganic concentrations equaled influent). For example, Gillham et al. (2001) determined a maximum porosity loss due to carbonate formation of about 20% of the original porosity. In addition, these researchers found that the hydraulic conductivity of their systems only declined by a factor of two or three.

It is, however, important to note that the influent water used by these researchers contained no dissolved oxygen. Dissolved oxygen has resulted in a significant loss in hydraulic conductivity in bench-scale column tests (Mackenzie et al., 1997; Fort, 2000; and ETI, unpublished data) and field-scale above-ground and in-situ fixed-bed reactors. Mackenzie et al. (1997) and Fort (2000) both used iron-sand mixtures to overcome the loss in hydraulic conductivity.

Gillham et al. (2001) reported that the reactivity of the iron was low behind the zone of carbonate precipitate migration. Vikesland et al. (2000) also showed that various inorganic precipitates can reduce iron reactivity.

Core analyses from pilot-scale systems in Upstate NY and Denver, CO revealed porosity losses in the upgradient few inches of iron in the range of 10% of the initial porosity, with losses declining sharply over the first foot to below 2% (Vogan et al., 1998 and 1999). These porosity losses were calculated based on carbonate analyses of iron material retrieved by coring the treatment zone. The porosity loss measured in the core samples were consistent with that predicted on the basis of changes in the inorganic water chemistry. Assuming an initial porosity of 0.5, the porosity after 18 months (Denver) to 2 years (New York) in the first few inches of the iron zones had declined to about 0.45. Concurrent field data (VOC and groundwater velocity measurements) indicated that system hydraulics and iron reactivity had not been adversely affected by the precipitates. Laboratory permeameter tests performed on intact core samples from the New York site gave hydraulic conductivity values ranging from  $6 \times 10^{-2}$  to  $10^{-1}$  cm/s. These compare favorably with hydraulic conductivity values of  $5 \times 10^{-2}$  to  $10^{-1}$  cm/s for "fresh" iron.

A commercial system in Sunnyvale, CA (Sorel et al., 2001) has also been performing consistently for over 9 years. Groundwater at this site exhibits TDS in the range of 1,000 to 3,500 mg/L. No significant precipitates were observed in cores from an in situ reactive wall at the University of Waterloo Borden test site two and four years after it was installed (O'Hannesin and Gillham, 1998). Recent tests at the Borden PRB indicated that the reactivity of the iron in this system has been maintained for 10 years.

#### 4.5 Potential for Biofouling of Reactive Material

There was no evidence of biofouling (sliming, etc.) observed during the bench-scale test. Field tests to date from other sites have been encouraging. Cores of the reactive wall at the Borden test site (O'Hannesin and Gillham, 1998), collected two years after the wall was installed, showed no significant population of iron oxidizing microbes, and only low numbers of sulphate reducers (Matheson and Tratnyek, 1994). Phospholipid-fatty acid analysis of groundwater from an above-ground test reactor at an industrial facility in California and an *in-situ* site in New York showed no enhanced microbial population in the reactive material relative to background groundwater samples. Core samples from the two sites described above were also analyzed for microbial population. The results indicated no evidence of increased microbial growth or fouling in the iron zone. Gu et al. (2001) found biomass 1 to 3 orders of magnitude higher in an iron PRB treating radionuclides and 120 mg/L of nitrate, compared to background soil and groundwater. They identified abundant sulphate reducers and denitrifiers in the PRB. However, no evidence of biofouling has been observed at the site

after about 2 years of operation. In summary, there is no reason to expect that microbial fouling would adversely affect PRB performance at Memphis Army Depot.

#### **4.6 Maintenance**

Other than groundwater monitoring, the major factor affecting maintenance costs is the possible need for periodic rejuvenation of iron sections affected by precipitates.

The objective of rejuvenation of the granular iron would be to restore the permeability loss due to precipitates and possibly to remove the precipitate from the iron to restore any lost reactivity of the iron. Possible rejuvenation methods may include:

- i) Using ultrasound to break-up the precipitate;
- ii) Using pressure pulse technology to break-up the precipitate; and
- iii) Using solid-stem augers to agitate the PRB.

To date these possible rejuvenation methods have not been needed and only ultrasound has been tested in a few limited field-scale tests to determine its effectiveness. At this point we can only state that these methods may prove to be successful in rejuvenating a PRB. Although inorganic results from the treatability study and data collected from long-term bench-scale tests and field sites indicate that mineral precipitates may not be a problem for perhaps decades at the site.



## 5.0 SUMMARY

Bench-scale testing using groundwater from monitoring wells MW-54 and MW-77 at Dunn Field, Memphis Army Depot, Memphis, TN, showed that:

- i) the granular iron technology can degrade the chlorinated VOCs present in the site waters to below the remediation goals;
- ii) the residence time required to degrade the VOC concentrations anticipated in PRBs located near well MW-54 and MW-77 to below the site risk target levels ranges from 1.0 to 1.2 days;
- iii) the low levels of nitrate appeared to pose no adverse affect on the granular iron technology;
- iv) redox potential (Eh) and pH trends were consistent with bench-scale tests with similar types of site water; and
- v) mineral precipitates (mainly carbonates) will likely occur in a field-scale in-situ treatment system, but should not significantly effect system performance for many years.

## 6.0 REFERENCES

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**Table 1: Iron and Column Properties**

<b>Materials:</b>		
Iron Source	Connelly-GPM, Chicago, IL	
Iron Grain Size	1.0 to 0.17 mm (-18 to +84 mesh)	
Iron Surface Area	1.5 m <sup>2</sup> /g	
Iron Hydraulic Conductivity	3.3 × 10 <sup>-2</sup> cm/sec (94 ft/day)	
<b>Column :</b>	<b>MW-54</b>	<b>MW-77</b>
Test Temperature	18°C	
Flow Velocity	1.2 ft/day (36 cm/day)	0.86 ft/day (26 cm/day)
Residence Time	32.8 hrs	45.8 hrs
Pore Volume	296 mL	289 mL
Porosity	0.52	0.51
Bulk Density	3.16 g/cm <sup>3</sup> (197 lb/ft <sup>3</sup> )	3.12 g/cm <sup>3</sup> (194 lb/ft <sup>3</sup> )
Iron to Volume of Solution Ratio	6.1 g : 1 mL	6.2 g : 1 mL
Surface Area to Volume of Solution Ratio	9.1 m <sup>2</sup> : 1 mL	9.2 m <sup>2</sup> : 1 mL

**Table 2: Method Detection Limits (MDL) and Detection Limits (DL)**

<b>Organic Compounds:</b>		<b>MDL (µg/L)</b>
Tetrachloroethene		0.9
Trichloroethene		0.6
cis 1,2-Dichloroethene		1.9
trans 1,2-Dichloroethene		2.3
1,1-Dichloroethene		3.9
Vinyl Chloride		1.3
1,1,2,2-Tetrachloroethane		0.5
1,1,1-Trichloroethane		0.7
1,1,2-Trichloroethane		0.5
Carbon Tetrachloride		0.8
Chloroform		0.7
1,1-Dichloroethane		1.0
1,2-Dichloroethane		1.1
Dichloromethane		1.0
<b>Inorganic Compounds:</b>		<b>DL (mg/L)</b>
Arsenic		0.001
Boron		0.01
Barium		0.005
Calcium		0.05
Chromium		0.005
Iron		0.01
Potassium		1
Magnesium		0.05
Molybdenum		0.02
Sodium		0.1
Silicon		0.05
Strontium		0.001
Zinc		0.005
Chloride		0.5 (0.5 <sup>a</sup> )
Ammonia (as N)		0.03
Nitrate (as N)		0.2 (0.5 <sup>a</sup> )
Sulphate		0.5 (0.6 <sup>a</sup> )
Alkalinity (mg CaCO <sub>3</sub> /L)		1
Total Organic Carbon (TOC)		0.2
Dissolved Organic Carbon (DOC)		0.2

<sup>a</sup> MDL for UW profile analysis

**Table 3: Interlaboratory Comparison for MW-54**

Compound	Concentration (µg/L)					
	Influent (0 PV)		Influent (43.7 PV)		Effluent (43.7 PV)	
	Kemron <sup>a</sup>	UW <sup>b</sup>	Kemron <sup>c</sup>	UW <sup>d</sup>	Kemron <sup>c</sup>	UW <sup>d</sup>
PCE	4.0	2.5	3.8 4.4	3.6	nd	nd
TCE	746 712	741	839 789	796	nd	nd
cis 1,2-Dichloroethene	42 38	56	38 46	40	0.36	nd
trans 1,2-Dichloroethene	8.7	6.7	7.0 8.2	8.6	nd	nd
Vinyl Chloride	nd	nd	0.61	nd	nd	nd
1,1,1,2-Tetrachloroethane	nd	nd	0.35	na	nd	na
1,1,2,2-Tetrachloroethane	456 470	467	441 459	491	nd	nd
1,1,2-Trichloroethane	3.7	3.6	3.1 3.5	nd	nd	nd
1,2-Dichloroethane	nd	nd	1.2	nd	nd	nd
Carbon Tetrachloride	185 184	80	62 78	57	nd	nd
Chloroform	1,220 1,340	434	418 408	491	nd	nd
Chloromethane	nd	nd	nd	na	1.6	na
Dichloromethane	nd	nd	nd	nd	27	40

nd – non detect

na – not applicable

<sup>a</sup> Date sampled 20 October 2003, sample received 23 October 2003, analyzed 27 October 2003

<sup>b</sup> Date sampled and analyzed 24 October 2003

<sup>c</sup> Date sampled 16 December 2003, sample received 17 December 2003 and analyzed 19 and 20 December 2003

<sup>d</sup> Date sampled and analyzed 15 September 2003



**Table 4: Interlaboratory Comparison for MW-77**

	Concentration (µg/L)					
	Influent (0 PV)		Influent (33.3 PV)		Effluent (33.3 PV)	
	Kemron <sup>a</sup>	UW <sup>b</sup>	Kemron <sup>c</sup>	UW <sup>d</sup>	Kemron <sup>c</sup>	UW <sup>d</sup>
Tetrachloroethene	14	11	54 58	51	nd	nd
Trichloroethene	2,780 3,030	3,094	3,400 3,620	3,285	nd	nd
cis 1,2-Dichloroethene	138	167	111 135	169	9.9	11
trans 1,2-Dichloroethene	25	26	18	16	nd	nd
Vinyl Chloride	nd	nd	nd	nd	0.88	nd
1,1,2,2-Tetrachloroethane	11,800 12,100	11,126	19,100 17,400	18,228	nd	nd
1,1,1-Trichloroethane	nd	7.9	3.4	nd	nd	nd
1,1,2-Trichloroethane	nd	7.9	9.4	12	nd	nd
1,2-Dichloroethane	nd	nd	2.5	na	1.5	1.5
Carbon Tetrachloride	nd	nd	nd	5.1	nd	nd
Chloroform	15	5	nd	nd	nd	nd
Dichloromethane	nd	na	nd	na	0.94	2.5

nd – non detect

na – not applicable

<sup>a</sup> Date sampled 21 October 2003, sample received 23 October 2003, analyzed 27 October 2003

<sup>b</sup> Date sampled and analyzed 24 October 2003

<sup>c</sup> Date sampled 16 December 2003, sample received 17 December 2003 and analyzed 19 and 20 December 2003

<sup>d</sup> Date sampled and analyzed 15 September 2003

**Table 5: Bench-Scale Test Half-Lives at 18°C at Steady State Conditions**

Volatile Organic Compound	MW-54			MW-77		
	Modeled Influent Concentration (µg/L)	Half-Life at 18°C <sup>a</sup> (hr)	r <sup>2</sup>	Modeled Influent Concentration (µg/L)	Half-Life at 18°C <sup>a</sup> (hr)	r <sup>2</sup>
CT	55	0.3	1.000	-	-	-
TCM	502	1.1	0.995	-	-	-
1122TeCA	508	1.5	0.973	22,238	1.3	0.995
112TCA	nd	-	-	11 (66) <sup>b</sup>	2.5	0.997
PCE	3.2	-	-	50	2.9	0.968
TCE	841	2.0	0.905	3,296	2.7	0.973
cDCE	33 (156) <sup>b</sup>	2.4	0.855	142 (3,685) <sup>b</sup>	4.1	0.976
tDCE	5.1 (26) <sup>b</sup>	1.2	0.857	nd (1,434) <sup>b</sup>	2.5	0.998
VC	nd	-	-	nd (106) <sup>b</sup>	2.4	0.941

r<sup>2</sup> = Coefficient of determination

nd = non detect

a – Half-lives are based on the last VOC profiles detected in the column test

b – Peak concentrations due to the dechlorination of 1122TeCA and TCE

**Table 6: Major Influent and Effluent Inorganic Concentrations at Steady State**

	Concentration (mg/L)			
	MW-54 <sup>a</sup>		MW-77 <sup>b</sup>	
	Influent	Effluent	Influent	Effluent
Arsenic	<0.001 <0.001	<0.001 <0.001	<0.001 <0.001	<0.001 <0.001
Boron	0.01 0.02	0.13 0.12	0.01 0.01	0.21 0.18
Barium	0.134 0.134	0.010 0.009	0.092 0.092	0.012 0.011
Calcium	17 17	10 10	20 20	11 13
Iron	0.01 <0.01	0.01 0.01	<0.01 0.01	0.02 0.01
Potassium	<1 <1	1 <1	<1 <1	1 1
Magnesium	8.3 8.3	0.07 0.07	11 11	0.14 0.10
Molybdenum	0.04 <0.02	0.07 0.05	<0.02 <0.02	0.04 0.06
Sodium	17 17	18 18	36 35	37 36
Silicon	17 17	0.67 0.73	17 17	0.67 0.61
Strontium	0.125 0.125	0.074 0.075	0.066 0.066	0.059 0.070
Zinc	0.008 0.006	0.037 0.015	<0.005 0.006	0.005 <0.005
Chloride	14 13	15 15	25 25	42 42
Nitrate (as N)	3.7 3.6	<0.2 <0.2	2.4 2.4	<0.2 <0.2
Sulphate	17 17	17 17	25 26	29 27
Alkalinity (mg CaCO <sub>3</sub> /L)	64 65	31 31	103 101	20 22
Ammonia (as N)	<0.03 0.05	3.0 2.7	0.04 0.05	1.3 1.3
Total Organic Carbon (TOC)	0.3 <0.2	1.4 0.9	4.0 6.4	2.4 2.4
Dissolved Organic Carbon (DOC)	0.6 <0.2	1.7 1.0	2.3 2.5	2.2 2.3

nd - not detected

a -effluent samples collected at PV 43.7 and 48.9

b -effluent samples collected at PV 36.1 and 40.3

**Table 7: Residence Time Calculation for Site Water From MW-54**

Volatile Organic Compound	Target Risk Levels <sup>a</sup> (µg/L)	Anticipated Field Half-Life (18°C) (hr)	Anticipated Field Concentration <sup>a</sup> (µg/L)	
			Scenario 1	Scenario 2
CT	3	0.3	ND	ND
TCM	12	1.1	502	502
1122TeCA	2.2	1.5	4,700	7,500
TCE	5	2.0	2,700	2,000
cDCE	35	2.4	70	60
tDCE	50	1.2	ND	ND
VC	2 <sup>b</sup>	2.4 <sup>c</sup>	ND	ND
DCM	Does Not Degrade		43 <sup>d</sup>	
Residence Time <sup>b</sup>			24 hrs (1.0 days)	26 hrs (1.1 days)
Groundwater Flow Velocity <sup>a</sup>			0.55 ft/day	
Required Iron Thickness			0.55	0.61

ND = not detected

<sup>a</sup> Provided by CH2M HILL

<sup>b</sup> U.S. Federal MCL assumed in the absence of a site target risk level

<sup>c</sup> Assumed VC half-life based on site water from MW-77

<sup>d</sup> Generated due to dechlorination of TCM.

**Table 8: Residence Time Calculation for Site Water From MW-77**

<b>Volatile Organic Compound</b>	<b>Target Risk Levels <sup>a</sup> (µg/L)</b>	<b>Anticipated Field Half-Life (18°C) (hr)</b>	<b>Anticipated Field Concentration <sup>a</sup> (µg/L)</b>	
			<b>Scenario 1</b>	<b>Scenario 2</b>
1122TeCA	2.2	1.3	4,700	6,200
112TCA	2	2.5	ND	ND
PCE	2.5	2.9	ND	ND
TCE	5	2.7	1,700	1,700
cDCE	35	4.1	64	60
tDCE	50	2.5	ND	ND
VC	2 <sup>b</sup>	2.4	ND	ND
<b>Residence Time</b>			<b>27 hrs (1.1 days)</b>	<b>29 hrs (1.2 days)</b>
<b>Groundwater Flow Velocity <sup>a</sup></b>			<b>1.1 ft/day</b>	
<b>Required Iron Thickness</b>			<b>1.2</b>	<b>1.3</b>

ND = not detected

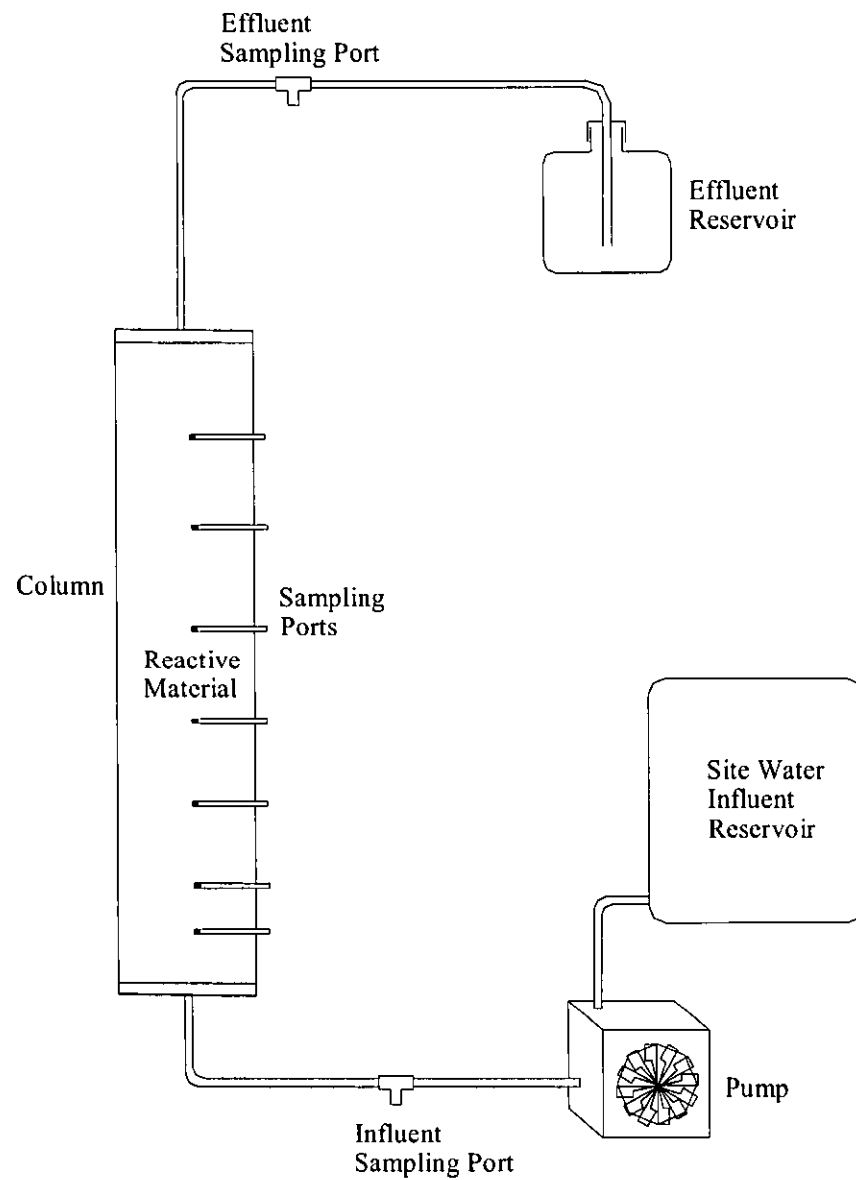
<sup>a</sup> Provided by CH2M HILL

<sup>b</sup> U.S. Federal MCL assumed in the absence of a site target risk level

**Table 9: Proposed PRB Design Parameters**

PRB/ Scenario	Residence Time (days)	GW Velocity (ft/day)	PRB Length (ft)	Saturated Thickness (ft)	Iron Thickness (ft)	Iron Volume (ft <sup>3</sup> )	Iron Amount <sup>a</sup> (ton)
PRB near MW-54							
Scenario 1	1.0	0.55	1,070	16	0.55	9,416	847
Scenario 2	1.1				0.61	10,443	940
PRB near MW-77							
Scenario 1	1.1	1.1	410	8	1.2	3,936	354
Scenario 2	1.2				1.3	4,264	384

<sup>a</sup> Assuming a bulk density of 0.09 ton/ft<sup>3</sup>



**Figure 1:** Schematic of the apparatus used in the bench-scale test.



Figure 2: Photograph of granular iron columns in refrigerator at 18°C (64°F).



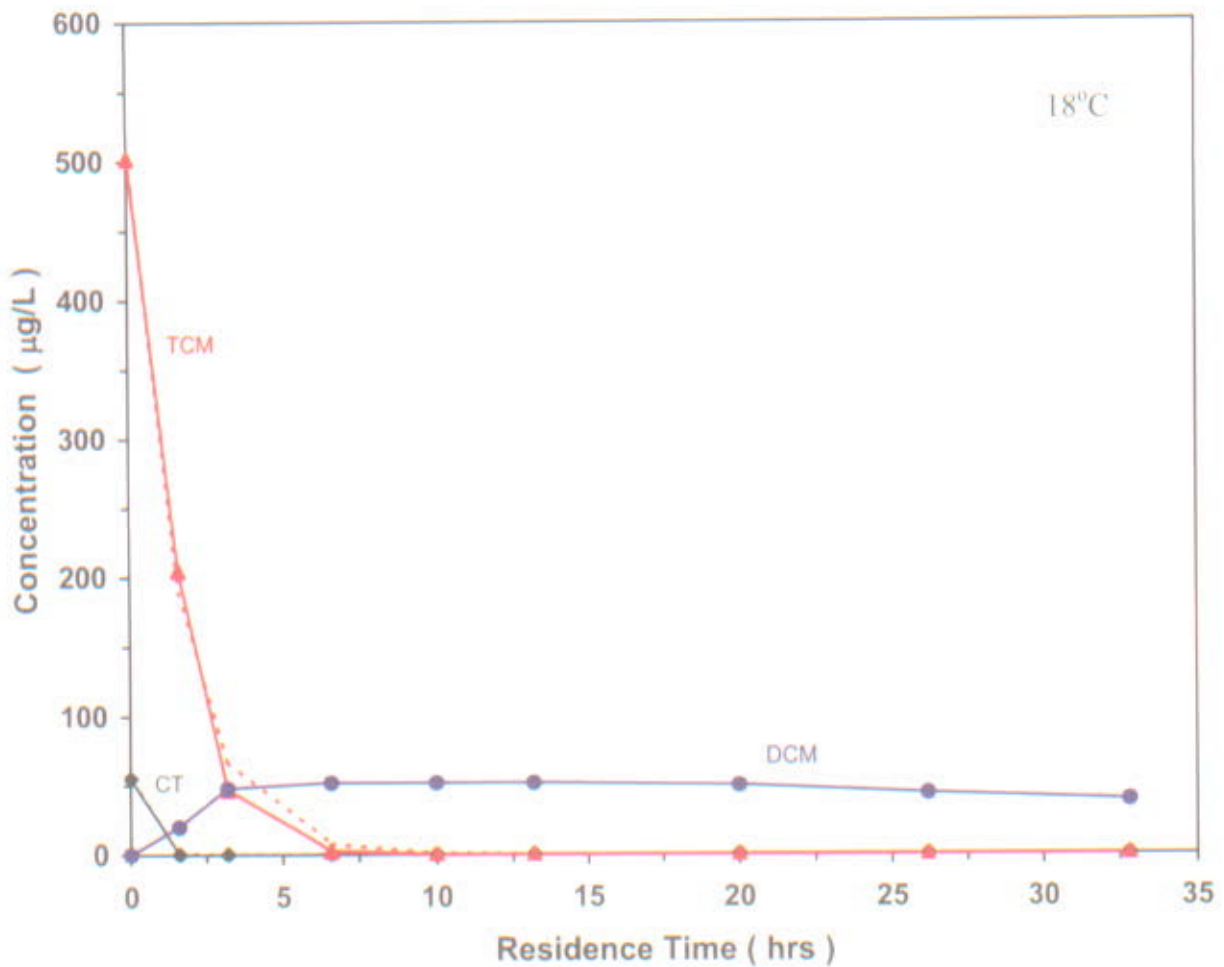


Figure 3: Carbon tetrachloride (CT), chloroform (TCM) and dichloromethane (DCM) concentration profiles versus residence time (solid line) along the bench-scale test column for MW-54. The dotted line represents the least squares best fit of the first-order kinetic model to the data.

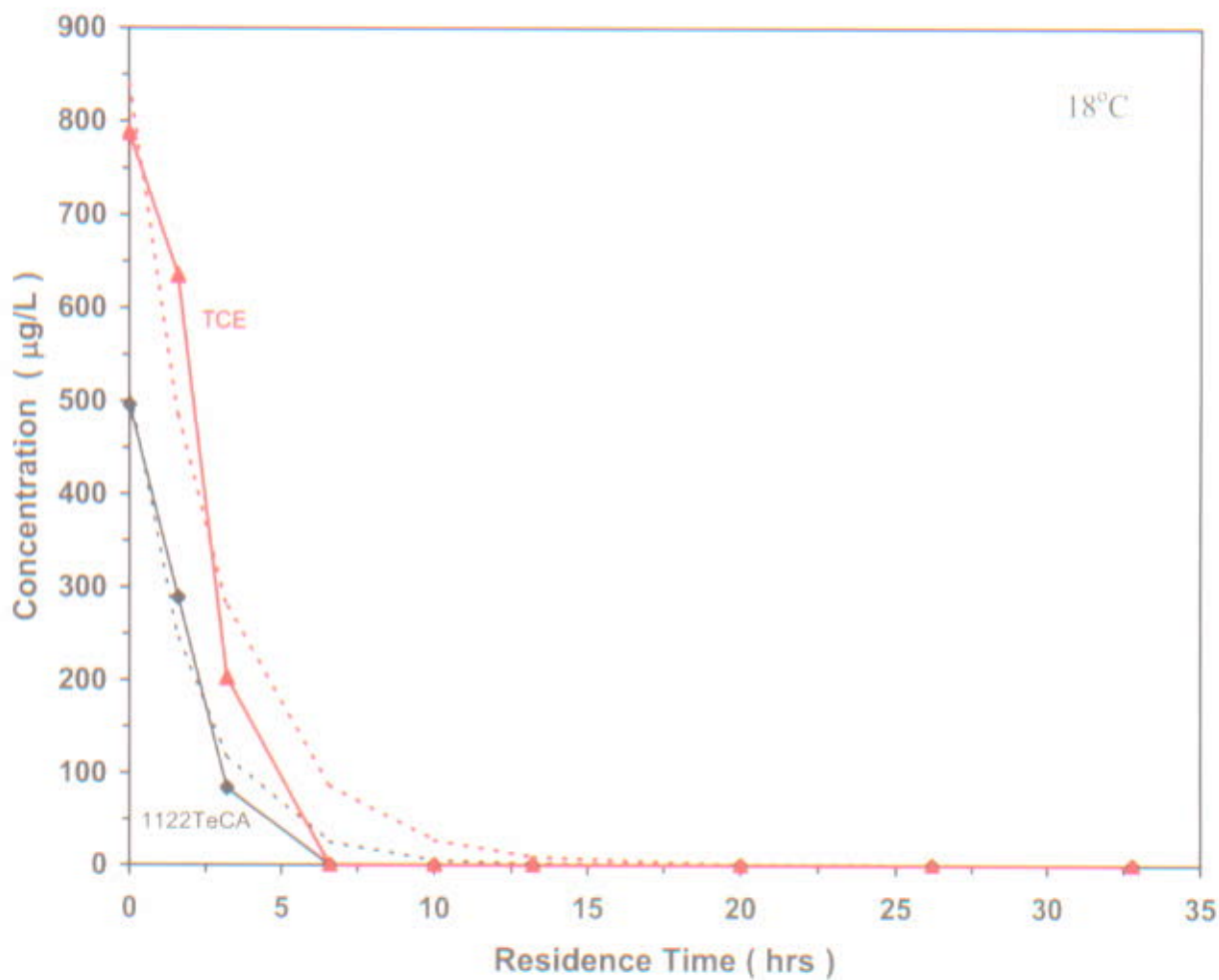


Figure 4: 1,1,2,2-Tetrachloroethane (1122TeCA) and trichloroethene (TCE) concentration profiles versus residence time (solid line) along the bench-scale test column for MW-54. The dotted line represents the least squares best fits of the first-order kinetic model to the data.

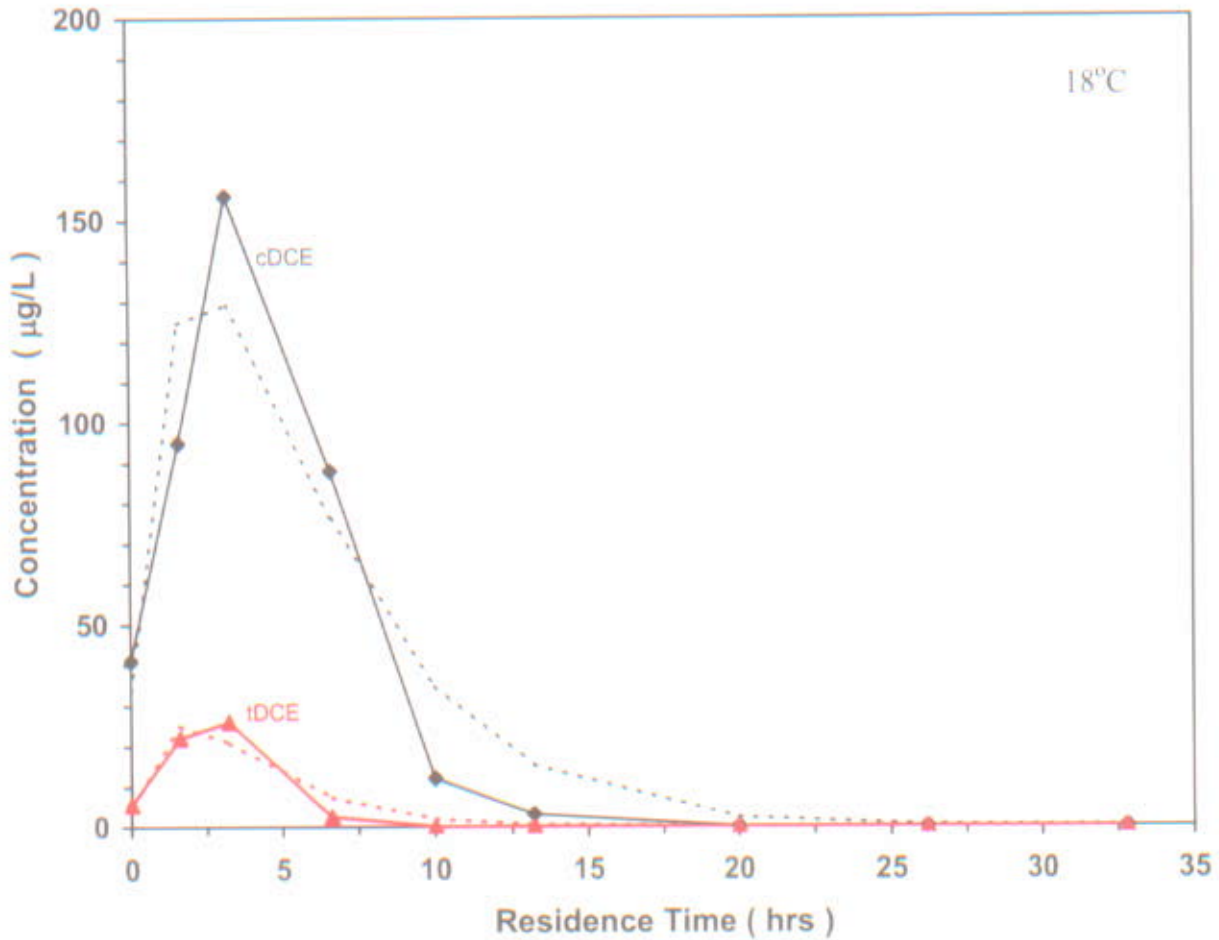
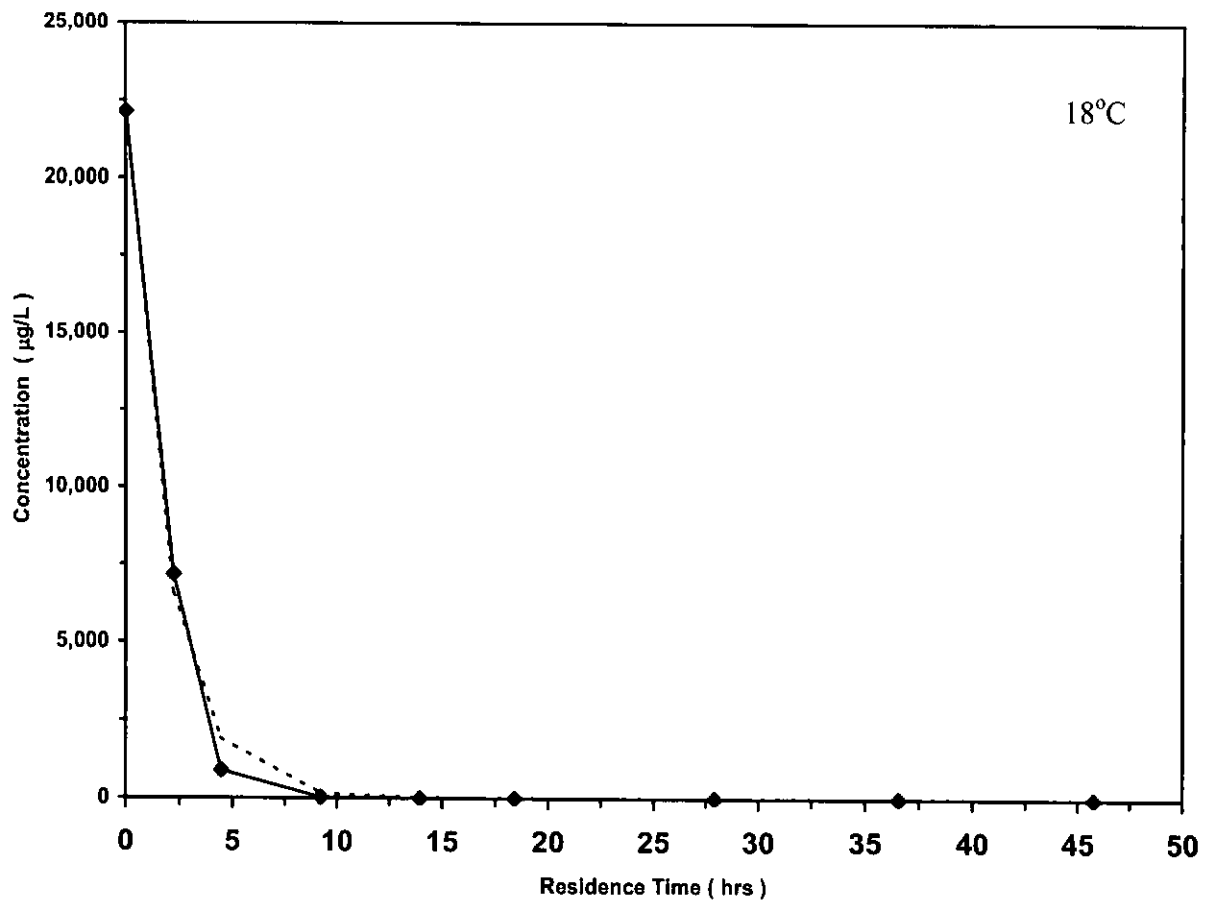


Figure 5: cis 1,2-dichloroethene (cDCE) and trans 1,2-dichloroethene (tDCE) concentration profiles versus residence time (solid line) along the bench-scale test column for MW-54. The dotted line represents the least squares best fits of the first-order kinetic model to the data.



**Figure 6:** 1,1,2,2-Tetrachloroethane (1122TeCA) concentration profile versus residence time (solid line) along the bench-scale test column for MW-77. The dotted line represents the least squares best fits of the first-order kinetic model to the data.

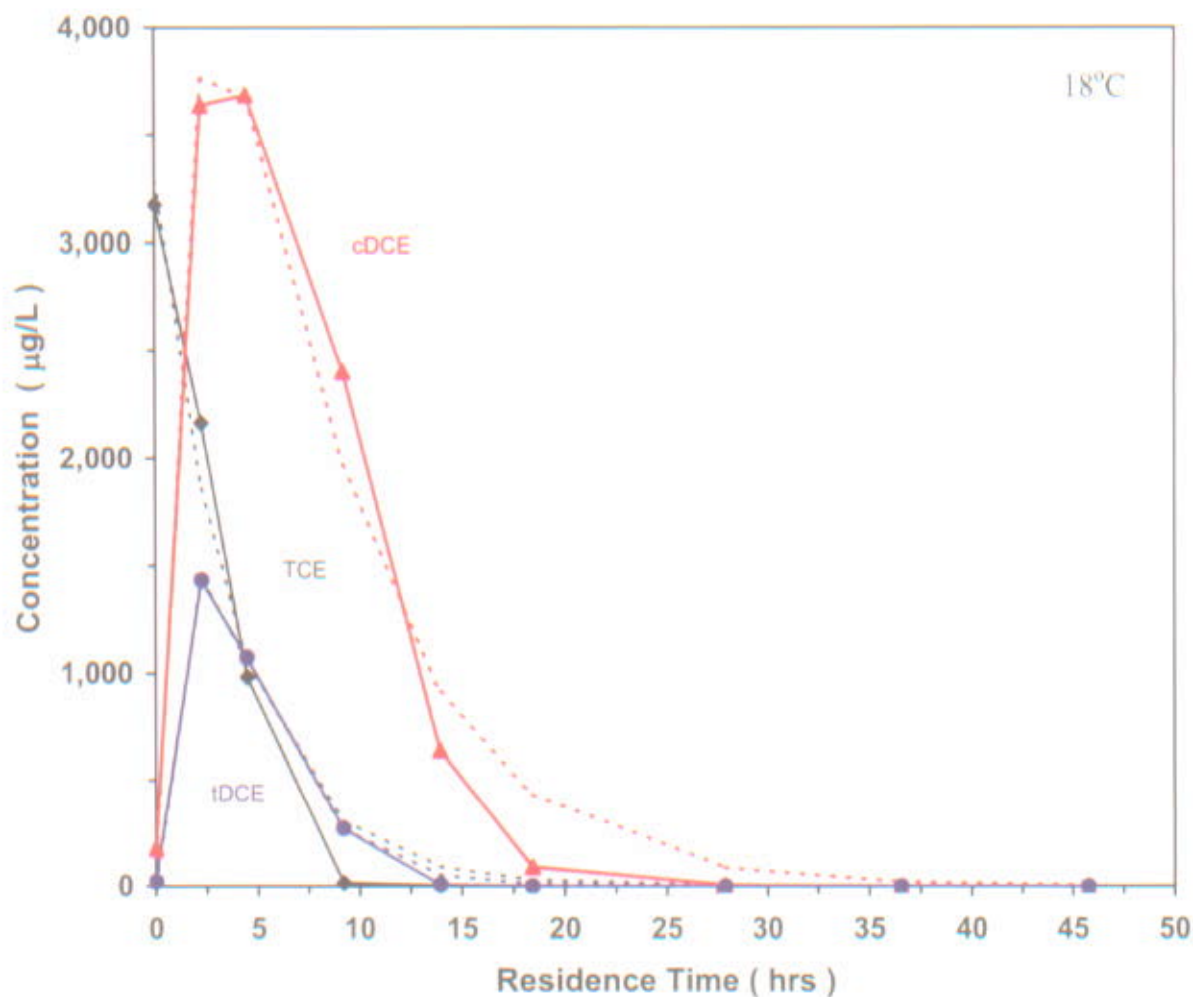


Figure 7: Trichloroethene (TCE), cis 1,2-dichloroethene (cDCE) and trans 1,2-dichloroethene (tDCE) concentration profiles versus residence time (solid line) along the bench-scale test column for MW-77. The dotted line represents the least squares best fits of the first-order kinetic model to the data.

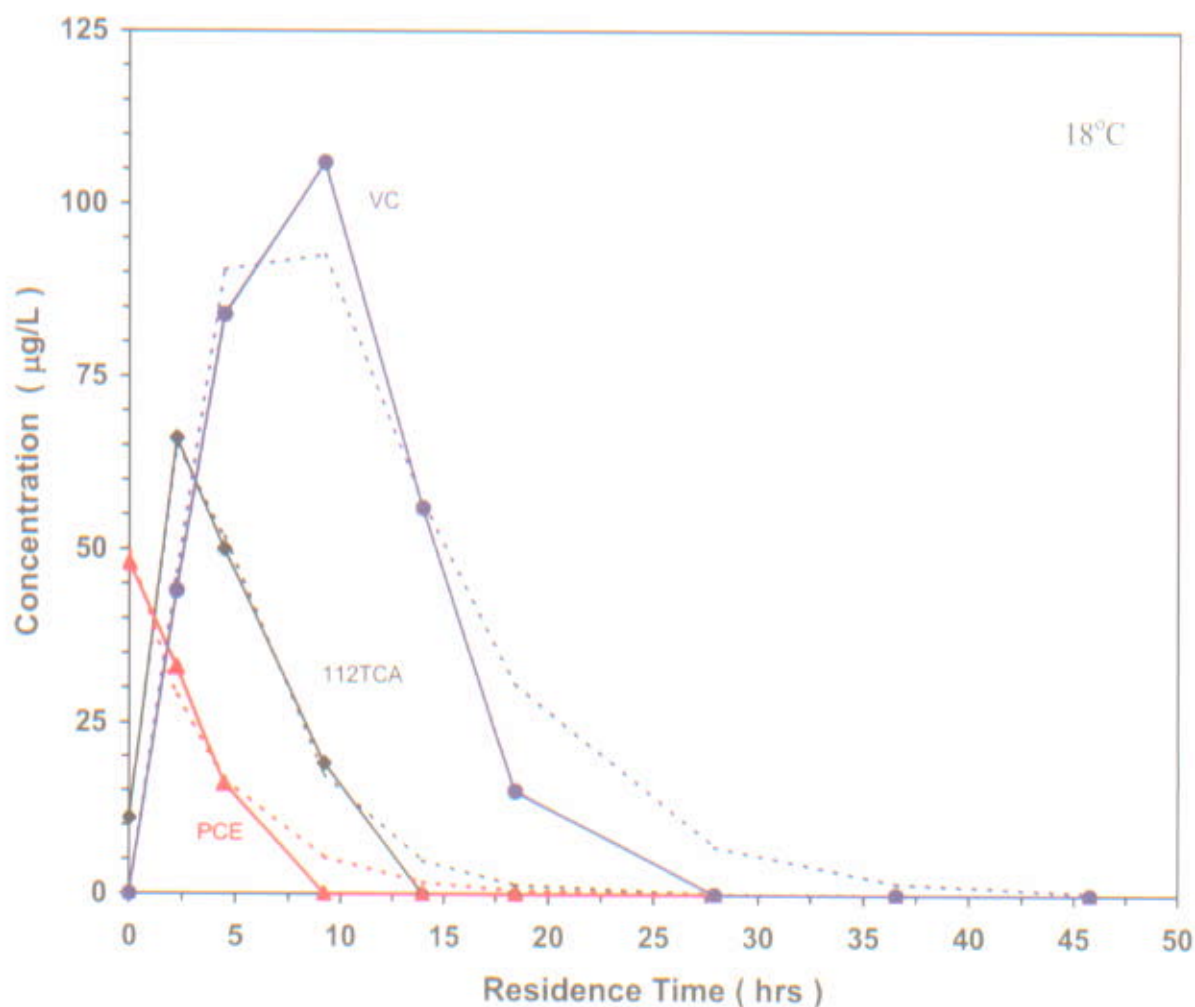
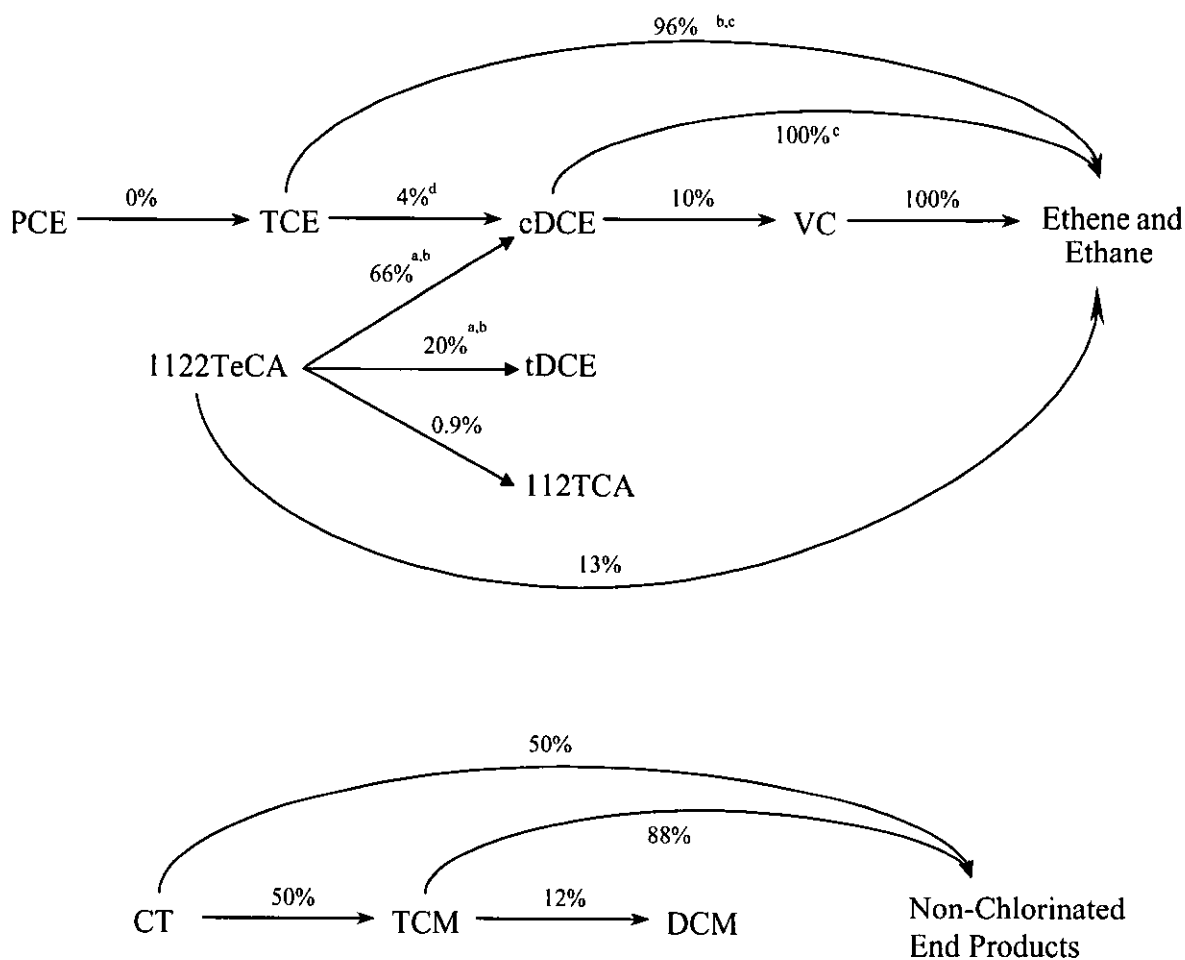
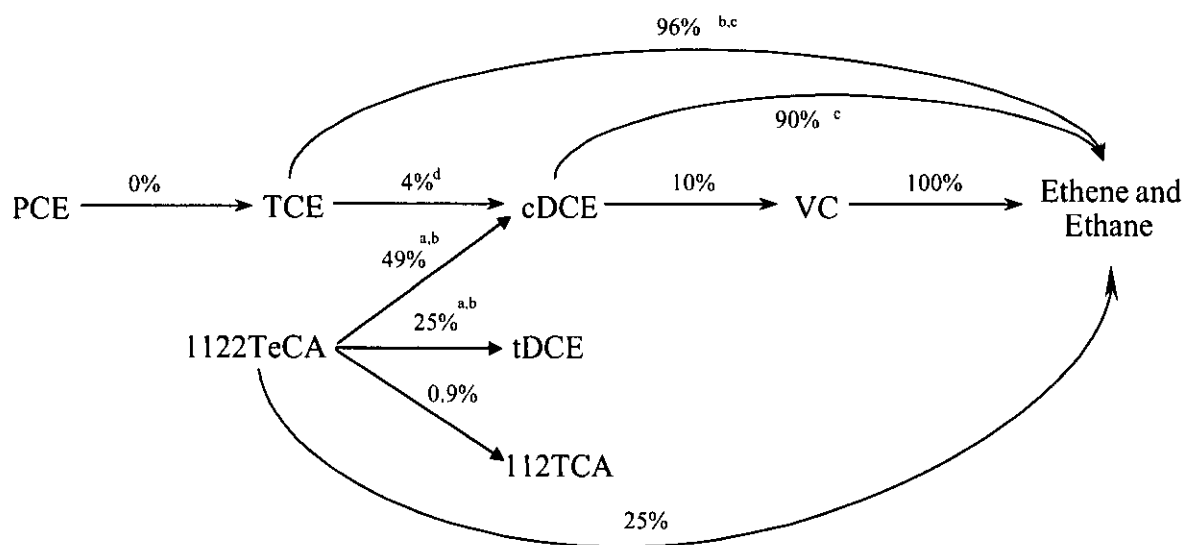


Figure 8: 1,1,2-Trichloroethane (112TCA), tetrachloroethene (PCE) and vinyl chloride (VC) concentration profile versus residence time (solid line) along the bench-scale test column for MW-77. The dotted line represents the least squares best fits of the first-order kinetic model to the data.



- <sup>a</sup> Degradation pathway through dichloroacetylene
- <sup>b</sup> Degradation pathway through chloroacetylene
- <sup>c</sup> Degradation pathway through acetylene
- <sup>d</sup> Fixed molar conversion (typical)

**Figure 9:** Molar conversions obtained from the least squares best fits of the first-order kinetic model to the bench-scale test column data for MW-54.

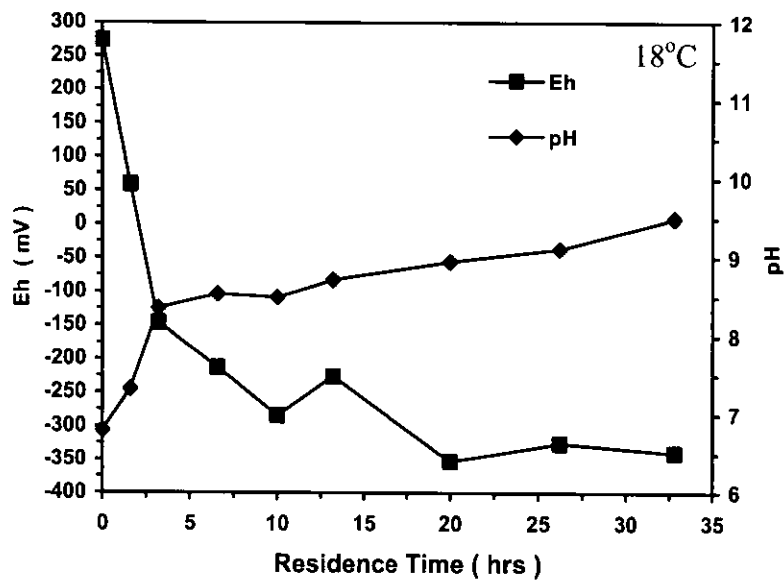


- <sup>a</sup> Degradation pathway through dichloroacetylene
- <sup>b</sup> Degradation pathway through chloroacetylene
- <sup>c</sup> Degradation pathway through acetylene
- <sup>d</sup> Fixed molar conversion (typical)

**Figure 10:** Molar conversions obtained from the least squares best fits of the first-order kinetic model to the bench-scale test column data for MW-77.



a)



b)

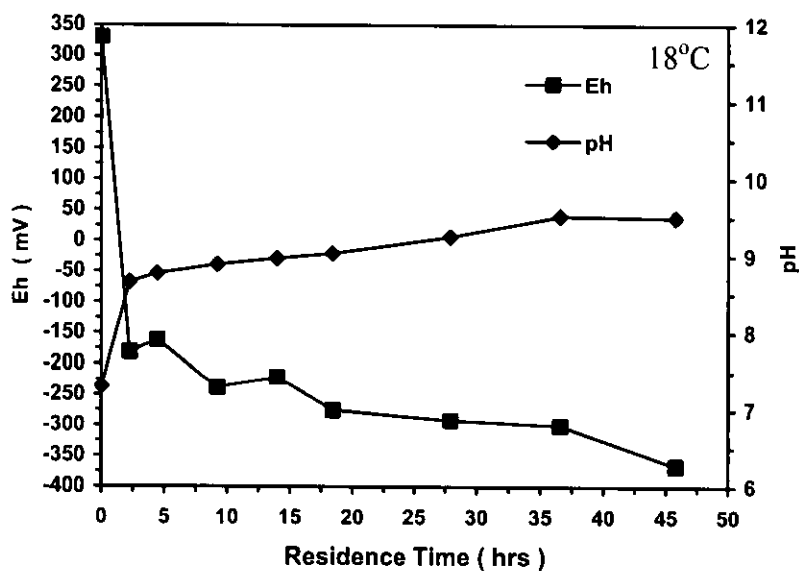
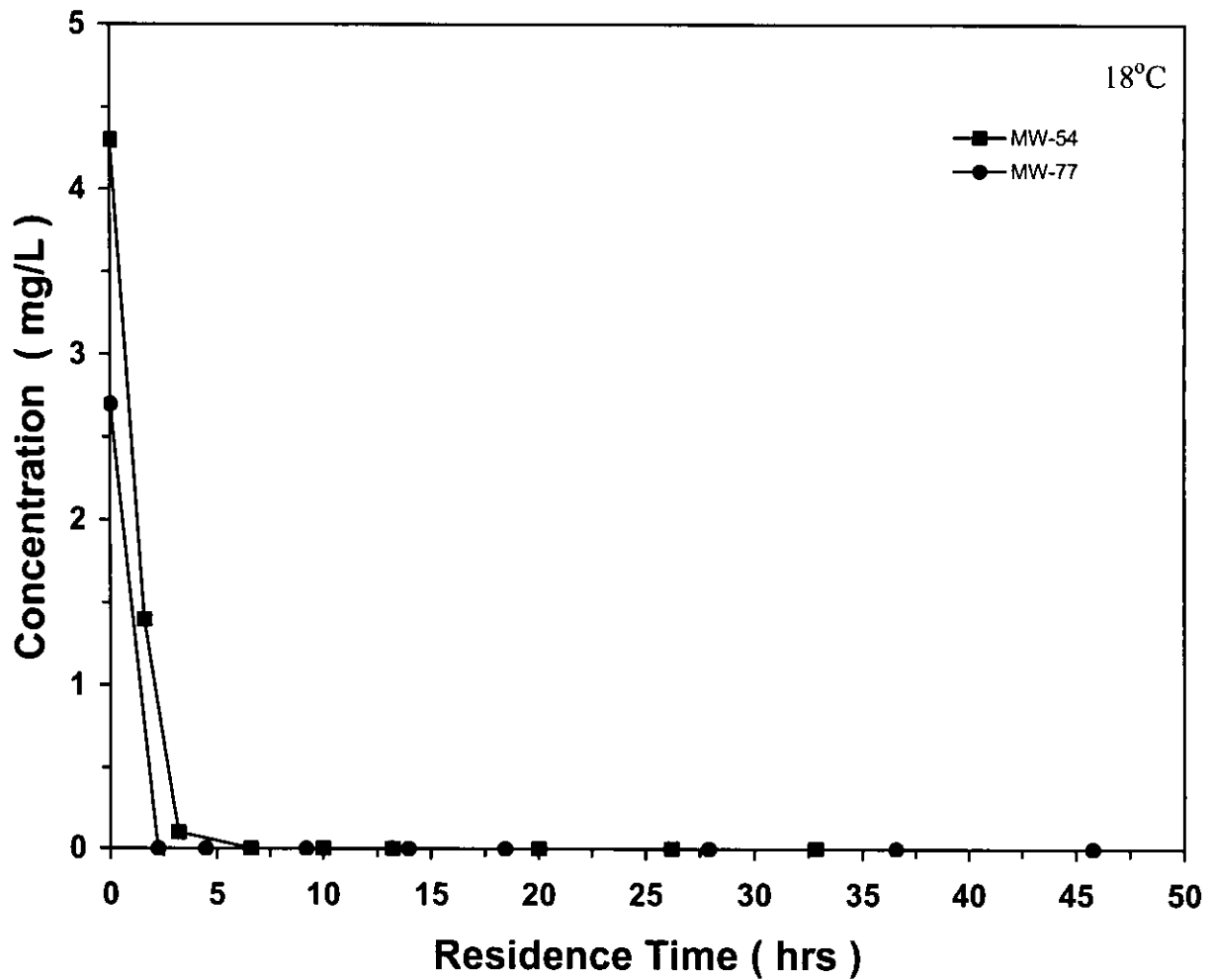
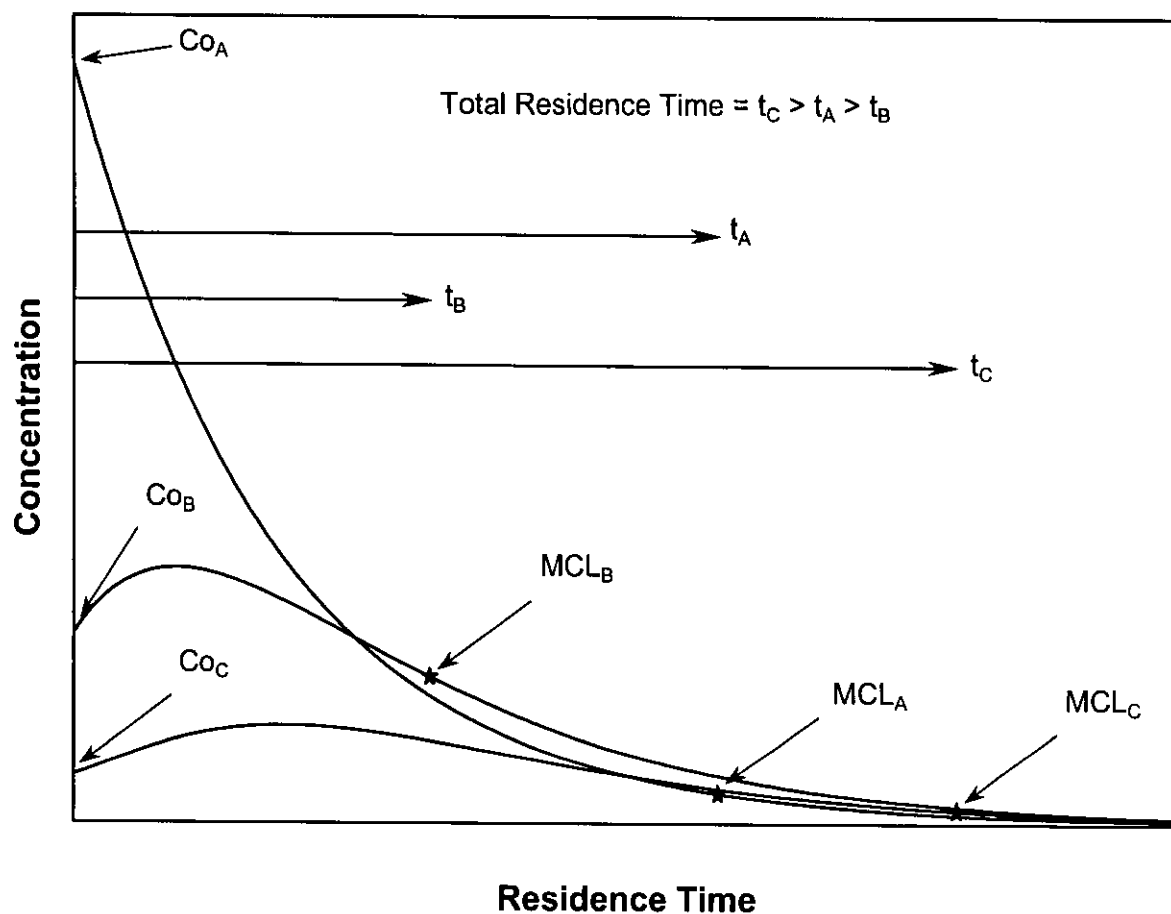


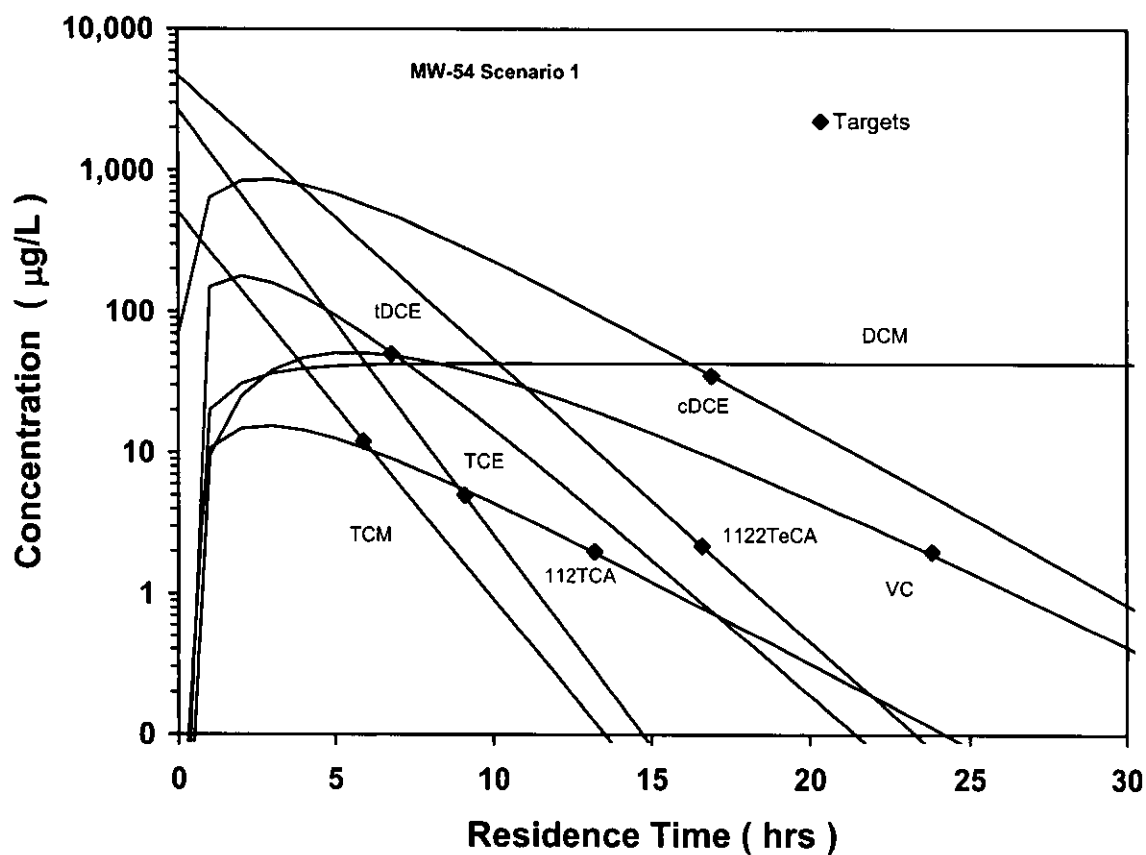
Figure 11: Redox potential (Eh) and pH profiles versus residence time along the bench-scale test columns for a) MW-54 and b) MW-77.



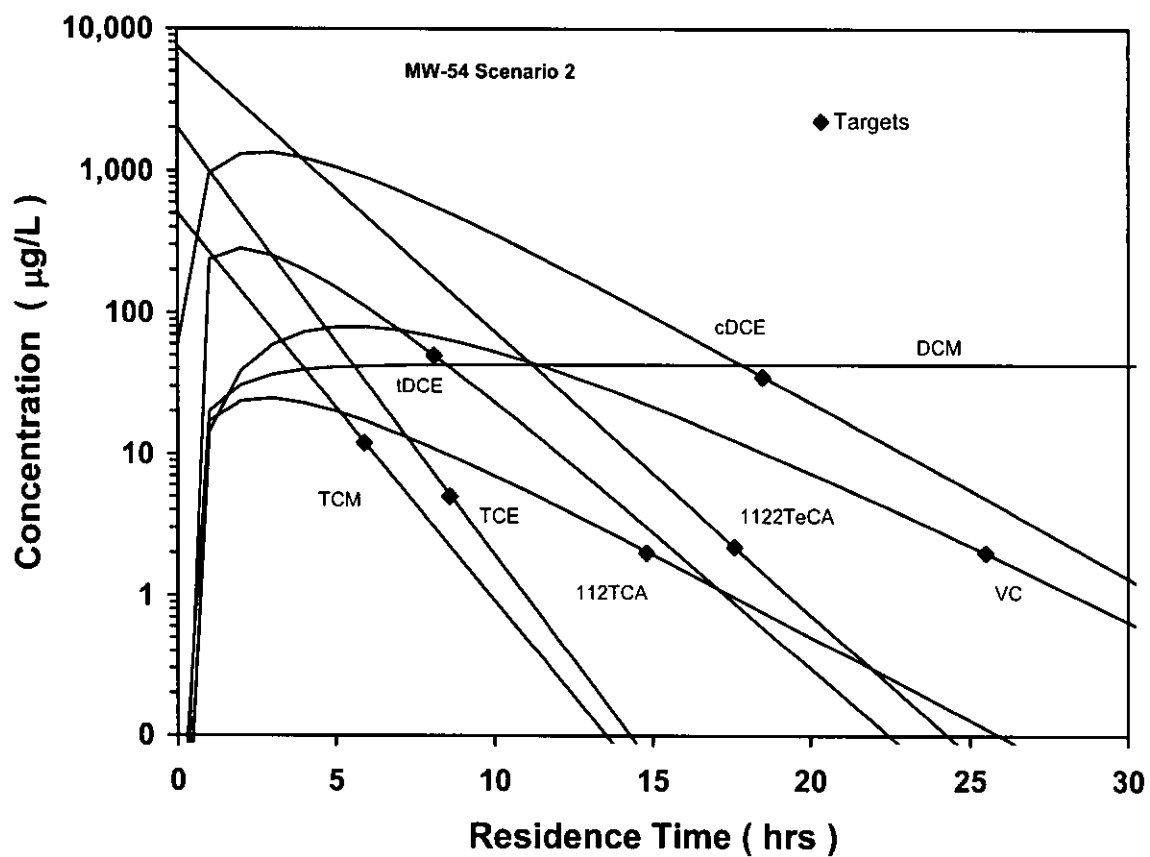
**Figure 12:** Nitrate (as N) profiles versus residence time along the bench-scale test columns for MW-54 and MW-77.



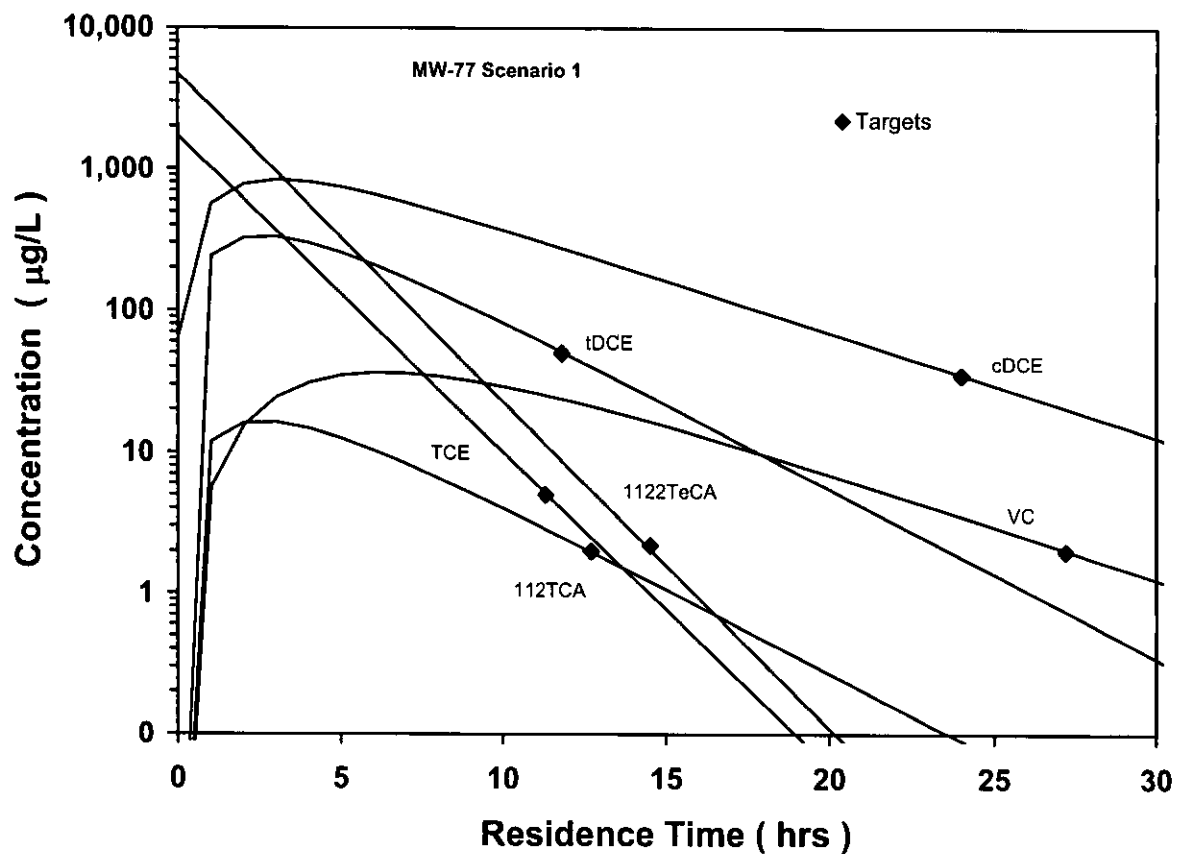
**Figure 13: Illustration of residence time calculations using the degradation model.**



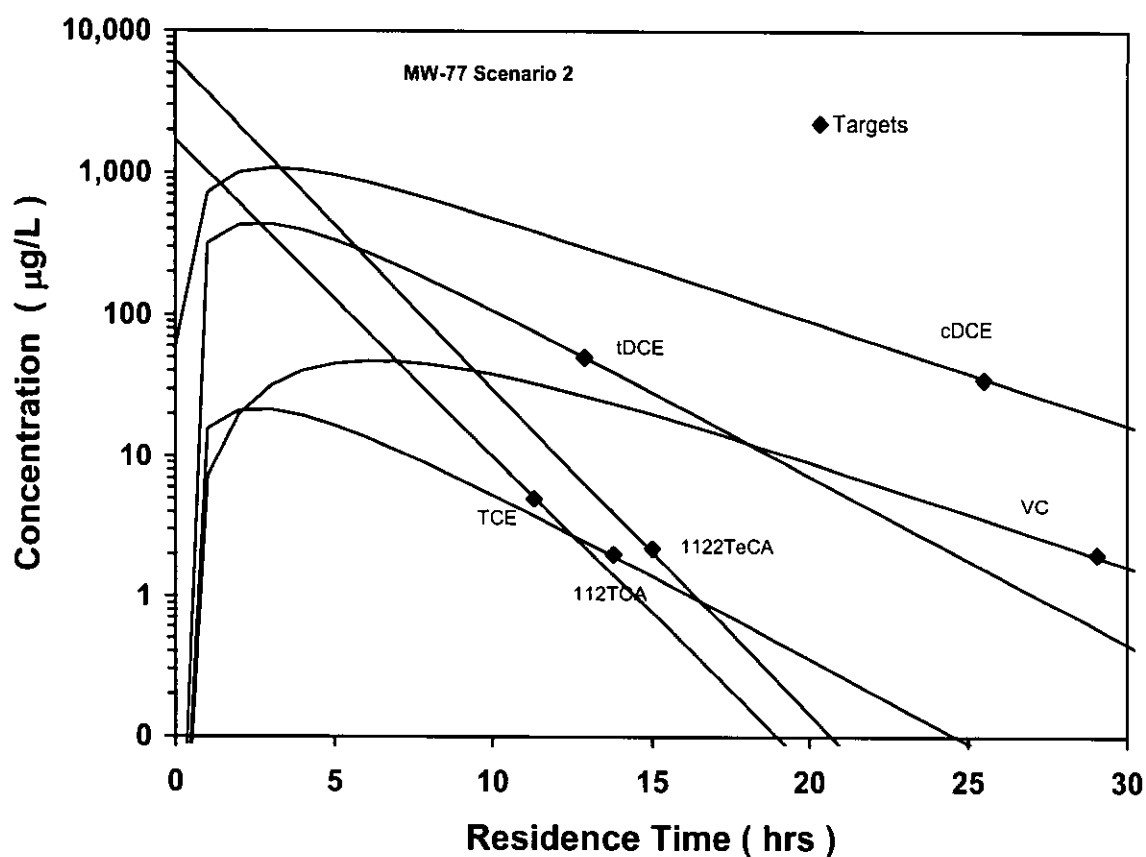
**Figure 14:** First-order kinetic model simulation results using concentrations and half-lives and molar conversions determined from the bench-scale column test for MW-54 and Scenario 1 of influent concentration.



**Figure 15:** First-order kinetic model simulation results using concentrations and half-lives and molar conversions determined from the bench-scale column test for MW-54 and Scenario 2 of influent concentration.



**Figure 16:** First-order kinetic model simulation results using concentrations and half-lives and molar conversions determined from the bench-scale column test for MW-77 and Scenario 1 of influent concentration.



**Figure 17:** First-order kinetic model simulation results using concentrations and half-lives and molar conversions determined from the bench-scale column test for MW-77 and Scenario 2 of influent concentration.

## **Appendix A**

### **Grain Size Distribution Curve**

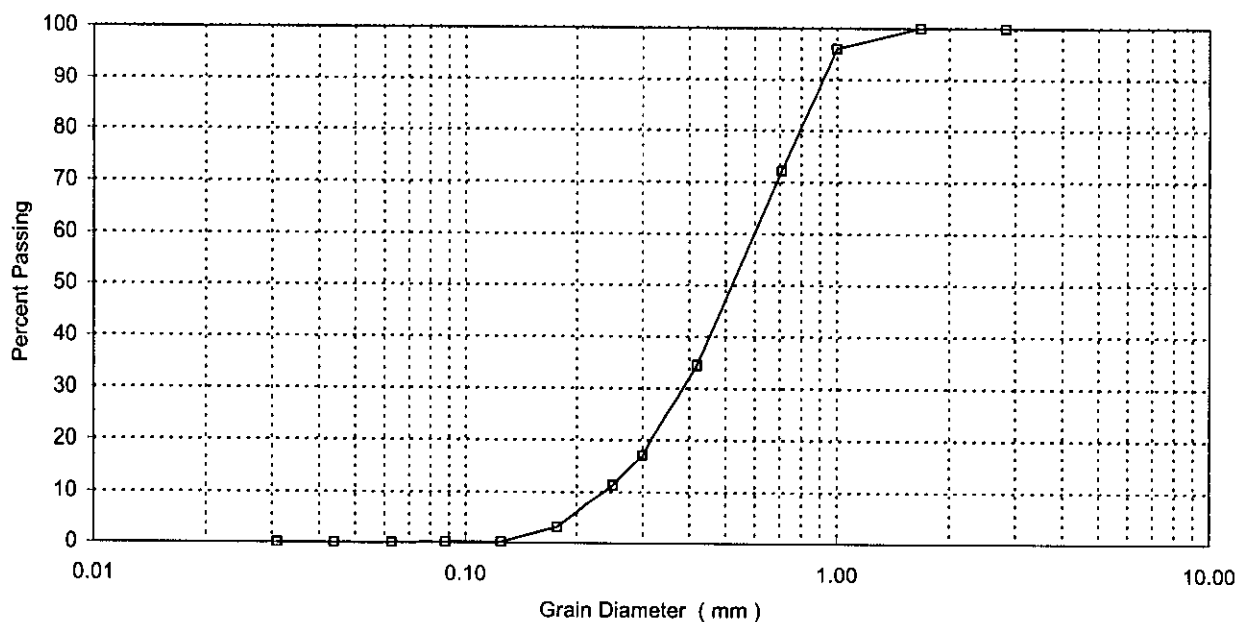


**Grain Size Distribution Curve**

**Date:** 08-Aug-03  
**UW Number:** UW 255  
**Iron Type/Date:** Connolly 18/84

US Sieve Mesh #	mm	Wt Retained On sieve (grams)	Percent ( % )	Percent Passing ( % )
				100
7	2.830	0.00	0.00	100.00
12	1.680	0.01	0.01	99.99
18	1.000	3.93	3.94	96.05
25	0.710	23.77	23.87	72.18
40	0.420	37.57	37.72	34.46
50	0.300	17.18	17.24	17.22
60	0.250	5.84	5.86	11.36
80	0.177	8.27	8.30	3.06
120	0.125	2.87	2.88	0.18
170	0.088	0.04	0.04	0.14
230	0.063	0.13	0.13	0.02
325	0.044	0.01	0.01	0.01
<325	0.031	0.01	0.01	0.00

99.60    100.00  
 Total Wt    Total %

**Grain Size Distribution Curve for Connolly Iron (UW# 255)**

## **Appendix B**

### **Interlaboratory Comparison**

## LABORATORY REPORT

L0310530

10/30/03 08:03

Submitted By

Kemron Environmental Services  
109 Starlite Park  
Marietta, Ohio 45750  
(740) 373-4071

For

Account Name: CCI/CH2MHILL  
115 Perimeter Place NE  
Suite 700  
Atlanta, GA 30346  
Attention: David Nelson

Account Number: 207-630  
Work ID: 42577/UNIV OF WATERLOO

P.O. Number: 56952

## Sample Summary

Client ID	Lab ID	Date Collected	Date Recieved
MW-54 @ OPV	L0310530-01	20-OCT-03	23-OCT-03
MW-77 @ OPV	L0310530-02	21-OCT-03	23-OCT-03

## KEMRON ENVIRONMENTAL SERVICES

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Report Number: L0310530

Report Date : October 30, 2003

Sample Number: L0310530-01  
 Client ID: MW-54  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 20-OCT-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 5  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 11:48  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 11:48  
 File ID: 11M17973

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	500	12.5
Benzene	71-43-2		U	25.0	0.625
Bromobenzene	108-86-1		U	25.0	0.625
Bromochloromethane	74-97-5		U	25.0	1.00
Bromodichloromethane	75-27-4		U	25.0	1.25
Bromoform	75-25-2		U	25.0	2.70
Bromomethane	74-83-9		U	50.0	2.50
2-Butanone	78-93-3		U	500	12.5
n-Butylbenzene	104-51-8		U	25.0	1.25
sec-Butylbenzene	135-98-8		U	25.0	1.25
tert-Butylbenzene	98-06-6		U	25.0	1.25
Carbon disulfide	75-15-0		U	25.0	2.50
Carbon tetrachloride	56-23-5	185		25.0	1.25
Chlorobenzene	108-90-7		U	25.0	0.625
Chlorodibromomethane	124-48-1		U	25.0	1.25
Chloroethane	75-00-3		U	50.0	2.50
2-Chloroethyl vinyl ether	110-75-8		U	50.0	10.0
Chloroform	67-66-3	1220	I	25.0	0.625
Chloromethane	74-87-3		U	50.0	1.25
2-Chlorotoluene	95-49-8		U	25.0	0.625
4-Chlorotoluene	106-43-4		U	25.0	1.25
1,2-Dibromo-3-chloropropane	96-12-8		U	25.0	5.00
1,2-Dibromoethane	106-93-4		U	25.0	1.25
Dibromomethane	74-95-3		U	25.0	1.25
1,2-Dichlorobenzene	95-50-1		U	25.0	0.625
1,3-Dichlorobenzene	541-73-1		U	25.0	1.25
1,4-Dichlorobenzene	106-46-7		U	25.0	0.625
Dichlorodifluoromethane	75-71-8		U	50.0	1.25
1,1-Dichloroethane	75-34-3		U	25.0	0.625
1,2-Dichloroethane	107-06-2		U	25.0	1.25
1,1-Dichloroethene	75-35-4		U	25.0	2.50
cis-1,2-Dichloroethene	156-59-2	41.5		25.0	1.25
trans-1,2-Dichloroethene	156-60-5	8.74		25.0	1.25
1,2-Dichloropropane	78-87-5		U	25.0	0.625
1,3-Dichloropropane	142-28-9		U	25.0	1.00
2,2-Dichloropropane	594-20-7		U	25.0	1.25
cis-1,3-Dichloropropene	10061-01-5		U	25.0	1.25
trans-1,3-Dichloropropene	10061-02-6		U	25.0	2.50
1,1-Dichloropropene	563-58-6		U	25.0	1.25
Ethylbenzene	100-41-4		U	25.0	1.25
2-Hexanone	591-78-6		U	50.0	12.5
Hexachlorobutadiene	87-68-3		U	25.0	1.25
Isopropylbenzene	98-82-8		U	25.0	1.25
p-Isopropyltoluene	99-87-6		U	25.0	1.25
4-Methyl-2-pentanone	108-10-1		U	50.0	12.5
Methylene chloride	75-09-2		U	25.0	1.25
Naphthalene	91-20-3		U	50.0	1.00
n-Propylbenzene	103-65-1		U	25.0	0.625
Styrene	100-42-5		U	25.0	0.625
1,1,1,2-Tetrachloroethane	630-20-6		U	25.0	1.25
1,1,1,2,2-Tetrachloroethane	79-34-5	456		25.0	0.625
Tetrachloroethene	127-18-4	3.99	J	25.0	1.25
Toluene	108-88-3		U	25.0	1.25
1,2,3-Trichlorobenzene	87-61-6		U	25.0	0.625
1,2,4-Trichlorobenzene	120-82-1		U	25.0	1.00
1,1,1-Trichloroethane	71-55-6		U	25.0	1.25
1,1,2-Trichloroethane	79-00-5	3.71	J	25.0	1.25
Trichloroethene	79-01-6	746		25.0	1.25
Trichlorofluoromethane	75-69-4		U	50.0	1.25

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0310530

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Report Date : October 30, 2003

Sample Number: L0310530-01  
 Client ID: MW-54  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 20-OCT-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 5  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 11:48  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 11:48  
 File ID: 11M17973

Analyte	CAS. Number	Result	Qual	RL	MDL
1,2,3-Trichloropropane	96-18-4		U	25.0	3.75
1,2,4-Trimethylbenzene	95-63-6		U	25.0	1.25
1,3,5-Trimethylbenzene	108-67-8		U	25.0	1.25
Vinyl acetate	108-05-4		U	50.0	12.5
Vinyl chloride	75-01-4		U	50.0	1.25
o-Xylene	95-47-6		U	25.0	1.25
m-,p-Xylene	136777-61-2		U	25.0	2.50
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	91.5	86	118		
1,2-Dichloroethane-d4	87.7	80	120		
Toluene-d8	103	88	110		
4-Bromofluorobenzene	101	86	115		

I Semiquantitative result (out of instrument calibration range)

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

Sample Number: L0310530-01  
 Client ID: MW-54  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 20-OCT-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 50  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 13:51  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 13:51  
 File ID: 11M17977

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	5000	125
Benzene	71-43-2		U	250	6.25
Bromobenzene	108-86-1		U	250	6.25
Bromochloromethane	74-97-5		U	250	10.0
Bromodichloromethane	75-27-4		U	250	12.5
Bromoform	75-25-2		U	250	27.0
Bromomethane	74-83-9		U	500	25.0
2-Butanone	78-93-3		U	5000	125
n-Butylbenzene	104-51-8		U	250	12.5
sec-Butylbenzene	135-98-8		U	250	12.5
tert-Butylbenzene	98-06-6		U	250	12.5
Carbon disulfide	75-15-0		U	250	25.0
Carbon tetrachloride	56-23-5	184	J	250	12.5
Chlorobenzene	108-90-7		U	250	6.25
Chlorodibromomethane	124-48-1		U	250	12.5
Chloroethane	75-00-3		U	500	25.0
2-Chloroethyl vinyl ether	110-75-8		U	500	100
Chloroform	67-66-3	1340		250	6.25
Chloromethane	74-87-3		U	500	12.5
2-Chlorotoluene	95-49-8		U	250	6.25
4-Chlorotoluene	106-43-4		U	250	12.5
1,2-Dibromo-3-chloropropane	96-12-8		U	250	50.0
1,2-Dibromoethane	106-93-4		U	250	12.5
Dibromomethane	74-95-3		U	250	12.5
1,2-Dichlorobenzene	95-50-1		U	250	6.25
1,3-Dichlorobenzene	541-73-1		U	250	12.5
1,4-Dichlorobenzene	106-46-7		U	250	6.25
Dichlorodifluoromethane	75-71-8		U	500	12.5
1,1-Dichloroethane	75-34-3		U	250	6.25
1,2-Dichloroethane	107-06-2		U	250	12.5
1,1-Dichloroethene	75-35-4		U	250	25.0
cis-1,2-Dichloroethene	156-59-2	37.9	J	250	12.5
trans-1,2-Dichloroethene	156-60-5		U	250	12.5

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0310530

Report Date : October 30, 2003

Sample Number: L0310530-01  
 Client ID: MW-54  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 20-OCT-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 50  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 13:51  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 13:51  
 File ID: 11M17977

Analyte	CAS. Number	Result	Qual	RL	MDL
1,2-Dichloropropane	78-87-5		U	250	6.25
1,3-Dichloropropane	142-28-9		U	250	10.0
2,2-Dichloropropane	594-20-7		U	250	12.5
cis-1,3-Dichloropropene	10061-01-5		U	250	12.5
trans-1,3-Dichloropropene	10061-02-6		U	250	25.0
1,1-Dichloropropene	563-58-6		U	250	12.5
Ethylbenzene	100-41-4		U	250	12.5
2-Hexanone	591-78-6		U	500	125
Hexachlorobutadiene	87-68-3		U	250	12.5
Isopropylbenzene	98-82-8		U	250	12.5
p-Isopropyltoluene	99-87-6		U	250	12.5
4-Methyl-2-pentanone	108-10-1		U	500	125
Methylene chloride	75-09-2		U	250	12.5
Naphthalene	91-20-3		U	500	10.0
n-Propylbenzene	103-65-1		U	250	6.25
Styrene	100-42-5		U	250	6.25
1,1,1,2-Tetrachloroethane	630-20-6		U	250	12.5
1,1,2,2-Tetrachloroethane	79-34-5	470		250	6.25
Tetrachloroethene	127-18-4		U	250	12.5
Toluene	108-88-3		U	250	12.5
1,2,3-Trichlorobenzene	87-61-6		U	250	6.25
1,2,4-Trichlorobenzene	120-82-1		U	250	10.0
1,1,1-Trichloroethane	71-55-6		U	250	12.5
1,1,2-Trichloroethane	79-00-5		U	250	12.5
Trichloroethene	79-01-6	712		250	12.5
Trichlorofluoromethane	75-69-4		U	500	12.5
1,2,3-Trichloropropane	96-18-4		U	250	37.5
1,2,4-Trimethylbenzene	95-63-6		U	250	12.5
1,3,5-Trimethylbenzene	108-67-8		U	250	12.5
Vinyl acetate	108-05-4		U	500	125
Vinyl chloride	75-01-4		U	500	12.5
o-Xylene	95-47-6		U	250	12.5
m-, p-Xylene	136777-61-2		U	250	25.0
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	89.9	86	118		
1,2-Dichloroethane-d4	86.8	80	120		
Toluene-d8	104	88	110		
4-Bromofluorobenzene	101	86	115		

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

Sample Number: L0310530-02  
 Client ID: MW-77  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 21-OCT-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 50  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 12:19  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 12:19  
 File ID: 11M17974

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	5000	125
Benzene	71-43-2		U	250	6.25
Bromobenzene	108-86-1		U	250	6.25
Bromochloromethane	74-97-5		U	250	10.0
Bromodichloromethane	75-27-4		U	250	12.5
Bromoform	75-25-2		U	250	27.0
Bromomethane	74-83-9		U	500	25.0

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0310530

Report Date : October 30, 2003

Sample Number: L0310530-02  
 Client ID: MW-77  
 Matrix: Water  
 Workgroup Number: WGI52829  
 Collect Date: 21-OCT-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 50  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 12:19  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 12:19  
 File ID: 11M17974

Analyte	CAS. Number	Result	Qual	RL	MDL
2-Butanone	78-93-3		U	5000	125
n-Butylbenzene	104-51-8		U	250	12.5
sec-Butylbenzene	135-98-8		U	250	12.5
tert-Butylbenzene	98-06-6		U	250	12.5
Carbon disulfide	75-15-0		U	250	25.0
Carbon tetrachloride	56-23-5		U	250	12.5
Chlorobenzene	108-90-7		U	250	6.25
Chlorodibromomethane	124-48-1		U	250	12.5
Chloroethane	75-00-3		U	500	25.0
2-Chloroethyl vinyl ether	110-75-8		U	500	100
Chloroform	67-66-3	15.0	J	250	6.25
Chloromethane	74-87-3		U	500	12.5
2-Chlorotoluene	95-49-8		U	250	6.25
4-Chlorotoluene	106-43-4		U	250	12.5
1,2-Dibromo-3-chloropropane	96-12-8		U	250	50.0
1,2-Dibromoethane	106-93-4		U	250	12.5
Dibromomethane	74-95-3		U	250	12.5
1,2-Dichlorobenzene	95-50-1		U	250	6.25
1,3-Dichlorobenzene	541-73-1		U	250	12.5
1,4-Dichlorobenzene	106-46-7		U	250	6.25
Dichlorodifluoromethane	75-71-8		U	500	12.5
1,1-Dichloroethane	75-34-3		U	250	6.25
1,2-Dichloroethane	107-06-2		U	250	12.5
1,1-Dichloroethene	75-35-4		U	250	25.0
cis-1,2-Dichloroethene	156-59-2	138	J	250	12.5
trans-1,2-Dichloroethene	156-60-5	24.5	J	250	12.5
1,2-Dichloropropane	78-87-5		U	250	6.25
1,3-Dichloropropane	142-28-9		U	250	10.0
2,2-Dichloropropane	594-20-7		U	250	12.5
cis-1,3-Dichloropropene	10061-01-5		U	250	12.5
trans-1,3-Dichloropropene	10061-02-6		U	250	25.0
1,1-Dichloropropene	563-58-6		U	250	12.5
Ethylbenzene	100-41-4		U	250	12.5
2-Hexanone	591-78-6		U	500	125
Hexachlorobutadiene	87-68-3		U	250	12.5
Isopropylbenzene	98-82-8		U	250	12.5
p-Isopropyltoluene	99-87-6		U	250	12.5
4-Methyl-2-pentanone	108-10-1		U	500	125
Methylene chloride	75-09-2		U	250	12.5
Naphthalene	91-20-3		U	500	10.0
n-Propylbenzene	103-65-1		U	250	6.25
Styrene	100-42-5		U	250	6.25
1,1,1,2-Tetrachloroethane	630-20-6		U	250	12.5
1,1,2,2-Tetrachloroethane	79-34-5	11800	I	250	6.25
Tetrachloroethene	127-18-4	14.3	J	250	12.5
Toluene	108-88-3		U	250	12.5
1,2,3-Trichlorobenzene	87-61-6		U	250	6.25
1,2,4-Trichlorobenzene	120-82-1		U	250	10.0
1,1,1-Trichloroethane	71-55-6		U	250	12.5
1,1,2-Trichloroethane	79-00-5		U	250	12.5
Trichloroethene	79-01-6	2780		250	12.5
Trichlorofluoromethane	75-69-4		U	500	12.5
1,2,3-Trichloropropane	96-18-4		U	250	37.5
1,2,4-Trimethylbenzene	95-63-6		U	250	12.5
1,3,5-Trimethylbenzene	108-67-8		U	250	12.5
Vinyl acetate	108-05-4		U	500	125
Vinyl chloride	75-01-4		U	500	12.5
o-Xylene	95-47-6		U	250	12.5
m-,p-Xylene	136777-61-2		U	250	25.0

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0310530

Report Date : October 30, 2003

Sample Number: L0310530-02  
 Client ID: MW-77  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 21-OCT-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 50  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 12:19  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 12:19  
 File ID: 11M17974

Surrogate	% Recovery	Lower	Upper	Qual
Dibromofluoromethane	86.8	86	118	
1,2-Dichloroethane-d4	84.9	80	120	
Toluene-d8	104	88	110	
4-Bromofluorobenzene	101	86	115	

- I Semiquantitative result (out of instrument calibration range)  
 J The analyte was positively identified, but the quantitation was below the RL  
 U Not detected at or above the method detection limit

Sample Number: L0310530-02  
 Client ID: MW-77  
 Matrix: Water  
 Workgroup Number: WG152829  
 Collect Date: 21-OCT-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 500  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 14:22  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 14:22  
 File ID: 11M17978

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	50000	1250
Benzene	71-43-2		U	2500	62.5
Bromobenzene	108-86-1		U	2500	62.5
Bromochloromethane	74-97-5		U	2500	100
Bromodichloromethane	75-27-4		U	2500	125
Bromoform	75-25-2		U	2500	270
Bromomethane	74-83-9		U	5000	250
2-Butanone	78-93-3		U	50000	1250
n-Butylbenzene	104-51-8		U	2500	125
sec-Butylbenzene	135-98-8		U	2500	125
tert-Butylbenzene	98-06-6		U	2500	125
Carbon disulfide	75-15-0		U	2500	250
Carbon tetrachloride	56-23-5		U	2500	125
Chlorobenzene	108-90-7		U	2500	62.5
Chlorodibromomethane	124-48-1		U	2500	125
Chloroethane	75-00-3		U	5000	250
2-Chloroethyl vinyl ether	110-75-8		U	5000	1000
Chloroform	67-66-3		U	2500	62.5
Chloromethane	74-87-3		U	5000	125
2-Chlorotoluene	95-49-8		U	2500	62.5
4-Chlorotoluene	106-43-4		U	2500	125
1,2-Dibromo-3-chloropropane	96-12-8		U	2500	500
1,2-Dibromoethane	106-93-4		U	2500	125
Dibromomethane	74-95-3		U	2500	125
1,2-Dichlorobenzene	95-50-1		U	2500	62.5
1,3-Dichlorobenzene	541-73-1		U	2500	125
1,4-Dichlorobenzene	106-46-7		U	2500	62.5
Dichlorodifluoromethane	75-71-8		U	5000	125
1,1-Dichloroethane	75-34-3		U	2500	62.5
1,2-Dichloroethane	107-06-2		U	2500	125
1,1-Dichloroethene	75-35-4		U	2500	250
cis-1,2-Dichloroethene	156-59-2	138	J	2500	125
trans-1,2-Dichloroethane	156-60-5		U	2500	125
1,2-Dichloropropane	78-87-5		U	2500	62.5
1,3-Dichloropropane	142-28-9		U	2500	100
2,2-Dichloropropane	594-20-7		U	2500	125
cis-1,3-Dichloropropene	10061-01-5		U	2500	125
trans-1,3-Dichloropropene	10061-02-6		U	2500	250
1,1-Dichloropropene	563-58-6		U	2500	125
Ethylbenzene	100-41-4		U	2500	125
2-Hexanone	591-78-6		U	5000	1250



## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0310530

Report Date : October 30, 2003

Sample Number: L0310530-02  
 Client ID: MW-77  
 Matrix: Water  
 Workgroup Number: WQ152829  
 Collect Date: 21-OCT-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 500  
 Units: ug/L

Instrument: HPMS11  
 Prep Date: 10/27/2003 14:22  
 Cal Date: 10/17/2003 14:43  
 Run Date: 10/27/2003 14:22  
 File ID: 11M17978

Analyte	CAS. Number	Result	Qual	RL	MDL
Hexachlorobutadiene	87-68-3		U	2500	125
Isopropylbenzene	98-82-8		U	2500	125
p-Isopropyltoluene	99-87-6		U	2500	125
4-Methyl-2-pentanone	108-10-1		U	5000	1250
Methylene chloride	75-09-2		U	2500	125
Naphthalene	91-20-3		U	5000	100
n-Propylbenzene	103-65-1		U	2500	62.5
Styrene	100-42-5		U	2500	62.5
1,1,1,2-Tetrachloroethane	630-20-6		U	2500	125
1,1,2,2-Tetrachloroethane	79-34-5	12100		2500	62.5
Tetrachloroethene	127-18-4		U	2500	125
Toluene	106-88-3		U	2500	125
1,2,3-Trichlorobenzene	87-61-6		U	2500	62.5
1,2,4-Trichlorobenzene	120-82-1		U	2500	100
1,1,1-Trichloroethane	71-55-6		U	2500	125
1,1,2-Trichloroethane	79-00-5		U	2500	125
Trichloroethene	79-01-6	3030		2500	125
Trichlorofluoromethane	75-69-4		U	5000	125
1,2,3-Trichloropropane	96-18-4		U	2500	375
1,2,4-Trimethylbenzene	95-63-6		U	2500	125
1,3,5-Trimethylbenzene	108-67-8		U	2500	125
Vinyl acetate	108-05-4		U	5000	1250
Vinyl chloride	75-01-4		U	5000	125
o-Xylene	95-47-6		U	2500	125
m,p-Xylene	136777-61-2		U	2500	250
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	89.6	86	118		
1,2-Dichloroethane-d4	87.1	80	120		
Toluene-d8	103	88	110		
4-Bromofluorobenzene	100	86	115		

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

## LABORATORY REPORT

L0312394

12/19/03 14:28

Submitted By

KEMRON Environmental Services  
156 Starlite Drive  
Marietta, Ohio 45750  
(740) 373-4071

For

Account Name: CCI/CH2M HILL  
115 Perimeter Place NE  
Suite 700  
Atlanta, GA 30346  
Attention: David Nelson

Account Number: 207-630  
Work ID: 42577/CH2MHILL

P.O. Number: 56952

## Sample Summary

Client ID	Lab ID	Date Collected	Date Recieved
563-EFF C 44PV	L0312394-01	16-DEC-03	17-DEC-03
564-EFF Q 34PV	L0312394-02	16-DEC-03	17-DEC-03
563-BAG C 44PV	L0312394-03	16-DEC-03	17-DEC-03
564-BAG Q 34PV	L0312394-04	16-DEC-03	17-DEC-03

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-01  
 Client ID: 563-BFF  
 Matrix: Water  
 Workgroup Number: WG157325  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: HES  
 Dilution: 1  
 Units: ug/L

Instrument: HPMS8  
 Prep Date: 12/20/2003 17:17  
 Cal Date: 12/14/2003 16:43  
 Run Date: 12/20/2003 17:17  
 File ID: 8M311393

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1	3.15	J	10.0	2.50
Benzene	71-43-2		U	1.00	0.125
Bromobenzene	108-86-1		U	1.00	0.125
Bromochloromethane	74-97-5		U	1.00	0.200
Bromodichloromethane	75-27-4		U	1.00	0.250
Bromoform	75-25-2		U	1.00	0.540
Bromomethane	74-83-9		U	1.00	0.500
2-Butanone	78-93-3		U	10.0	2.50
n-Butylbenzene	104-51-8		U	1.00	0.250
sec-Butylbenzene	135-98-8		U	1.00	0.250
tert-Butylbenzene	98-06-6		U	1.00	0.250
Carbon disulfide	75-15-0		U	1.00	0.500
Carbon tetrachloride	56-23-5		U	1.00	0.250
Chlorobenzene	108-90-7		U	1.00	0.125
Chlorodibromomethane	124-48-1		U	1.00	0.250
Chloroethane	75-00-3		U	1.00	0.500
2-Chloroethyl vinyl ether	110-75-8		U	10.0	2.00
Chloroform	67-66-3		U	1.00	0.125
Chloromethane	74-87-3	1.62		1.00	0.250
2-Chlorotoluene	95-49-8		U	1.00	0.125
4-Chlorotoluene	106-43-4		U	1.00	0.250
1,2-Dibromo-3-chloropropane	96-12-8		U	5.00	1.00
1,2-Dibromoethane	106-93-4		U	1.00	0.250
Dibromomethane	74-95-3		U	1.00	0.250
1,2-Dichlorobenzene	95-50-1		U	1.00	0.125
1,3-Dichlorobenzene	541-73-1		U	1.00	0.250
1,4-Dichlorobenzene	106-46-7		U	1.00	0.125
Dichlorodifluoromethane	75-71-8		U	1.00	0.250
1,1-Dichloroethane	75-34-3		U	1.00	0.125
1,2-Dichloroethane	107-06-2		U	1.00	0.250
1,1-Dichloroethene	75-35-4		U	1.00	0.500
cis-1,2-Dichloroethene	156-59-2	0.361	J	1.00	0.250
trans-1,2-Dichloroethene	156-60-5		U	1.00	0.250
1,2-Dichloropropane	78-87-5		U	1.00	0.125
1,3-Dichloropropane	142-28-9		U	1.00	0.200
2,2-Dichloropropane	594-20-7		U	1.00	0.250
cis-1,3-Dichloropropene	10061-01-5		U	1.00	0.250
trans-1,3-Dichloropropene	10061-02-6		U	1.00	0.500
1,1-Dichloropropene	563-58-6		U	1.00	0.250
Ethylbenzene	100-41-4		U	1.00	0.250
2-Hexanone	591-78-6		U	10.0	2.50
Hexachlorobutadiene	87-68-3		U	1.00	0.250
Isopropylbenzene	98-82-8		U	1.00	0.250
p-Isopropyltoluene	99-87-6		U	1.00	0.250
4-Methyl-2-pentanone	108-10-1		U	10.0	2.50
Methylene chloride	75-09-2	27.1		5.00	0.250
Naphthalene	91-20-3		U	1.00	0.200
n-Propylbenzene	103-65-1		U	1.00	0.125
Styrene	100-42-5		U	1.00	0.125
1,1,1,2-Tetrachloroethane	630-20-6		U	1.00	0.250
1,1,2,2-Tetrachloroethane	79-34-5		U	1.00	0.125
Tetrachloroethene	127-18-4		U	1.00	0.250
Toluene	108-88-3		U	1.00	0.250
1,2,3-Trichlorobenzene	87-61-6		U	1.00	0.125
1,2,4-Trichlorobenzene	120-82-1		U	1.00	0.200
1,1,1-Trichloroethane	71-55-6		U	1.00	0.250
1,1,2-Trichloroethane	79-00-5		U	1.00	0.250
Trichloroethene	79-01-6		U	1.00	0.250
Trichlorofluoromethane	75-69-4		U	1.00	0.250

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-01  
 Client ID: 563-EFF  
 Matrix: Water  
 Workgroup Number: WGI57325  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: MRS  
 Dilution: 1  
 Units: ug/L

Instrument: HPMS8  
 Prep Date: 12/20/2003 17:17  
 Cal Date: 12/14/2003 16:43  
 Run Date: 12/20/2003 17:17  
 File ID: 8M311393

Analyte	CAS. Number	Result	Qual	RL	MDL
1,2,3-Trichloropropane	96-18-4		U	1.00	0.750
1,2,4-Trimethylbenzene	95-63-6		U	1.00	0.250
1,3,5-Trimethylbenzene	108-67-8		U	1.00	0.250
Vinyl acetate	108-05-4		U	10.0	2.50
Vinyl chloride	75-01-4		U	1.00	0.250
o-Xylene	95-47-6		U	1.00	0.250
m-,p-Xylene	136777-61-2		U	1.00	0.500
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	91.8	86	118		
1,2-Dichloroethane-d4	99.9	80	120		
Toluene-d8	104	88	110		
4-Bromofluorobenzene	110	86	115		

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

Sample Number: L0312394-02  
 Client ID: 564-EFF  
 Matrix: Water  
 Workgroup Number: WGI57325  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: MRS  
 Dilution: 1  
 Units: ug/L

Instrument: HPMS8  
 Prep Date: 12/20/2003 17:48  
 Cal Date: 12/14/2003 16:43  
 Run Date: 12/20/2003 17:48  
 File ID: 8M311394

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1	4.63	J	10.0	2.50
Benzene	71-43-2	0.182	J	1.00	0.125
Bromobenzene	108-86-1		U	1.00	0.125
Bromochloromethane	74-97-5		U	1.00	0.200
Bromodichloromethane	75-27-4		U	1.00	0.250
Bromoform	75-25-2		U	1.00	0.540
Bromomethane	74-83-9		U	1.00	0.500
2-Butanone	78-93-3		U	10.0	2.50
n-Butylbenzene	104-51-8		U	1.00	0.250
sec-Butylbenzene	135-98-8		U	1.00	0.250
tert-Butylbenzene	98-06-6		U	1.00	0.250
Carbon disulfide	75-15-0		U	1.00	0.500
Carbon tetrachloride	56-23-5		U	1.00	0.250
Chlorobenzene	108-90-7		U	1.00	0.125
Chlorodibromomethane	124-48-1		U	1.00	0.250
Chloroethane	75-00-3		U	1.00	0.500
2-Chloroethyl vinyl ether	110-75-8		U	10.0	2.00
Chloroform	67-66-3		U	1.00	0.125
Chloromethane	74-87-3		U	1.00	0.250
2-Chlorotoluene	95-49-8		U	1.00	0.125
4-Chlorotoluene	106-43-4		U	1.00	0.250
1,2-Dibromo-3-chloropropane	96-12-8		U	5.00	1.00
1,2-Dibromoethane	106-93-4		U	1.00	0.250
Dibromomethane	74-95-3		U	1.00	0.250
1,2-Dichlorobenzene	95-50-1		U	1.00	0.125
1,3-Dichlorobenzene	541-73-1		U	1.00	0.250
1,4-Dichlorobenzene	106-46-7		U	1.00	0.125
Dichlorodifluoromethane	75-71-8		U	1.00	0.250
1,1-Dichloroethane	75-34-3		U	1.00	0.125
1,2-Dichloroethane	107-06-2	1.52		1.00	0.250
1,1-Dichloroethene	75-35-4		U	1.00	0.500
cis-1,2-Dichloroethene	156-59-2	9.91		1.00	0.250
trans-1,2-Dichloroethene	156-60-5		U	1.00	0.250
1,2-Dichloropropane	78-87-5		U	1.00	0.125

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-02  
 Client ID: 564-EFF  
 Matrix: Water  
 Workgroup Number: W015725  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: MES  
 Dilution: 1  
 Units: ug/L

Instrument: HPMS8  
 Prep Date: 12/20/2003 17:48  
 Cal Date: 12/14/2003 16:43  
 Run Date: 12/20/2003 17:48  
 File ID: 8M311394

Analyte	CAS. Number	Result	Qual	RL	MDL
1,3-Dichloropropane	142-28-9		U	1.00	0.200
2,2-Dichloropropane	594-20-7		U	1.00	0.250
cis-1,3-Dichloropropene	10061-01-5		U	1.00	0.250
trans-1,3-Dichloropropene	10061-02-6		U	1.00	0.500
1,1-Dichloropropene	563-58-6		U	1.00	0.250
Methylbenzene	100-41-4		U	1.00	0.250
2-Hexanone	591-78-6		U	10.0	2.50
Hexachlorobutadiene	87-66-3		U	1.00	0.250
Isopropylbenzene	98-82-8		U	1.00	0.250
p-Isopropyltoluene	99-87-6		U	1.00	0.250
4-Methyl-2-pentanone	108-10-1		U	10.0	2.50
Methylene chloride	75-09-2	0.938	J	5.00	0.250
Naphthalene	91-20-3		U	1.00	0.200
n-Propylbenzene	103-65-1		U	1.00	0.125
Styrene	100-42-5		U	1.00	0.125
1,1,1,2-Tetrachloroethane	630-20-6		U	1.00	0.250
1,1,2,2-Tetrachloroethane	79-34-5		U	1.00	0.125
Tetrachloroethene	127-18-4		U	1.00	0.250
Toluene	108-88-3		U	1.00	0.250
1,2,3-Trichlorobenzene	87-61-6		U	1.00	0.125
1,3,4-Trichlorobenzene	120-82-1		U	1.00	0.200
1,1,1-Trichloroethane	71-55-6		U	1.00	0.250
1,1,2-Trichloroethane	79-00-5		U	1.00	0.250
Trichloroethene	79-01-6		U	1.00	0.250
Trichlorofluoromethane	75-69-4		U	1.00	0.250
1,2,3-Trichloropropane	96-18-4		U	1.00	0.750
1,2,4-Trimethylbenzene	95-63-6		U	1.00	0.250
1,3,5-Trimethylbenzene	108-67-8		U	1.00	0.250
Vinyl acetate	108-05-4		U	10.0	2.50
Vinyl chloride	75-01-4	0.882	J	1.00	0.250
o-Xylene	95-47-6		U	1.00	0.250
m-,p-Xylene	136777-61-2		U	1.00	0.500
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	91.8	86	118		
1,2-Dichloroethane-d4	98.8	80	120		
Toluene-d8	105	88	110		
4-Bromofluorobenzene	108	86	115		

J The analyte was positively identified, but the quantitation was below the RL  
 U Not detected at or above the method detection limit

Sample Number: L0312394-03  
 Client ID: 563-BAG  
 Matrix: Water  
 Workgroup Number: W0157257  
 Collect Date: 16-DEC-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 10  
 Units: ug/L

Instrument: HPMS8  
 Prep Date: 12/19/2003 22:13  
 Cal Date: 11/24/2003 19:30  
 Run Date: 12/19/2003 22:13  
 File ID: 6M41760

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	100	25.0
Benzene	71-43-2		U	10.0	1.25
Bromobenzene	108-86-1		U	10.0	1.25
Bromochloromethane	74-97-5		U	10.0	2.00
Bromodichloromethane	75-27-4		U	10.0	2.50
Bromoform	75-25-2		U	10.0	5.40
Bromomethane	74-83-9		U	10.0	5.00
2-Butanone	78-93-3		U	100	25.0
n-Butylbenzene	104-51-8		U	10.0	2.50

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-03

Client ID: 563-BAG

Matrix: Water

Workgroup Number: W0157257

Collect Date: 16-DEC-03

Sample Tag: D1

Prep Method: 5030B

Analytical Method: 8260B

Analyst: CMS

Dilution: 10

Units: ug/L

Instrument: HPMS6

Prep Date: 12/19/2003 22:13

Cal Date: 11/24/2003 19:30

Run Date: 12/19/2003 22:13

File ID: 6M41760

Analyte	CAS. Number	Result	Qual	RL	MDL
sec-Butylbenzene	115-98-8		U	10.0	2.50
tert-Butylbenzene	98-06-6		U	10.0	2.50
Carbon disulfide	75-15-0		U	10.0	5.00
Carbon tetrachloride	56-23-5	62.2		10.0	2.50
Chlorobenzene	108-90-7		U	10.0	1.25
Chlorodibromomethane	124-48-1		U	10.0	2.50
Chloroethane	75-00-3		U	10.0	5.00
2-Chloroethyl vinyl ether	110-75-8		U	100	20.0
Chloroform	67-66-3	418		10.0	1.25
Chloromethane	74-87-3		U	10.0	2.50
2-Chlorotoluene	95-49-8		U	10.0	1.25
4-Chlorotoluene	106-43-4		U	10.0	2.50
1,2-Dibromo-3-chloropropane	96-12-8		U	50.0	10.0
1,2-Dibromoethane	106-93-4		U	10.0	2.50
Dibromomethane	74-95-3		U	10.0	2.50
1,2-Dichlorobenzene	95-50-1		U	10.0	1.25
1,3-Dichlorobenzene	541-73-1		U	10.0	2.50
1,4-Dichlorobenzene	106-46-7		U	10.0	1.25
Dichlorodifluoromethane	75-71-8		U	10.0	2.50
1,1-Dichloroethane	75-34-3		U	10.0	1.25
1,2-Dichloroethane	107-06-2		U	10.0	2.50
1,1-Dichloroethene	75-35-4		U	10.0	5.00
cis-1,2-Dichloroethane	156-59-2	37.8		10.0	2.50
trans-1,2-Dichloroethene	156-60-5	6.95	J	10.0	2.50
1,2-Dichloropropane	78-87-5		U	10.0	1.25
1,3-Dichloropropane	142-28-9		U	10.0	2.00
2,2-Dichloropropane	594-20-7		U	10.0	2.50
cis-1,3-Dichloropropene	10061-01-5		U	10.0	2.50
trans-1,3-Dichloropropene	10061-02-6		U	10.0	5.00
1,1-Dichloropropene	563-58-6		U	10.0	2.50
Ethylbenzene	100-41-4		U	10.0	2.50
2-Hexanone	591-78-6		U	100	25.0
Hexachlorobutadiene	87-68-3		U	10.0	2.50
Isopropylbenzene	98-82-8		U	10.0	2.50
p-Isopropyltoluene	99-87-6		U	10.0	2.50
4-Methyl-2-pentanone	108-10-1		U	100	25.0
Methylene chloride	75-09-2		U	50.0	2.50
Naphthalene	91-20-3		U	10.0	2.00
n-Propylbenzene	103-65-1		U	10.0	1.25
Styrene	100-42-5		U	10.0	1.25
1,1,1,2-Tetrachloroethane	630-20-6		U	10.0	2.50
1,1,2,2-Tetrachloroethane	79-34-5	441		10.0	1.25
Tetrachloroethene	127-18-4	3.83	J	10.0	2.50
Toluene	108-88-3		U	10.0	2.50
1,2,3-Trichlorobenzene	87-61-6		U	10.0	1.25
1,2,4-Trichlorobenzene	120-82-1		U	10.0	2.00
1,1,1-Trichloroethane	71-55-6		U	10.0	2.50
1,1,2-Trichloroethane	79-00-5	3.07	J	10.0	2.50
Trichloroethane	79-01-6	839		10.0	2.50
Trichlorofluoromethane	75-69-4		U	10.0	2.50
1,2,3-Trichloropropane	96-18-4		U	10.0	7.50
1,2,4-Trimethylbenzene	95-63-6		U	10.0	2.50
1,3,5-Trimethylbenzene	108-67-8		U	10.0	2.50
Vinyl acetate	108-05-4		U	100	25.0
Vinyl chloride	75-01-4		U	10.0	2.50
o-Xylene	95-47-6		U	10.0	2.50
m-,p-Xylene	136777-61-2		U	10.0	5.00

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-03	Prep Method: 5030B	Instrument: HPMS6
Client ID: 563-BAG	Analytical Method: 8260B	Prep Date: 12/19/2003 22:13
Matrix: Water	Analyst: CMS	Cal Date: 11/24/2003 19:30
Workgroup Number: W0157257	Dilution: 10	Run Date: 12/19/2003 22:13
Collect Date: 16-DEC-03	Units: ug/L	File ID: 6M41760
Sample Tag: D1		

Surrogate	% Recovery	Lower	Upper	Qual
Dibromofluoromethane	94.5	86	118	
1,2-Dichloroethane-d4	96.5	80	120	
Toluene-d8	92.8	88	110	
4-Bromofluorobenzene	102	86	115	

J The analyte was positively identified, but the quantitation was below the RL  
 U Not detected at or above the method detection limit

Sample Number: L0312394-03	Prep Method: 5030B	Instrument: HPMS6
Client ID: 563-BAG	Analytical Method: 8260B	Prep Date: 12/19/2003 23:17
Matrix: Water	Analyst: CMS	Cal Date: 11/24/2003 19:30
Workgroup Number: W0157257	Dilution: 1	Run Date: 12/19/2003 23:17
Collect Date: 16-DEC-03	Units: ug/L	File ID: 6M41762

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	10.0	2.50
Benzene	71-43-2		U	1.00	0.125
Bromobenzene	108-86-1		U	1.00	0.125
Bromochloromethane	74-97-5		U	1.00	0.200
Bromodichloromethane	75-27-4		U	1.00	0.250
Bromoform	75-25-2		U	1.00	0.540
Bromomethane	74-83-9		U	1.00	0.500
2-Butanone	78-93-3		U	10.0	2.50
n-Butylbenzene	104-51-8		U	1.00	0.250
sec-Butylbenzene	135-98-8		U	1.00	0.250
tert-Butylbenzene	98-06-6		U	1.00	0.250
Carbon disulfide	75-15-0		U	1.00	0.500
Carbon tetrachloride	56-23-5	78.1		1.00	0.250
Chlorobenzene	108-90-7	0.317	J	1.00	0.125
Chlorodibromomethane	124-48-1		U	1.00	0.250
Chloroethane	75-00-3		U	1.00	0.500
2-Chloroethyl vinyl ether	110-75-8		U	10.0	2.00
Chloroform	67-66-3	408	I	1.00	0.125
Chloromethane	74-87-3		U	1.00	0.250
2-Chlorotoluene	95-49-8		U	1.00	0.125
4-Chlorotoluene	106-43-4		U	1.00	0.250
1,2-Dibromo-3-chloropropane	96-12-8		U	5.00	1.00
1,2-Dibromoethane	106-93-4		U	1.00	0.250
Dibromomethane	74-95-3		U	1.00	0.250
1,2-Dichlorobenzene	95-50-1		U	1.00	0.125
1,3-Dichlorobenzene	541-73-1		U	1.00	0.250
1,4-Dichlorobenzene	106-46-7		U	1.00	0.125
Dichlorodifluoromethane	75-71-8		U	1.00	0.250
1,1-Dichloroethane	75-34-3		U	1.00	0.125
1,2-Dichloroethane	107-06-2	1.19		1.00	0.250
1,1-Dichloroethane	75-35-4		U	1.00	0.500
cis-1,2-Dichloroethane	156-59-2	45.9		1.00	0.250
trans-1,2-Dichloroethane	156-60-5	8.19		1.00	0.250
1,2-Dichloropropane	78-87-5		U	1.00	0.125
1,3-Dichloropropane	142-28-9		U	1.00	0.200
2,2-Dichloropropane	594-20-7		U	1.00	0.250
cis-1,3-Dichloropropene	10061-01-5		U	1.00	0.250
trans-1,3-Dichloropropene	10051-02-6		U	1.00	0.500
1,1-Dichloropropene	563-58-6		U	1.00	0.250
Ethylbenzene	100-41-4	0.291	J	1.00	0.250
2-Hexanone	591-78-6		U	10.0	2.50
Hexachlorobutadiene	87-68-3		U	1.00	0.250

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-03  
 Client ID: 563-BAG  
 Matrix: Water  
 Workgroup Number: WQ157257  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 1  
 Units: ug/L

Instrument: HPMS6  
 Prep Date: 12/19/2003 23:17  
 Cal Date: 11/24/2003 19:30  
 Run Date: 12/19/2003 23:17  
 File ID: 6M41762

Analyte	CAS. Number	Result	Qual	RL	MDL
Isopropylbenzene	98-82-8		U	1.00	0.250
p-Isopropyltoluene	99-87-6		U	1.00	0.250
4-Methyl-2-pentanone	108-10-1		U	10.0	2.50
Methylene chloride	75-09-2		U	5.00	0.250
Naphthalene	91-20-3		U	1.00	0.200
n-Propylbenzene	103-65-1		U	1.00	0.125
Styrene	100-42-5		U	1.00	0.125
1,1,1,2-Tetrachloroethane	630-20-6	0.347	J	1.00	0.250
1,1,2,2-Tetrachloroethane	79-34-5	459	I	1.00	0.125
Tetrachloroethene	127-18-4	4.37		1.00	0.250
Toluene	108-88-3	0.146	J	1.00	0.250
1,2,3-Trichlorobenzene	87-61-6		U	1.00	0.125
1,2,4-Trichlorobenzene	120-82-1		U	1.00	0.200
1,1,1-Trichloroethane	71-55-6		U	1.00	0.250
1,1,2-Trichloroethane	79-00-5	3.52		1.00	0.250
Trichloroethene	79-01-6	789	I	1.00	0.250
Trichlorofluoromethane	75-69-4		U	1.00	0.250
1,2,3-Trichloropropane	96-18-4		U	1.00	0.750
1,2,4-Trimethylbenzene	95-63-6		U	1.00	0.250
1,3,5-Trimethylbenzene	108-67-8		U	1.00	0.250
Vinyl acetate	108-05-4		U	10.0	2.50
Vinyl chloride	75-01-4	0.614	J	1.00	0.250
o-Xylene	95-47-6		U	1.00	0.250
m-p-Xylene	136777-61-2		U	1.00	0.500
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	101	86	118		
1,2-Dichloroethane-d4	103	80	120		
Toluene-d8	92.6	88	110		
4-Bromofluorobenzene	107	86	115		

I Semi-quantitative result (out of instrument calibration range)

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

Sample Number: L0312394-04  
 Client ID: 564-BAG  
 Matrix: Water  
 Workgroup Number: WQ157257  
 Collect Date: 16-DEC-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 100  
 Units: ug/L

Instrument: HPMS6  
 Prep Date: 12/19/2003 22:45  
 Cal Date: 11/24/2003 19:30  
 Run Date: 12/19/2003 22:45  
 File ID: 6M41761

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	1000	250
Benzene	71-43-2		U	100	12.5
Bromobenzene	108-86-1		U	100	12.5
Bromochloromethane	74-97-5		U	100	20.0
Bromodichloromethane	75-27-4		U	100	25.0
Bromoform	75-25-2		U	100	54.0
Bromomethane	74-83-9		U	100	50.0
2-Butanone	78-93-3		U	1000	250
n-Butylbenzene	104-51-8		U	100	25.0
sec-Butylbenzene	135-98-8		U	100	25.0
tert-Butylbenzene	98-06-6		U	100	25.0
Carbon disulfide	75-15-0		U	100	50.0
Carbon tetrachloride	56-23-5		U	100	25.0
Chlorobenzene	108-90-7		U	100	12.5
Chlorodibromomethane	124-48-1		U	100	25.0
Chloroethane	75-00-3		U	100	50.0



## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-04  
 Client ID: 564-BAG  
 Matrix: Water  
 Workgroup Number: W0157257  
 Collect Date: 16-DEC-03  
 Sample Tag: D1

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 100  
 Units: ug/L

Instrument: HPMS6  
 Prep Date: 12/19/2003 22:45  
 Cal Date: 11/24/2003 19:30  
 Run Date: 12/19/2003 22:45  
 File ID: 6M41761

Analyte	CAS. Number	Result	Qual	RL	MDL
2-Chloroethyl vinyl ether	110-75-8		U	1000	200
Chloroform	67-66-3		U	100	12.5
Chloromethane	74-87-3		U	100	25.0
2-Chlorotoluene	95-49-8		U	100	12.5
4-Chlorotoluene	106-43-4		U	100	25.0
1,2-Dibromo-3-chloropropane	96-12-8		U	500	100
1,2-Dibromomethane	106-93-4		U	100	25.0
Dibromomethane	74-95-3		U	100	25.0
1,2-Dichlorobenzene	95-50-1		U	100	12.5
1,3-Dichlorobenzene	541-73-1		U	100	25.0
1,4-Dichlorobenzene	106-46-7		U	100	12.5
Dichlorodifluoromethane	75-71-8		U	100	25.0
1,1-Dichloroethane	75-34-3		U	100	12.5
1,2-Dichloroethane	107-06-2		U	100	25.0
1,1-Dichloroethene	75-35-4		U	100	50.0
cis-1,2-Dichloroethane	156-59-2	111		100	25.0
trans-1,2-Dichloroethane	156-60-3		U	100	25.0
1,2-Dichloropropane	78-87-5		U	100	12.5
1,3-Dichloropropane	142-28-9		U	100	20.0
2,2-Dichloropropane	594-20-7		U	100	25.0
cis-1,3-Dichloropropene	10061-01-5		U	100	25.0
trans-1,3-Dichloropropene	10061-02-6		U	100	50.0
1,1-Dichloropropene	563-58-6		U	100	25.0
Ethylbenzene	100-41-4		U	100	25.0
2-Hexanone	591-78-6		U	1000	250
Hexachlorobutadiene	87-68-1		U	100	25.0
Isopropylbenzene	98-82-8		U	100	25.0
p-Isopropyltoluene	99-87-6		U	100	25.0
4-Methyl-2-pentanone	108-10-1		U	1000	250
Methylene chloride	75-09-2		U	500	25.0
Naphthalene	91-20-3		U	100	20.0
n-Propylbenzene	103-65-1		U	100	12.5
Styrene	100-42-5		U	100	12.5
1,1,1,2-Tetrachloroethane	630-20-6		U	100	25.0
1,1,1,2-Tetrachloroethane	79-34-5	19100		100	12.5
Tetrachloroethene	127-18-4	53.6	J	100	25.0
Toluene	108-88-3		U	100	25.0
1,2,3-Trichlorobenzene	87-61-6		U	100	12.5
1,2,4-Trichlorobenzene	120-82-1		U	100	20.0
1,1,1-Trichloroethane	71-55-6		U	100	25.0
1,1,2-Trichloroethane	79-00-5		U	100	25.0
Trichloroethene	79-01-6	3400		100	25.0
Trichlorofluoromethane	75-69-4		U	100	25.0
1,2,3-Trichloropropane	96-18-4		U	100	75.0
1,2,4-Trimethylbenzene	95-63-6		U	100	25.0
1,3,5-Trimethylbenzene	108-67-8		U	100	25.0
Vinyl acetate	108-05-4		U	1000	250
Vinyl chloride	75-01-4		U	100	25.0
o-Xylene	95-47-6		U	100	25.0
m,p-Xylene	136777-61-2		U	100	50.0
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	92.0	86	118		
1,2-Dichloroethane-d4	98.7	80	120		
Toluene-d8	91.9	88	110		
4-Bromofluorobenzene	102	86	115		

J The analyte was positively identified, but the quantitation was below the RL  
 U Not detected at or above the method detection limit

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-04  
 Client ID: 564-SAG  
 Matrix: Water  
 Workgroup Number: NG157257  
 Collect Date: 16-DEC-03

Prep Method: 5030B  
 Analytical Method: 8260B  
 Analyst: CMS  
 Dilution: 10  
 Units: ug/L

Instrument: HPMS6  
 Prep Date: 12/19/2003 23:48  
 Cal Date: 11/24/2003 19:30  
 Run Date: 12/19/2003 23:48  
 File ID: 6M41763

Analyte	CAS. Number	Result	Qual	RL	MDL
Acetone	67-64-1		U	100	25.0
Benzene	71-43-2		U	10.0	1.25
Bromobenzene	108-86-1		U	10.0	1.25
Bromochloromethane	74-97-5		U	10.0	2.00
Bromodichloromethane	75-27-4	12.7		10.0	2.50
Bromoform	75-25-2	19.1		10.0	5.40
Bromomethane	74-83-9		U	10.0	5.00
2-Butanone	78-93-3		U	100	25.0
n-Butylbenzene	104-51-8		U	10.0	2.50
sec-Butylbenzene	135-98-8		U	10.0	2.50
tert-Butylbenzene	98-06-6		U	10.0	2.50
Carbon disulfide	75-15-0		U	10.0	5.00
Carbon tetrachloride	56-23-5		U	10.0	2.50
Chlorobenzene	108-90-7		U	10.0	1.25
Chlorodibromomethane	124-48-1		U	10.0	2.50
Chloroethane	75-00-3		U	10.0	5.00
2-Chloroethyl vinyl ether	110-75-8		U	100	20.0
Chloroform	67-66-3	6.61	J	10.0	1.25
Chloromethane	74-87-3		U	10.0	2.50
2-Chlorotoluene	95-49-8		U	10.0	1.25
4-Chlorotoluene	106-43-4		U	10.0	2.50
1,2-Dibromo-3-chloropropane	96-12-8		U	50.0	10.0
1,2-Dibromoethane	106-93-4		U	10.0	2.50
Dibromomethane	74-95-3		U	10.0	2.50
1,2-Dichlorobenzene	95-50-1		U	10.0	1.25
1,3-Dichlorobenzene	541-73-1		U	10.0	2.50
1,4-Dichlorobenzene	106-46-7		U	10.0	1.25
Dichlorodifluoromethane	75-71-8		U	10.0	2.50
1,1-Dichloroethane	75-34-3		U	10.0	1.25
1,2-Dichloroethane	107-06-2	2.54	J	10.0	2.50
1,1-Dichloroethene	75-35-4		U	10.0	5.00
cis-1,2-Dichloroethane	156-59-2	135		10.0	2.50
trans-1,2-Dichloroethane	156-60-5	18.4		10.0	2.50
1,2-Dichloropropane	78-87-5		U	10.0	1.25
1,3-Dichloropropane	142-28-9		U	10.0	2.00
2,2-Dichloropropane	594-20-7		U	10.0	2.50
cis-1,3-Dichloropropane	10061-01-5		U	10.0	2.50
trans-1,3-Dichloropropane	10061-02-6		U	10.0	5.00
1,1-Dichloropropene	863-58-6		U	10.0	2.50
Ethylbenzene	100-41-4		U	10.0	2.50
2-Hexanone	591-78-6		U	100	25.0
Hexachlorobutadiene	87-68-3		U	10.0	2.50
Isopropylbenzene	98-82-8		U	10.0	2.50
p-Isopropyltoluene	99-87-6		U	10.0	2.50
4-Methyl-2-pentanone	108-10-1		U	100	25.0
Methylene chloride	75-09-2		U	50.0	2.80
Naphthalene	91-20-3		U	10.0	2.00
n-Propylbenzene	103-65-1		U	10.0	1.25
Styrene	100-42-5		U	10.0	1.25
1,1,1,2-Tetrachloroethane	630-20-6		U	10.0	2.50
1,1,1,2,2-Tetrachloroethane	79-34-5	17400	I	10.0	1.25
Tetrachloroethene	127-18-4	57.8		10.0	2.50
Toluene	108-88-3		U	10.0	2.50
1,2,3-Trichlorobenzene	87-61-6		U	10.0	1.25
1,2,4-Trichlorobenzene	120-82-1		U	10.0	2.00
1,1,1-Trichloroethane	71-55-6	3.17	J	10.0	2.50
1,1,2-Trichloroethane	79-00-5	9.38	J	10.0	2.50
Trichloroethene	79-01-6	3620	I	10.0	2.50
Trichlorofluoromethane	75-69-4		U	10.0	2.50

## KEMRON ENVIRONMENTAL SERVICES

Report Number: L0312394

Report Date : December 29, 2003

Sample Number: L0312394-04

Client ID: 564-BAG

Matrix: Water

Workgroup Number: W0157257

Collect Date: 16-DEC-03

Prep Method: 5030B

Analytical Method: 8260B

Analyst: CMS

Dilution: 10

Units: ug/L

Instrument: HPMS6

Prep Date: 12/19/2003 23:48

Cal Date: 11/24/2003 19:30

Run Date: 12/19/2003 23:48

File ID: 6M41763

Analyte	CAS. Number	Result	Qual	RL	MDL
1,2,3-Trichloropropane	96-18-4		U	10.0	7.50
1,2,4-Trimethylbenzene	95-63-6		U	10.0	2.50
1,3,5-Trimethylbenzene	108-67-8		U	10.0	2.50
Vinyl acetate	108-05-4		U	100	25.0
Vinyl chloride	75-01-4		U	10.0	2.50
o-Xylene	95-47-6		U	10.0	2.50
m-,p-Xylene	136777-61-2		U	10.0	5.00
Surrogate	% Recovery	Lower	Upper	Qual	
Dibromofluoromethane	92.2	86	118		
1,2-Dichloroethane-d4	99.5	80	120		
Toluene-d8	93.1	88	110		
4-Bromofluorobenzene	106	86	115		

I Semiquantitative result (out of instrument calibration range)

J The analyte was positively identified, but the quantitation was below the RL

U Not detected at or above the method detection limit

KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK SUMMARY

Login Number: L0312394  
Blank File ID: 6M41744  
Date Analyzed: 12/19/03  
Time Analyzed: 13:44  
Analyst: CMS

Work Group: WG157257  
Blank Sample ID: WG157257-01  
Instrument ID: HPMS6  
Method: 8260B

This Method Blank Applies To The Following Samples:

Client ID	Lab Sample ID	Lab File ID	Time Analyzed	TAG
LCS	WG157257-02	6M41745	12/19/03 14:16	
LCS2	WG157257-03	6M41746	12/19/03 14:48	
563-BAG	L0312394-03	6M41760	12/19/03 22:13	D1
564-BAG	L0312394-04	6M41761	12/19/03 22:45	D1
563-BAG	L0312394-03	6M41762	12/19/03 23:17	
564-BAG	L0312394-04	6M41763	12/19/03 23:48	

KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK SUMMARY

Login Number: L0312394  
Blank File ID: 8M311381  
Date Analyzed: 12/20/03  
Time Analyzed: 11:17  
Analyst: MRR

Work Group: WG157325  
Blank Sample ID: WG157325-01  
Instrument ID: HPM88  
Method: 8260B

This Method Blank Applies To The Following Samples:

Client ID	Lab Sample ID	Lab File ID	Time Analyzed	TAG
LCS	WG157325-02	8M311382	12/20/03 11:47	
563-EFF	L0312394-01	8M311393	12/20/03 17:17	
564-EFF	L0312394-02	8M311394	12/20/03 17:48	

KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK REPORT

Login Number: L0312394 Run Date: 12/19/2003 Sample ID: WQ157257-01  
Instrument ID: HPMS6 Run Time: 13:44 Prep Method: 5030B  
File ID: 6M41744 Analyst: CMS Method: 8260B  
Workgroup (AAB#): WQ157257 Matrix: Water Units: ug/L  
Contract #: DACA87-94-D-0009 Cal ID: HPMS6-24-NOV-03

Analytes	MDL	RDL	Concentration	Dilution	Qualifier
Acetone	2.50	10.0	2.50	1	U
Benzene	0.125	1.00	0.125	1	U
Bromobenzene	0.125	1.00	0.125	1	U
Bromochloromethane	0.200	1.00	0.200	1	U
Bromodichloromethane	0.250	1.00	0.250	1	U
Bromoform	0.540	1.00	0.540	1	U
Bromomethane	0.500	1.00	0.500	1	U
2-Butanone	2.50	10.0	2.50	1	U
n-Butylbenzene	0.250	1.00	0.250	1	U
sec-Butylbenzene	0.250	1.00	0.250	1	U
tert-Butylbenzene	0.250	1.00	0.250	1	U
Carbon disulfide	0.500	1.00	0.500	1	U
Carbon tetrachloride	0.250	1.00	0.250	1	U
Chlorobenzene	0.125	1.00	0.125	1	U
Chlorodibromomethane	0.250	1.00	0.250	1	U
Chloroethane	0.500	1.00	0.500	1	U
2-Chloroethyl vinyl ether	2.00	10.0	2.00	1	U
Chloroform	0.125	1.00	0.125	1	U
Chloromethane	0.250	1.00	0.250	1	U
2-Chlorotoluene	0.125	1.00	0.125	1	U
4-Chlorotoluene	0.250	1.00	0.250	1	U
1,2-Dibromo-3-chloropropane	1.00	5.00	1.00	1	U
1,2-Dibromoethane	0.250	1.00	0.250	1	U
Dibromomethane	0.250	1.00	0.250	1	U
1,2-Dichlorobenzene	0.125	1.00	0.125	1	U
1,3-Dichlorobenzene	0.250	1.00	0.250	1	U
1,4-Dichlorobenzene	0.125	1.00	0.125	1	U
Dichlorodifluoromethane	0.250	1.00	0.250	1	U
1,1-Dichloroethane	0.125	1.00	0.125	1	U
1,2-Dichloroethane	0.250	1.00	0.250	1	U
1,1-Dichloroethene	0.500	1.00	0.500	1	U
cis-1,2-Dichloroethene	0.250	1.00	0.250	1	U
trans-1,2-Dichloroethene	0.250	1.00	0.250	1	U
1,2-Dichloropropane	0.125	1.00	0.125	1	U
1,3-Dichloropropane	0.200	1.00	0.200	1	U
2,2-Dichloropropane	0.250	1.00	0.250	1	U
cis-1,3-Dichloropropene	0.250	1.00	0.250	1	U
trans-1,3-Dichloropropene	0.500	1.00	0.500	1	U
1,1-Dichloropropene	0.250	1.00	0.250	1	U
Ethylbenzene	0.250	1.00	0.250	1	U
2-Hexanone	2.50	10.0	2.50	1	U
Hexachlorobutadiene	0.250	1.00	0.414	1	J

**KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK REPORT**

Login Number: L0312394 Run Date: 12/19/2003 Sample ID: WG157257-01  
 Instrument ID: HPMS6 Run Time: 13.44 Prep Method: 5030B  
 File ID: 6M41744 Analyst: CMS Method: 8260B  
 Workgroup (AAB#): WG157257 Matrix: Water Units: ug/L  
 Contract #: Cal ID: HPMS6-24-NOV-03

Analytes	MDL	RDL	Concentration	Dilution	Qualifier
Isopropylbenzene	0.250	1.00	0.250	1	U
p-Isopropyltoluene	0.250	1.00	0.250	1	U
4-Methyl-2-pentanone	2.50	10.0	2.50	1	U
Methylene chloride	0.250	5.00	0.250	1	U
Naphthalene	0.200	1.00	0.200	1	U
n-Propylbenzene	0.125	1.00	0.125	1	U
Styrene	0.125	1.00	0.125	1	U
1,1,1,2-Tetrachloroethane	0.250	1.00	0.250	1	U
1,1,2,2-Tetrachloroethane	0.125	1.00	0.125	1	U
Tetrachloroethene	0.250	1.00	0.250	1	U
Toluene	0.250	1.00	0.250	1	U
1,2,3-Trichlorobenzene	0.125	1.00	0.125	1	U
1,2,4-Trichlorobenzene	0.200	1.00	0.200	1	U
1,1,1-Trichloroethane	0.250	1.00	0.250	1	U
1,1,2-Trichloroethane	0.250	1.00	0.250	1	U
Trichloroethene	0.250	1.00	0.250	1	U
Trichlorofluoromethane	0.250	1.00	0.250	1	U
1,2,3-Trichloropropane	0.750	1.00	0.750	1	U
1,2,4-Trimethylbenzene	0.250	1.00	0.250	1	U
1,3,5-Trimethylbenzene	0.250	1.00	0.250	1	U
Vinyl acetate	2.50	10.0	2.50	1	U
Vinyl chloride	0.250	1.00	0.250	1	U
o-Xylene	0.250	1.00	0.250	1	U
m,p-Xylene	0.500	1.00	0.500	1	U

Surrogates	% Recovery	Surrogate Limits	Qualifier
Dibromofluoromethane	91.3	86 - 118	PASS
1,2-Dichloroethane-d4	98.8	80 - 120	PASS
Toluene-d8	91.4	88 - 110	PASS
4-Bromofluorobenzene	99.7	86 - 115	PASS

\* Analyte detected above RDL

ND Analyte Not detected at or above reporting limit

KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK REPORT

Login Number: L0112394 Run Date: 12/20/2003 Sample ID: WG157325-01  
Instrument ID: HPMS8 Run Time: 11:17 Prep Method: 5030B  
File ID: BM311381 Analyst: MES Method: 8260B  
Workgroup (AAB#): WG157325 Matrix: Water Units: ug/L  
Contract #: DACAS7-94-D-0009 Cal ID: HPMS8-14-DEC-03

Analytes	MDL	RDL	Concentration	Dilution	Qualifier
Acetone	2.50	10.0	2.50	1	U
Benzene	0.125	1.00	0.125	1	U
Bromobenzene	0.125	1.00	0.125	1	U
Bromochloromethane	0.200	1.00	0.200	1	U
Bromodichloromethane	0.250	1.00	0.250	1	U
Bromoform	0.540	1.00	0.540	1	U
Bromomethane	0.500	1.00	0.500	1	U
2-Butanone	2.50	10.0	2.50	1	U
n-Butylbenzene	0.250	1.00	0.250	1	U
sec-Butylbenzene	0.250	1.00	0.250	1	U
tert-Butylbenzene	0.250	1.00	0.250	1	U
Carbon disulfide	0.500	1.00	0.500	1	U
Carbon tetrachloride	0.250	1.00	0.250	1	U
Chlorobenzene	0.125	1.00	0.125	1	U
Chlorodibromomethane	0.250	1.00	0.250	1	U
Chloroethane	0.500	1.00	0.500	1	U
2-Chloroethyl vinyl ether	2.00	10.0	2.00	1	U
Chloroform	0.125	1.00	0.125	1	U
Chloromethane	0.250	1.00	0.250	1	U
2-Chlorotoluene	0.125	1.00	0.125	1	U
4-Chlorotoluene	0.250	1.00	0.250	1	U
1,2-Dibromo-3-chloropropane	1.00	5.00	1.00	1	U
1,2-Dibromoethane	0.250	1.00	0.250	1	U
Dibromomethane	0.250	1.00	0.250	1	U
1,2-Dichlorobenzene	0.125	1.00	0.125	1	U
1,3-Dichlorobenzene	0.250	1.00	0.250	1	U
1,4-Dichlorobenzene	0.125	1.00	0.125	1	U
Dichlorodifluoromethane	0.250	1.00	0.250	1	U
1,1-Dichloroethane	0.125	1.00	0.125	1	U
1,2-Dichloroethane	0.250	1.00	0.250	1	U
1,1-Dichloroethene	0.500	1.00	0.500	1	U
cis-1,2-Dichloroethene	0.250	1.00	0.250	1	U
trans-1,2-Dichloroethene	0.250	1.00	0.250	1	U
1,2-Dichloropropane	0.125	1.00	0.125	1	U
1,3-Dichloropropane	0.200	1.00	0.200	1	U
2,2-Dichloropropane	0.250	1.00	0.250	1	U
cis-1,3-Dichloropropene	0.250	1.00	0.250	1	U
trans-1,3-Dichloropropene	0.500	1.00	0.500	1	U
1,1-Dichloropropene	0.250	1.00	0.250	1	U
Ethylbenzene	0.250	1.00	0.250	1	U
2-Hexanone	2.50	10.0	2.50	1	U
Hexachlorobutadiene	0.250	1.00	0.250	1	U



KEMRON ENVIRONMENTAL SERVICES  
METHOD BLANK REPORT

Login Number: L0312394 Run Date: 12/20/2003 Sample ID: WG157325-01  
Instrument ID: HPMSR Run Time: 11.17 Prep Method: 5030B  
File ID: 8M311381 Analyst: MES Method: 8260B  
Workgroup (AAB#): WG157325 Matrix: Water Units: ug/L  
Contract #: Cal ID: HPMSR-14-DEC-03

Analytes	MDL	RDL	Concentration	Dilution	Qualifier
Isopropylbenzene	0.250	1.00	0.250	1	U
p-Isopropyltoluene	0.250	1.00	0.250	1	U
4-Methyl-2-pentanone	2.50	10.0	2.50	1	U
Methylene chloride	0.250	5.00	0.250	1	U
Naphthalene	0.200	1.00	0.200	1	U
n-Propylbenzene	0.125	1.00	0.125	1	U
Styrene	0.125	1.00	0.125	1	U
1,1,1,2-Tetrachloroethane	0.250	1.00	0.250	1	U
1,1,1,2-Tetrachloroethane	0.125	1.00	0.125	1	U
Tetrachloroethane	0.250	1.00	0.250	1	U
Toluene	0.250	1.00	0.250	1	U
1,2,3-Trichlorobenzene	0.125	1.00	0.125	1	U
1,2,4-Trichlorobenzene	0.200	1.00	0.200	1	U
1,1,1-Trichloroethane	0.250	1.00	0.250	1	U
1,1,2-Trichloroethane	0.250	1.00	0.250	1	U
Trichloroethane	0.250	1.00	0.250	1	U
Trichlorofluoromethane	0.250	1.00	0.250	1	U
1,2,3-Trichloropropane	0.750	1.00	0.750	1	U
1,2,4-Trimethylbenzene	0.250	1.00	0.250	1	U
1,3,5-Trimethylbenzene	0.250	1.00	0.250	1	U
Vinyl acetate	2.50	10.0	2.50	1	U
Vinyl chloride	0.250	1.00	0.250	1	U
o-Xylene	0.250	1.00	0.250	1	U
m-,p-Xylene	0.500	1.00	0.500	1	U

Surrogates	% Recovery	Surrogate Limits	Qualifier
Dibromofluoromethane	91.4	86 - 118	PASS
1,2-Dichloroethane-d4	95.7	80 - 120	PASS
Toluene-d8	106	88 - 110	PASS
4-Bromofluorobenzene	109	86 - 115	PASS

\* Analyte detected above RDL  
ND Analyte Not detected at or above reporting limit

KEMRON ENVIRONMENTAL SERVICES  
LABORATORY CONTROL SAMPLES

Login Number: L0312394 Analyst: CMS Prep Method: 5030B  
Instrument ID: HPMS6 Matrix: Water Method: 8260B  
Workgroup (AAB#): WQ157257 Units: ug/L  
Sample ID: WQ157257-02 LCH File ID: 6M41745 Run Date: 12/19/2003 14:16  
Sample ID: WQ157257-03 LCH2 File ID: 6M41746 Run Date: 12/19/2003 14:48

Analytes	LCS			LC92			RPD	%Rec Limits	RPD Limit	Q
	Known	Found	% REC	Known	Found	% REC				
Acetone	20.0	20.5	102	20.0	20.5	103	1.83	40 - 142	63	
Benzene	20.0	20.4	102	20.0	21.1	105	3.29	80 - 121	21	
Bromobenzene	20.0	20.2	101	20.0	20.6	103	1.59	80 - 120	18	
Bromochloromethane	20.0	21.6	108	20.0	21.9	110	1.64	80 - 124	20	
Bromodichloromethane	20.0	22.5	112	20.0	22.7	114	1.12	80 - 131	25	
Bromoform	20.0	22.0	110	20.0	22.4	112	1.79	74 - 130	35	
Bromomethane	20.0	18.4	91.8	20.0	18.7	93.5	1.78	61 - 151	56	
2-Butanone	20.0	24.1	120	20.0	23.1	115	4.21	58 - 149	56	
n-Butylbenzene	20.0	19.2	95.9	20.0	19.7	98.4	2.57	80 - 131	29	
sec-Butylbenzene	20.0	19.6	98.0	20.0	20.3	101	3.47	80 - 127	28	
tert-Butylbenzene	20.0	19.1	95.4	20.0	19.4	97.1	1.68	80 - 126	27	
Carbon disulfide	20.0	21.6	108	20.0	22.9	115	5.8	58 - 138	49	
Carbon tetrachloride	20.0	20.4	102	20.0	21.1	105	3.51	80 - 137	32	
Chlorobenzene	20.0	20.1	101	20.0	20.7	104	2.96	80 - 120	16	
Chlorodibromomethane	20.0	21.4	107	20.0	22.0	110	2.5	80 - 127	26	
Chloroethane	20.0	18.9	94.3	20.0	19.5	97.7	3.57	77 - 133	34	
2-Chloroethyl vinyl ether	20.0	28.0	140	20.0	29.3	146	4.31	10 - 211	125	
Chloroform	20.0	19.8	98.9	20.0	20.4	102	3.02	80 - 125	23	
Chloromethane	20.0	18.3	91.5	20.0	18.9	94.5	3.19	60 - 130	43	
2-Chlorotoluene	20.0	21.1	106	20.0	21.1	106	0.067	80 - 127	28	
4-Chlorotoluene	20.0	20.4	102	20.0	21.2	106	4.14	80 - 126	26	
1,2-Dibromo-3-chloropropane	20.0	22.0	110	20.0	21.5	108	2.29	65 - 129	39	
1,2-Dibromoethane	20.0	22.4	112	20.0	22.4	112	0.236	80 - 125	20	
Dibromomethane	20.0	21.6	108	20.0	22.2	111	2.62	80 - 126	24	
1,2-Dichlorobenzene	20.0	20.1	100	20.0	20.4	102	1.72	80 - 125	15	
1,3-Dichlorobenzene	20.0	19.7	98.3	20.0	20.0	100	1.95	80 - 120	16	
1,4-Dichlorobenzene	20.0	19.4	96.9	20.0	19.7	98.6	1.78	80 - 120	15	
Dichlorodifluoromethane	20.0	17.3	86.4	20.0	17.7	88.6	2.62	50 - 133	51	
1,1-Dichloroethane	20.0	20.2	101	20.0	20.6	104	2.8	60 - 126	21	
1,2-Dichloroethane	20.0	22.5	112	20.0	22.6	113	0.631	80 - 129	29	
1,1-Dichloroethene	20.0	20.7	104	20.0	21.8	109	4.97	80 - 132	26	
cis-1,2-Dichloroethene	20.0	20.2	101	20.0	20.6	103	2.12	80 - 121	19	
trans-1,2-Dichloroethene	20.0	20.3	101	20.0	20.9	104	2.96	80 - 127	24	
1,2-Dichloropropane	20.0	20.5	103	20.0	21.5	107	4.53	80 - 130	20	
1,3-Dichloropropane	20.0	21.7	109	20.0	22.0	110	1.04	80 - 120	20	
2,2-Dichloropropane	20.0	21.0	105	20.0	21.6	108	2.74	80 - 133	29	
cis-1,3-Dichloropropene	20.0	23.8	119	20.0	24.3	122	2.13	80 - 132	26	
trans-1,3-Dichloropropene	20.0	22.3	112	20.0	22.6	113	1.43	80 - 130	25	
1,1-Dichloropropene	20.0	21.1	105	20.0	21.6	108	2.61	74 - 139	40	
Ethylbenzene	20.0	20.2	101	20.0	20.6	103	1.96	80 - 122	20	

KEMRON FORMS - Modified 10/24/2003

Version 1.2

Report generated 12/19/2003 14:33

KEMRON ENVIRONMENTAL SERVICES  
LABORATORY CONTROL SAMPLES

Login Number: L0312394      Analyst: CMS      Prep Method: 5030B  
 Instrument ID: HPMS6      Matrix: Water      Method: 8260B  
 Workgroup (AAB#): WQ157257      Units: ug/L  
 Sample ID: WQ157257-02 LCS      File ID: 6M41745      Run Date: 12/19/2003 14:16  
 Sample ID: WQ157257-03 LCS2      File ID: 6M41746      Run Date: 12/19/2003 14:48

Analytes	LCS			LCS2			%RPD	%Rec Limits	RPD Limit	Q
	Known	Found	% REC	Known	Found	% REC				
2-Hexanone	20.0	24.0	120	20.0	24.6	123	2.21	56 - 136	49	
Hexachlorobutadiene	20.0	16.3	81.5	20.0	16.4	82.1	.734	72 - 132	36	
Isopropylbenzene	20.0	20.9	104	20.0	21.6	108	3.54	80 - 122	24	
p-Isopropyltoluene	20.0	19.7	98.3	20.0	20.3	101	3.04	80 - 122	24	
4-Methyl-2-pentanone	20.0	26.7	133	20.0	28.0	140	4.97	64 - 140	47	
Methylene chloride	20.0	20.0	100	20.0	20.4	102	2.01	80 - 123	22	
Naphthalene	20.0	19.6	98.0	20.0	20.1	101	2.79	59 - 149	55	
n-Propylbenzene	20.0	20.8	104	20.0	21.2	106	1.73	80 - 129	27	
Styrene	20.0	21.4	107	20.0	22.0	110	2.58	80 - 123	20	
1,1,1,2-Tetrachloroethane	20.0	24.1	120	20.0	24.3	121	.862	80 - 130	25	
1,1,2,2-Tetrachloroethane	20.0	21.6	108	20.0	21.7	109	.649	79 - 125	28	
Tetrachloroethane	20.0	19.3	96.7	20.0	20.0	100	3.55	80 - 124	22	
Toluene	20.0	20.4	102	20.0	21.0	105	2.86	80 - 124	22	
1,2,3-Trichlorobenzene	20.0	18.7	93.7	20.0	19.4	96.8	3.2	62 - 140	48	
1,2,4-Trichlorobenzene	20.0	18.5	92.4	20.0	18.8	94.0	1.65	77 - 131	33	
1,1,1-Trichloroethane	20.0	21.7	108	20.0	22.2	111	2.19	80 - 134	28	
1,1,2-Trichloroethane	20.0	21.7	109	20.0	21.9	110	.798	80 - 125	20	
Trichloroethene	20.0	19.3	96.7	20.0	20.3	101	4.73	80 - 122	21	
Trichlorofluoromethane	20.0	18.3	91.3	20.0	18.7	93.7	2.55	62 - 151	55	
2,2,3-Trichloropropane	20.0	22.5	112	20.0	21.6	108	3.79	80 - 126	25	
1,2,4-Trimethylbenzene	20.0	19.5	97.5	20.0	19.9	99.4	1.9	80 - 125	26	
1,3,5-Trimethylbenzene	20.0	20.4	102	20.0	20.9	105	2.41	80 - 127	25	
Vinyl acetate	20.0	28.6	143	20.0	28.6	143	.1	10 - 285	201	
Vinyl chloride	20.0	19.3	96.5	20.0	19.6	97.8	1.3	65 - 140	46	
o-Xylene	20.0	20.2	101	20.0	20.8	104	2.61	80 - 123	18	
m-,p-Xylene	40.0	40.8	102	40.0	41.7	104	2.27	80 - 122	21	

Surrogates	LCS	LCS2	Surrogate Limits	Qualifier
	% Recovery	% Recovery		
Dibromofluoromethane	94.4	94.2	86 - 118	PASS
1,2-Dichloroethane-d4	97.8	96.7	80 - 120	PASS
Toluene-d8	91.5	90.4	88 - 110	PASS
4-Bromofluorobenzene	95.7	96.6	86 - 115	PASS

FAILS %REC LIMIT

FAILS RPD LIMIT

KEMRON FORMS - Modified 10/24/2003

Version 1.2

Report generated 12/29/2003 14:33

## **Appendix C**

### **Laboratory Organic Analyses for Bench-Scale Testing Involving the Granular Iron Technology**

Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

	PV	RN	Influent	Organic Concentration ( µg/L )							Effluent	HL	r2
CTET	4.3	a	80	nd	nd	nd	nd	nd	nd	nd	nd		
	9.8	a	63	nd	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	64	nd	nd	nd	nd	nd	nd	nd	nd		
	20.4	a	64	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	47	nd	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	42	nd	nd	nd	nd	nd	nd	nd	nd	0.3	1.000
	40.2	b	42	nd	nd	nd	nd	nd	nd	nd	nd	0.3	1.000
	43.7	c	57	nd	nd	nd	nd	nd	nd	nd	nd	0.3	1.000
	48.9	c	55	nd	nd	nd	nd	nd	nd	nd	nd	0.3	1.000
TCM	4.3	a	398	3.2	nd	nd	nd	nd	nd	nd	nd		
	9.8	a	413	23	6.3	nd	nd	nd	nd	nd	nd		
	12.8	a	442	21	1.9	nd	nd	nd	nd	8.0	nd		
	20.4	a	425	47	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	350	76	2.5	nd	nd	nd	nd	nd	nd		
	35.6	b	433	125	8.2	nd	nd	nd	nd	nd	nd	0.8	0.996
	40.2	b	408	135	23	nd	nd	nd	nd	nd	nd	0.9	0.997
	43.7	c	491	160	35	nd	nd	nd	nd	nd	nd	0.9	0.962
	48.9	c	502	205	47	2.7	nd	nd	nd	nd	nd	1.1	0.995
1122TECA	4.3	a	525	4.0	nd	nd	nd	nd	60	nd	nd		
	9.8	a	540	22	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	527	27	1.2	nd	nd	nd	nd	nd	nd		
	20.4	a	496	68	1.9	nd	nd	nd	nd	nd	nd		
	25.7	b	499	116	6.2	nd	19	nd	nd	nd	nd		
	35.6	b	526	216	22	nd	nd	nd	nd	nd	nd	1.1	0.978
	40.2	b	449	222	38	nd	nd	nd	nd	nd	nd	1.3	0.967
	43.7	c	491	241	52	1.4	nd	nd	nd	nd	nd	1.3	0.983
	48.9	c	496	289	84	nd	nd	nd	nd	nd	nd	1.5	0.973

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

	PV	RN	Influent	Organic Concentration ( µg/L )							Effluent	HL	r2
111TCA	4.3	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	9.8	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	20.4	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	40.2	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	48.9	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
112TCA	4.3	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	9.8	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	20.4	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	40.2	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	48.9	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
PCE	4.3	a	2.5	nd	nd	nd	nd	nd	nd	nd	nd		
	9.8	a	2.3	nd	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	2.3	nd	nd	nd	nd	nd	nd	nd	nd		
	20.4	a	1.9	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	2.9	nd	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	2.9	nd	nd	nd	nd	nd	nd	nd	nd		
	40.2	b	3.1	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	3.6	nd	nd	nd	nd	nd	nd	nd	nd		
	48.9	c	3.2	nd	nd	nd	nd	nd	nd	nd	nd		

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

	PV	RN	Influent		Organic Concentration ( µg/L )					Effluent		HL	r2
TCE	4.3	a	776	18	nd	nd	6.1	nd	26	nd	nd		
	9.8	a	757	103	1.8	nd	nd	nd	nd	nd	nd		
	12.8	a	759	111	2.0	nd	nd	nd	nd	15	2.3		
	20.4	a	693	204	4.5	nd	nd	nd	nd	nd	nd		
	25.7	b	750	370	14	nd	nd	nd	nd	nd	nd		
	35.6	b	752	514	58	nd	nd	nd	nd	nd	nd	1.5	0.908
	40.2	b	686	508	105	nd	nd	nd	nd	nd	nd	1.8	0.851
	43.7	c	796	566	141	1.2	nd	nd	nd	nd	nd	1.7	0.983
	48.9	c	788	635	203	nd	nd	nd	nd	nd	nd	2.0	0.905
cDCE	4.3	a	56	170	170	80	nd	nd	nd	nd	nd		
	9.8	a	36	131	85	79	70	30	nd	nd	nd		
	12.8	a	37	120	81	77	58	21	nd	nd	nd		
	20.4	a	37	112	85	40	28	16	7.5	nd	nd		
	25.7	b	18	97	72	20	10	9.8	nd	nd	nd		
	35.6	b	23	76	152	28	9.1	nd	nd	nd	nd	2.3	0.701
	40.2	b	28	60	142	37	11	nd	nd	nd	nd	2.4	0.639
	43.7	c	40	119	158	93	11	3.1	nd	nd	nd	3.1	0.888
	48.9	c	41	95	156	88	12	3.1	nd	nd	nd	2.4	0.855
tDCE	4.3	a	6.7	21	6.8	nd	nd	nd	nd	nd	nd		
	9.8	a	4.6	24	4.8	nd	nd	nd	nd	nd	nd		
	12.8	a	4.6	23	3.1	nd	nd	nd	nd	nd	nd		
	20.4	a	6.5	27	6.3	nd	nd	nd	nd	nd	nd		
	25.7	b	3.2	26	9.0	nd	nd	nd	nd	nd	nd		
	35.6	b	6.1	21	22	nd	nd	nd	nd	nd	nd	1.5	0.899
	40.2	b	4.8	18	24	nd	nd	nd	nd	nd	nd	1.5	0.804
	43.7	c	8.6	22	21	nd	nd	nd	nd	nd	nd	1.2	0.924
	48.9	c	5.6	22	26	2.5	nd	nd	nd	nd	nd	1.2	0.857

PV = pore volume  
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Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

	PV	RN	Influent	Organic Concentration ( µg/L )							Effluent	HL	r2
11DCE	4.3	a	nd	1.4	4.0	1.6	nd	nd	nd	nd	nd		
	9.8	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	12.8	a	nd	nd	nd	nd	nd	nd	nd	5.5	nd		
	20.4	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	nd	2.4	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	40.2	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	48.9	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
VC	4.3	a	nd	2.5	16	nd	nd	nd	nd	nd	nd		
	9.8	a	nd	nd	nd	2.7	nd	3.7	nd	nd	nd		
	12.8	a	nd	nd	nd	nd	5.6	7.8	nd	3.9	nd		
	20.4	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	25.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	35.6	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	40.2	b	nd	nd	nd	3.9	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	48.9	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
DCM	45.1	c	nd	25	41	48	48	49	44	44	40		
	47.1	c	nd	20	48	52	52	52	50	44	39		
11DCA	45.1	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	47.1	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
12DCA	45.1	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	47.1	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		

PV = pore volume  
RN = reservoir number  
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r2 = coefficient of determination  
nd = not detected  
na = not applicable



Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

PV	RN	Influent		Organic Concentration ( µg/L )						Effluent	HL	r2
Nitrate (NO3-N)												
12.1	a	4.0	0.2	nd	nd	nd	na	na	na	na		
13.5	a	3.9	0.2	nd	nd	nd	nd	nd	nd	nd		
24.3	b	3.8	0.2	nd	nd	nd	na	na	na	na		
24.9	b	3.7	0.1	nd	nd	nd	nd	nd	nd	nd		
34.8	b	3.7	0.5	nd	nd	nd	nd	nd	nd	nd		
41.5	b	3.9	1.2	nd	nd	nd	nd	na	nd	nd		
49.5	c	4.3	1.4	0.1	nd	nd	nd	nd	nd	nd		
Chloride (Cl-)												
13.5	a	12	13	14	13	14	13	14	15	14		
24.9	b	13	14	14	15	14	14	14	15	15		
34.8	b	13	13	14	14	14	15	14	14	14		
41.5	b	12	13	13	14	14	14	na	15	14		
49.5	c	14	14	15	15	15	16	15	16	16		
Sulphate (SO4=)												
41.5	b	18	18	17	17	16	16	na	17	18		
49.5	c	19	19	19	18	17	17	17	17	19		

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RN = reservoir number  
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nd = not detected  
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Treatability Test  
CH2M Hill MW-54

Column Identification: 563  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 296 mL  
Porosity: 0.52  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 1.2 ft/day (36 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	1.6	3.2	6.6	10.0	13.2	20.0	26.2	32.8

PV	RN	Influent	Organic Concentration ( µg/L )							Effluent	HL	r2
pH Values												
3.7	a	6.6	8.7	9.0	9.2	9.2	9.2	9.1	9.2	9.0		
8.1	a	6.7	8.5	8.73	9.0	9.1	9.4	9.3	9.5	9.2		
13.5	a	7.2	8.6	8.8	9.2	9.2	9.3	9.5	9.3	9.3		
18.8	a	7.6	8.8	8.8	9.1	9.2	9.3	9.5	9.6	9.5		
28.7	b	6.8	8.5	8.7	8.9	9.1	9.2	9.4	9.8	9.4		
34.8	b	7.1	8.7	8.8	8.9	9.1	9.1	9.3	9.7	9.5		
40.8	b	7.2	8.7	8.8	8.9	8.8	9.1	9.3	9.6	9.7		
44.3	c	6.6	8.2	8.5	9.0	9.0	9.2	9.3	9.6	9.7		
49.5	c	6.9	8.2	8.8	8.8	9.0	9.0	9.2	9.4	9.6		
58.5	d	6.8	7.3	8.4	8.5	8.5	8.7	9.0	9.1	9.5		

Eh (mV)												
3.7	a	257	-197	-156	-132	-189	-124	-116	-149	-91		
8.1	a	359	-14	-36	35	-253	-195	-448	-231	-287		
13.5	a	349	-26	-29	-176	-154	-251	-311	-422	-118		
18.8	a	313	50	-281	-336	-113	-292	-260	-304	-380		
28.7	b	312	2	-229	-207	-267	-274	-274	-366	-405		
34.8	b	262	72	-147	-256	-188	-256	-221	-366	-226		
40.8	b	350	54	-217	-234	-181	-171	-306	-326	-256		
44.3	c	324	26	-297	-399	-308	-479	-508	-536	-414		
49.5	c	321	94	-225	-211	-299	-256	-291	-377	-443		
58.5	d	274	59	-146	-213	-284	-226	-353	-326	-340		

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

eof//

Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

	PV	RN	Influent		Organic Concentration ( µg/L )						Effluent	HL	r2
CTET	4.0	a	1.1	nd	nd	nd	nd	nd	nd	nd	nd		
	9.9	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	16.1	a	4.8	nd	nd	nd	nd	nd	nd	nd	nd		
	20.1	b	1.5	nd	nd	nd	nd	nd	nd	nd	nd		
	30.7	b	3.2	nd	nd	nd	nd	nd	nd	nd	nd		
	33.3	b	5.1	nd	nd	nd	nd	nd	nd	nd	nd		
	37.0	b	6.2	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	2.8	nd	nd	nd	nd	nd	nd	nd	nd		
TCM	4.0	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	9.9	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	16.1	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	20.1	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	30.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	33.3	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	37.0	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
1122TECA	4.0	a	11249	101	1.4	9.5	nd	nd	nd	nd	nd		
	9.9	a	21238	3112	140	nd	nd	nd	nd	nd	nd		
	16.1	a	18966	2197	204	nd	nd	nd	nd	nd	nd		
	20.1	b	20211	9658	895	6.5	nd	nd	nd	nd	nd		
	27.7	b	23328	1989	117	0.9	nd	nd	nd	nd	nd		
	30.7	b	20888	1549	339	3.2	nd	nd	nd	nd	nd	0.6	0.999
	33.3	b	18228	5064	879	nd	nd	nd	nd	nd	nd	1.2	0.999
	37.0	b	19529	7231	535	1.3	nd	nd	nd	nd	nd	1.4	0.987
	43.7	c	22145	7179	892	18	nd	nd	nd	nd	nd	1.3	0.995

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

	PV	RN	Influent		Organic Concentration ( µg/L )						Effluent	HL	r2
111TCA	4.0	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	9.9	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	16.1	a	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	20.1	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	27.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	30.7	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	33.3	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	37.0	b	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	43.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd		
112 TCA	4.0	a	9.9	26	7.1	nd	nd	nd	nd	nd	nd		
	9.9	a	19	76	38	nd	nd	nd	nd	nd	nd		
	16.1	a	10	51	34	5.4	nd	nd	nd	nd	nd		
	20.1	b	10	52	45	9.5	nd	nd	nd	nd	nd		
	27.2	b	12	59	19	3.9	nd	nd	nd	nd	nd		
	30.7	b	11	50	36	11	nd	nd	nd	nd	nd	3.1	0.889
	33.3	b	12	47	41	11	nd	nd	nd	nd	nd	2.6	0.985
	37.0	b	12	42	20	1.0	nd	nd	nd	nd	nd	0.8	0.839
	43.7	c	11	66	50	19	nd	nd	nd	nd	nd	2.5	0.997
PCE	4.0	a	12	nd	nd	nd	nd	nd	nd	nd	nd		
	9.9	a	31	4.8	nd	nd	nd	nd	nd	nd	nd		
	16.1	a	37	nd	nd	nd	nd	nd	nd	nd	nd		
	20.1	b	35	15	2.5	nd	nd	nd	nd	nd	nd		
	27.7	b	39	16	4.1	nd	nd	nd	nd	nd	nd		
	30.7	b	50	18	8.3	nd	nd	nd	nd	nd	nd		
	33.3	b	51	24	9.2	nd	nd	nd	nd	nd	nd	1.9	0.997
	37.0	b	51	32	8.2	nd	nd	nd	nd	nd	nd	2.3	0.936
	42.4	c	48	23	21	nd	nd	nd	nd	nd	nd	2.7	0.945
	43.7	c	48	33	16	nd	nd	nd	nd	nd	nd	2.9	0.968

PV = pore volume  
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Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

	PV	RN	Influent		Organic Concentration ( µg/L )					Effluent		HL	r2
TCE	4.0	a	2969	411	16	6.0	nd	16	nd	nd	nd		
	9.9	a	3253	1592	146	2.0	1.6	1.7	1.4	1.7	2.4		
	16.1	a	2796	849	246	nd	nd	nd	nd	nd	nd		
	20.1	b	3375	1733	633	nd	nd	nd	nd	nd	nd		
	27.7	b	3335	1189	297	3.1	nd	nd	nd	nd	nd		
	30.7	b	3235	1115	564	7.9	nd	nd	nd	nd	nd	1.6	0.996
	33.3	b	3285	1682	571	nd	nd	nd	nd	nd	nd	2.0	0.989
	37.0	b	3415	1903	294	5.0	nd	nd	nd	nd	nd	1.9	0.960
	43.7	c	3176	2162	982	16	2.5	nd	nd	nd	nd	2.7	0.973
cDCE	4.0	a	175	2013	1951	1684	1625	963	nd	nd	nd		
	9.9	a	137	4836	4908	3548	3012	1060	1522	309	nd		
	16.1	a	136	2934	3120	1714	1379	1358	575	140	77		
	20.1	b	112	2701	3155	2564	910	385	131	87	17		
	27.7	b	151	1897	2641	1164	314	201	51	44	21		
	30.7	b	108	3320	3134	1922	536	131	23	25	19	5.1	0.972
	33.3	b	169	3317	3859	676	252	112	18	17	11	2.7	0.947
	43.7	c	177	3636	3685	2404	638	91	5.3	nd	nd	4.1	0.976
tDCE	4.0	a	28	820	705	339	12	1.3	nd	nd	nd		
	9.9	a	18	766	1172	102	94	16	nd	nd	nd		
	16.1	a	15	912	672	76	13	nd	nd	nd	nd		
	20.1	b	16	937	780	134	nd	nd	nd	nd	nd		
	27.7	b	20	925	437	29	5.9	nd	nd	nd	nd		
	30.7	b	12	864	714	97	1.6	nd	nd	nd	nd	2.8	0.96
	33.3	b	16	969	729	17	nd	nd	nd	nd	nd	1.6	0.973
	43.7	c	21	1434	1075	272	7.3	nd	nd	nd	nd	2.5	0.998

PV = pore volume  
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HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
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Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

	PV	RN	Influent	Organic Concentration ( µg/L )								Effluent	HL	r2
11DCE	4.0	a	nd	9.3	7.8	5.8	2.0	nd	nd	nd	nd			
	9.9	a	nd	6.0	4.1	nd	nd	2.1	nd	nd	nd			
	16.1	a	nd	8.9	3.1	nd	nd	nd	nd	nd	nd			
	20.1	b	nd	4.7	1.4	nd	1.7	nd	nd	nd	nd			
	27.7	b	nd	nd	nd	nd	nd	nd	nd	4.1	nd			
	30.7	b	nd	nd	2.3	nd	4.4	nd	nd	nd	nd			
	33.3	b	nd	nd	nd	nd	nd	nd	nd	nd	nd			
	43.7	c	nd	nd	nd	3.1	nd	nd	nd	nd	nd			
VC	4.0	a	nd	63	88	95	118	97	35	nd	nd			
	9.9	a	nd	22	81	44	85	77	76	44	12			
	16.1	a	nd	40	36	75	69	52	37	13	14			
	20.1	b	nd	33	24	79	43	31	5.3	nd	nd			
	27.7	b	nd	34	82	49	17	11	nd	nd	nd			
	30.7	b	nd	46	52	49	26	23	nd	nd	nd	1.8	0.919	
	33.3	b	nd	30	44	18	15	5.9	9.6	nd	nd	1.1	0.873	
	43.7	c	nd	44	84	106	56	15	nd	nd	nd	2.4	0.941	
DCM	37.0	b	na	0.7	1.4	na	nd	nd	nd	0.8	2.5			
	41.7	c	nd	nd	1.4	3.1	4.8	2.1	1.1	8.3	nd			
11DCA	37.0	b	na	nd	nd	na	nd	nd	nd	nd	nd			
	41.7	c	nd	nd	nd	nd	nd	nd	nd	nd	nd			
12DCA	37.0	b	na	2.2	1.9	na	1.5	1.4	2.4	1.5	1.5			
	41.7	c	nd	nd	1.3	1.8	2.3	1.8	nd	1.5	1.2			

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connelly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

PV	RN	Influent		Organic Concentration ( µg/L )						Effluent		HL	r2
Nitrate (NO3-N)													
9.2	a	4.0	0.5	0.2	nd	nd	na	na	na	na			
10.6	a	3.0	0.3	0.1	0.1	nd	nd	nd	0.1	nd			
18.7	b	3.0	nd	nd	nd	nd	na	na	na	na			
19.3	b	2.9	nd	0.1	nd	nd	nd	nd	nd	nd			
27.0	b	2.4	nd	nd	nd	nd	nd	nd	nd	nd			
32.0	b	2.5	nd	nd	nd	nd	nd	nd	nd	nd			
37.6	b	2.7	nd	nd	nd	nd	nd	nd	nd	nd			
Chloride (Cl-)													
10.6	a	24	36	34	34	34	34	36	38	41			
19.3	b	29	37	35	41	38	39	36	42	41			
27.0	b	25	35	37	46	42	41	40	1.9	40			
32.0	b	25	35	37	40	41	40	39	41	39			
37.6	b	26	34	36	39	39	38	37	45	53			
Sulphate (SO4-)													
32.0	b	27	28	27	27	27	27	29	28	30			
37.6	b	28	28	27	28	28	28	31	21	26			

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

Treatability Test  
CH2M Hill MW-77

Column Identification: 564  
Column Composition: 100% Connolly (UW #255) 18/84  
Pore Volume (PV): 289 mL  
Porosity: 0.51  
Column Length: 1.6 ft (50 cm)  
Column Diameter: 1.5 in (3.8 cm)  
Flow Velocity: 0.86 ft/day (26 cm/day)  
Column Temp: 18°C (64°F)

Column Distance (ft)	0.0	0.08	0.16	0.33	0.50	0.66	1.0	1.3	1.6
Residence Time (hr)	0.0	2.2	4.5	9.2	14.0	18.4	27.9	36.6	45.8

PV	RN	Influent	Organic Concentration ( µg/L )							Effluent	HL	r2
pH Values												
3.5	a	6.7	8.8	9.0	9.2	9.3	9.2	9.1	9.2	8.8		
6.1	a	6.8	8.6	8.9	9.1	9.3	9.4	9.4	9.3	9.2		
10.6	a	7.0	8.5	8.7	9.1	9.2	9.4	9.2	9.1	9.1		
14.5	a	7.0	8.5	8.6	9.1	9.3	9.5	9.5	9.6	9.2		
22.3	b	6.5	8.2	8.6	8.8	9.1	9.2	9.5	9.5	9.0		
27.0	b	6.7	8.5	8.7	8.9	9.2	9.1	9.4	9.5	9.0		
31.3	b	6.7	8.7	8.9	8.8	9.0	9.1	9.3	9.7	9.5		
34.0	b	6.6	8.6	9.0	9.1	9.2	9.6	9.9	8.8	9.4		
37.6	b	7.3	8.7	8.8	8.9	9.0	9.0	9.3	9.5	9.5		
Eh (mV)												
3.5	a	278	-156	-45	-131	-139	-187	-46	-231	-36		
6.1	a	351	82	45	-96	-33	-362	-329	-411	-236		
10.6	a	338	-52	-33	-36	-152	-250	-95	-246	-226		
14.5	a	329	-75	-197	-291	-146	-336	-360	-402	-278		
22.3	b	319	-242	-98	-193	-238	-295	-326	-317	-200		
27.0	b	315	-226	-217	-219	-181	-236	-157	-261	-178		
31.3	b	351	-266	-184	-110	-252	-242	-272	-347	-250		
34.0	b	322	-127	-63	-290	-308	-368	-318	-397	-267		
37.6	b	330	-181	-162	-238	-221	-275	-292	-301	-366		

PV = pore volume  
RN = reservoir number  
HL = half life (hours)  
r2 = coefficient of determination  
nd = not detected  
na = not applicable

eof//



## **Appendix D**

### **Laboratory Inorganic Analyses for Bench-Scale Testing Involving the Granular Iron Technology**

Jan 17 2004 4:49PM Groundwater Lab

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P.3

Jan-16-04 04:28pm From-PHILP SERVICES CORP.

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T-011 P.001/007 T-675

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## Water Samples

Sample Id	Ag ICAP mg/L	Al ICAP mg/L	B ICAP mg/L	Ba ICAP mg/L	Pb ICAP mg/L	Bi ICAP mg/L	Ca ICAP mg/L	Cd ICAP mg/L
UW-654 563 in	<0.005	<0.05	0.01	0.134	<0.0005	<0.2	16.7	<0.005
UW-655 564 in	<0.005	<0.05	0.01	0.092	<0.0005	<0.2	19.7	<0.005
UW-656 563 64 43.7 PV	<0.005	<0.05	0.13	0.010	<0.0005	<0.2	10.1	<0.005
UW-657 564 64 34.1 PV	<0.005	<0.05	0.21	0.012	<0.0005	<0.2	11.3	<0.005
UW-658 563 64 48.9 PV	<0.005	<0.05	0.12	0.009	<0.0005	<0.2	9.58	<0.005
UW-659 563 in	<0.005	<0.05	0.02	0.134	<0.0005	<0.2	16.7	<0.005
UW-660 564 64 40.3	<0.005	<0.05	0.18	0.011	<0.0005	<0.2	12.6	<0.005
UW-661 564 in	<0.005	<0.05	0.01	0.092	<0.0005	<0.2	19.9	<0.005
Blank	<0.005	<0.05	<0.01	<0.005	<0.0005	<0.2	<0.05	<0.005
QC Standard (found)	0.028	10.0	0.20	0.966	1.00	0.9	49.3	0.976
QC Standard (expected)	0.030	10.0	0.20	1.00	1.00	1.0	51.0	1.00
Repeat UW-654	<0.005	<0.05	<0.01	0.134	<0.0005	<0.2	16.7	<0.005



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## Water Samples

Sample Id	Co ICAP mg/L	Cr ICAP mg/L	Cu ICAP mg/L	Fe ICAP mg/L	K ICAP mg/L	Mg ICAP mg/L	Mn ICAP mg/L	Mo ICAP mg/L
UW-654 573 In	0.012	<0.005	<0.005	0.61	<1	8.30	0.012	0.04
UW-655 564 In	<0.005	<0.005	<0.005	<0.01	<1	10.9	<0.005	<0.02
UW-656 573 Eff 43.7 PV	<0.005	<0.005	<0.005	0.01	1	0.07	<0.005	0.07
UW-657 564 Eff 36.1 PV	<0.005	<0.005	<0.005	0.02	1	0.14	<0.005	0.04
UW-658 563 Eff 48.9 PV	<0.005	<0.005	<0.005	0.01	<1	0.07	<0.005	0.05
UW-659 573 In	<0.005	<0.005	<0.005	<0.01	<1	8.33	<0.005	<0.02
UW-660 564 Eff 40.3 PV	<0.005	<0.005	<0.005	0.01	1	0.10	<0.005	0.06
UW-661 574 In	<0.005	<0.005	<0.005	0.01	<1	10.9	<0.005	<0.02
Blank	<0.005	<0.005	<0.005	<0.01	<1	<0.05	<0.005	<0.02
QC Standard (found)	0.989	1.00	1.01	0.93	10	10.7	0.999	1.06
QC Standard (expected)	1.00	1.00	1.00	1.00	10	11.0	1.00	1.10
Repeat UW-654	<0.005	<0.005	<0.005	0.01	<1	8.31	<0.005	<0.02



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p.5

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T-011 P.003/007 F-575

Water Samples

Sample Id	Na ICAP mg/L	Ni ICAP mg/L	P ICAP mg/L	Si ICAP mg/L	Sn ICAP mg/L	Sr ICAP mg/L	Ti ICAP mg/L	V ICAP mg/L
UW-654 823 in	17.1	<0.02	<0.1	17.4	<0.05	0.125	<0.005	<0.005
UW-655 564 in	35.8	<0.02	<0.1	16.8	<0.05	0.066	<0.005	<0.005
UW-656 563 eff 43.7PV	17.9	<0.02	<0.1	0.67	<0.05	0.074	<0.005	<0.005
UW-657 524 eff 34.1PV	36.6	<0.02	<0.1	0.67	<0.05	0.059	<0.005	<0.005
UW-658 563 eff 48.9PV	17.8	<0.02	<0.1	0.73	<0.05	0.075	<0.005	<0.005
UW-659 563 in	17.2	<0.02	<0.1	17.4	<0.05	0.125	<0.005	<0.005
UW-660 564 eff 40.3PV	36.1	<0.02	<0.1	0.61	<0.05	0.070	<0.005	<0.005
UW-661 564 in	35.4	<0.02	<0.1	16.6	<0.05	0.066	<0.005	<0.005
Blank	<0.1	<0.02	<0.1	<0.05	<0.05	<0.001	<0.005	<0.005
QC Standard (found)	48.1	0.98	1.9	2.06	0.88	0.925	0.970	0.988
QC Standard (expected)	50.0	1.00	2.0	2.00	1.00	1.00	1.00	1.00
Repeat UW-654	17.2	<0.02	<0.1	17.4	<0.05	0.125	<0.005	<0.005

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## Water Samples

Sample Id	Zn ICAP mg/L	Cl- SM 4110B mg/L	NO2-N SM 4110B mg/L	PO4-3 SM 4110B mg/L	NO3-N SM 4110B mg/L	SO4- SM 4110B mg/L	pH	Alk 4.2 SM 2320B mg CaCO3/L
DW-654 563 1m	0.008	13.6	<0.2	<1	3.7	16.8	7.03	64
DW-655 564 1m	<0.005	25.0	<0.2	<1	2.4	25.3	7.35	103
DW-656 563 4m	0.037	14.8	<0.2	<1	<0.2	17.4	10.1	31
DW-657 564 4m	0.005	42.4	<0.2	<1	<0.2	29.0	9.91	20
DW-658 563 4m	0.015	14.8	<0.2	<1	<0.2	17.3	10.3	31
DW-659 563 1m	0.006	13.1	<0.2	<1	3.6	16.5	7.25	65
DW-660 564 4m	<0.005	41.9	<0.2	<1	<0.2	27.4	9.88	22
DW-661 564 1m	0.006	25.3	<0.2	<1	2.4	25.9	7.69	101
Blank	<0.005	<0.5	<0.2	<1	<0.2	<0.5	---	<1
QC Standard (found)	0.993	20.4	10.4	49	9.9	49.0	7.02	258
QC Standard (expected)	1.00	20.0	10.0	50	10.0	50.0	7.00	250
Repeat DW-654	0.007	13.6	<0.2	<1	3.7	17.2	7.01	65

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## Water Samples

Sample Id	NH3-N SM 4500H SM 5310C mg/L	DOC mg/L	Th. TDS Calc. mg/L	pHs Calc. pH Units	Cation Sum Calc. eq/L	Anion Sum Calc. eq/L	CAB Calc. %
UW-654 563 In	<0.03	0.6	112	8.35	2.29	2.28	-0.32
UW-655 564 In	0.04	2.3	180	8.12	3.47	3.46	-0.14
UW-656 563 Eff 43.7 PV	3.04	1.7	80	8.87	1.54	1.41	-4.33
UW-657 564 Eff 36.1 PV	1.28	2.2	133	9.04	2.29	2.21	-1.73
UW-658 563 Eff 48.9 PV	2.74	1.0	79	8.89	1.48	1.41	-2.38
UW-659 563 In	0.05	<0.2	112	8.35	2.30	2.27	-0.72
UW-660 564 Eff 40.3 PV	1.34	2.3	133	8.95	2.34	2.21	-2.90
UW-661 564 In	0.05	2.5	179	8.12	3.47	3.44	-0.32
Blank	<0.03	<0.2	3	12.6	0.04	0.06	20.6
QC Standard (found)	1.52	4.6	342	7.36	5.79	7.46	12.5
QC Standard (expected)	1.50	5.0	342	7.36	5.99	7.32	9.99
Repeat UW-654	<0.03	0.6	113	8.35	2.29	2.31	0.25

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Water Samples

Sample Id	Hard(Calc) SM 2340B		CO3=		HCO3-		L.I.		Colour		Sp. Cond.		Pb-GFAAS	
	mg	CaCO3/L	Calc.	mg/L	Calc.	mg/L	Calc.	None	SM 2120B	TGU	SM 2510B	umhos/cm	SW 7421	mg/L
UW-654	76.0		1		76		-1.3		8		233		<0.001	
UW-655	94.4		1		123		-0.8		6		336		<0.001	
UW-656	25.6		9		0		1.2		4		167		<0.001	
UW-657	28.9		5		0		0.9		12		256		<0.001	
UW-658	24.2		8		0		1.4		6		162		<0.001	
UW-659	76.2		1		77		-1.1		4		228		<0.001	
UW-660	32.0		7		0		0.9		4		260		<0.001	
UW-661	94.9		1		121		-0.4		4		325		<0.001	
Blank	0.3		nan		nan		nan		<2		<1		<0.001	
QC Standard (found)	167.4		64		54		-0.3		50		719		0.026	
QC Standard (expected)	172.6		75		0		-0.4		50		718		0.025	
Repeat UW-654	76.0		1		77		-1.3		8		234		<0.001	

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Received: 7-Jan-2004 09:26

Job: 2450068

Status: Final

## Water Samples

Sample Id	TOC
	SM 5310C mg/L
UW-654	0.3
UW-655	4.0
UW-656	1.4
UW-657	2.4
UW-658	0.5
UW-659	<0.2
UW-660	2.4
UW-661	6.4
Sample+Spike (found)	5.1
Sample+Spike (expected)	5.1
Blank	<0.2
QC Standard (found)	9.7
QC Standard (expected)	10.0
Repeat UW-654	0.4

All work recorded herein has been done in accordance with normal professional standards using accepted testing methodologies and QA/QC procedures. Philip Analytical is limited in liability to the actual cost of the pertinent analyses done unless otherwise agreed upon by contractual arrangement. Your samples will be retained by PASC for a period of 30 days following reporting or as per specific contractual arrangements.

Job approved by:

Signed:

*[Signature]*  
Ralph J. Robert, B.Sc.  
Section Supervisor, Metals



Feb-20-04 12:00pm From-PHILP SERVICES CORP.

8058808368

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20-Feb-2004

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Attn: Wayne Nobel  
Project:

PO #:

Received: 16-Feb-2004 12:22

Job: 2451079

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## Water Samples

Sample Id	As	
	SW 7061	mg/L
UW-654 563 in		<0.001
UW-655 564 in		<0.001
UW-656 563 Eff 43.7 PV		<0.001
UW-657 564 Eff 36.1 PV		<0.001
UW-658 563 Eff 16.7 PV		<0.001
UW-659 563 in		<0.001
UW-660 564 Eff 40.3 PV		<0.001
UW-661 564 in		<0.001
Sample+Spike (found)		0.015
Sample+Spike (expected)		0.015
Blank		<0.001
QC Standard (found)		0.014
QC Standard (expected)		0.015
Repeat UW-654		<0.001

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Signed:

Malcolm Danziger  
Project Manager

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8058908575

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Job approved by:

Signed:

  
 Robert Siebert, B.Sc.

Section Supervisor, Metals

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# Analytical Method Summary

Parameters	Units	LOQ	Analytical Method	Preservative	Holding Time
RCAP Calculations	Listed below	Listed below	PASC Internal Reference Method		
Total Dissolved Solids(Calculated)	mg/L	1			
Hardness(as CaCO3)	mg/L	0.1			
Bicarbonate(as CaCO3, calculated)	mg/L	1			
Carbonate(as CaCO3, calculated)	mg/L	1			
Cation Sum	meq/L	na			
Anion Sum	meq/L	na			
Saturation pH at 20°C	units	na			
Saturation pH at 4°C	units	na			
Langelier Index at 20°C	na	na			
Langelier Index at 4°C	na	na			
Ion Balance	%	na			
Colour	TCU	3	U.S. EPA Method No. 110.3(Modified)	General (unpreserved)	48 hours
Conductivity - @25°C	uS/cm	1	U.S. EPA Method No. 120.1	General (unpreserved)	28 days
pH	Units	0.01	U.S. EPA Method No. 150.1	General (unpreserved)	
Turbidity	NTU	0.2	U.S. EPA Method No. 180.1	General (unpreserved)	48 hours
	Listed below	Listed below	U.S. EPA Method No. 200.7	Metals (HNO3)	6 months
RCAP 30 Package, ICPAES Scan(Cu,Mn,Fe,Zn,Ca,Mg,Na,K)					
Copper	mg/L	0.005			
Iron	mg/L	0.01			
Manganese	mg/L	0.005			
Zinc	mg/L	0.005			
Calcium	mg/L	0.05			
Magnesium	mg/L	0.05			
Potassium	mg/L	1			
Sodium	mg/L	0.1			
Reactive Silica(SiO2)	mg/L	0.5	Standard Methods(17th ed.) No. 4500-Si G	Metals (HNO3)	
Alkalinity(as CaCO3)	mg/L	1	U.S. EPA Method No. 310.2	General (unpreserved)	14 days
Anions RCAP 30(Cl,NO2+NO3,PO4 & SO4) by IC	Listed below	Listed below	U.S. EPA Method No. 300.0 or U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.	General (unpreserved)	48 hours

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Chloride	mg/L	0.5			
Sulphate	mg/L	0.5			
Orthophosphate(as P)	mg/L	0.3			
Nitrite(as N) and Nitrate(as N)	mg/L	0.2			
Dissolved Organic Carbon(DOC)	mg/L	0.2	MOE Method No. ROM - 102ACE(Modified) Standard Method 5310C	Nutrients(H2SO4)	28 days
Total Organic Carbon(TOC)	mg/L	0.2	MOE Method No. ROM - 102ACE(Modified) Standard Method 5310C	Nutrients(H2SO4)	28 days
Ammonia(as N)	mg/L	0.03	ASTM Method No. D1426-79 C Refer - Method No. 1100106 Issue 122289 Standard Method 4500H	Nutrients(H2SO4)	28 days

## **Magnetic Separation Testing Procedure**

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## Magnetic Separation Testing Procedure

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1. Weigh the empty containers that the samples will be collected in.
2. Samples (approximately 1,000 g) of the iron-sand mixture are collected from the discharge of the mixing device (e.g., chute of a concrete mixer) and/or from the recovered soil core.
3. Dry the sample. If cemented together during drying, lightly breakup, weigh and record the net weight.
4. Weigh the sample (empty container and sample) and record the weight. Determine the net weight of the sample by subtracting the empty sample container weight. A suitable weighing device must be used.
5. Spread the sample out in a suitable container (e.g., bowl, pan, cardboard box, etc.).
6. Cover the magnet in a material (such as a plastic bag) to allow the magnetic material to be easily separated from the magnet.
7. Pass the magnet over the sample to remove the magnetic fraction. Care must be taken to minimize the trapping sand particles within the iron grains. The magnetic fraction is removed from the magnet and placed in a container.
8. Continue passing the magnet over the material until no more magnetic material is removed. Mixing of the non-magnetic fraction between passes may be required to obtain all the magnetic particles.
9. The magnetic fraction may contain some non-magnetic (sand) particles. **Steps 5 to 8** should be repeated at least three more times to completely separate the magnetic and non-magnetic fractions. After each separation, the non-magnetic fraction should be added to the non-magnetic fraction from the previous separation.
10. Weigh the magnetic and non-magnetic fractions and record the results. The total net weight of the magnetic and non-magnetic fractions should be the same as the weight prior to separation.
11. The dry iron net weight percent is calculated as follows:

$$\text{Dry Iron Net Weight Percent} = \frac{\text{Net Weight of Magnetic Material}}{\text{Total Net Weight of Dry Sample}} \times 100$$

Depending on the iron/sand sample moisture content, the estimated time to complete the magnetic separation test is about 15 to 25 minutes.

### **Equipment Required for Magnetic Separation Testing**

- Sample containers
- Balance/Scale capable of weighing a 1 kilogram soil sample to a resolution of 0.5 grams (battery powered scale if electrical outlet is not available)
- Hot plate, if electrical outlet available (or propane camping stove)
- Frying pan (8- or 10 inch)
- Large spoon (metal is better than plastic)
- Disposable aluminum cookie sheet
- Magnet
- Zip top bags (e.g., Ziploc®)
- Permanent ink pen (e.g., Sharpie®)
- Worksheets/Log Book

**FINAL PAGE**

**ADMINISTRATIVE RECORD**

**FINAL PAGE**