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IN REPLY REFER TO

April 29, 2002

MEMORANDUM FOR GREG PARKER (Memphis - Shelby County Health Department, Water Quality Branch)

SUBJECT: Information on Injection Wells Main Installation of the Former Memphis Depot Memphis, Shelby County, Tennessee

As a follow-up to our conversation of Thursday, April 18, 2002, I am providing additional information to your office on several underground injection wells that are being installed as part of the groundwater clean-up action at the Main Installation of the former Memphis Depot. The Base Re-alignment and Closure (BRAC) Cleanup Team (BCT) approved this activity in a Record of Decision (dated September 2001) as part of the response actions being conducted pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The BCT is composed of representatives from the Defense Logistics Agency (DLA), the U.S. Environmental Protection Agency, Region IV (EPA), and the Tennessee Department of Environment and Conservation (TDEC). A Federal Facility Agreement between these same parties requires the cleanup actions at the former Memphis Depot.

Under CERCLA Section 121 (e) (1), no Federal, State, or local permit is required for the portion of any removal or response action conducted entirely onsite ("site" referring to the areal extent of contamination), where such a response action is selected and carried out in compliance with Section 121. However, the planned groundwater remedial action must comply with the substantive provisions of the Underground Injection Control regulations for Class V wells at Rules of the TDEC Chapter 1200-4-6.-14 that are identified as "applicable or relevant and appropriate requirements" (ARARs).

Consequently, DLA (or its contractors) will design and construct the wells in accordance with good engineering practices so that their intended use does not violate water quality standards. In addition, these wells will not be used in a manner that could present a hazard to any existing or future use of the groundwater, which may be classified pursuant to Chapter 1200-4-3.-07. As presented in the attached work plan, the two reductive dechlorination substrates planned for injection in to the fluvial aquifer at the site to provide enhanced bioremediation of the chlorinated hydrocarbons are: (1) an emulsion of vegetable oil (specifically food-grade soybean oil) and liquid lecithin (a food grade surfactant); and (2) a 60% solution of sodium lactate with water. Although a permit and approval is not required, any input or guidance as well as overview from your office are welcome. We are committed to meeting all requirements, as necessary and we look forward to working with you and the Groundwater Quality Control Board. For more information, please contact Clyde Hunt or me at (901) 544-0617.

In Back

JOHN P. DE BACK BRAC Environmental Coordinator

Attachment[.]

Enhanced Bioremediation Treatment Treatability Study Workplan (Rev. 1)

Distribution:

Turpin Ballard, U.S. EPA Jim Morrison, TDEC

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Defense Distribution Center (Memphis) Main Installation

Enhanced Bioremediation Treatment Treatability Study Workplan

Rev. 1

PREPARED FOR



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PREPARED BY

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Acronyms

BCT	Base Cleanup Team
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, and xylenes
САН	chlorinated aliphatic hydrocarbon
°C	degrees Celsius
Cis-1,2-DCE	Cis-1,2-dichloroethene
COC	Chain-of-Custody
COCs	Constituents of concern
ср	centipoise
DCE	Dichloroethene
DLA	Defense Logistics Agency
DQOs	data quality objectives
DRC	Depot Redevelopment Corporation
EBT	Enhanced Bioremediation Treatment
EPA	Environmental Protection Agency
FS	Feasibility Study
ft	feet
H ₂	Hydrogen
HRC™	Hydrogen Releasing Compound
LTOA	Long Term Operational Area
MCLs	Maximum Contaminant Level
MI	Main Installation
µg/L	micrograms per liter
MNA	Monitored Natural Attenuation
OVA-FID	Organic Vapor Analyzer-Flame Ionization Detector
PCE	Tetrachloroethene
POL	petroleum/oil/lubricants
QA	quality assurance
RAB	Restoration Advisory Board
RD	Remedial Design
RI	Remediation Investigation
ROD	Record of Decision

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RPO	Remedial Process Optimization
TCE	Trichloroethylene
TDEC	Tennessee Department of Environment and Conservation
TS	Treatability Study
UIC	underground injection control
VC	Vinyl chloride
VOC	Volatile organic compound

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1.0 Introduction

This Enhanced Bioremediation Treatment (EBT) Treatability Study Workplan for accelerated bioremediation of chlorinated volatile organic compounds or, as referred to in this document, chlorinated aliphatic hydrocarbon (CAH) compounds, in groundwater at the Main Installation (MI) of the former Memphis Depot has been prepared for the U.S. Army Corps of Engineers – Huntsville Center as part of the Remedial Design (RD) for the remediation of groundwater. The Defense Logistics Agency (DLA) is the lead agency for site activities at the Memphis Depot. The supporting regulatory agencies are the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC). Together, DLA, EPA, and TDEC compose the Base Realignment and Closure (BRAC) Base Cleanup Team (BCT).

Alternative GW3 – Enhanced Bioremediation, as described in the MI *Record of Decision* (ROD) document (CH2M HILL, 2001), employs the use of injection of electron donor to enhance the natural biodegradation processes and states that pilot tests will be required to determine injection volumes, spacing, and depth. This workplan is a result of the need for a pilot test/treatability study of EBT and has been prepared with reference to *Guidance for Conducting Treatability Studies under CERCLA. Final.* (EPA, October 1992).

1.1 Scope of Treatability Study

The development of the EBT Treatability Study has occurred in two phases. The first phase involved gathering available information to support selection of appropriate electron donor substrates for accelerated biodegradation of CAHs to evaluate in the field study. Review of this information has allowed CH2M HILL to construct this Treatability Study workplan and recommend two of the more promising electron donor substrates to be evaluated in the field. The following electron donors are considered to be potentially applicable for the treatability study at the MI:

- Hydrogen Releasing Compound (HRC™) (e.g., Regenesis's[®] polylactate ester);
- Commercially available organic carbon electron donor (e.g., lactate, butyrate, propionate, ethanol, vegetable oil, or other material); and
- Direct hydrogen addition (e.g., hydrogen sparging).

This workplan also outlines the need to examine certain subsurface conditions that need to be present for in-situ anaerobic biodegradation to be effective. These conditions generally include presence of appropriate bacteria capable of degrading the target compounds, suitable electron donors (such as organic carbon or hydrogen), an appropriate terminal electron acceptor process (such as methanogenic conditions), and essential nutrients (e.g., nitrogen, phosphorus, sulfur and low levels of iron, manganese, magnesium, etc). Appropriate physical and chemical conditions (such as pH, temperature, DO, ORP), must also be present.

The second phase of the treatability study will include installing two test sites to evaluate the two different electron donor substrates. Each test site, located in the southeast and southwestern areas of the MI, will consist of injection wells screened across the aquifer, and monitoring wells where the electron donors and changes in contaminant levels will be monitored. Monitoring will include baseline and post-injection sampling events. The postinjection events are scheduled for 6 months after the injection phase ends. At the completion of the monitoring events, an EBT Technical Memorandum describing treatability study procedures and results will be produced that will be included in the Intermediate (60 percent) MI Remedial Design document.

This Treatability Study Workplan is organized into the following sections and appendices:

Section 1.0 Introduction includes a discussion of the work plan structure and organization

Section 2.0 Project Description provides background information on the site and summarizes pertinent waste characterization data. Section 2 also introduces the type of study to be conducted.

Section 3.0 Treatment Technology Description describes the principles and characteristics of biodegradation behind EBT as a treatment technology.

Section 4.0 Test Objectives defines the objectives of the treatability study and the intended use of the data.

Section 5.0 Electron Donor Selection defines the selection criteria and conclusion of the electron donor selection process.

Section 6.0 Experimental Design and Procedures identifies the tier and scale of testing, the volume of waste material to be tested, delivery system, critical parameters, and the type and amount of replication.

Section 7.0 Equipment and Materials lists the equipment, materials and reagents that will be used in the performance of the treatability study.

Section 8.0 Sampling and Analysis describes how the Sampling and Analysis Plan will address field sampling, waste characterization, and sampling and analysis activities in support of the treatability study.

Section 9.0 Data Management, Analysis, and Interpretation describes the 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 treatability study.

Section 10.0 Health and Safety describes how the Health and Safety Plan will address the hazards associated with treatability testing.

Section 11.0 Residuals Management describes the management of treatability study residuals.

Section 12.0 Community Relations describes the community relations activities performed in conjunction with the treatability study.

Section 13.0 Reporting describes the preparation of interim and final reports documenting the results of the treatability study.

Section 14.0 Schedule indicates the planned starting and ending dates for the tasks outlined in the work assignment.

Section 15.0 References lists all documents cited in this plan.

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2.0 Site History and Setting

2.1 Site History

Starting in the 1940s, the Memphis Depot received, warehoused, and distributed supplies common to all U.S. military services and some civil agencies. Activities at the MI included storing and shipping various materials (e.g., food, clothing, medical supplies) and industrial supplies (e.g., hazardous materials). Several commonly used hazardous materials were also used for facility maintenance. Hazardous materials which were used or stored at the Depot during its operational period include: flammables, solvents, petroleum/oil/lubricants (POL), paints, pesticides, herbicides, wood treating products, oxidizers, corrosives, and reactives. The Memphis Depot was deactivated as a military supply center in 1997.

The Memphis Depot, now known as the Memphis Depot Business Park, covers 642 acres of land and is separated into two distinct areas. The MI comprises 574 acres and Dunn Field, to the north of the MI, comprises the balance. A map with the former RI functional unit boundaries within the MI is presented in Figure 2-1.

The MI was extensively developed. The only significant vegetated area is the golf course, located in the MI's southeastern sector. Topography in the MI is nearly level. The two surface water bodies on the Depot are too shallow to intercept the local water table.

2.2 Hydrogeology

The fluvial aquifer beneath the Memphis Depot occurs under unconfined conditions in fluvial-type deposits at an average depth of 87 feet below ground surface (CH2M HILL, January 2000). Aquifer thickness in the fluvial deposits ranges from <1 foot the northwest corner of the MI to as high as 57 feet (ft) in the west central portion of the MI. Hydrogeologic cross-sections typical of the geology beneath the MI are presented in Figures 2-2 and 2-3. The cross-sections were developed as part of the 2002 MI Long Term Operational Area (LTOA) Technical Memorandum. Groundwater flow in this aquifer is variable but is primarily southwest, south, and southeast. Figure 2-4 presents the most recent interpretation of the potentiometric surface underlying the MI.

The fluvial aquifer is typically underlain by a clay-rich unit that occurs beneath most of the MI. This upper clay of the Jackson Formation/Upper Claiborne Group does not appear to be present at the base of the fluvial deposits in the northwestern part of MI and in the southwestern part of Dunn Field (the northern half of the Memphis Depot). The MI RI concluded that clay-rich units (clay or clayey sand) occur in the Jackson Formation/Upper Claiborne Group at variable elevations, and also are highly variable in thickness. The Memphis Sand aquifer is separated from the overlying fluvial aquifer by units of the Jackson Formation/Upper Claiborne Group. The Memphis Sand is the source of water supply for the City of Memphis.

A more focused discussion of the hydrogeology of each study area is presented in Section 5.

2.3 Nature and Extent of Contamination

The constituents of concern (COCs) reported in groundwater beneath the MI, as described by the MI Remedial Investigation (RI) Report (CH2M HILL, 2000), are CAHs, primarily tetrachloroethene (PCE) and trichloroethylene (TCE). Impacted groundwater is present within the fluvial aquifer. This Treatability Study workplan focuses on contamination in the fluvial aquifer beneath portions of the MI (Figure 2-5). An apparent source for this groundwater contamination has not been revealed.

Two distinct volatile organic compound (VOC) groundwater plumes were delineated in the southwestern and southeastern portions of the MI within the RI document. These plumes appear to have different origins and, based on recent data, do not commingle. Figure 2-6 illustrates concentrations of PCE and TCE as well as other CAHs in the fluvial aquifer, on the basis of data achieved from the 2001 LTOA investigation. As revealed in groundwater sample data from this investigation, average PCE concentrations range from below laboratory detection limit to 480 micrograms per liter (μ g/L). Average TCE concentrations range from below laboratory detection limit to 79 μ g /L. In addition, an unusual detection of carbon tetrachloride and chloroform at average concentrations of 122 μ g/L and 77 μ g/L, respectively, was revealed in the southeast corner of the MI.

Table 2-1 presents additional details on CAHs detected at least once in groundwater samples collected during the 2001 LTOA investigation. These samples were collected through use of diffusion bag samplers, which allows for sampling at defined intervals. Review of Table 2-1 indicates that contamination by CAHs is spread throughout the entire thickness of the aquifer and, in some instances, contaminant levels are highest in the upper portion of the aquifer.

3.0 Treatment Technology Description

Biological natural attenuation processes include biodegradation through either co-metabolic reactions, direct dechlorination, or oxidation. Whether an aquifer is aerobic or anaerobic has a direct effect on which biological process is prevalent. Co-metabolic transformation of CAHs such as TCE in aerobic or anaerobic environments has been reported by McCarty (1994) CAHs such as VC, 1,2-DCE, and chloroethane have been reported by Bradley and Chapelle (1996) as being degraded by oxidation effects in aerobic and anaerobic environments. The process that occurs frequently for the transformation of contaminant compounds such as CAHs is, however, anaerobic reductive dechlorination.

Anaerobic reductive dechlorination is a series of reductions through dechlorination reactions. For example, PCE degrades to TCE, which degrades primarily to cis-1,2-dichloroethene (cis-1,2-DCE), which in turn degrades to vinyl chloride (VC), which is dechlorinated to ethene. Figure 3-1 presents this anaerobic reductive dechlorination pathway. Each step requires a lower reduction/oxidation (redox) potential than the previous one. PCE degradation occurs in a wide range of reducing conditions, whereas VC is reduced to ethene only under sulfate reducing and methanogenic conditions. During each of these transformations, the parent compound releases one chloride ion and gains one hydrogen atoms. Two electrons are transferred during the process, which may provide a source of energy for the microorganism. The ultimate source for the hydrogen and electrons in this reaction is some type of organic substrate. Hydrogen (H₂) is released during fermentation of the substrate. The hydrogen liberated from this substrate acts as the actual electron donor for respiration (ITRC, 1998).

Subsurface microorganisms create energy for life processes by oxidizing organic matter. Only those redox reactions that yield energy are facilitated by microorganisms. During redox reactions, the oxidation of an electron donor (e.g., native organic carbon, fuel hydrocarbons, landfill leachate) combined with the reduction of an electron acceptor (e.g., oxygen, nitrate, manganese, ferric iron, sulfate, carbon dioxide, and anthropogenic compounds such as CAHs) ultimately yields energy for use by organisms. The microbes are using carbon (electron donors) as a food source and are breathing, or respiring, electron acceptors. Dissolved oxygen (DO) yields the most energy and is used first as the prime electron acceptor. After DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, ferric iron oxyhydroxide, sulfate, and eventually CAHs (EPA, 1998).

CAH plumes in groundwater can exhibit three types of biodegradation behavior depending on the amount of solvent, the amount of organic (native and anthropogenic) carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being used. Individual plumes may exhibit all three types of behavior in different areas of the plume (EPA, 1998). These three behavior types are as follows:

• Type 1 behavior occurs where the primary substrate is anthropogenic carbon (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX] or landfill leachate), and this anthropogenic carbon drives reductive dechlorination. Type 1 behavior results in the

rapid and extensive degradation of highly chlorinated solvents such as PCE, TCE, and dichloroethene (DCE).

- Type 2 behavior dominates in areas characterized by relatively high concentrations of biologically available native organic carbon; the natural carbon source drives reductive dechlorination. This behavior generally results in slower biodegradation of the highly chlorinated solvents when compared to Type 1 behavior. But, areas with high concentrations of natural organic carbon can result in rapid degradation of CAHs.
- Type 3 behavior dominates in areas characterized by low concentrations of native and/or anthropogenic carbon and concentrations of DO greater than 1.0 milligrams per liter (mg/L). Under these conditions, reductive dechlorination will not occur; therefore, little or no removal of PCE, TCE, and DCE will occur. Biodegradation may proceed via the much slower process of co-metabolism, but will be limited by the low concentrations of native or anthropogenic carbon. Type 3 behavior also occurs in groundwater that does not contain microbes capable of biodegradation of chlorinated solvents.

The list of conditions that a microbial population involved in bioremediation requires for sustainability includes a source of carbon, an electron donor, an electron acceptor, appropriate nutrients, a suitable temperature range, pH, and other environmental conditions. Very often the carbon source serves as the electron donor. A system that stimulates the biodegradation of chlorinated solvents by manipulating these requirements in the subsurface is referred to as enhanced anaerobic biodegradation or as used here, EBT.

There are several different designs of EBT systems for groundwater using various delivery mechanisms, degradation mechanisms, and electron donor or biological amendments. The appropriateness of a particular type of delivery, degradation, or amendment system will vary and will depend on the goal of the proposed project. Table 3-1 presents available mechanisms and amendments available for or used within EBT systems.

TABLE 3-1

Available Mechanisms and Amendments for EBT Systems

Typical Available Delivery Mechanisms

Dual Vertical and Horizontal Wells – injection through well screen of oriented wells	Dual Recirculating Wells – injection of material via extracted groundwater and introduction through re-injection system	Direct Injection – gravity or forced injection into one or more vertical wells	Horizontal and Vertical Gas Injection Wells – injection of gases through oriented wells	Passive-Reactive Wells – direct placement of solid or cartridge at well screen or in filter pack of wells	
Typical Degradation Mecha	nisms			·····	
Reductive Dechlorination – reduction of CAHs through removal of chlorine atoms	Aerobic Cometabolism – incidental oxidation of CAHs while reducing other VOCs	Oxidation – direct degradation through generation of oxygen			
Common Available Amendments					
Nutrients – inorganics such as ammonium chloride, ammonium sulfate, etc.	Electron Acceptors – oxygen, hydrogen peroxide	Bioaugmentation various species of microorganisms			

**Source ITRC, 1998

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One of the objectives of the electron donor injection at the MI is to define if groundwater concentrations of regulated compounds may degrade below concentrations set by EPA Maximum Contaminant Level (MCLs) criteria, as specified in the MI ROD, within a full-scale system. Table 3-2 presents the groundwater cleanup target concentrations for PCE and TCE and enhanced reductive dechlorination products. Other objectives for this EBT Treatability Study are presented in Section 4.

TABLE 3-2

Groundwater Cleanup Target Levels

Analytes	Units	Federal MCLs	Maximum Reported Concentration
Tetrachlorethene (PCE)	μg/L	5	480
Trichtoroethene (TCE)		5	179
Cis-1,2-Dichloroethylene		70	53
Trans-1,2-Dichloroethylene		100	164
1,1-Dichloroethene		7	170
Vinyl chloride		2	0.2

μg/L micrograms per liter

4.0 Test Objectives

The EBT Treatability Study will be conducted in order to compare the effectiveness of selected electron donor materials and define the design parameters for a full-scale injection at the MI. The objectives of the treatability study and additional information required are as follows:

- Obtain additional information on the geology of the aquifer within the study areas. The development of detailed information on the geology of the aquifer will be accomplished during installation of study injection points and monitoring wells.
- Ascertain the effectiveness of electron donor addition as a remedial treatment by comparing pre-injection to post-injection CAH concentrations. Seven post-injection monitoring events are currently scheduled. Samples will be analyzed for VOC and geochemical parameters.
- Evaluate transport of electron donors within the aquifer, following injection. The monitoring points to be installed during this study will be installed downgradient of the injection location in a pattern designed to reveal dechlorination aspects along aquifer flowpaths.
- Estimate the radius of influence of electron donors through analytical monitoring. The study monitoring wells will be installed in a pattern designed to capture as much information on the radius of influence as possible.
- Estimate time for aquifer remediation using electron donors by comparing CAH concentrations before and after the 6-month treatment period, against the magnitude and extent of the remaining groundwater plume.
- Define the effect of the injection pressure on the aquifer by measuring water and
 pressure levels in adjacent wells during electron donor injection. Equipment to
 accomplish this objective will be installed within each monitoring well prior to injection.
- Define the electron donor depletion period in the aquifer by analytical monitoring after introduction of the donors has been terminated. Six post-injection monitoring events are currently scheduled and the sample analytical results are expected to reveal the depletion of the enhancement materials.
- Identify preferential pathways for CAH migration or retention, relative to lithology and groundwater flow. A "tracer" compound (sodium bromide) will be mixed with each electron donor to provide groundwater velocity and flowpath data. In addition, hydrogeologic information will be compared to groundwater sample analytical results from each monitoring well.

5.0 Enhancement Material Selection

This section will examine several factors that will influence the selection of an electron donor for the EBT Treatability Study. These factors include the geochemistry of the aquifer, concentration of CAHs in the aquifer, dechlorination aspects of electron donors, rate of electron donor depletion, and deliverability of the substrate to the targeted portion of the aquifer.

5.1 Aquifer Geochemistry

The geochemistry of the fluvial aquifer was analyzed by CH2M HILL in 2000 while completing a Monitored Natural Attenuation (MNA) study for the Groundwater Feasibility Study (FS) portion of the MI Remediation Investigation (RI)/FS. The MNA study results were reviewed and commented on by Parsons Engineering Science (Parsons) within their *Final Remedial Process Optimization* (RPO) *Report* (Parsons, 2001). CH2M HILL revised the MNA document according to comments made by Parsons and presented the latest version within the Rev. 0 Memphis Depot Dunn Field RI. Several important findings from the revised MNA study applicable to fluvial aquifer geochemistry underlying the MI are reviewed in this section.

Table 5-1 presents a summary of geochemical marker values from the fluvial aquifer underlying the MI. CH2M HILL (2000), during their review of this data, concluded that limited biodegradation (primarily by reductive dechlorination) of the PCE plume in the MI groundwater appears to be occurring. The limitation on the reductive dechlorination appears to be a result of low anthropogenic or natural carbon in groundwater and elevated DO concentrations in groundwater. If the dechlorination process is to be enhanced, the general aerobic conditions (DO levels above 1 milligram per liter) will have to be altered to anaerobic conditions and the level of carbon increased. Parsons (2001) agreed with this interpretation, stating in the RPO report that degradation of PCE and TCE within the CAH plume "to innocuous daughter products is limited by the low organic carbon content in the substrate and the relatively oxidizing redox conditions."

CH2M HILL (2001) through analysis of data from other sites with active EBT studies has also determined that the presence or absence of potentially competing electron acceptors may affect reductive dechlorination of CAHs activity at a site. Reviewing data presented in Table 5-1 indicates that, other than oxygen, electron accepting nitrate is present at levels where microorganisms may use this instead of anthropogenic electron acceptors (i.e., CAHs). However, the data also show that ferric iron and sulfate are at levels supportive of reductive dechlorination, indicating that microorganisms may use CAHs for electron acceptance once nitrate levels decrease. Ferric iron was actually not reported above laboratory detection limits; however, it is important to note that ferric iron is not soluble. Also, Byl (Personal Communication, 2002) reported that the sands and clay of the fluvial aquifer in West Tennessee does contain significant quantities of ferric iron. According to Bouwer and McCarty (1984), the absence of ferric iron may lead to direct use of CAHs as an electron acceptor.

5.2 Electron Donor Description

Potential electron donors for the EBT Treatability Study can be categorized as highly soluble compounds, slow release compounds, or as direct hydrogen addition.

Highly soluble compounds

- Lactate was reported by Murt (2001) to be a successful donor for stimulating dechlorination of PCE in a "geochemically challenged" site in Nebraska. Other reports have also shown successful reduction of chlorinated contaminants with the use of lactate. Lactate is normally expected to be fermented rather rapidly to acetate and H₂, resulting in high H₂ levels that persist for only short periods as various H₂-using organisms deplete it. However, lactate may be fermented to propionate, which itself can serve as a more slowly fermentable source of persistent, low H₂ levels. Lactic acid can be prepared as very strong stock solutions to prevent microbial growth. Murt (2001) reported using 60 percent food-grade sodium lactate. The viscosity of a 60 percent solution of sodium lactate at 20° C is 38 centipoise (cp) as compared to the viscosity of water at this same temperature of 1.002 cp.
- Butyrate acid amendment in one laboratory study resulted in less methanogenesis than did amendment with ethanol or lactic acid, which generated much higher H₂ levels. Butyrate acid can be prepared as very strong stock solutions to prevent microbial growth (ITRC, 1998).
- Ethanol did not support complete dechlorination, during the short-term tests of one microcosm study, but was a viable donor over long-term tests because a portion was converted to propionic acid. Ethanol can be stored as a pure solvent to prevent microbial growth (ITRC, 1998).
- Molasses was the fastest acting substrate in a CH2M HILL microcosm study, but this substrate was also used primarily to generate methane, not to drive reductive dechlorination. Multiple studies reported in the literature suggest these results with molasses to be typical. The viscosity of molasses at 20°C is 5000 cp.

Slow release compounds

- HRC® is a proprietary food-grade polylactate ester, which breaks down to a polylactate ester complex when introduced into water. The HRC® degrades to lactic acid then to organic acids including pyruvic acid and acetic acid, releasing hydrogen along each step. The release of the HRC® is dissolution and time to breakdown ester dependent. The viscosity of HRC® at 20° C is 20,000 cp.
- Vegetable Oil has been shown in some studies to cause immediate declines in aqueous TCE concentrations, due to solubility of the TCE in the oil phase. Results of microcosm and field studies have been mixed. Evaluation of groundwater analytical results 2 months into a vegetable oil interim remedial action in Orlando indicates that groundwater quality data are relatively stable, with no upward or downward trends of CAH degradation evident but with strong indication of increasing natural attenuation. The slow release of the vegetable oil is dissolution dependent. The viscosity of soybean oil at 20°C is 69 cp.

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Direct addition of hydrogen

Hydrogen sparging of aquifers contaminated with chlorinated solvents has shown
promise as a method to enhance microbial dechlorination in-situ. However, the low
solubility, explosive nature of this gas, and poor aquifer distribution have limited the
use of hydrogen as an in-situ electron donor.

5.3 Injection Site Description

Effective enhanced in situ bioremediation requires delivery of amendments to the targeted portion of the plume. Site specific characteristics that drive electron donor selection and affect the deliverability of donors include contaminant concentrations and location, hydraulic conductivity, and soil types and heterogeneities.

5.3.1 MI Southwest Corner – Treatability Study Area 1

According to the MI ROD, areas in the southwest corner of the MI were chosen as the site of the EBT Treatability Study (Figure 5-1). These areas were chosen because existing data indicated that higher and more persistent levels of VOCs concentrations are found in the underlying groundwater. Table 5-2 presents the VOC groundwater sample analytical results from the MI RI (CH2M HILL, 2000) for monitoring wells and piezometers that are present in this area (i.e., MW-21, MW-22, MW-47, and PZ-04; see Figure 5-2). Additional monitoring wells MW-100, -101, and -102 have been installed in this area as part of the recent LTOA investigation efforts. Groundwater samples collected from these newly installed wells and the results of that sampling are summarized in Table 5-3.

As presented in Table 5-2, groundwater sample analytical results from the MI RI for monitoring wells MW-21, MW-22, MW-47, and PZ-04 indicate that the magnitude of PCE and TCE concentrations in on-site wells MW-21 and MW-22 have been fairly consistent over the sampling period and that, when analyzed for, the degradation product cis-1,2dichloroethene is present. Concentrations of PCE have ranged from an estimated concentration of 2 μ g /L to 120 μ g /L. TCE concentrations have ranged from an estimated concentration of 2 μ g /L to 39 μ g /L. Offsite monitoring well MW-47 and piezometer PZ-04 has revealed that southwest of the MI relatively high concentration slugs of PCE have migrated through the fluvial aquifer. PCE was detected at 200 μ g /L in a March 2000 sample from MW-47. Sampling of MW-47 since then has revealed PCE at only estimated levels less than 1 μ g /L.

Groundwater analytical data for Treatability Study Area 1 has been recently supplemented with analytical data from the 2001 LTOA investigation (Tables 2-1 and 5-3). Results from LTOA monitoring wells MW-100 and MW-101 indicate that contamination by PCE and TCE of this area of the fluvial aquifer is greater than previously known. Specifically, in MW-101, PCE was revealed as high as $530 \mu g/L$, a concentration approximately 4.5 times greater than previously detected in MW-21. In addition, the contamination appears to be spread throughout the aquifer, not just within the lower portion of the aquifer, and is, on average, at higher concentrations in the center of the aquifer.

Average depth to water in Treatability Study Area 1 is approximately 99 ft below ground surface. The aquifer is estimated to be approximately 35 ft thick and bounded by an

underlying clay. Hydraulic gradient for the area, as measured from MW-22 to MW-101, is 3.3E-03 ft/ft. The hydraulic conductivity for monitoring wells MW-21, MW-22, and MW-47, as reported in the MI RI, were found to be 1.7E-02, 9.4E-03, and 7.7E-03 centimeters per second, respectively, which is equal to 48, 27, and 22 ft/day, respectively. These values correspond to hydraulic conductivities reported by Driscoll (1989) and Fetter (1988) for a well-sorted silt and sand with groundwater. As reported in the MI RI, the fluvial aquifer in the southwestern corner of the MI is composed of gravel with clay silt or sand. Assuming an effective porosity of 30 percent and an average hydraulic conductivity of 32 ft/day, groundwater flow in this portion of the fluvial aquifer is, on average, 0.35 ft/day or approximately 128 ft/year.

5.3.2 MI Southeast Corner – Treatability Study Area 2

The groundwater sample data presented in Tables 2-1, 5-2a, and 5-3 reveal that groundwater contamination in the southeast corner of the MI is comparable to contaminant levels in the southwest corner. As a result, one of the study areas will be placed in this location, specifically the area centered around monitoring wells MW-86 to MW-92 (Figure 5-3).

Average PCE concentrations detected in monitoring wells installed during the LTOA investigation in the southeast corner of the MI (i.e., MW-85, -86, -88, -92, and -96) were found to range from below laboratory detection limit to 198 μ g /L in monitoring well MW-86. The highest concentration of PCE detected was 280 μ g/L in MW-86. Average TCE concentrations in these same wells were found to range from below laboratory detection limit to 23 μ g /L in monitoring well MW-85. The highest TCE concentration was revealed within MW-85 at 26 μ g/L. The wells in Treatability Study Area 2 also contained significant levels of cis-1,2-DCE, the highest average concentration was revealed at 53 μ g/L in MW-86. Also, carbon tetrachloride was revealed as high as 140 μ g/L in MW-85. An additional finding of the analytical data is that, just as in Treatability Study Area 1, contamination by CAHs is spread throughout the entire thickness of the aquifer, but is, on average, at higher concentration in the central portions of the aquifer.

Average depth to water in Treatability Study Area 2 is approximately 99 ft below ground surface. The aquifer is estimated to be approximately 13 ft thick and bounded by an underlying clay. Hydraulic gradient for the area, as measured from MW-86 to MW-26, is 7.8E-03 ft/ft. The hydraulic conductivities for monitoring wells MW-25, MW-26, MW-50, and MW-52, as reported in the MI RI, were found to be 2.7E-03, 1.6E-03, 2.9E-03, and 5.9E-03 centimeters per second, respectively, which is equal to 7.6, 4.5, 8.2, and 16.7 ft/day, respectively. These values correspond to hydraulic conductivities reported by Driscoll (1989) and Fetter (1988) for a well-sorted silt and sand with groundwater. As reported in the MI RI, the fluvial aquifer in the southeastern corner of the MI is composed of gravel with clay silt or sand. Assuming an effective porosity of 30 percent and an average hydraulic conductivity of 9 ft/day, groundwater flow in this portion of the fluvial aquifer is, on average, 0.23 ft/day or approximately 85 ft/year.

5.4 Electron Donor Decision Summary

The Defense Logistics Agency decided that vegetable oil could be used as one of the reductive dechlorination substrates, based upon the results of the June 2001 *Final Remedial Optimization Report* developed by Parsons Engineering Science, Inc. (Parsons) for the Memphis Depot. The decision was based on the successful enhancement of reductive dechlorination by vegetable oil at other sites with underlying aquifers contaminated by CAHs, as reported by Parsons (personal communication, 2002). CH2M HILL has also used vegetable oil as a substrate at several sites and has reported little to moderate reduction in contaminant levels as a result. An emulsion of vegetable oil (specifically food-grade soybean oil) and liquid lecithin (a food grade surfactant) as supplied by Central Soya Company of Fort Wayne, Indiana will be used as an EBT electron donor source in Treatability Study Area 1.

A process of elimination was used to determine the second substrate based on data collected from other enhanced reductive dechlorination sites. Several factors important to the decision making process included use of substrate at other sites, contaminant concentrations at the EBT Treatability Study in comparison to other sites, aquifer characteristics versus viscosity of the substrate, equipment required for delivery of the substrate, and general success level at other sites. Table 5-4 presents the summary of this data analysis and comparison. Based on these factors, hydrogen sparging was eliminated due to the complexity of donor delivery. High viscosity substrates such as HRC[©] and molasses were eliminated, due to depth to the water table and potential distribution problems in a matrix with a clay content. Although lactate, butyrate acid, and ethanol are all considered effective, consistently fast and effective results were reported in both field test and microcosm studies with the lactate. Therefore, lactate in the form of 60 percent sodium lactate as supplied by JRW Technologies of Lenexa, Kansas has been chosen as the second electron donor substrate for the field evaluation. The lactate will be injected at Treatability Study Area 2.

6.0 Experimental Design and Procedures

This section describes the activities and processes required to complete the EBT Treatability Study and to meet the study objectives. The effectiveness of reductive dechlorination through addition of vegetable oil will be evaluated against the effectiveness of lactate, based on groundwater data collected from test sites.

6.1 Overview

The design and execution of enhanced bioremediation must reliably distribute the electron donor through the treatability study test area, without displacing contaminated groundwater within the testing zone with injected solutions. Options for application of the vegetable oil emulsion and lactate include:

- Dual Well or Trench Recirculation extraction and reinjection of groundwater through groundwater wells.
- Injection Only Systems injection through groundwater wells or direct push points.

Based on the depth to groundwater and concentrations of VOCs, "injection only" through injection wells was selected for the EBT Treatability Study. The advantages of the injection only system alternative are that wells provide the option of electron donor addition, bioaugmentation, or a batch electron donor feed mechanism at several points in the source area or along the plume length typically at lower costs than establishing a stationary recirculation system.

Treatability Study Area 1 will be the soybean oil and lecithin emulsion test site. In Treatability Study Area 2, a substrate mixture consisting of 60 percent food-grade sodium lactate will be injected. The proposed injection point and monitoring well configuration for the two test areas are illustrated in Figures 6-1 and 6-2, respectively.

6.2 Preliminary Study Activities

Table 6-1 lists the preliminary activities associated with the EBT Treatability Study. Section 14 presents the schedule of activities for the study effort. Preliminary study activities associated with the implementation of the treatability study include:

- Coordination with Memphis Depot personnel on the location of utilities in the area;
- Coordination with the Depot Redevelopment Corporation (DRC) and the appropriate tenants;
- Baseline groundwater sampling event;
- Definition of the electron donor injection quantities;
- Treatability study monitoring and injection well installation and sampling;

- Designation of areas for temporary storage of equipment and materials; and
- Site-specific security and safety concerns.

Applications will be submitted for any required drilling and groundwater injection permits. Injection of the electron donor substrate is considered to be the start of the EBT Treatability Study test period.

6.2.1 Utility Locating

The field engineer will mark locations of approximately 19 additional monitoring wells and 7 injection wells at least 2 weeks prior to commencement of the activity. All locations will be approved by Memphis Depot and DRC representatives, and all utilities will be marked by a professional utilities locating service prior to the start of drilling. The preliminary monitoring and injection well locations are depicted in Figures 6-1 and 6-2 but final locations will be based on the results of the baseline groundwater sampling event (see next section) and utility locations and conditions encountered in the field. The installation of the monitoring and injection wells is the only intrusive activity planned for this field effort.

6.2.2 Baseline Groundwater Sampling Event

A baseline groundwater sampling event encompassing all existing monitoring wells (except for those recently sampled as part of the LTOA investigation) and piezometers on- and offsite of the MI will be conducted as a preliminary activity. The workplan describing the basis for this baseline event and well purging and sampling procedures is included as Appendix A (Baseline Groundwater Sampling Plan for Main Installation Monitoring Wells) to this workplan. Samples will be analyzed for VOC content and several important geochemical parameters, as shown in Table 6-2.

Analytical results from this sampling event will be used to: (1) establish monitoring well and injection point locations for the EBT Treatability Study; (2) provide up-to-date VOC contaminant concentration data for the fluvial and intermediate aquifer; (3) provide up-todate geochemical parameter data for the fluvial aquifer; and (4) refine the quantity of electron donor needed to enhance reductive dechlorination within the fluvial aquifer.

6.2.3 Electron Donor Injection Quantity Determination

After analytical data from the baseline sampling event have been reviewed and tabulated, the data will be used along with other geologic and hydrogeologic data from the fluvial aquifer to define the dose of electron donor to be injected at the test areas. Factors to consider in the development of the dosage level are contaminant concentrations, effective porosity of the aquifer, aquifer matrix (i.e., sand, silt, or clay), area of influence, geochemistry of the aquifer, and delivery method.

Preliminary dosage estimates to be injected at the two test sites during the EBT Treatability Study tests are described within Section 7.0.

6.2.4 Treatability Study Monitoring and Injection Well Installation and Sampling

Approximately 19 monitoring wells will be installed within the two test areas as part of the preliminary activities to serve as downgradient monitoring points from the injection zones.

In addition, approximately 7 injection wells will be installed sequentially (Figures 6-1 and 6-2). Each well will be installed by Prosonic Corporation using rotasonic drilling methods. Rotasonic drilling was selected because it is the most effective method for boring advancement and well installation under the site hydrogeologic conditions. The depth to water (e.g., 95 to 105 feet below ground surface [ft bgs] on average) and geologic characteristics of the fluvial aquifer (i.e., tight sands mixed with gravel up to cobble size) may cause problems with installation of the wells using other drilling methods. Final locations of each well will be based partially on the results of a baseline groundwater sampling event scheduled to take place as part of the MI RD in February and March 2002. The procedures and specifications that will be followed during well installation are presented in Appendix B – EBT Treatability Study Monitoring and Injection Well Installation Procedures.

As shown in Figures 6-3 and 6-4, monitoring wells will be located downgradient no closer than 5 feet and no greater than 40 feet from the injection area to intercept the potential radius of influence as the injected substrate begins to migrate from each point. Each monitoring well will have no more than fifteen feet of screen and the position of the screened interval within the aquifer will be dependent upon the following: (1) thickness of the fluvial aquifer as determined by field personnel; (2) CAH contaminant distribution within the aquifer as determined by the baseline groundwater sampling results and LTOA groundwater sample analysis results; and (3) CAH contaminant distribution within the aquifer matrix as determined by soil sampling. Where applicable, monitoring wells will be set as pairs at each location. During the drilling effort, soil samples will be collected from the vadose zone wherever Organic Vapor Analyzer/Flame Ionization Detector (OVA/FID) measurements are above 20 ppm or wherever there appears to be obvious staining in the soil profile. No more than one sample will be collected from each boring. In addition soil samples will be collected from the aquifer and analyzed for TOC content. Final locations of each well will be based partially on the results of the baseline groundwater sampling event to be conducted in February and March 2002.

At both study areas, the screens for monitoring wells will be set at specific zones within the thickness of the aquifer. The depth of each zone is based on a review of historical analytical data for the MI, particularly the 2001 LTOA data that indicated the entire aquifer thickness is contaminated by CAHs and the center portion of the aquifer contains, on average, higher levels of contamination than either the upper or lower portion of the aquifer. For Treatability Study Area 1, where the aquifer thickness is approximately 35 feet, screens are to be set within the upper, middle, and lower zones of the aquifer in the well closest to the injection area. This is to ensure that analytical data is being developed across the entire aquifer. The monitoring well within the upper zone will utilize a 15-foot-long screen while the remaining two zones will have wells with 10-foot-long screens only. For the other monitoring well locations in Treatability Study Area 1, the screens will be set in the central portion of the aquifer to ascertain representative changes in the contaminant and chemistry of the groundwater.

For Treatability Study Area 2, the aquifer thickness is on average 13 feet. However, based on data collected from MW-86 during the LTOA study, the aquifer can be as thick as approximately 19 feet. Therefore, screens will be placed in both the upper and lower zone for all monitoring wells. The final length of each screen will depend upon the thickness of the aquifer as defined during the drilling effort. However, no screen will be greater than 10 feet

in length. Two wells to the south of MW-86 are an exception to this. Based on hydrogeologic data from the LTOA investigation, these wells are likely to be installed within a portion of the aquifer with average thickness and for that reason will utilize 15-foot-long screens.

Injection wells will be placed perpendicular to the groundwater flow direction in each study area. Since information developed during the LTOA effort on the vertical distribution of the CAH plume in each study area indicates that contamination by CAHs is spread throughout the aquifer, the screen interval for each injection well will be set across the entire thickness of the aquifer. However, for Treatability Study Area 1, the well screens will be placed 10 feet below the top of the water table to hinder possible "floating" of the injected substrate.

Monitoring and injection well points will be sampled after each has been developed as a baseline event prior to injection of the electron donor substrate. The samples will be collected and analyzed according to the procedures presented in Appendix A and list of parameters shown in Table 6-2.

6.2.5 Other Preliminary Activities

Prior to commencement of field activities, CH2M HILL representatives will contact personnel at the Memphis Depot and DRC to locate temporary storage facilities that will be accessible during the entire 6-month testing period. The facilities will be used to store field equipment required for sampling activities or other well maintenance tools. During the discussions with the Memphis Depot and DRC personnel, site-specific security and safety of personnel and equipment will be reviewed. The information gained from these discussions will also be included within the site-specific Health and Safety Plan for further reference.

6.3 EBT Treatability Study Process

The EBT Treatability Study will begin with introduction of the electron donor substrate into the fluvial aquifer via injection points and will conclude with the last groundwater sampling event at the end of a 6-month monitoring period.

6.3.1 Substrates and Tracer

As stated in Section 5.4, the electron donor substrates will consist of an emulsion of vegetable oil (specifically food-grade soybean oil) and liquid lecithin in Treatability Study Area 1 and lactate in the form of 60 percent sodium lactate as the second electron donor substrate at Treatability Study Area 2. The electron donors are available commercially. Quantities of substrate are presented in Section 7.0.

In addition to the substrate, a tracer will be injected that will allow for monitoring of the movement of groundwater away from each of the injection wells. Sodium bromide, a salt with high solubility in water, will be used as the tracer and will be mixed with both of the electron donors prior to injection. Once injected, the bromide ion will be analyzed for in all groundwater samples collected from the downgradient monitoring wells.

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6.3.2 Substrate Injection Method

6.3.2.1 Substrate Preparation

The preparation process will begin with the loading of potable water from the City of Memphis into onsite mixing tanks. A temporary water meter will be obtained from the city for this purpose. The water, which is free of turbidity and potential contaminants, will be used to mix with each electron donor. The vegetable oil emulsion mixture and sodium lactate that is brought to the site will be placed within the storage tanks for initiation of the mixing process. In addition to the substrate, a tracer will be injected that will allow for monitoring of the movement of groundwater away from each of the injection wells. Sodium bromide, a salt with high solubility in water, will be used as the tracer.

Prior to injection, the in-tank mixers will be activated to properly mix the soybean oillecithin mixture or sodium lactate, the bromude tracer, and water in preparation for injection.

6.3.2.2 Substrate Injection

The electron donor substrate will be injected into the fluvial aquifer via the 2-inch-diameter injection wells. The fluids will be pumped by a Watson Marlow SPX-40 high-pressure hose pump capable of producing 20 gallons per minute, down through the well casing, and through a 2-foot "travelling screen block". The pumping will beginning at the bottom of the well and move upwards, pushing the electron donor out into the fluvial aquifer at an approximate rate of 3 gallons per minute. Prior to injection of the vegetable oil emulsion, a high shear mixer will be used to form a micro-emulsion of each fluid with droplets less than 10 micrometers in diameter.

Pressure gauges connected to the injection pipeline will allow observers at the surface to note the amount of resistance to the fluid being pumped into the aquifer. Injection pressure is expected to be less than 100 pounds per square inch. The pumping will continue until the prescribed quantity of substrate has been pumped into the aquifer. Current estimated quantity to pump into the injection wells is 21,138 gallons in Treatability Study Area 1 and 10,569 gallons in Treatability Study Area 2 (see Section 7). Water obtained from the fluvial aquifer will be used to flush the remaining electron donor from the injection pipeline.

Assuming the volumes of emulsion/water mixture and volume of water flush can be successfully injected into the formation equally and radial along the entire length of the injection screen, and assuming a 30 percent effective porosity in the fluvial aquifer, the column of substrate formed in the aquifer should be approximately 10 feet in diameter around each injection well. The effective soybean oil/lecithin saturation in the subsurface after injection is complete is targeted at 25 percent of the effective porosity. For the sodium lactate, this target is 15 percent of the effective porosity.

During the course of injection, water samples from downgradient wells will be monitored to check for emulsion/water breakthrough. The presence of phase-separated oil emulsion in each well and the impact on the groundwater table will be measured with an oil-water interface probe. The presence of soybean oil or soybean oil emulsion in each well will also be checked visually using by collecting samples with a clear polyethylene bailer.

6.3.3 Performance Verification Monitoring

After the electron donor has been injected into the fluvial aquifer, a period of time will be required before an increase in the enhanced bioremediation process can be confirmed. During and after this process, CH2M HILL will collect groundwater samples from each test area monitoring well. Samples will be collected on a bi-weekly basis for the first month and monthly for the next 5 months from each treatability study monitoring well and existing monitoring wells, where applicable. Sample collection methods will be the same as those presented in Appendix A. Samples will be analyzed for VOCs as well as several geochemical parameters, as described in Table 6-2, by Kemron Analytical Services.

6.3.4 Bioaugmentation

A number of microorganisms can be used to promote the reductive dechlorination process if the system does not proceed past the degradation of a daughter product. For example, if PCE were degraded to cis-1,2-dichloroethene but not degraded beyond that to other products such as vinyl chloride to ethene, then microorganisms could be added to the system to enhance the process. For the fluvial aquifer, the need to bioaugment may occur because relatively high levels of DO may keep the system aerobic or the system may only have limited amounts of microorganisms that exist in an aerobic environment. Anaerobic dechlorinating microorganisms that may be applicable include *Dehalococcus ethegenes* strain 195 or the Pinellas-type.

In most cases, such bioaugmentation results in the establishment of non-native bacterial populations that decrease within days or weeks due to competitive pressures or other environmental factors. At this time, there are no plans to implement bioaugmentation at either test area; however, if this approach is instituted, an addendum to this workplan will be submitted to the BCT for review and approval.

7.0 Equipment and Materials

Other than standard field equipment necessary for field activities, the field equipment required for the implementation of the EBT Treatability Study will include a drilling rig to install the monitoring and injection wells and pumps and ancillary equipment to inject the electron donor substrate. Groundwater sampling equipment is described in Appendix A. Additional materials necessary for this project include the quantity and type of electron donor substrate.

Monitoring and injection wells will be drilled via rotasonic drilling techniques. Rotasonic drilling was selected because it is the most effective method for boring advancement and well installation under the site hydrogeologic conditions. The depth to water (e.g., 95 to 105 feet below ground surface [ft bgs] on average) and geologic characteristics of the fluvial aquifer (i.e., tight sands mixed with gravel up to cobble size) may cause problems with installation of the wells using other drilling methods. Also, heaving sands and gravel up to cobble size have caused serious problems for hollow-stem auger equipped rigs at the Depot in the recent past. Air rotary style drilling has not been used because of the heaving sand problem. Mud rotary style drilling might be applicable in some instances; however, the time spent handling investigative derived waste and generating fluids for the drilling process decrease the likelihood of using this drilling method.

The method of injection will be the same for both test areas and will include the use of a Watson Marlow SPX-40 high-pressure hose pump capable of producing 20 gallons per minute effectively delivering the substrate to the subsurface. Prior to injection, the material will be mixed in an onsite mixing tank. For further mixing and shearing of the soybean oil/lecithin electron donor, a high shearing mixer will be placed in the injection pipeline to form a microemulsion.

Tables 7-1 and 7-2 present the preliminary estimates for the dose of electron donor substrate to be injected at both test sites. The total quantity to be injected was based on the highest level of PCE detected to date, $530 \,\mu g/L$. An electron donor substrate dosage of four times the highest contaminant level was estimated as the quantity required to stimulate the reductive dechlorination process. Therefore, the mixture injected into the aquifer should not have less than 2 mg/L electron donor substrate.

8.0 Sampling and Analysis

The sampling and analysis procedures presented below outline required activities associated with the EBT Treatability Study to define its effectiveness in decreasing CVOC concentrations in groundwater underlying the Memphis Depot. In addition, the information below outlines locations, frequency, and analyses for soil and groundwater to be collected during and after installation activities and system operation as well as analyses required for disposal characterization for wastes generated during removal activities.

8.1 Data Quality Objectives

The data quality objectives (DQOs) detailed in Table 8-1 are established to achieve objectives outlined in Section 4.

TABLE 8-1

Data Quality Objectives

Objective	Qualitative DQO	Quantitative DQO	Method to Obtain DQO
Vertical profile of CAH distribution	Develop vertical profile of CAH distribution within fluvial aquifer.	Analyze groundwater samples collected during baseline and monitoring events. Analyze all by SW-846 Method 8260B. In addition, analyze groundwater samples for geochemical parameters	Collect groundwater samples from monitoring wells during site-wide groundwater baseline sampling event, samples from injection and monitoring wells during baseline event, and samples from monitoring wells during periodic monitoring events.
Electron donor effectiveness	Comparison of CAH levels prior to injection to CAH levels post-injection and companson of parent/daughter ratios of CAHs from previous to subsequent injections.	Compare results of groundwater sample analysis for VOC and geochemical parameters for pre- and post- injection samples.	Collect groundwater samples from monitoring wells in pre- and post- injection events and analyze according to SW-846 Method 8260B and geochemical parameters. Obtain results and compare in tabular form.
Evaluate transport of reductive dechlorination enhancement materials within aquifer	Develop understanding of concentration changes and flow patterns within aquifer.	Analyze downgradient groundwater samples results for CAH levels, geochemical parameters, and groundwater tracer	Inject groundwater tracer prior to injection of electron donor substrate. Install monitoring wells and collect groundwater samples according to SW-846 Method 8260B and analyze for patterns of results in each downgradient well.
Estimate radius of influence	Define volume effected by introduction of electron donor substrate material.	Analyze downgradient groundwater samples to determine concentration change of contaminants and geochemical parameters as well as tracer component.	Install monitoring wells and collect groundwater samples according to SW-846 Method 8260B and for bromide and analyze for patterns of results in each downgradient well.

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TABLE 8-1
Data Quality Objectives

Objective	Qualitative DQO	Quantitative DQO	Method to Obtain DQO
Rate of reduction of CAH levels and time required for reduction to regulatory levels	Define the time elapsed since introduction of electron donor substrate and compare baseline levels of CAHs to end of test levels to provide estimate of time required to reduce entire plume to required levels	Analyze downgradient groundwater samples to determine concentration change of contaminants and geochemical parameters. Compare concentrations after end of test to baseline levels and time elapsed, and using rate of flow from tracer test, define time required to reduce entire plume to regulatory levels.	Install injection wells. Install monitoring wells and collect baseline groundwater samples according to SW-846 Method 8260B. Inject groundwater tracer prior to injection of electron donor substrate. Collect groundwater samples from monitoring wells and analyze for patterns of results in each downgradient well.
Effect of injection pressures	Determine if injection of electron donor substrate results in mounding of water/substrate above static top of water table.	Utilize pressure or water level transducers or depth to water measuring instrument in surrounding injection and monitoring wells to determine if mounding results from injection.	Install injection and monitoring wells and prepare each with transducers connected to data logger except for injection well. Set transducers for static water level and inject material. From response of water level, determine if mounding results from injection.
Depletion of electron donor substrate in aquifer	Define the time elapsed since introduction of electron donor substrate and compare baseline levels of CAHs. Also, determine if substrate continues to appear in monitoring wells as product.	Analyze downgradient groundwater samples to determine concentration change of contaminants and geochemical parameters. Compare concentrations after end of test to baseline levels and time elapsed.	Install injection wells. Install monitoring wells and collect baseline groundwater samples according to SW-846 Method 8260B. Also analyze for substrate content. Inject electron donor substrate. Collect groundwater samples from monitoring wells and analyze for patterns of results in each downgradient well.

8.2 Soil

8.2.1 Soil Core Sampling

During the drilling of each boring for monitoring and injection wells, soil cores will be collected in continuous sampling mode from land surface to the bottom of each boring. 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. Headspace field screening (see field screening SOP in Technical Memorandum SA.01 – Data Collection Plan for Long-Term Operational Areas (LTOAs), Main Installation, Memphus Depot) will be conducted over each core using an Organic Vapor Analyzer-Flame Ionization Detector (OVA-FID) until the last core is removed from the boring.

Soil samples will be collected from the vadose zone wherever OVA-FID measurements are above 20 ppm or wherever there appears to be obvious staining in the soil profile. No more

NPEACHTREEVPROJ/160492/TASK TS 01 - MI EBT TREAT STUDY/EBT TREATABILITY STUDY WPLANREV 1 EBT TREAT STUDY/REV 1_MI EBT TREAT STUDY WP DOC than one sample will be collected from each boring. In addition, one soil samples will be collected from the aquifer from each boring and analyzed for TOC content.

8.3 Groundwater Sampling

8.3.1 Baseline

A baseline sampling event will be conducted across the MI prior to the locating and drilling of monitoring and injection wells associated with the EBT Treatability Study. All on-site and off-site monitoring wells and piezometers, except for those recently sampled as part of the LTOA Investigation, will be sampled. All samples will be analyzed for VOC content. In addition, 18 wells will be selected for geochemical analysis sampling. Additional information on this sampling event is provided in Table 6-2 and Appendix A.

8.3.2 Pre-Injection

Prior to injection and after development of each of the newly installed monitoring and injection wells, groundwater samples will be collected from each location. Groundwater samples will be collected according to procedures described in Appendix A. Groundwater samples intended for analysis of VOC content will be collected through the use of polyethylene diffusion bags. Groundwater samples intended for geochemical analysis will be collected by a low-flow bladder pump system. All groundwater samples for VOC analysis will be analyzed according to EPA Method SW8260B.

8.3.3 Post-Injection

Seven groundwater sampling events will take place after the electron donor substrate has been injected into the fluvial aquifer. The first two events will be bi-weekly followed by monthly events for the next 5 months. Groundwater will be sampled from each EBT monitoring well and samples will be analyzed for VOC and geochemical analyte content (Table 6-2). Sampling procedures will be similar to those described in Appendix A except that collection of the diffusion bags will take place on a 2-week basis instead of three.

In addition to collecting samples for VOC and geochemical content, samples will be collected for electron donor substrate or breakdown product distribution in the aquifer, including:

- Metabolic acids to detect lactic acid
- EPA Method 1664 to detect soybean oil.

9.0 Data Management, Analysis, and Interpretation

9.1 Data Description

Information generated from the EBT Treatability Study will include geologic, hydrogeologic, and geochemical data. In addition, biologic information may also be generated if bioaugmentation procedures are implemented during the study. Geologic data will be derived from the installation of monitoring and injection wells and will include:

- Lithologic and stratigraphic characteristics of the loess and fluvial deposits that overlie the fluvial aquifer;
- Lithologic and stratigraphic characteristics of the fluvial aquifer.

Hydrogeologic data will derive from review of samples collected for analysis of the groundwater tracer that is to be injected prior to start of the injection phase. The data will include definition of the groundwater flow rate within the fluvial aquifer. Geochemical information from this study will derive from analysis of all groundwater samples collected for VOC and geochemistry. These data are critical for determination of the effectiveness of enhanced bioremediation in the fluvial aquifer. If necessary, biologic information will also be gathered during the study and will reflect the type of microorganisms present in the aquifer as well as the type required for augmentation.

9.2 Data Management

Data management for the EBT Treatability Study will match the requirements of the DQOs presented in Section 8. Most of the field data will be obtained through the efforts of field screening, which includes use of direct-reading instruments, and laboratory analysis of samples. The information presented in this section is considered supplemental to the *Final Generic QAPP* for the Memphis Depot activities.

9.2.1 Sample Numbering System

During sampling events conducted for the EBT Treatability Study, nomenclature will be used to distinguish between categories of sampling events, sample locations, and, where appropriate, depth of sample collection. Sample numbering protocol will be as shown in Table 9-1.

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MEMPHIS DEPOT MAIN INSTALLATION EBT TREATABILITY STUDY - REV 0

TABLE 9-1 Sample Numbering Protocol

Sample Event	Type of Sample(s) and Location	Sample Number Description	Exampie Sampie Number
Baseline Groundwater Sampling for VOCs and Geochemistry	Groundwater; Sitewide across Main Installation	For VOC samples, sample numbers will reflect depth of diffusion bag sampler located in each well. Samples for geochemistry will reflect sample location only.	For VOCs: MW92_95- 100-BL For Geochemistry. MW92-BL
Monitoring and Injection Well Installation	Soil; In both study areas	Samples will reflect location and depth of sample collection.	MW109_100-110 MW110_110-120
Baseline Sampling of Monitoring and Injection Wells	Groundwater; In both study areas	All samples will have an EBT-B designation to reflect this baseline event. For VOC samples, sample numbers will also reflect depth of diffusion bag sampler located in each well. Samples for geochemistry will also reflect sample location only.	For VOCs [•] MW92- EBT-B_95-100 For Geochemistry: MW92-EBT-B
Treatability Study Sampling Events of EBT Monitoring Wells	Groundwater; In both study areas	All samples will have an EBT- TS designation followed by an number (beginning wth 1) reflecting the sequential sampling events. For VOC samples, sample numbers will also reflect depth of diffusion bag sampler located in each well. Samples for geochemistry will also reflect sample location only.	For VOCs: MW92- EBT-TS-1_95-100 For Geochemistry: MW92-EBT-TS-1

For Duplicate samples, a "D" will be inserted at the end of the sample number. 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.

9.2.2 Field Screening Data Management

Field screening efforts will include ambient air screening around monitoring and injection wells with an OVA-FID and screening of groundwater during purging procedures with portable direct-reading instruments. The data collected from these instruments will require the full attention of the operator to ensure that reported values are not misinterpreted or misunderstood. 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; and
- Instrument measurement.

Each measurement will be handwritten into a bound field notebook and, after the entire test has been completed, the data will be transferred into an electronic file for use within the EBT Treatability Study report.

Other field notes to be collected during performance of the Treatability Study and written in the field notebook(s) include: weather information; personnel present during onsite activities; subcontractor names and activities; sketches of the test system used during the study; notes on the proximity of the system to established facilities within the MI; and all other pertinent information that may effect study results. This information will be included in the Treatability Study report, as necessary.

9.2.3 Analytical Laboratory Data Management

Multiple samples will be submitted to an analytical laboratory for VOC and geochemical analysis and reporting. During collection of groundwater and soil samples, the date, time, location of sample collection, and sample number will be recorded in the field notebook. This information will be transferred, as required, to the Chain-of-Custody (COC) documents. Copies of the COC will be kept at the site until the study is over and will 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 EBT technical memorandum. 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 results from the study. Electronic Deliverable Data will be delivered according to EDMS 4.0.

9.3 Data Analysis And Interpretation

The data collected during the study will be tabulated and graphed to observe trends in relevant groundwater parameters. Data collected at each monitoring location will be compiled to provide an overview of the changes that occurred throughout the test plots. In addition, a statistical analysis will be performed to determine if observed changes in measured concentrations are statistically significant. These changes will be compared to the variation observed in the water extracted from the observation well. A t-test with a 5 percent significance level (α = 0.05) will be used to compare the mean value of measured concentrations from separate sampling events.

All data and resulting interpretation will be presented and described within the EBT technical memorandum and each Remedial Design document for the MI. The data will also be used as a basis for the design of the groundwater remedy.
10.0 Health and Safety

A site-specific HASP for the tasks presented herein was prepared by CH2M HILL in February 2002. Issues particular to the EBT study are discussed within the HASP. These issues may include but not be limited to the following:

- 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.
- Monitoring and Injection Well Installation: Drilling The installation of wells at the MI 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 potential slips, trips, and fall possibilities.
- Soil Sampling Soil from the fluvial aquifer may potentially 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.
- Ambient Air Monitoring Action Levels The existing HASP provides action levels for upgrading levels of personnel protection from Level D to Level C and LEVEL B. However, employing engineering controls to prevent VOC emissions is preferable to using personnel protective equipment. If the action levels for Level D are exceeded during the operation of this study, the study work efforts will be revised for corrective actions. Actions may include changing ambient air measurement locations or bringing in equipment to reduce the hazards.

11.0 Residuals Management

Waste handling will be dealt with during the Treatability Studies. Waste may be classified as noninvestigative waste or investigative/field-generated waste.

Noninvestigative waste, such as litter and household garbage, will be collected on an asneeded 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.

Investigative/field-generated waste will be properly containerized and temporarily stored at each site, prior to transportation. Depending on the constituents of concern, fencing or other special marking may be required. The number of containers will be estimated on an as-needed basis. Acceptable containers will be sealed, U.S. Department of Transportationapproved steel 55-gallon drums or roll-off box-type containers. The containers will be transported in a manner to prevent spillage or particulate loss to the atmosphere. To facilitate handling, the containers will be no more than half full when moved.

The investigative/field-generated waste will be segregated at the site according to matrix (solid or liquid) and means of derivation (drill cuttings and decontamination fluids). Each container will be properly labeled with site identification, sampling point, depth, matrix, constituents of concern, and other pertinent information for handling.

Soil cuttings generated from the monitoring point installation procedures 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 corporation. Once the soil analytical data have been obtained, the soil will be removed from the MI within 60 days. Previous IDW soil samples were analyzed by TCLP methods and were found to be non-hazardous. The soil did not require special procedures for transportation and disposal.

Wastewater generated from well development, purging, sampling and equipment decontamination activities must also be stored at the site prior to removal from the MI. Once analytical data have been obtained, the water will be removed from the MI within 60 days. During past investigation activities at the MI, IDW water 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 the effluent from the operating Dunn Field groundwater extraction system, which discharges into the City's sewer system.

12.0 Community Relations

The Memphis Depot has an active community involvement that monitors the events that occur at the Memphis Depot site as well as the MI. The EBT Treatability Study will occur with the knowledge of members of the community, many of which live just beyond the perimeter of the MI. It is imperative that this study be conducted according to the specifications presented herein and that if any changes are necessary proper notification is followed along with discussions with all stakeholders.

It is anticipated that the plans for the treatability study will be presented to the Memphis Depot Restoration Advisory Board (RAB) prior to field activities. In addition, prior to initiation of field activities, fact sheets describing the treatability test and duration of the fieldwork will be distributed to the local community members that live in the area surrounding the MI. The findings from the study will also be presented to the RAB members once they are finalized.

13.0 Reports

An EBT Treatability Study technical memorandum will provide the necessary documentation of the completed Treatability Study process. CH2M HILL will complete the technical memorandum according to the schedule presented in Section 14.0. The technical memorandum will include, but not be limited to the following:

- A description of the EBT system construction and additional monitoring and injection well installation;
- Description of methods, including injection, monitoring, and sampling, enacted during the study and electron donor substrate performance;
- Field measurement methods;
- Summary of field and laboratory analytical data as presented in graphs and tables;
- Results of analysis of the analytical data via computer models, including contaminant concentrations, groundwater geochemistry, change in contaminant concentration versus baseline concentrations; and
- Recommended parameters for the final design.

The EBT technical memorandum will also contain a separate section that covers the data quality and validity. At a minimum, the following information will be included in this section:

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

14.0 Schedule

14.1 Preliminary Schedule

The following preliminary schedule (Table 14-1) is presented for the EBT Treatability Study fieldwork and preparation of the final technical memorandum.

TABLE 14-1

Preliminary Schedule

Task	Date Completed
Submit Rev. 0 EBT Treatability Study (TS) Workplan as part of the RD Workplan to the U S. Army Corps of Engineers and BCT	January 14, 2002
Conduct Baseline Groundwater Sampling Event	February 19, 2002
Receive Comments on Rev. 0 TS Workplan from Agencies and USACE	March 15, 2002
Submit Rev. 1 TS Workplan	April 14, 2002
Contact Utility Locators (Tenn. Utilities Hotline at 800-351-1111)	March 30, 2002
Install Monitoring and Injection Wells within each Treatability Study Area (Event includes well development and baseline sampling of each new well)	May 15, 2002
Analyze Baseline Samples of Monitoring and Injection Wells	May 25, 2002
Injection of Electron Donor Substrate into Study Areas	June 25, 2002
Performance Monitoring of Substrate Effect	January 15, 2002
Conduct Laboratory Analyses of Final Groundwater Samples	January 15, 2002
Conduct Final Laboratory Data Evaluation	January 31, 2003
Prepare EBT Technical Memorandum for submittal with MI Intermediate RD report	February 15, 2003
Submit Weekly Field Status Report to USACE & BCT and Conduct Monthly Teleconferences to Discuss Field/Lab Results	February through January 2003

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Table 5-1 Geochemical Markers of the Fluvial Aquifer Underlying the Mi Rev. 1 Memphus Depot Main Installation EBT Treatability Study Workplan

Geochemical Marker	Reported Range*	Background Values	Units	Biodegradation Activity?
Soluble Chloride Ion	11 - 24	10	ma/L	Supportive
ORP	145 - 238	209	mV	Not supportive
Dissolved hydrogen	1 39 - 3 13	1.19	nm/L	Supportive
Dissolved oxygen	5 45 - 7.56	6.51	mg/L	Not supportive
Nitrate	1.8 - 2.9	2.1	mg/L	Not supportive
Ferrous(Fe ²⁺) iron	ND	ND	ma/L	Not supportive
Ferric (Fe3+) iron	ND	ND	ma/L	Supportive
Manganese	ND	ND	ma/L	Supportive
Sulfate/Sulfide	4 3 - 18/ND	30/ND	ma/L	Supportive
Methane	0.002142 - 0.005964	0.000067	mg/L	Not supportive
Alkalinity	45 - 90	95	mag	Supportive
рН	5 78 - 5.79	6.17	su	Supportive
Temperature	19.96 - 21.38	18.44	degrees C	Supportive
Ammonia	ND - 0 5	0.2	ppm	Not supportive
Total Organic Carbon	ND	ND	ma/L	Not supportive
BOD	ND	ND	mg/L	
CAH daughter products	present	ND	ug/L	Supportive

*Range is reported for wells within the plume area

ORP = Oxidation/Redox Potential

BOD = Biochemical Oxygen Demand

CAH = Chlorinated Aliphatic Hydrocarbons

mg/L = milligrams per liter

mV = millivoits

nm/L = nanometers per liter

ppm = parts per million

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su = standard units

C = centigrade

ug/L = micrograms per liter

Table \$.1 Summary of Historical Voistile Organic Compound Data Bioniboring Wilsi WW-21, MW-22, MW-47, and P2-04 Pier 1 Mempia Depat M EET Treedsbirg Stop Worksten

Locatio	9	PZOH	MW21	MW21	MW21	MW21	MW21	12WW	MW21
Date Colle	otted	11/03/1998	11/18/1993	02/10/1996	06/20/1997	2661/12/60	03/27/1998	10/19/1998	03/24/2000
Parameter Name Rank	Units			Aller and a second	Press and a second	100 C 100 C	and the second second		N. N. N. S.
1,1,2,2-TETRACHLOROETHANE	ğ	0 000 0	0 001 U	0 10 0	001U	0 01 U	0010	0 01 U	ţ
1,1-DICHLOROETHENE	ğ	0.005 U	0 2005 U	0 10 0	0010	0 00 0	0.01 U	0 10 0	120
ACETONE	ş	0 01 U	8	0 60 0	0010	0 01 U	0.01 U	0 01 U	76
CAPBON DISULFIDE	Å	0.005 U	2	0 01 U	001U	0 01 U	0010	0 10 0	5
CARBON TETRACHLORIDE	ş	0.005 U	U 1000	0010	001 U	0 01 U	0010	0 01 0	0.4.0
CHLOROFORM	ş	0.005 U	0 100 0	0 01 U	0 0 I U	0 60 0	0010	0 01 0	10
cia-1,2-Olchiorothylene	ş	2	Ē	g	8	2	2	2	+
da-1,3-DICHLOROPROPENE	ķ	U 200-0	0 100 U	001 U	0010	0 10 0	0 01 U	0 01 U	Ĵ.
STYRENE	ğ	0 000 U	2	0 10 O	001U	0 10 0	U 100	0010	J.
TETRACHLOROETHYLENE(PCE)	ş	110=	1 9	å	12	2		120=	18
TOTAL 1,2-DICHLOROETHENE	ş	0 002 U	2	0 to 0	0 10 O	0010	0.01 U	2	2
trans-1,2-OICHLOROETHENE	ß	2	0 000 U	2	2	2	2	æ	₽
TRICHLOROETHYLENE (TCE)	[ug/L	0.005 U	4 42=	3	4	ě	ş	31=	Å
(=) Dedinite detection									

J = Extincted detection. Contactivent detected at or below laboratory detection first.
 na = not included in list of analytes

Locatio	ġ	MW22	WW22	MW22	MW22	27.MM	MW22	MW22	MW22
Data Colls	cted :	11/17/1993	11/17/1993	02/10/1996	06/19/1997	09/25/1997	03/28/1998	10/19/1998	03/23/2000
and the stanleter Name we want	Units	STREET, ST		And the second second	A REAL FRAMEWORK	VIEW CONTRACT	- Andrewskinster	Sector Sector	a Management
1.122-TETRACHLOROETHANE	γđη	0 100 0	0 001 U	0 01 U	D 01 U	0 01 U	0 01 U	0 01 U	5
1.1-DICHLOROETHENE	5	0 001 U	0 000	0.01 U	0010	0010	0010	0 00 U	ņ
ACETONE	ş	2	8	0 01 U	0 01 U	0 01 N	0 01 U	0 01 N	5U
CARBON DISULFIDE	ş	2	2	0 10 0	0 01 U	0010	0 01 U	0 01 U	0.3 J
CARBON TETRACHLORIDE	ğ	0 001 U	0 100 0	0 10 0	0010	0.01 U	0 01 U	0 01 U	5
CHLOROFORM	Ś	0 001 U	0 000 U	0 01 U	0010	0 01 U	0 01 U	0 01 U	ņ
cia-1.2-Dichiorothytene	Ş	2	2	ş	2	2	ę	2	L 2 0
die-1.3-DICHLOROPROPENE	Ś	0 001 U	0001	0 01 U	0 01 N	0 01 U	0010	0 01 U	5
STYRENE	, de	2	2	0 10 0	0010	0 01 U	0.01 U	0 01 U	5
TETRACHLOROETHM.ENE(PCE)	Ś	U 100 0	00010	ล	001U	ิล	0010	0 01 U	760
TOTAL 1,2-DICHLOROETHENE	Å	2	2	0 01 U	0 01 U	0 01 U	0010	0 01 U	8
TIME-1,2-DICHLOROETHENE	Ś	0 001 U	0 001 U	2	Ę	2	ŧ	2	10
TRICHLOROETHMLENE (TCE)	ug/L	1.24=	0 001 U	21	2,1	7	7	0 01 U	-
(=) Definition detection									

 $J=E_{\rm B}$ parameter detection. Contarritent detected at or below laboratory detection limit, as a rock included in list of analytes

Locat	tion 1D	MW47	MW47	MW47	MW47	MW47	MW47	MW47	MW47	MW47
Date Co	liected :	02/08/1996	06/22/1997	09/26/1997	03/28/1998	10/19/1998	03/23/2000	03/09/2001	03/09/2001	03/09/2001
and the Parameter Name (1999)	新 Units	Contraction of the	·A.S.S.S.	A STATE OF	14 State 1 - 1	A STATE OF A		10 Mar 10 Mar	of the second second	Children and an
1122-TETRACHLOROETHANE	3	0010	0.01 U	0 01 U	0 10 0	0 01 U	n:	1450	0.17 J	-r:
1.1-DICHLOROETHENE	3	0010	0 01 U	0 01 U	0 01 0	0010	5	2	ç	2
ACETONE	3	0010	0 01 U	0 01 U	0 D1 U	0010	50	25	24J	26.J
CARBON DISULFIDE	ş	0.01 U	0010	0 01 U	0 D1 U	0000	2	2	2	2
CARRON TETRACHLORIDE	3	0.01 U	0100	0 00 0	0 01 0	0000	2	<u>,</u>	2	2
CHLOROPORM	3	0010	0010	0 00 U	0 01 U	000	ņ	÷	2	2
cia-1 2-Dictriorothylene	3	2	2	2	2	2	÷	ņ	5	2
H-1 LUICH OROPROPENE	3	001 U	0010	0 01 U	0 10 0	0010	2	ţ	2	5
STYRENE	3	0010	0010	0 01 U	0 01 U	000	2	ţ	2	2
TETRACHLOROETHMENE(PCE)	ş	23=	ล	ł	ŧ	2	200-	0.57 J	5	2
TOTAL 1.2-DICHLOROETHENE	Š	ล	0010	3	2	2	2	5	2	ą
mane 1 2-DICHLOROETHENE	ğ	5	8	8	2	2	2	2	5	2
	Ì	•	1100	2	3	0010	2=	-	2	2

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Tatla \$.22 Summery of Kistorical Volatila Organic Compound Data Monitoring Wells MW-23, MW-24, MW-30, and MM-44 Rar I Margers Dapt da E81 Transitily Study Murgen

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Locatio	: 9 5	MW25	MW25	MW25	MW25	MW25	MW25
Date Colli	itted :	11/13/1993	2/9/1996	6/19/1997	9/25/1997	3/26/1998	10/16/1998
And the Parameter Name April 10	Unite				State of the state		
1.1.2.2-TETRACHLOROETHANE	ηθη	0 001 U	0 01 U	0 01 U	0010	0 01 U	0 01 U
1.1-DICHLOROETHENE	ş	0 001 U	0 01 U	001U	0 01 U	0 01 U	0 01 U
ACETONE	Ŕ	8	0 01 U	0 01 U	0 01 U	0 01 U	00100
CARBON DISULFIDE	ş	8	0 01 U	0010	0 01 U	0010	0 01 U
CARBON TETRACHLORIDE	ş	0 001 U	0 01 U	0 01 U	1,	11	2.7
CHLOROFORM	Ś	0 001 U	0 01 U	0 01 U	0 01 U	0 01 U	0 01 U
cts-1,2-Dictriorothytene	ş	E.	8	2	ş	2	2
da-1,3-DICHLOROPROPENE	ş	0 001 U	0010	0 10 0	0 01 U	0 01 U	0 01 U
TETRACHLOROETHYLENE(PCE)	ş	11.2 =	4.)	4.1	11 =	6.1	78
TOTAL 1,2-DICHLOROETHENE	Å	Į	0 01 U	0 01 U	0 01 U	0 01 U	0 01 U
ITEMA-1,2-DICHLOROETHENE	ş	0.001 U	8	2	8	2	2
TRICHLOROETHYLENE (TCE)	ugl	0 001 U	0 01 U	0 01 U	0 01 U	0 01 U	0 01 U
(=) Definitie detection							

J= Estimated detection. Contacting detected at or below is locationy detection limit, re = not bridden in list of analysis

Locatic	i di no	92.MW	MW/26	MW26	MW26	92.MW	MW26
Date Colle	ected -	11/9/1993	2/8/1996	6/20/1997	9/26/1997	3/28/1998	10/20/1998
Parameter Name 20 and	Units	CORPORATION AND	Support State	A STREET BOARD	South and the second second	AND DESCRIPTION	
1,1,2,2-TETRACHLOROETHANE	γðn	0 001 U	0010	0 10 0	0010	0 01 U	0 01 U
1,1-DICHLOROETHENE	Å	0 001 U	0 01 N	0 01 U	001 0	001U	0010
ACETONE	ş		0010	0 01 U	0 01 U	0 01 U	0 01 U
CARBON DISULFIDE	ş	g	001 U	0010	001 U	0 01 U	0 01 U
CARBON TETRACHLORIDE	ş	3.16 =	74	. 4	Ş	4	ר ד
CHLOROFORM	ş	0 001 U		7	0010	2,1	-
da-1,2-Dichiorothylene	ş	ę	80	2	ę	BC	đ
dia-1,3-DICHLOROPROPENE	ß	0 001 U	0 01 U	0 01 U	0 01 U	0010	0010
TETRACHLOROETHMENE(PCE)	Ş	6.5 =	1	12 =	:	14 =	16 =
TOTAL 1,2-DICHLOROETHENE	ş	108	0 01 U	0 01 U	001 U	0010	0 01 U
Tane-1,2-DICHLOROETHENE	ş	D 100 0	80	2	ę	2	ĝ
(RICHLOROETHYLENE (TCE)	ugl	1.29 =	21	7	2.1	2.7	2 J
 Definitin detection 							

 $J=Eatimated detection. Containing detected at or below laboratory detection limit, <math display="inline">n_{\rm B}=not$ bectuded in list of ensignes

Location	0	MW50	MW50	MWSO	MW50	MW50	MW64
Date Collec	cted -	2/11/1996	6/19/1997	9/24/1997	3/25/1998	10/16/1998	10/25/1998
-traded Parameter Name aparage [Unite	The Property is a		- A Martineta A	Contraction of the second	18. 18. 18. 18. 18. 18. 18. 18. 18. 18.	10000
1,1,2,2-TETRACHLOROETHANE	Å	0010	0 01 U	0 10 0	0 00 U	0 01 U	4.1
1,1-DICHLOROETHENE	ş	0 01 U	0 01 U	0 1 U	0 01 U	0 01 U	0 01 U
ACETONE	ş	0048U	0 01 U	N 100	0 10 0	0 01 UN	0 01 U
CARBON DISULFIDE	ş	0 01 U	0 01 U	0 01 U	0 00 U	0 01 U	,
CARBON TETRACHLORIDE	ş	0010	0 01 U	0 01 U	0 01 U	0010	2.5
CHLORDFORM	Å	0010	0 01 U	0 01 U	0 001 U	0 01 U	L1
cis-1,2-Dichlorothylene	ş	8	82	5	물	2	ß
cie-1,3-DICHLOROPROPENE	ş	0 01 U	0 01 U	0 01 U	0 10 0	0 01 U	0 01 U
TETRACHLOROETHMLENE(PCE)	ş	001U	0 01 U	0 01 U	0 01 U	0010	10 =
TOTAL 1,2-DICHLOROETHENE	ş	0 01 U	0 01 U	0 01 U	0 01 U	0010	001 U
trans-1,2-DICHLOROETHENE	Å	줟	B	an B	â	2	82
TRICHLOROETHYLENE (TCE)	ug/L i	0 01 U	0 01 U	0 01 U	0 01 U	0 01 U	28 =

(*) Definition detendion J = Extinment detendion. Contaminant detected at or beiow indomiziny detection limit, na = not included in fait of analytes

Table 5.3 Summary of LTOA Groundwater Sample Analytical Results - VOCs for 1 Memora Decor Man tratation EDT Treatably Study Worksian

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	Diffusion Bag Intervals					Analytik	cal Lab Data*				Ι.	
Monitoring		PCE	TCE	cis-12-DCE	trans-1,2-DCE	1,1-DCE	1,1-DCA	1,2-DCA	1,1,2,2-PCA	Chloroform	Carbon	
Well	upper to Lower Bag	_									Tetrachloride	
٩	(ft btoc)	(1/Bn)	(ng/L)	(ng/L)	(n8/L)	(1/6n)	(1/5n)	(1/6n)	(1/6/L)	(ng/L)	(10g/L)	
MW-85	100 9 to 110 9	49	23	28	0.7	v	•	13	1.0	3	122	
MW-86	99 5 to 115 5	198	20	8	0.9	ŗ	÷	3.6	•	4	7	
MW-88	81 to 97	10.7	2.4	13	÷	ŗ	÷	•	Ť	t.	30	
MW-92	98 to 108	150	4.4	6.6	0.7	÷	v	<u>.</u>	Ţ	6.5	19	
MW-93	103 to 107	ţ	÷	ţ	÷	÷	Ÿ	÷	ŗ	98	Ÿ	
MW-94	108 5 to 110 5	ţ	÷	Ť	5	•	÷	ŗ	<u>.</u>	Ÿ	Ŷ	
96-WW	83 5 to 95 5	•1	• •			ţ	÷	ŗ	ź	0.8	£	
MW-97	101 5 to 117 5	ī	0.9	÷	Ţ	Ţ	Ţ	•1	ĉ	Ŧ	÷	
MW-98	137 to 147	46	80	÷		ŗ	÷	÷	ž	02	•	
66-WW	91 5 to 109 5	, ,	07	÷	÷	2	•	v	ž	0.5	2	
MW-100	107 5 to 125 5	8	79	12	0.2	0.3	ŕ	0.2	0.5	Ŷ	÷	
MW-101	NA.	480	0.9J	0.3J	⊽	7	r	r	v	0.61	v	
MW-102	120 5 to 138 5	ţ	0.7	•	÷.	÷	Ÿ	•	0.6	÷	÷	_
MW-103	70 to 88	ÿ	4.0	0.5	<u>,</u>	12	<u>د</u> .	50	Ţ	13		
MW-104	70 5 to 88 5	:	ŧ	0.6	÷.	÷	0.5	Ť	£	12	÷	
MW-107	N	0.0	2.7	0.3	2	r	v	Ł	2	0.2	0.6	
LANAY 100	11 A **	4 6	4		ĭ	ĩ	,	1	ĩ	4	v	

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 Table 5-4

 Practicality of Electron Donor Substrates

 Rev. 1 Memphis Depot Main Installation EBT Treatability Sturby Workplan

	Success Level	Reduction of contaminant occurred after 0.5 month period.	TCE and DCE levels below cleanup goals	19 Contaminant levels vary after injection, some sites show marked decrease and show no decrease.	After six-month period, TCE levels decreased to 160 mg/L. Daughter product levels increased along with total VC levels	 After one week - extensive biological utilization of hydrogen After 4 months data indicate significant reductions in TCE and cs-DCE concentrations compared to a control point (injected with nitrogen only)
Equipment	Delivery	Direct injection	Direct injection through injection wells	Injection through pumpin	Injection and Recirculation System	Gas putsed through three injection points
Aquifer	Viscosity of Substrate	Laboratory Test	High permeability aquifer vs Low viscosity substrate	Sandy suit aquifers to sand aquifers	Sandy aquifer; viscosity of oil dependent upon mixing	Sandy aquifer; gas - high viscosity substrate
Contaminant Concentrations	Memphis Depot	1CE = 760 mg/L	TCE = 67 ug/L, DCE =7 ug/L, VC = <1 ug/L	Concentrations comparable or greater than at Memphis Depot	TCE = 100.000 mg/L, VC = 330 mg/L	TCE = 48 mg/l, cis-DCE = 140 mg/L - 3
Substrate Use at Other	Sites	MCLB-Albany, GA	AVCO Lycoming Superfund Site	Various Sites	Demo Site, Cape Canaveral, FL,	AFCEE - Cape Canaveral Air Station
Substrate Tyne		Lactate	Molasses	НКС	Vegetable Oil	Hydrogen sparging

Table 6-1 List of Preliminary Activities of the MI EBT Treatability Study Rev. 1 Memphys Depot MI EBT Treatability Study Workplan

Activity	Description	Purpose
Utility Locating	Location of site utilities prior to intrusive activities.	Ensure that no service lines or other utilities may be present in the locations selected for monitoring or injection wells
Baseline Groundwater Sampling	Sampling of all exisiting on- and offsite monitoring wells and piezometers and analyze samples for VOC, metals, and geochemical parameters.	Define current VOC plume configuration in the fluvial aquifer and set baseline for reductive dechlorination and long-term natural attenuation monitoring studies, as defined by the MI ROD.
Electron Donor Injection Quantity Determination	Determination of quantity required to inject into the fluvial aquifer to ehance reductive dechlorination processes.	Quantity of material to inject is vital to enhancement of the reductive dechlorination process
Monitoring and Injection Well Installation and Sampling	Install 28 monitoring and 20 injection wells in two EBT study areas using rotasonic methods. Screened intervals for each type well will be located for most effective sample and injection results.	Wells required as part of study activities. Sampling of groundwater subsequent to injection will be critical to define if reductive dechlorination is progressing and reducing current levels of CAHs in fluvial aquifer.
Other Field Activities (Site communications, temporary storage, security)	Communicate with DRC and personnel at Memphis Depot Business Park regarding communications, storage needs, and site security.	Establish roles and chain-of- command, storage for equipment required during study, and security of equipment and personnel.

Table 6-2 Analytical Protocols for EBT Samples Ray, 1 Memohis Depot Main Installation EBT Tech FBT Tech

Rev. 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Matrix and Analytes	Method	Field (F) or Analytical (L) Laboratory
Groundwater*		
Redox Potential	Direct-reading meter	F F
Dissolved Oxygen	Direct-reading meter	F
	Direct-reading meter	F
Specific Conductance	Direct-reading meter	F
Temperature	Direct-reading meter	F
VOCs	SW8260B	L L
Dissolved Gases (ethene, ethane, and methane)	RSK175	L
Dissolved organic carbon	SW9060	L
Nitrate, nitrite	SW9056	
Sulfate	SW9056	
Sulfide	E376.1	
Carbon dioxide	CHEMetrics Method 4500	F
Bromide	E320.1	Ĺ
Chloride	SW9056	L -
Ferrous Iron	Hach Kits	F
Manganese	SW6010B	L L
Alkalinity	E310.1	
Metabolic Fatty Acids	E300.0	L L
Oil in Water	SW1664	L.
<u>Soil</u>		
Total Organic Carbon	SW9060	L
Vegetable Oil, Lactate, and		
<u>Tracer</u>	1 1	
TAL/TCL	TAL/TCL	L
		L L

*Reported in sequence of sample collection.

Table 7-1

Treatability Study Area 1 (MI Southwest Corner) Injection Scenarlo Rev 1 Memphis Depot Main Installaton EBT Treatability Study Workplan

	-			_		_	
Water Flush Flow Rate (hours)	(c.mo.u)			0.3	0.3	0.3	0.9
Water Flush Flow Rate	(indR)			e	3	3	
Emulsion Injection Time	(emoil)			39.1	39.1	39.1	117.4
Emulsion Flow Rate (gpm)				3	3	3	
Radius of Influence (feet)				5	5	5	
Screened Interval (feet)				40	40	40	
Final Percent Oil				25	25	25	
Total Volume (gallons)				7046	7046	7046	21138
Water Flush Amount				55	55	55	165
Emulsifier (agent)				Lecithin	Lecithin	Lecithin	
r Mixture	Water	(gallons)	fer	5230	5230	5230	15689
Oil/Wate	lio	(gallons)	Entire Aqui	1762	1762	1762	5285
Weil			Test Area -	1-1N	NJ-2	INJ-3	

Assumptions

An effective porosity of 30 percent for the fluvial aquifer.
 Fluid will be injected into two wells at the same time
 Water for mixture will include a sodium bromide tracer as a groundwater tracer.

gpm = gallons per minute

Table 7-2

Treatability Study Area 2 (MI Southeast Corner) Injection Scenario Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Well	Lactatı Mix	e/Water ture	Water Flush Amount	Total Volume (gallons)	Final Percent Lactate	Screened Interval (feet)	Radius of Influence (feet)	Substrate Flow Rate (qpm)	Substrate Injection Time	Water Flush Flow Rate	Water Flush Flow Rate	
	Lactate (gallons)	Water (gallons)		 !				į	(nours)	(mdg)	(hours)	
Test Area-	Entire Aquif	er										
INJ-4	661	1927	55	2642	15	15	5	e	14.7	e	03	
INJ-5	661	1927	55	2642	15	15	5	e	14.7	e	0.3	
INJ-6	661	1927	55	2642	15	15	5	ო	14.7	e	0.3	
11J-7	661	1927	55	2642	15	15	5	3	14.7	3	0.3	
:	2642	7077	220	10569					58.7		1.2	

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Assumptions.

An effective porosity of 30 percent for the fluvial aquifer.
 Fluid will be injected into two wells at the same time

3 Water for mixture will include a sodium bromide tracer as a groundwater tracer

gpm = gallons per minute

Figures











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26-FEB-2002 8071fig4 dgn





ATLANTA/CAD1/PROJECTS/148071 DDMT/LTOA

04-FEB-2002 8071fig6 dgn



ATLANTA/CAD1/PROJECTS/148071 DDMT/LTOA 04-APRIL-2002

8071fig7 dgn



