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THE MEMPHIS DEPOT
TENNESSEE

ADMINISTRATIVE RECORD
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Memphis Depot
Main Installation
Remedial Design Workplan

DEFENSE LOGISTICS AGENCY

Defense Distribution Center (Memphis)
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and Support Center, Huntsville

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Acronyms

BCT	BRAC Cleanup Team
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, compensation, and Liability Act
COCs	chemicals of concern
DLA	Defense Logistics Agency
DNAPL	dense non-aqueous phase liquid
DoD	Department of Defense
DOI/NPS	Department of Interior/National Park Service
DQOs	data quality objectives
DRC	Depot Redevelopment Corporation
EBT	Enhanced Bioremediation Treatment
ELCR	Excess lifetime cancer risk
EPA	U S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FFA	Federal Facilities Agreement
FR	Federal Register
FS	Feasibility Study
ft^2	square feet
FU	Functional Unit
HASP	Health and Safety Plan
HHRA	human health risk assessment
IR	Information Repository
IRAs	Interim remedial actions
LTOA	Long-Term Operational Area
LUCIP	land use controls implementation plan
MCLs	maximum contaminant levels
μg/L	micrograms per liter
mg/kg	milligrams per kilogram
MI	Main Installation
NCP	National Oil and Hazardous Pollution Contingency Plan
NPL	National Priorities List
O&M	Operation and maintenance

OU	Operable Unit
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PCP	products with pentachlorophenol
POL	petroleum/oil/lubricants
QAPP	Quality Assurance Project Plan
RA	remedial action
RAOs	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RFA	Resource Facility Assessment
RI	Remedial Investigation
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
USACE	U S Army Corps of Engineers
USAESCH	U.S Army Engineering and Support Center
USC	United States Code
VOCs	volatile organic compounds

1.0 Introduction

This Rev. 1 Remedial Design (RD) Workplan for the Main Installation (MI) of the former Memphis Depot (Depot) in Memphis, Shelby County, Tennessee, has been prepared for the U.S. Army Corps of Engineers (USACE) - Huntsville Center as part of Task Order 13 under contract number DACA87-94-D-0009. This document is in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and to the extent applicable, the National Oil and Hazardous Pollution Contingency Plan (NCP). This workplan is also consistent with the Record of Decision (ROD) for the MI issued on September 7, 2001 The Rev 0 version of this document was submitted for review on January 14, 2002. Comments have been received and responded to accordingly.

This document complies with CERCLA guidance on conducting an RD and has been submitted to satisfy the requirements outlined by the Base Realignment and Closure (BRAC) Act as well as requirements set forth by the BRAC Cleanup Team (BCT) for the Depot The BCT, which is composed of representatives of the Defense Logistics Agency (DLA), Tennessee Department of Environment and Conservation (TDEC), and the U.S. Environmental Protection Agency (EPA), will monitor the progress of the RD and will review all documents prior to issuance as a final document.

Subsequent to the signing the Final MI ROD and prior to the issuance of this RD Workplan, a Long-Term Operational Area (LTOA) investigation was conducted from September through December 2001 at the MI at the request of TDEC The following information was included in the ROD to address the pre-design LTOA data collection activity:

> *"TDEC requested additional confirmation that no dense non-aqueous phase liquid (DNAPL) sources occur beneath historic long-term operational areas on the MI. There is no evidence from the* [Remedial Investigation] *RI and groundwater* [Feasibility Study] *FS that a DNAPL is present in the groundwater on the MI; however, the Depot and EPA agreed to complete this testing prior to beginning the remedial design The pre-design tests will include drilling new soil borings and monitoring wells at selected locations within the MI and obtaining soil and groundwater samples for targeted laboratory analysis. The results of these pre-design tests are not expected to change the effectiveness of the selected remedy for groundwater, however if results of the pre-design tests indicate a significant or fundamental change to the remedy is warranted, then an Explanation of Significant Differences (ESD) or a ROD amendment would be required in accordance with CERCLA §117(c) and NCP §§300 435(c)(2)(i) and (ii)."*

The results of the LTOA investigation, which will be presented as Appendix A to this workplan, have been used to supplement the Rev. 1 Enhanced Bioremediation Treatment (EBT) Treatability Study workplan. That workplan is presented as Appendix B to this document and presents the requirements for the work to be conducted at the MI as part of the RD. Based on a March 25, 2002, decision, the Rev. 1 version of the LTOA Technical Memorandum has been temporarily separated from this RD Workplan to complete discussions about the future of the LTOA investigation. The Rev. 1 LTOA Technical Memorandum will be included in the final version of the MI RD Workplan.

1.1 Purposes of RD Workplan

The purposes of the RD workplan are to:

- Describe the remedy selected for the MI as stated within the ROD;
- Present the RD/Remedial Action (RA) objectives for the MI;
- Present the RD tasks along with a schedule for accomplishing each task; and
- Identify major deliverables and their submittal dates

1.2 Organization of RD Workplan

This RD workplan is organized as follows:

Section 2	Site Description
Section 3	Remedial Design Tasks
Section 4	Remedial Design Schedule
Section 5	Project Management Plan
Section 6	References
Appendix A	Rev. 1 LTOA Technical Memorandum (to be submitted at a later date)
Appendix B	Rev. 1 MI EBT Treatability Study Workplan
Appendix C	August 1995 Final Generic Quality Assurance Project Plan (amended)

2.0 Site Description

2.1 Site Name, Location, and Description

The Memphis Depot (Depot) is a former military supply facility that closed in September 1997 under the BRAC Act. The Depot is located in southeastern Memphis, Tennessee (Figure 2-1), approximately 5 miles east of the Mississippi River and just northeast of Interstate 240. The Depot includes two components: the MI, which is the focus of this workplan, and Dunn Field. Airways Boulevard borders the Depot on the east and provides primary access to the site Dunn Avenue, Ball Road, and Perry Road form the northern, southern, and western boundaries of the MI, respectively. At the time of closure, the Depot included approximately 118 buildings, 26 miles of railroad track, and 28 miles of paved streets, the majority of which lie within the MI The facility includes approximately 5.5 million square feet (ft^2) of covered storage space and approximately 6 million ft^2 of open space.

For the purposes of completing the remedial investigation (RI) and feasibility study (FS), while complying with BRAC requirements, the term "Functional Unit" (FU) was established to identify groups of sites on the MI based on operational history, expected use, location, and generally uniform human health exposure. The FUs are a refinement of the "Operable Unit" (OU) designation and are based on common past and anticipated future use of the land on the MI The MI is divided into six FUs A seventh FU is the groundwater beneath the MI. The FUs are defined in Table 2-1 and shown graphically on Figure 2-2. The ROD for the MI addressed FUs 1 through 7. The lead agency for site activities at the Depot is the DLA. The regulatory oversight agencies are EPA and TDEC. DLA will implement the selected response actions and will incur all associated costs The Depot has an EPA Identification Number listed as TN4210020570.

2.2 Site History and Enforcement Activities

Starting in the 1940s, the 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.

Types of past activities that led to the presence of hazardous materials in the environmental media at the facility included pesticide application, painting and sandblasting, vehicle maintenance, and hazardous material handling/storage. Other historical activities in open and enclosed storage areas included storing transformers with polychlorinated biphenyls (PCBs), storing and using pesticides/herbicides, and treating wood products with pentachlorophenol (PCP) These industrial activities (e.g , sandblasting of lead-based paints, application of pesticides, use of hazardous materials) resulted in the presence of metals, pesticides, and other less frequently detected chemicals in surface soil, surface water, and sediment above background concentrations.

Important dates for the Depot as part of the cleanup process for these chemicals are as follows:

- From **1989 through 1990**, Law Environmental through a contract with the U.S. Army Engineering and Support Center (USAESCH) conducted an RI at the Depot .
- In **January 1990**, EPA Region 4 conducted a Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) at the facility through a contract with A.T. Kearney, Inc. (EPA, 1990).
- On **September 28, 1990**, the Depot was issued a RCRA Part B permit (No TN4 210-020-570) by EPA Region 4 and TDEC. Subsequently, in accordance with Section 120(d)(2) of CERCLA, Title 42, Section 9620(d)(2) of CERCLA, and Title 42, Section 9620(d) (2) of the United States Code (USC), EPA prepared a final Hazard Ranking System (HRS) Scoring Package for the facility. On the basis of the final HRS score of 58.06, EPA added the Depot to the National Priorities List (NPL) by publication in the *Federal Register* (FR), 57 FR 47180 No 199, on **October 14, 1992**.
- On **March 6, 1995**, a Federal Facilities Agreement (FFA) under CERCLA, Section 120, and RCRA, Sections 3008(h), and 3004(u) and (v), was reached by EPA, TDEC, and the Depot. The FFA identified a list of sites for investigation. Table 2-2 of the MI ROD presents these sites. The FFA also outlined the terms under which the investigation and cleanup will be conducted. The selected remedy addresses all concerns related to these sites.
- In **July 1995**, the Depot was identified for closure under the BRAC process, which requires environmental restoration at the Depot to comply with requirements for property transfer under Public Law 101-510 of Title XXIX, Defense Base Closure and Realignment. After the Depot was placed on the BRAC closure list, the City of Memphis and County of Shelby established the Memphis Depot Redevelopment Agency, now the Depot Redevelopment Corporation (DRC), to plan and coordinate the reuse of the Depot. The DRC conducted several public meetings during the preparation of its *Memphis Depot Redevelopment Plan* to obtain community feedback on future land use plans. The *Memphis Depot Redevelopment Plan* was approved in 1997.
- From **1995 through 2000**, the Depot conducted an RI/FS under EPA, TDEC, and DLA oversight. The RI workplans were prepared in 1995 (and amended in 1998), and the RI report was finalized in January 2000. Separate FS reports were prepared for the soils and groundwater on the MI. Both FS reports were finalized in July 2000. The Proposed Plan for the MI was finalized in August 2000.

In addition, a number of interim remedial actions (IRAs) were conducted at the MI These IRAs included removal of soils containing pesticides, PCBs and PCP surrounding the MI Housing Area, cafeteria (Building 274), and PCP dip vat area (Building 737), respectively. The removal of surface soils containing elevated metals and polynuclear aromatic hydro carbons (PAHs) near the southwest corner of the MI (FU3) was completed in August 2000. IRAs that have been performed at the MI are detailed below.

- Approximately 602 cy^3 of surface and subsurface soil was removed from the PCP dip vat area in FU4 (Building 737) because of elevated levels of PCP (completed in 1985).
- Approximately 5,000 tons or 3,700 cy^3 of surface soil in the Housing Area of FU6 was removed because of the presence of dieldrin (began in June 1998; completed in October 1998). The soil was disposed at a RCRA-permitted Subtitle D landfill. The Housing Area is an exception to the overall industrial land use for MI and is acceptable for residential reuse.
- Approximately 530 tons or 400 cy^3 of surface soil surrounding the cafeteria (Building 274) in FU6 was removed because of elevated levels of PCBs (began in October 1998, completed in November 1998) The soil was disposed at a RCRA-permitted Subtitle D landfill.
- Approximately 980 cy^3 of surface and subsurface soil from near Buildings 1084, 1085, 1087, 1088, 1089 and 1090 was removed because of elevated levels of metals and PAHs (began in May 2000; completed in August 2000). The soil was disposed at a RCRA-permitted Subtitle D landfill.

In addition to these IRAs, one other remedial action (RA) was accomplished in July and August 2001. Approximately 300 cy^3 of surface soil was excavated near Building 949 in FU4 because of elevated levels of lead. The removal included contaminated surface soils where lead concentrations were equal to or greater than 1,536 milligrams per kilogram (mg/kg) and were disposed of at a RCRA-approved off-site landfill. Following excavation of the contaminated soil, clean backfill was placed in all areas excavated, and the entire area was restored to pre-RA conditions. To accomplish the removal, the DLA exercised its removal authority under CERCLA Section 104, as delegated in Executive Order 12580, and removed the lead-contaminated soil after development of, but before final execution of, the ROD Both EPA and TDEC agreed that the action was an appropriate part of a final, protective remedy, regardless of the timing of the action and the CERCLA authority under which it was performed. As of the writing of this document, a final report on the removal is being developed.

2.3 Planned Response Actions at the MI

The ROD detailed several RAs to achieve acceptable residual risk levels and allow for the planned industrial and recreational land use for the MI. These include·

- Restrict (1) future residential land use (except for the existing Housing Area in FU6) in FUs 1 through 6, (2) day care operations in FUs 1 through 6, and (3) casual access to FU2 from adjacent off-site residents through land use controls. It should be noted that FU6 consists of BRAC Parcels 1, 2, 4, and 5. In 1998, surface soil in the Housing Area of FU6, BRAC Parcel 2, was removed because of the presence of dieldrin The Housing Area is the only portion of the MI that may be used for future residential purposes, according to the DRC's *Memphis Depot Redevelopment Plan*. As such, it has been restored to meet the risk criteria for both industrial and residential use. Analytical results from soil samples collected in the open area around Building 144 and the north and south paved parking lots within BRAC Parcel 1 also indicated contaminant levels that are not inconsistent with unrestricted use The remainder of FU6 is safe for industrial use but not suitable for future residential use. Land use controls will be placed on these areas to prevent future residential use and day care operations, etc

- Prevent future groundwater use on the MI while concentrations of chemicals of concern (COCs) are above maximum contaminant levels (MCLs).
- Reduce to MCLs the concentrations of COCs in groundwater within the entire plume both on- and offsite of the MI.
- Conduct 5-year reviews of the RA according to Section 121(c) of CERCLA and NCP §300 430(f)(5)(iii)(C) if there are any hazardous substances, pollutants, or contaminants remaining at the site above levels that would allow for unlimited use and unrestricted exposure The review will be conducted no less often than every 5 years after the initiation of such RA to assure that human health and the environment are being protected by the RA being implemented.

In addition to the RAs developed within the ROD, a Long-Term Monitoring (LTM) Plan will be developed for both groundwater and land use controls at the MI. The LTM for groundwater is further described in Section 2.5.2.1. The land use controls LTM plan will be completed through a through a land use controls implementation plan (LUCIP), as described in Section 2.5.1.1.

2.4 RD/RA Objectives

Remedial action objectives (RAOs) are medium-specific goals that the RAs are expected to accomplish to protect human health and the environment They guide the formulation and evaluation of remedial alternatives. RAOs have been developed to reflect the anticipated future land use for the MI in accordance with EPA Policy, *Land Use in the CERCLA Remedy Selection Process (OSWER Directive No 9355 7-04)*

The groundwater RAOs are expected to prevent ingestion of water contaminated with volatile organic compounds (VOCs) in excess of MCLs from potential future onsite wells; restore groundwater to levels at or less than MCLs, and prevent horizontal and vertical offsite migration of groundwater contaminants in excess of MCLs. The MCLs for trichloroethene (TCE) (5 micrograms per liter [μg/L]) and tetrachloroethene (PCE) (5 μg/L) are the relevant and appropriate requirements for groundwater beneath the MI.

The surface soil RAO for protection of future on-site residents is to prevent direct contact/ingestion of surface soils contaminated with dieldrin and arsenic in excess of human health risk assessment (HHRA) criteria for residents and to prevent direct contact/ingestion of surface soils contaminated with lead in excess of risk-based criteria for protection of residential children.

The RAOs will reduce the excess lifetime cancer risk (ELCR) and hazard index (HI) associated with exposure to contaminated soil to acceptable levels for future workers and will prevent future residential development of the site. This will be achieved by reducing

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the exposure concentration of lead to the target cleanup level of 1,536 mg/kg (calculated using blood-lead uptake models) and by imposing land use restrictions. As discussed in Section 2 2, the reduction of lead to the target cleanup level has been accomplished with removal of soil from the Building 949 area.

Because there are no federal or state clean-up standards for soil contamination, these clean-up standards were established on the basis of the HHRA. Targets were selected that will (1) reduce the risk associated with exposure to soil contaminants to an acceptable level and (2) restrict the migration of contaminants into the groundwater.

2.5 Remedies Selected for the MI

The selected surface soil and groundwater remedies as identified in the final ROD for the MI are discussed below.

2.5.1 Surface Soil

2.5.1.1 Land Use Controls

Land use controls will leave contaminated surface soil in place, but will provide deed restrictions, in addition to the existing land use controls, thereby limiting exposure by defining the future use of the MI.

Deed (including lease) restrictions will restrict residential land use in FU1 through FU6 (exclusive of Parcels 1 and 2 in FU6 which are available for unrestricted use) where dieldrin, arsenic, and/or lead in the surface soil pose an unacceptable risk for such use. Residential use controls will include preventing day care operations in all FUs In addition, a boundary fence surrounding FU2 will be maintained to preclude casual access by adjacent off-site residents.

Restrictions and controls will be coordinated with the Depot reuse implementation plans, and will be included in all deeds and leases. The deed restrictions and site controls, in addition to the existing land use controls, to be applied are as follows.

FU	Deed Restrictions Preventing Residential Land Use[a]	Site Controls
1	X	
2	X	X[b]
3	X	
4	X	
5	X	
6	X[c]	

[a] Includes day care restriction

[b] Maintaining a boundary fence surrounding FU2 to preclude casual access by adjacent off-site residents

[c] Deed restrictions do not ably to Parcels 1 and 2 of FU6

Land use controls selected in the ROD (excluding Parcels 1 and 2 of FU6) will:

- Prevent future residential land use in FUs 1 through 6, thus eliminating the risks associated with that land use scenario.
- Prevent casual access by adjacent off-site residents through maintenance of a boundary fence surrounding FU2.
- Prevent day care operations in FU1 through 6.

Applying land use controls will result in the following in each FU (excluding Parcels 1 and 2 of FU6):

- FUs 1, 3, 4, 5, and 6 are acceptable for industrial use. Land use controls to prevent residential development are the only remedial action needed to address unacceptable risk in surface soils at FU 1, 3, 4, 5,and 6.
- FU2 is acceptable for recreational use. With land use controls in place to prevent future residential development, and to prevent casual access by adjacent off-site residents through maintenance of a boundary fence, FU2 can be used for recreational purposes. In addition, according to Section 24 of the Memphis and Shelby County zoning regulations, single-family and multi-family residential uses are prohibited. Also, under the Federal Property Management Regulations, FU2 is slated for transfer from the Department of Defense (DoD), specifically the Army, to the Department of Interior/National Park Service (DOI/NPS) It will then be transferred by public benefit conveyance to the City of Memphis for use as a park. According to 41 CFR 101-47.308-7, property for use as a public park or recreational area must be used and maintained for the purpose for which it was conveyed in perpetuity, or be returned to the United States (24 CFR 51D)

Land use controls are part of the selected remedy for the MI, and will be implemented through a land use controls implementation plan (LUCIP). The LUCIP is being developed as part of the MI RD by the DLA and the Army The timing and nature of the monitoring and reporting for the land use controls shall be specified in the LUCIP. However, to remain protective, land use controls depend on annual monitoring, as well as maintenance of site controls. The results of the annual evaluation shall be reported to TDEC and EPA. The deed restrictions will add a layer of protection against future residential use that will augment current zoning restrictions.

2.5.1.2 Excavation and Off-site Disposal

As described in Section 2 2 of this document, this RA has been accomplished with acceptance from EPA, TDEC, and the DLA.

2.5.2 Groundwater

2.5.2.1 Enhanced Bioremediation

This RA uses injection of nutrients to enhance the natural biodegradation processes. The remedy will accelerate biodegradation in the most contaminated parts of the plume. Untreated parts of the plume will degrade as a result of natural attenuation processes. In the absence of pilot test data, a conservative assumption was made that the nutrients will triple the biodegradation rate within the aquifer, and the duration of the remedial action was assumed to be 10 years. Therefore, enhanced bioremediation must also include land use controls and groundwater monitoring.

Preliminary design components will include the following·

- Nutrient injection into the fluvial aquifer will be conducted via borings or wells. Treatment zones will be established in the most contaminated parts of the plume within the MI. Treatability studies will be required to determine injection volumes, spacing, and depth. Nutrient re-injection will occur at intervals determined by pilot tests and monitoring results
- Deed restrictions will prohibit the installation and use of production and consumptive use wells and drilling into aquifers below the fluvial aquifer until cleanup levels are achieved. The deed restrictions will also guarantee access to contingency areas, all injection, boundary, sentinel, and monitoring wells for the life of the remedy. These restrictions might be removed at the completion of the remedy. An annual evaluation will be conducted in accordance with the LUCIP to verify that land use controls and deed restrictions are in effect and to ensure that land use changes that may pose an unacceptable risk to the users have not occurred The LUCIP is being developed as part of the RD by the DLA and the Army .
- A network of groundwater wells will be monitored at a frequency that will be determined during the RD; however, monitoring will be no less than annual for the first 5 years. Well locations will be chosen during the RD with the following guidelines:
    - Wells inside the groundwater plumes to measure the effect of enhanced bioremediation and natural attenuation. Water samples will be analyzed for VOCs as well as degradation products
    - Boundary wells to detect potential migration of a plume to the MI boundary. Water samples will be analyzed for VOCs.
    - Sentinel wells to detect potential migration of a plume into the deeper intermediate aquifer. Water samples will be analyzed for VOCs.
- Monitoring well maintenance (cleaning, wellhead repairs) will be performed as needed.
- Annual summaries of monitoring data will be produced to document the site conditions and progress of the remedy
- Groundwater concentrations will meet MCLs in all monitoring wells for four consecutive monitoring periods to demonstrate completion of the remedy. The sampling schedule will therefore be subject to change in response to observed trends and variability.
- Contingency provisions will ensure that if groundwater contamination exceeds MCLs at the boundary wells or the sentinel wells, more active measures for plume control will be implemented.
- Without detailed information regarding the magnitude of MCL exceedances at boundary or sentinel wells in the future, development of a detailed contingency plan is

> not possible. Rather, should it be determined that the selected RA is not achieving RAOs and an alternative remediation strategy is warranted, a detailed contingency plan would be completed at that time The contingency plan would evaluate the existing site data and evaluate alternatives that could be implemented to achieve RAOs. The contingency plan would be reviewed by stakeholders, commented upon, and revised as necessary for the purpose of finalizing the revised remedy. The public notification and remedy modification phases of work would then be completed to document the revised remedy. Finally, the revised remedy would be designed and then implemented. The time between identifying the need for an alternative remedy and implementation of the revised remediation strategy is estimated at 8 to 12 months, provided funding is available.

Groundwater sampling conducted as part of the LTOA pre-design data collection activities have identified additional areas of groundwater contamination on the MI, and higher concentrations of VOCs from those detected during the RI/FS (see Appendix A). The EBT Treatability Study (see Appendix B) and RD will be adjusted to address this new information, however, the results of the pre-design tests don't indicate a significant or fundamental change to the remedy nor is the effectiveness of the selected remedy for groundwater expected to change

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3.0 Remedial Design Tasks

This section presents the approach for the RD and a description of the RD tasks As described in Section 2 5, the remedies selected for surface soil have been executed prior to completion of the ROD or will be implemented through completion of the LUCIP document. The Memphis Depot will implement the tasks described herein to develop the RD for the Alternative GW3 remedy.

After the RD workplan and the EBT Treatability Study are completed, the RD will begin with the intermediate design, which will include the draft drawings and specifications, design analysis, construction needs, operation and maintenance (O&M) requirements, initial RA component cost estimate, and a Performance Standards Verification Plan. The intermediate design will represent the 60 percent completion of the design effort The Rev. 1 LTOA Technical Memorandum and Rev. 0 EBT Treatability Study report will be submitted along with the intermediate design to the BCT. A value engineering analysis will be performed for the intermediate design. The results of the analysis will be presented in the intermediate design submittal.

The prefinal design will represent the 90 percent completion point of the design effort. The prefinal design submittal will include a complete design analysis, the final drawings and basis of design specifications, prefinal construction schedule, and revised construction cost estimate. BCT comments on the prefinal design will be addressed in the final design.

Table 3-1 provides a complete list of the tasks to be performed, information needed for each task, results expected from each task, and a description of the work products that will be submitted to the BCT.

3.1 Task I – Project Planning

This task includes gathering existing information about the site and determining if additional data are needed to support the RD process.

3.1.1 Site Background

Section 2.0 discussed the current regulatory status of the MI as described in the September 2001 ROD. The presentation of this material included information from the MI RI and FS. This task has been completed.

3.1.2 Project Planning

Planning activities prior to initiating the development of the MI RD Workplan included completion of the MI ROD and the November and December 2001 BCT meetings in Memphis and Atlanta, respectively. The BCT meetings included discussions of the schedule of activities for the RD as well as discussion of additional data needs for the RD. The additional data needs are based upon review of data in the MI RI/FS documents and comparison of these data to data requirements described in the EBT Treatability Study workplan.

3.1.2.1 Documentation of Additional Data Requirements

Groundwater samples were collected from monitoring wells installed at the MI in 1996, 1997, and 1998. The 1998 event included sampling of groundwater in existing and newly installed wells and push points from both on- and offsite locations. In 2000, a Monitored Natural Attenuation Study was conducted across the Memphis Depot to define the efficacy of natural attenuation as a remedy within the fluvial aquifer that underlies the area. During this study, geochemical parameters were collected from a specific number of monitoring wells. Since the last groundwater sampling event at the MI, 5 additional monitoring wells were installed to support the CSM and 17 additional monitoring wells were installed as part of the LTOA investigation.

Review of the existing groundwater data indicates that sampling events have not occurred consistently and have only included monitoring wells that were existing at that time (i.e., not comprehensive sampling events). In addition, during comprehensive sampling events, not all wells were sampled. There has not been a recent site-wide sampling event that involves all on- and offsite monitoring wells and sample analysis for VOC and geochemical parameter content. The BCT has therefore decided to include a baseline groundwater sampling event as part of the RD process, except for those recently (December 2001) installed and sampled as part of the LTOA investigation. The data from the baseline event, which was conducted during the week of March 18 through 22, 2002, will be used to (1) establish monitoring well locations for the EBT Treatability Study; (2) provide up-to-date VOC contaminant concentration data for the fluvial aquifer; (3) provide up-to-date geochemical parameter data for the fluvial aquifer, and (4) define the quantity of nutrient source needed to enhance reductive dechlorination within the fluvial aquifer. In addition, the data from the baseline sampling event will be reviewed along with existing groundwater sample analytical data for the MI to define those wells that will be required for long-term monitoring purposes

The methods used to sample on- and offsite monitoring wells, as well as the analytical methods to be used for VOC and geochemical parameters, are described in the Baseline Groundwater Sampling Plan for Main Installation Monitoring Wells. This document was given approval for action by the BCT members during the December 2001 meeting and is included as an Appendix A to the EBT Treatability Study Workplan, which is Appendix B to this document

3.2 Task II – Remedial Design

The RD will be implemented in accordance with standard professional engineering and construction practices using currently accepted environmental protection technologies. Work products of the RD are described below.

3.2.1 Remedial Design Planning

The RD will require additional data in the form of a baseline groundwater sampling event and an EBT Treatability Study. To provide these data, additional sampling and the treata-

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bility study will be conducted based on the RD workplan as the governing document for directing this work. The baseline event field effort was conducted from March 18 through 22, 2002. In addition, the Rev. 1 EBT Treatability Study workplan for the MI has been developed and is submitted with this document as Appendix B for BCT review and comment. In addition, the MI Generic Health and Safety Plan (HASP) has been completely revised to include those tasks pertinent to this RD. The MI Generic Quality Assurance Project Plan (QAPP) has also been internally revised to include amendments completed as required for additional data collection activities during the RI and a compendium has been added to describe these changes.

3.2.2 Preparation of the RD Workplan

This document provides information on the additional site work and the steps required to develop the RD. The workplan is based upon CERCLA guidance as well as the Federal Facility Agreement. Other resources include the *RD/RA Handbook* from the EPA Office of Emergency and Remedial Response (June 1995). Before work is conducted, the RD workplan and the EBT Treatability Study workplan will be approved by the BCT. The RD workplan will be used to prepare the intermediate, prefinal, and final RD documents.

3.2.3 Preparation of the EBT Treatability Study Workplan

EBT was selected as the groundwater remedy in the MI ROD, which outlined the requirements for a treatability study of this remedy The treatability study workplan is included as Appendix B. The workplan will be revised after review comments are received. The final version will be included in the intermediate and final RD documents.

The EBT Treatability Study will assess the natural biodegradability of site-specific chemicals (specifically CVOCs) in groundwater underlying the site in response to the injection of nutrients The nutrients will accelerate biodegradation in the most contaminated parts of the aquifer. The nutrients will typically consist of a carbon source such as vegetable oil or lactic acid. Other commercially available sources exist, including Hydrogen Releasing Compounds or HRC® from Regensis®. As described in Appendix B, the study focuses on the use of vegetable oil and lactic acid.

3.2.4 Intermediate Design

The intermediate design, submitted to the BCT when the design effort is 60 percent complete, will consist of information presented as the draft design analysis, draft drawings and specifications, draft construction schedule, operation and maintenance (O&M) requirements, initial RA component cost estimate, and a draft Performance Standards Verification Plan. A value engineering analysis will be performed for the intermediate design. The results of the analysis will be presented in the intermediate design submittal.

The design analysis will include evaluations conducted to establish the design criteria for each remedy component in sufficient detail to provide the basis for the design approach and subsequent design decisions and production activities. Where necessary, supporting design calculations will be included in the intermediate design submittal.

Draft construction drawings and technical specifications for the remedy components will be prepared and submitted. Specifications may include but not be limited to specifications for construction, installation, site preparation, and field work standards Specifications will conform to USACE ETL 1006, *Technical Requirements for Pre-design and Design Submittals*. The intermediate design will also include a draft construction schedule for the RA. The schedule will include project milestones, estimated activity duration, estimated task completion dates, and critical path tasks.

The intermediate design will also include a draft O&M plan for facilities, equipment, or and remedial methods outlined in the RD documents. The plan will include all activities that require routine maintenance, as well as a draft schedule of these activities. In addition to the O&M plan, an initial RA cost estimate will be presented. The cost estimate will include, as necessary, operating labor, maintenance material and labor, component costs, materials and energy, purchased services, and administrative costs. The cost estimate at this point will be accurate to within plus 40 percent and minus 20 percent.

A Performance Standards Verification Plan will be developed and submitted in the intermediate design. The plan will include the following:

- The Performance Standards Verification Sampling and Analysis Plan, which provides guidance for field work by defining sampling and data gathering methods to be used.
- The Performance Standards Verification Quality Assurance/Quality Control Project Plan, which describes the quality assurance and quality control protocols to be followed in demonstrating compliance with performance standards.
- A schedule for tasks to be performed to demonstrate compliance with performance standards The schedule will also include implementation activities for the Land Use Controls as part of the overall RA.

In addition, the LUCIP, which is part of the RD, shall be submitted during the design development process in accordance with the Memphis Depot Master Schedule, so that it will be ready for approval not later than the approval date for the pre-final/final RD.

3.2.5 Prefinal/Final Design

The prefinal design, submitted to the BCT when the design effort is 90 percent complete, will consist of information presented in the complete design analysis, prefinal drawings and specifications, prefinal construction schedule, prefinal O&M plan, and a prefinal RA component cost estimate. After review by the BCT, the prefinal design will be modified to address review comments, and the modified design will be the final design The final design submittal will include a memorandum that will describe how the prefinal design comments have been incorporated into the final design.

All completed design calculations and analyses of design criteria will be presented in support of the selected design approach. Construction drawings and technical specifications will be submitted in final form in the prefinal design along with a prefinal construction schedule, O&M plan, and cost estimate. The final construction schedule will be reviewed with Jacobs Engineering, Inc. (Jacobs), the RA contractor for the Memphis Depot. The cost estimate will also be reviewed with Jacobs, and will be within plus 15 to minus 10 percent of the construction costs associated with implementation of the RD

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4.0 Remedial Design Schedule

This section presents the RD schedule (Figure 4-1), which includes the following:

- RD tasks as described in this document;
- Start and end dates, the duration, and the predecessors(s) for each task;
- Project milestones, including submittal dates for each deliverable
- Duration of BCT review for each deliverable; and
- Critical path for the RD

The dates for submittal of deliverables are presented in Table 4-1.

The RD consists of five major components.

- Review of site-specific data to define the procedures for the baseline groundwater sampling event required for the RD,
- Baseline groundwater sampling event;
- EBT Treatability Study to evaluate the effectiveness of the selected groundwater remedy;
- LUCIP development and completion; and
- Intermediate and prefinal and final designs

5.0 Project Management Plan

This section presents the project organization for the RD, including key personnel and their responsibilities, a project communications matrix, a data management plan, and the reporting requirements.

5.1 Project Organization and Communication

The MI RD project team includes the BCT members (DLA , EPA and TDEC), USACE-Huntsville, CH2M HILL, USACE-Mobile, and the RAC contractor, Jacobs. CH2M HILL is developing the RD as specified in the contract with USACE-Huntsville USACE-Huntsville, which is under contract to the DLA, will review and approve all RD material before submittal to the BCT. After approval by the BCT, USACE-Huntsville and CH2M HILL will coordinate with USACE-Mobile and their contractor, Jacobs, for implementation of the RD.

Key personnel involved in the MI RD are presented in Figure 5-1. Mr Turpin Ballard of EPA Region IV, Mr. Jim Morrison of TDEC, and Mr. John De Back of the DLA are the BCT members. Mr. Clyde Hunt is the Remedial Program Manager for DLA for the Memphis Depot project and has responsibility as a BCT member in the absence of Mr. De Back.

Ms. Dorothy Richards is the Project Manager for the Memphis Depot project at USACE-Huntsville. She is responsible for coordinating with DLA and BCT members as well as with the contractor for the Memphis Depot project, CH2M HILL.

Mr. David Nelson, P G , is the CH2M HILL Project Manager for the MI RD. He is the primary CH2M HILL contact and is responsible for overall management of the RD phase of the project.

Messrs. Steve Offner, P G., Mike Harris, P E., and Tom Simpkin, P.E. of CH2M HILL are involved in the Memphis Depot project as the USACE-Huntsville/Memphis Depot Program Manager, Senior Consultant, and Technical Advisor, respectively. They will participate in the RD phase in these same roles but will also lend their experience and knowledge of the Memphis Depot project to the RD development. Mr. Offner has been involved on the Memphis Depot project since 1997 in various roles and has been involved in several phases of this project beginning with the RI stage. Mr. Harris will also serve as the CH2M HILL Technical Manager for design and will be responsible for approval of project-related designs. Mr Simpkin has extensive experience with enhanced bioremediation projects and the use of carbon sources to spur bioremediation of groundwater.

Figure 5-2 presents a project communications matrix for the MI RD The matrix identifies communications and reporting relationships.

5.2 Data Management Plan

The CH2M HILL Data Management Plan describes procedures that will be used to document and track investigation data and results. The plan includes the following:

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- Data quality objectives (DQOs), documentation and processing procedures;
- Project-related progress reporting procedures, and
- Project file requirements

Implementation of the procedures described herein will ensure proper documentation and retrieval of data and results.

5.2.1 Data Quality Objectives, Documentation and Processing Procedures

During the pre-design baseline sampling event and the EBT Treatability Study, groundwater sampling analytical data will be collected. This subsection presents documentation and processing procedures for the data.

5.2.1.1 Field Data

All sampling procedures will be noted within field logbooks according to the SAP for this effort. Geochemical parameter measurements will also be noted in the field logbooks. The information in the field logbooks will be used as a backup for data quality evaluation as well as a primary source for geochemical parameters.

5.2.1.2 Laboratory Data

Laboratory analytical data will be collected during the pre-design effort and will be handled according to procedures described in Sections 7, 8, and 9 in the Memphis Depot Generic QAPP (Appendix C) The data will be reviewed and processed through data quality procedures, as described in Section 8 of the QAPP (Appendix C).

5.2.1.3 Investigation Results

The results of the pre-design baseline sampling effort will be presented in a brief document entitled Results of RD Baseline Sampling Event, which will be presented to the BCT for review and approval The data will be used to select final locations for the injection and monitoring points for the EBT Treatability Study.

5.2.2 Project File Requirements

This project will require the administration of a central project file. The data and records management protocols will provide adequate controls and retention of all materials related to the project Record control will include receipt from external sources, transmittals, transfer to storage, and indication of record status. Record retention will include receipt at storage areas, indexing, filing, storage, maintenance, and retrieval

5.2.2.1 Record Control

Incoming materials related to the project will be forwarded to the CH2M HILL Project Manager or a designee. These documents will be placed in the project file. Project personnel will work from a copy of necessary documents. Records shall be legible and easily identifiable

Examples of records that will be maintained in the project file are as follows:

- Field documents
- Authorizations;

- Correspondence
- Logs;
- Photographs;
- Drawings and sketches;
- Specifications;
- Reports, and
- Procurement agreements.

Outgoing project correspondence and reports will be reviewed and signed by the CH2M HILL Project Manager or his designee.

5.2.2.2 Record Status

The CH2M HILL Project Manager will inform the organizations involved in the RD about revisions to records. Revisions to records shall be subject to the same level of review and approval as the original document. The revised document will be distributed to all holders of the original document and discussed with project personnel. Outdated records will be marked "void " In addition, the date a document is marked "void" will be recorded.

Documents will be distributed to the BCT in various formats, including use of Adobe Acrobat software to convert documents to .pdf format. These re-formatted documents will be either posted on the Memphis Depot File Transfer Protocol website that CH2M HILL supports or issued to BCT members as compact discs.

5.2.2.3 Record Storage

Project-related information will be maintained by CH2M HILL. Designated personnel will assure that incoming records are legible and are in suitable condition for storage.

Record storage will be performed in two stages. Storage will occur during and immediately following the project and permanent storage of records directly related to the project.

All records designated for permanent storage by CH2M HILL will be placed into suitable containers with appropriate project identification labeling and stored in a facility with an environment that will prevent deterioration, damage, and loss. Material from the project file may include reports, drawings, QA documents, verifications records, electronic files, and software program documentation. The DLA maintains a separate records inventory known as an Information Repository (IR).

5.3 Reporting Requirements

Major submittals for this RD will include this RD workplan, the EBT Treatability Study Workplan, the LTOA Technical Memorandum, the Intermediate Design, and the Prefinal/Final Design. Table 5-1 presents the MI RD submittals to all stakeholders including number of copies per each submittal.

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Table 2-1
Description of Functional Units at the MI
Rev 1 MI RD Workplan

FU No.	Name	Size (acres)	Common Past Land Use	Description
1	Twenty Typical Warehouses	89	Transportation to and storage in closed warehouses	Located in the northeastern area of the MI, consisting of about 20 large warehouses, with interspersed roadways and railroad tracks.
2	Southeast Golf Course/ Recreational Area	53	Golf, other recreation	Located in the southeastern corner of the MI1, consisting of golf course (Parcel 3). This FU also includes a baseball field and a small playground in the southeastern corner. This FU includes two constructed ponds and two concrete-lined drainage ditches from the ponds leading to the off-site area.
3	Southwest Open Area	92	Transportation to and storage in open-sided warehouses, painting and sandblasting, open storage	Located in the southwestern corner of the MI, consisting of varied type of parcels and sites
4	Northern and Open Areas	193	Open storage, and transportation to and storage in closed warehouses	Located in the north-central to northwest area of the MI, covering a large area.
5	Newer Warehouses	109	Transportation to and storage in closed warehouses	Located in the south-central area of the MI and includes 10 large warehouse buildings
6	Administrative and Residential Areas	33	Offices, equipment storage and maintenance, on-base housing	Located along the property boundary of the Depot along the Airways Boulevard This FU includes the old Residential Unit Area, parking lots, and other asphalt-paved areas.

Table 3-1
List of RD Tasks
Rev 1 Memphis MI RD Workplan

Task	Activities	Information Required/Source	Work Product
Task I – Project Planning			
Site Background	Gather previously collected data and documentation for additional data	MI RI/FS documents, LTOA data	Preliminary information to be included within the RD workplan
Project Planning	Review items and steps for collecting additional data	MI RI/FS documents, LTOA data	Preliminary information to be included within the RD workplan
Task II – Remedial Design			
Remedial Design Planning	Preparation of the RD workplan (Includes Rev 0 LTOA Tech Memo and EBT Treatability Study Workplan with Baseline Sampling Plan)	MI RI/FS, ROD documents	RD Workplan
EBT Treatability Study	Describe test(s) to be conducted at site, test and data quality objectives, procedures, data management	MI RI/FS, ROD documents	EBT Treatability Study Workplan
	Revise MI Generic Health and Safety Plan (HASP) Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) with addenda as necessary	MI RI/FS, ROD, MI Generic HASP, SAP, and QAPP documents	Revisions to be included as part of effort for EBT Treatability Study Workplan
	EBT Treatability Study at the MI	EBT Treatability Study Workplan	EBT Treatability Study Technical Memorandum
Intermediate Design	Present data from treatability study and evaluation of design approach	Results from the EBT Treatability Study	MI Intermediate RD document (will include Rev 0 EBT Treatability Study Tech Memo and Rev 1 LTOA Tech Memo)
	Develop draft drawings and specifications	Listing of drawings and specifications	
	Operation and maintenance plan and component cost estimate	Design parameters, ROD	
	Develop draft construction schedule	Schedule of construction activities from RD workplan	
	Develop LUCIP	Review LUCAP and MI ROD	
	Performance Standards Verification Plan	Design parameters, ROD	
Prefinal/Final Design	Prepare design approach based on BCT comments received from EPA	Intermediate RD document and comments	Prefinal/Final RD document (will include Rev 1 EBT Treatability Study Tech Memo and Rev 1 LTOA Tech Memo)
	Develop final drawings and specifications	Draft drawings and specifications	
	Develop final construction schedule	Draft construction schedule	
	Develop construction cost estimate	Results of EBT Treatability Study, additional site investigation, and vendor contractor cost estimates	

Table 4-1
MI RD Deliverable Submittal Dates
Rev. 1 Memphis Depot MI RD Workplan

Deliverable	Projected Submittal Date
MI RD Workplan	
Rev. 0 MI RD Workplan with Rev. 0 LTOA Technical Memorandum and Rev 0 EBT Treatability Study Workplan	January 14, 2002
Rev. 1 MI RD Workplan with Rev. 1 LTOA Technical Memorandum and Rev. 1 EBT Treatability Study Workplan	April 14, 2002
Rev. 1 MI RD Workplan with Rev 1 LTOA Technical Memorandum and Rev. 2 EBT Treatability Study Workplan	May 29, 2002
LUCIP	
Rev. 0 Land Use Control and Implementation Plan	June 1, 2002
Rev 1 Land Use Control and Implementation Plan	September 1, 2002
Intermediate (60%) Design	
Rev. 0 Intermediate (60%) RD Report	December 13, 2002
Prefinal (90%) Design	
Rev 1 Prefinal (90%) RD Report	March 13, 2003
Final (100%) Design	
Rev 2 Final (100%) RD Report	April 27, 2003

Table 5-1
MI RD Deliverables
Rev. 1 Memphis Depot MI RD Workplan

Deliverable	Copy Requirement
Task I - Project Planning	
Baseline Groundwater Sampling Event	3 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 2 copies to TDEC
Task II - Remedial Design	
Rev. 0 RD Work Plan, includes Rev. 0 EBT Treatability Study and Rev. 0 LTOA Technical Memorandum	3 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 2 copies to TDEC
Rev. 1 RD Work Plan, includes Rev. 1 EBT Treatability Study and Rev 1 LTOA Technical Memorandum	3 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 2 copies to TDEC
Rev. 2 RD Work Plan, includes Rev 2 EBT Treatability Study and Rev. 1 LTOA Technical Memorandum	6 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 2 copies to TDEC
Intermediate (60%) Design	3 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 2 copies to TDEC, 2 copies to USACE-Mobile and Jacobs (4 copies will be provided for the Information Repositories [IR])
Results of EBT Treatability Study Draft Design Analysis Draft Drawings and Specifications Draft Construction Schedule O&M Requirements Rev. 1 LUCIP Performance Standards Verification Plan	
Prefinal (90%)/Final (100%) Design	6 copies to DLA, 3 copies to USACE-Huntsville, 3 copies to EPA, 3 copies to TDEC, 2 copies to USACE-Mobile and Jacobs (20 copies will be made of the Prefinal in CD ROM format for RAB members) Final RD document distribution will include 4 copies for the IR and 20 copies in CD ROM format for RAB members
Design Analysis Prefinal/Final Drawings and Specifications Prefinal/Final Construction Schedule Prefinal/Final O&M Plan	

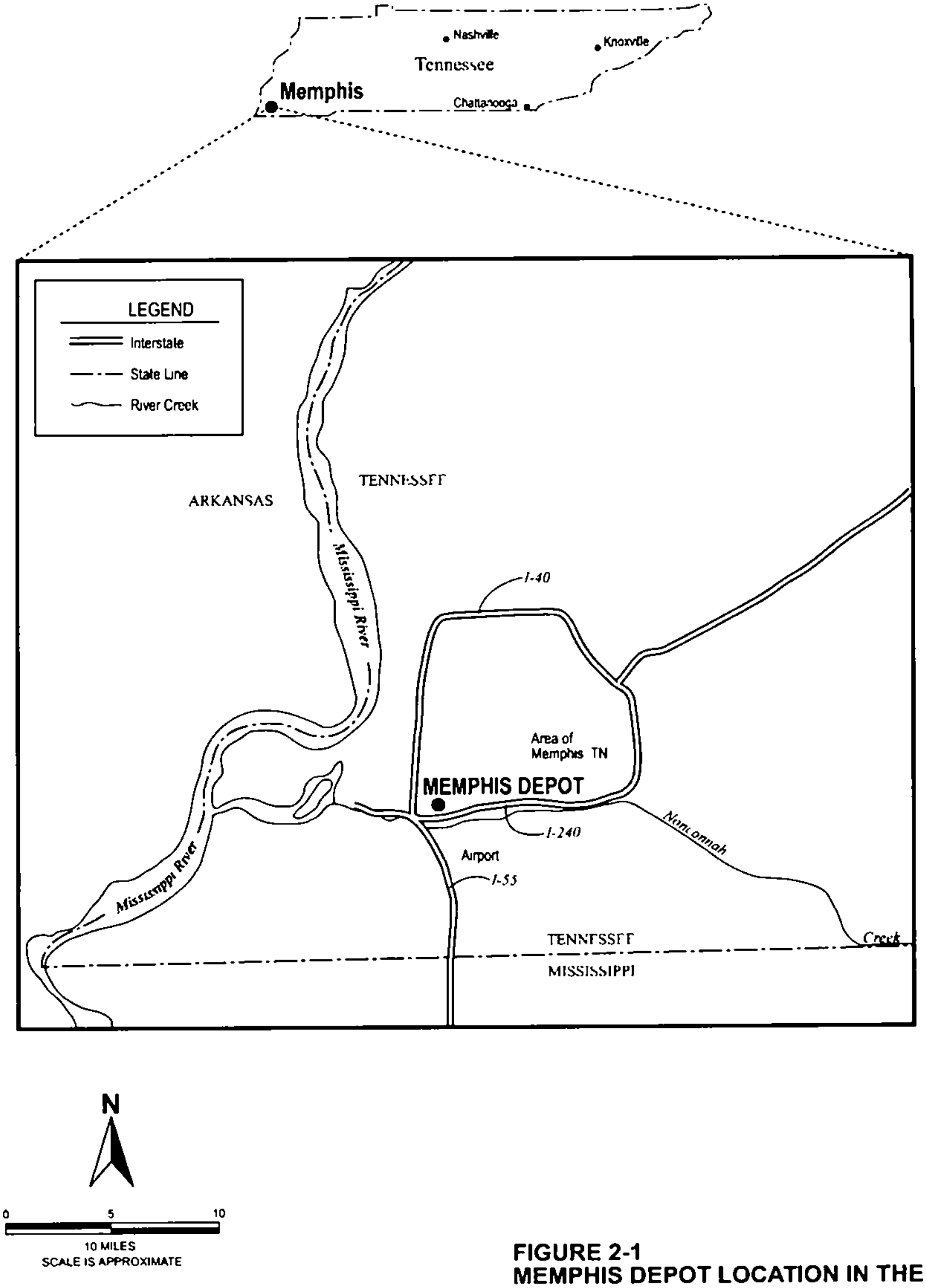

FIGURE 2-1
MEMPHIS DEPOT LOCATION IN THE MEMPHIS METROPOLITAN AREA
REV 1 MEMPHIS DEPOT MAIN INSTALLATION RD WORKPLAN

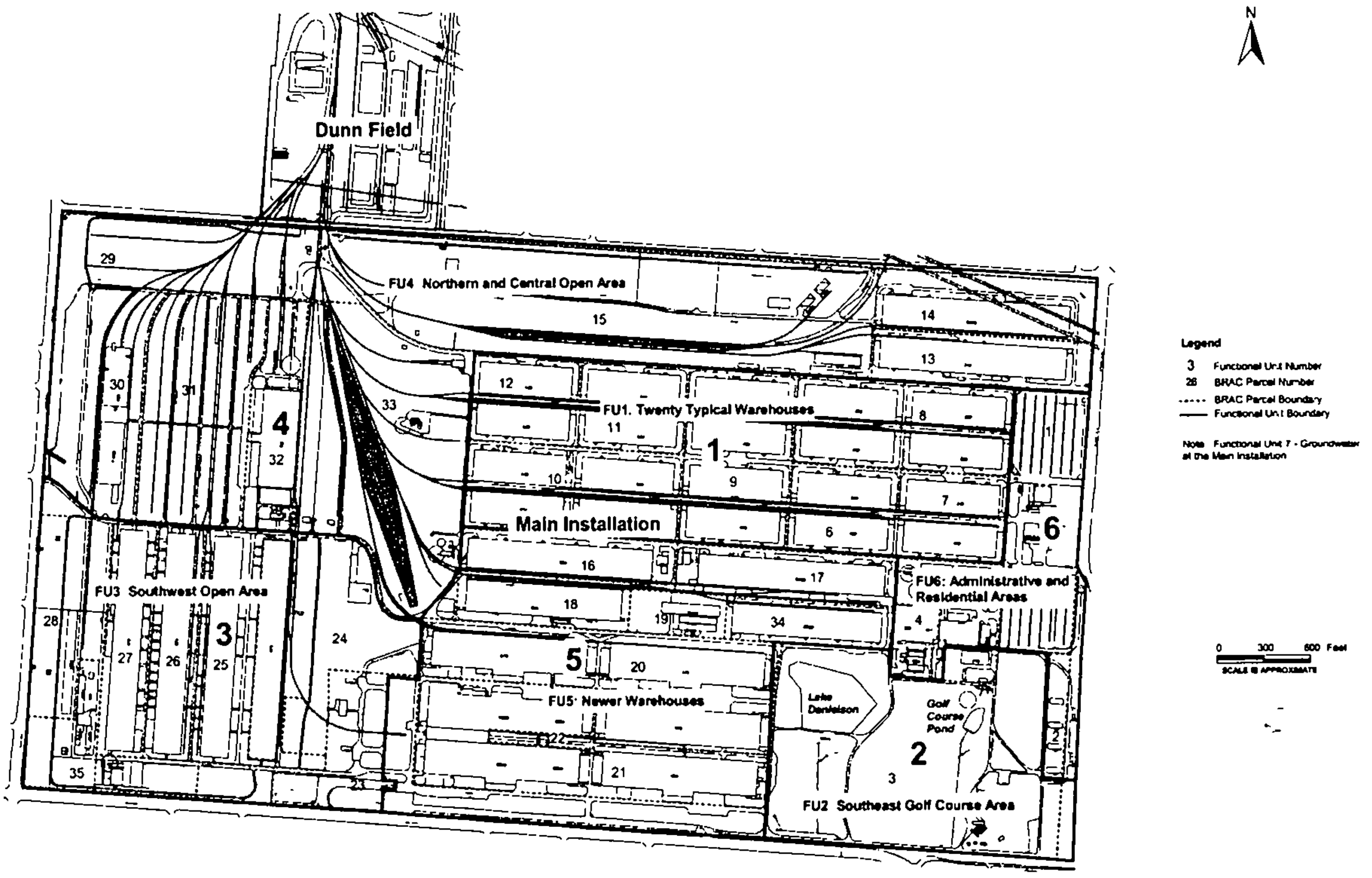

FIGURE 2-2
Functional Units at Main Installation
Memphis Depot Main Installation RD Workplan

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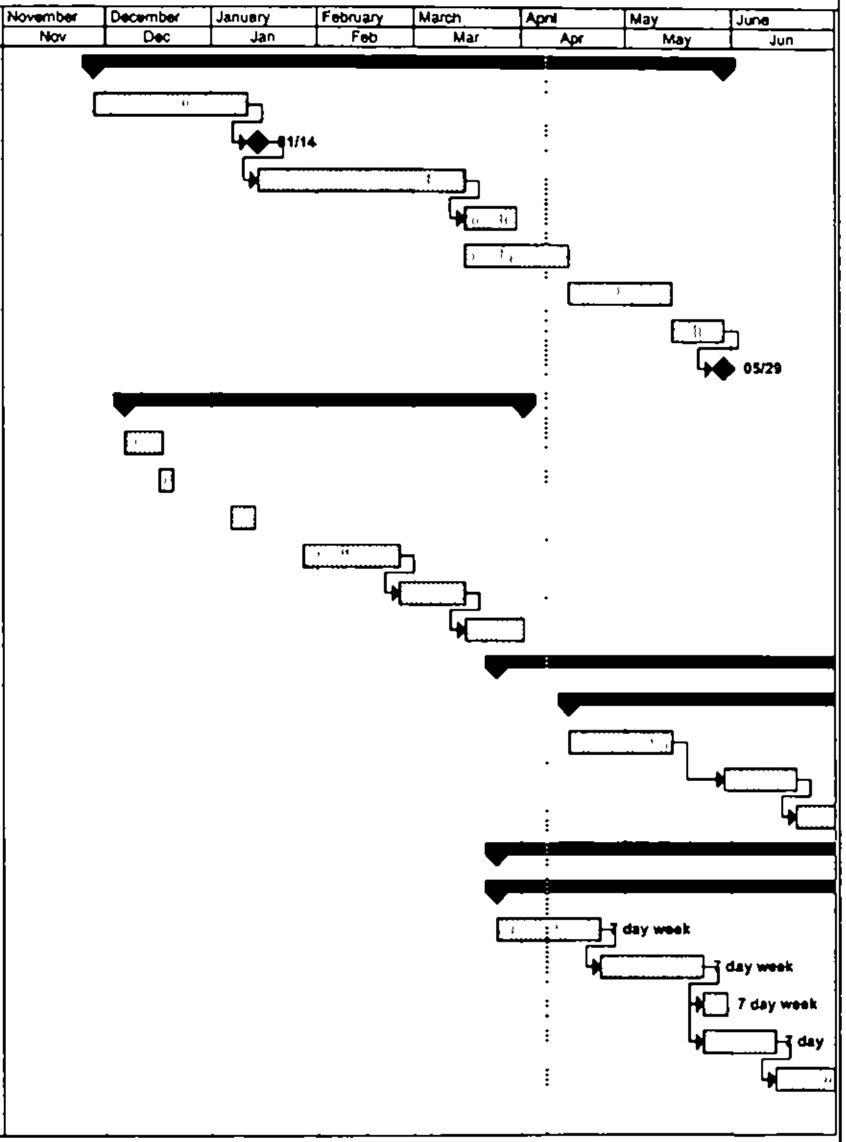
Figure 4-1
Memphis Depot Main Installation Remedial Design Schedule

ID	Task Name	Duration	Start	Finish
1	**MI Remedial Design Workplan**	**183 days**	**Wed 11/28/01**	**Wed 05/29/02**
2	RD Workplan Development	45 days	Wed 11/28/01	Fri 01/11/02
3	Submit Rev 0 MI RD Workplan to BCT (with LTOA Tech Memo & EBT Treat	0 days	Mon 01/14/02	Mon 01/14/02
4	BCT Review and Submit Comments on Rev 0 MI RD Workplan	60 days	Tue 01/15/02	Fri 03/15/02
5	Respond to BCT Comments on Rev 0 MI RD Workplan	15 days	Sat 03/16/02	Sat 03/30/02
6	Prepare & Submit Rev 1 MI RD Workplan	30 days	Sat 03/16/02	Sun 04/14/02
7	BCT Review of Rev 1 MI RD Workplan w/ Concurrence	30 days	Mon 04/15/02	Tue 05/14/02
8	Prepare & Submit Rev 2 MI RD Workplan Slip Sheets	15 days	Wed 05/15/02	Wed 05/29/02
9	Submit Rev 2 MI RD Workplan	0 days	Wed 05/29/02	Wed 05/29/02
10	**Pre-Design Baseline Groundwater Sampling and Analyses (SAP)**	**116 days**	**Fri 12/07/01**	**Mon 04/01/02**
11	Prepare and Submit Baseline Groundwater SAP to BCT	11 days	Fri 12/07/01	Mon 12/17/01
12	BCT Review and Submit Comments on Baseline SAP	4 days	Mon 12/17/01	Thu 12/20/01
13	Revise Baseline SAP and Begin Sampling Event	7 days	Mon 01/07/02	Sun 01/13/02
14	Baseline Groundwater Sampling Event	28 days	Mon 01/28/02	Sun 02/24/02
15	Analyze Groundwater Sample Analytical Data	19 days	Mon 02/25/02	Fri 03/15/02
16	Review and Discuss Analytical Data with BCT	17 days	Sat 03/16/02	Mon 04/01/02
17	**Main Installation Remedial Design**	**399 days**	**Mon 03/25/02**	**Sun 04/27/03**
18	**Enhanced Biological Treatment (EBT) Pilot Test**	**248 days**	**Mon 04/15/02**	**Wed 12/18/02**
19	Injection Well Installation	30 days	Mon 04/15/02	Tue 05/14/02
20	Nutrient Source Injection into Groundwater	21 days	Thu 05/30/02	Wed 06/19/02
21	Performance Monitoring and Data Analysis	182 days	Thu 06/20/02	Wed 12/18/02
22	**Design Tasks**	**399 days**	**Mon 03/25/02**	**Sun 04/27/03**
23	**Land Use Control Implementation Plan (LUCIP)**	**118 days**	**Mon 03/25/02**	**Sat 07/20/02**
24	Prepare & Submit Rev 0 LUCIP	30 days	Mon 03/25/02	Tue 04/23/02
25	BCT Review & Submit Comments on Rev 0 LUCIP	30 days	Wed 04/24/02	Thu 05/23/02
26	Respond to BCT Comments on Rev 0 LUCIP	7 days	Fri 05/24/02	Thu 05/30/02
27	Prepare & Submit Rev 1 LUCIP	21 days	Fri 05/24/02	Thu 06/13/02
28	BCT Review of Rev 1 LUCIP w/ Concurrence	30 days	Fri 06/14/02	Sat 07/13/02
29	Prepare & Submit Rev 2 LUCIP Slip Sheets	7 days	Sun 07/14/02	Sat 07/20/02



Project: Figure 4-1- MI RD Schedule
Date: Mon 04/08/02
Figure 4-1 mpp

Task	▭	Milestone	◆	Rolled Up Split	· · · · · · ·	External Tasks	▨
Split	· · · · · · ·	Summary	▬	Rolled Up Milestone	◇	Project Summary	▬
Progress	▬	Rolled Up Task	▭	Rolled Up Progress	▬		

Figure 4-1
Memphus Depot Main Installation Remedial Design Schedule

ID	Task Name	Duration	Start	Finish
30	Submit Rev 2 LUCIP	0 days	Sat 07/20/02	Sat 07/20/02
31	**Intermediate Design**	**149 days**	**Tue 10/01/02**	**Wed 02/26/03**
32	Design Analysis	20 days	Tue 10/01/02	Sun 10/20/02
33	Drawings and Specifications	20 days	Mon 10/21/02	Sat 11/09/02
34	Construction Schedule	14 days	Mon 11/11/02	Sun 11/24/02
35	Operation and Maintenance Requirements	20 days	Tue 11/12/02	Sun 12/01/02
36	Remedial Action (RA) Component Cost Estimate	17 days	Wed 11/20/02	Fri 12/06/02
37	Performance Standards Verification Plan	30 days	Fri 11/01/02	Sat 11/30/02
38	Value Engineering	30 days	Mon 11/11/02	Tue 12/10/02
39	Submit Rev 0 (60%) Intermediate RD Report	0 days	Fri 12/13/02	Fri 12/13/02
40	BCT Review and Submit Comments on Rev 0 Inter RD Report	60 days	Sat 12/14/02	Tue 02/11/03
41	Respond to BCT Comments on Rev 0 Inter RD Report	15 days	Wed 02/12/03	Wed 02/26/03
42	**Prefinal Design**	**72 days**	**Fri 01/31/03**	**Sat 04/12/03**
43	Design Analysis	15 days	Fri 01/31/03	Fri 02/14/03
44	Drawings and Specifications	33 days	Mon 02/03/03	Fri 03/07/03
45	Construction Schedule	10 days	Tue 02/04/03	Thu 02/13/03
46	Operation and Maintenance Plan	28 days	Sat 02/08/03	Fri 03/07/03
47	RA Component Cost Estimate	12 days	Mon 02/10/03	Fri 02/21/03
48	Submit Rev 1 (90%) Prefinal RD Report	0 days	Thu 03/13/03	Thu 03/13/03
49	BCT Review and Comment on Rev 1 MI RD Prefinal Report	30 days	Fri 03/14/03	Sat 04/12/03
50	**Final Design**	**40 days**	**Wed 03/19/03**	**Sun 04/27/03**
51	Revise Specific Sections as Required	40 days	Wed 03/19/03	Sun 04/27/03
52	Submit Rev 2 (100%) Final MI RD Report w/ slip sheets	0 days	Sun 04/27/03	Sun 04/27/03

November	December	January	February	March	April	May	June
Nov	Dec	Jan	Feb	Mar	Apr	May	Jun

Project Figure 4-2 MI RD Schedule
Date Mon 04/08/02
Figure 4-1 mpp

Task	☐	Milestone	◆	Rolled Up Split	....	External Tasks	▨
Split	.. ..	Summary	▬	Rolled Up Milestone	◇	Project Summary	▬
Progress	▬	Rolled Up Task	☐	Rolled Up Progress	▬		

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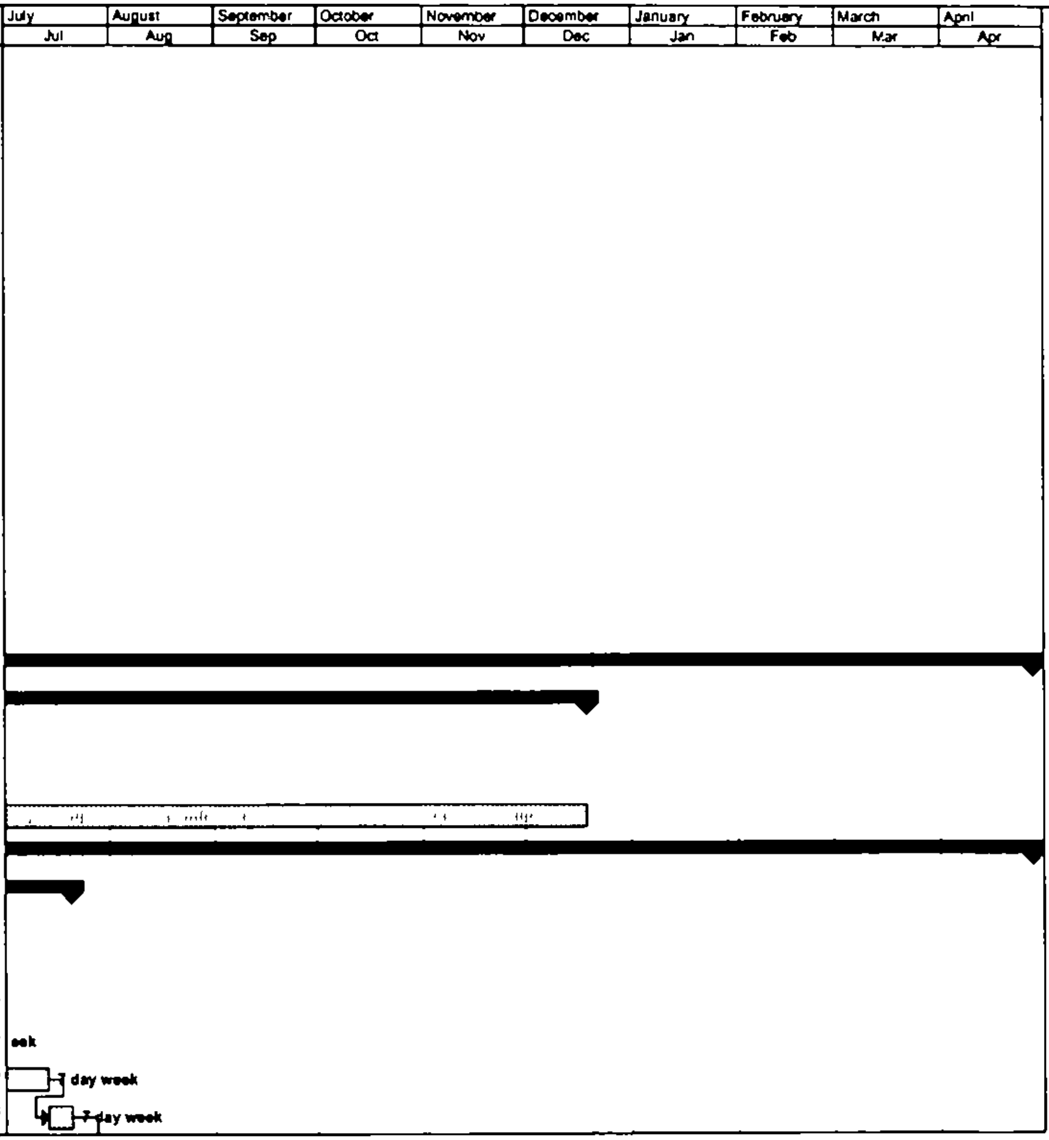
Figure 4-1
Memphis Depot Main Installation Remedial Design Schedule

ID	Task Name	Duration
1	**MI Remedial Design Workplan**	**183 days**
2	RD Workplan Development	45 days
3	Submit Rev O MI RD Workplan to BCT (with LTOA Tech Memo & EBT Treat	0 days
4	BCT Review and Submit Comments on Rev 0 MI RD Workplan	60 days
5	Respond to BCT Comments on Rev 0 MI RD Workplan	15 days
6	Prepare & Submit Rev 1 MI RD Workplan	30 days
7	BCT Review of Rev 1 MI RD Workplan w/ Concurrence	30 days
8	Prepare & Submit Rev 2 MI RD Workplan Slip Sheets	15 days
9	Submit Rev 2 MI RD Workplan	0 days
10	**Pre-Design Baseline Groundwater Sampling and Analyses (SAP)**	**116 days**
11	Prepare and Submit Baseline Groundwater SAP to BCT	11 days
12	BCT Review and Submit Comments on Baseline SAP	4 days
13	Revise Baseline SAP and Begin Sampling Event	7 days
14	Baseline Groundwater Sampling Event	28 days
15	Analyze Groundwater Sample Analytical Data	19 days
16	Review and Discuss Analytical Data with BCT	17 days
17	**Main Installation Remedial Design**	**399 days**
18	**Enhanced Biological Treatment (EBT) Pilot Test**	**248 days**
19	Injection Well Installation	30 days
20	Nutrient Source Injection into Groundwater	21 days
21	Performance Monitoring and Data Analysis	182 days
22	**Design Tasks**	**399 days**
23	**Land Use Control Implementation Plan (LUCIP)**	**118 days**
24	Prepare & Submit Rev 0 LUCIP	30 days
25	BCT Review & Submit Comments on Rev 0 LUCIP	30 days
26	Respond to BCT Comments on Rev 0 LUCIP	7 days
27	Prepare & Submit Rev 1 LUCIP	21 days
28	BCT Review of Rev 1 LUCIP w/ Concurrence	30 days
29	Prepare & Submit Rev 2 LUCIP Slip Sheets	7 days

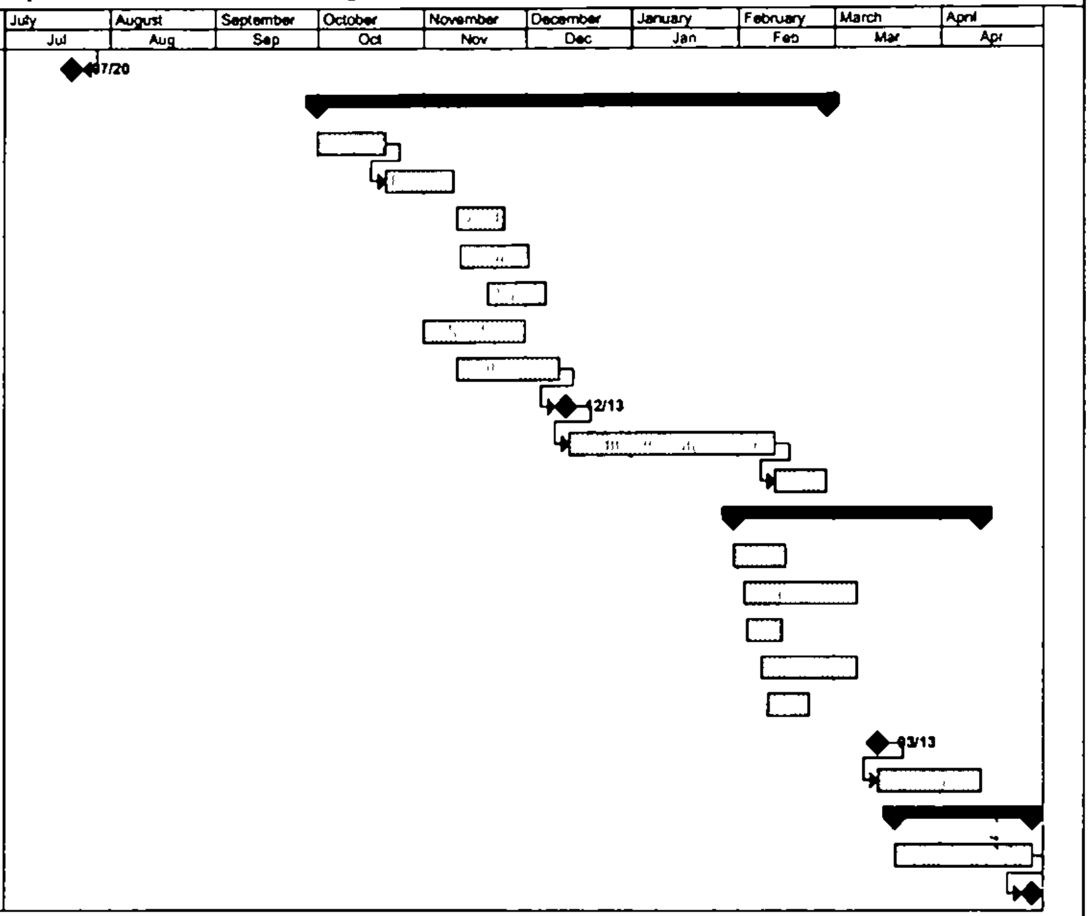


Project Figure 4-1 MI RD Schedule
Date Mon 04/08/02
Figure 4 1 mpp

Task	▭	Milestone	◆	Rolled Up Split	………………	External Tasks	▨
Split	………………	Summary	▬	Rolled Up Milestone	◇	Project Summary	▬
Progress	▬	Rolled Up Task	▭	Rolled Up Progress	▬		

Figure 4-1
Memphis Depot Main Installation Remedial Design Schedule

ID	Task Name	Duration
30	Submit Rev 2 LUCIP	0 days
31	**Intermediate Design**	**149 days**
32	Design Analysis	20 days
33	Drawings and Specifications	20 days
34	Construction Schedule	14 days
35	Operation and Maintenance Requirements	20 days
36	Remedial Action (RA) Component Cost Estimate	17 days
37	Performance Standards Verification Plan	30 days
38	Value Engineering	30 days
39	Submit Rev 0 (60%) Intermediate RD Report	0 days
40	BCT Review and Submit Comments on Rev 0 Inter RD Report	60 days
41	Respond to BCT Comments on Rev 0 Inter RD Report	15 days
42	**Prefinal Design**	**72 days**
43	Design Analysis	15 days
44	Drawings and Specifications	33 days
45	Construction Schedule	10 days
46	Operation and Maintenance Plan	28 days
47	RA Component Cost Estimate	12 days
48	Submit Rev 1 (90%) Prefinal RD Report	0 days
49	BCT Review and Comment on Rev 1 MI RD Prefinal Report	30 days
50	**Final Design**	**40 days**
51	Revise Specific Sections as Required	40 days
52	Submit Rev 2 (100%) Final MI RD Report w/ slip sheets	0 days



Project: Figure 4-1 MI RD Schedule
Date: Mon 04/08/02
Figure 4-1 mpp

Task	▭	Milestone	◆	Rolled Up Split	......	External Tasks	▨
Split	....	Summary	▬	Rolled Up Milestone	◇	Project Summary	▬
Progress	▬	Rolled Up Task	▭	Rolled Up Progress	▬		

Figure 5-1
Key Personnel for the Memphis Depot Main Installation Remedial Design

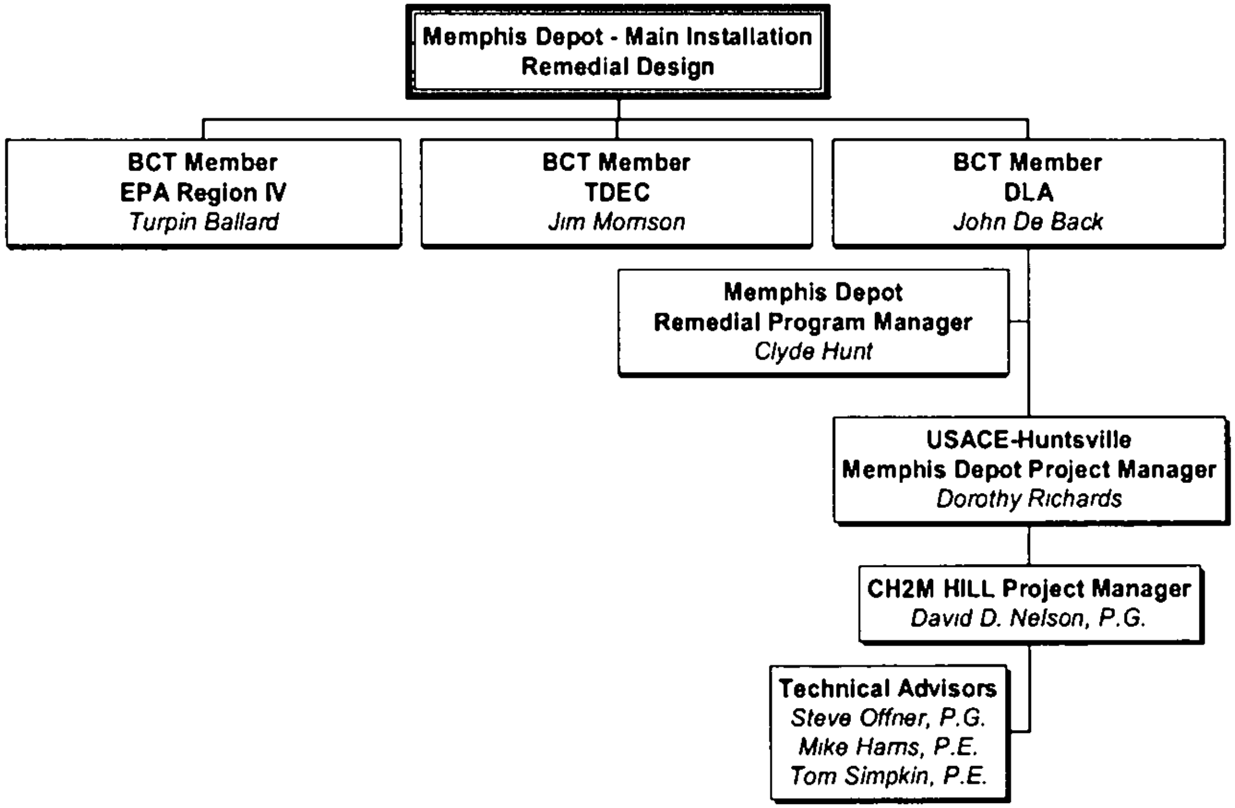
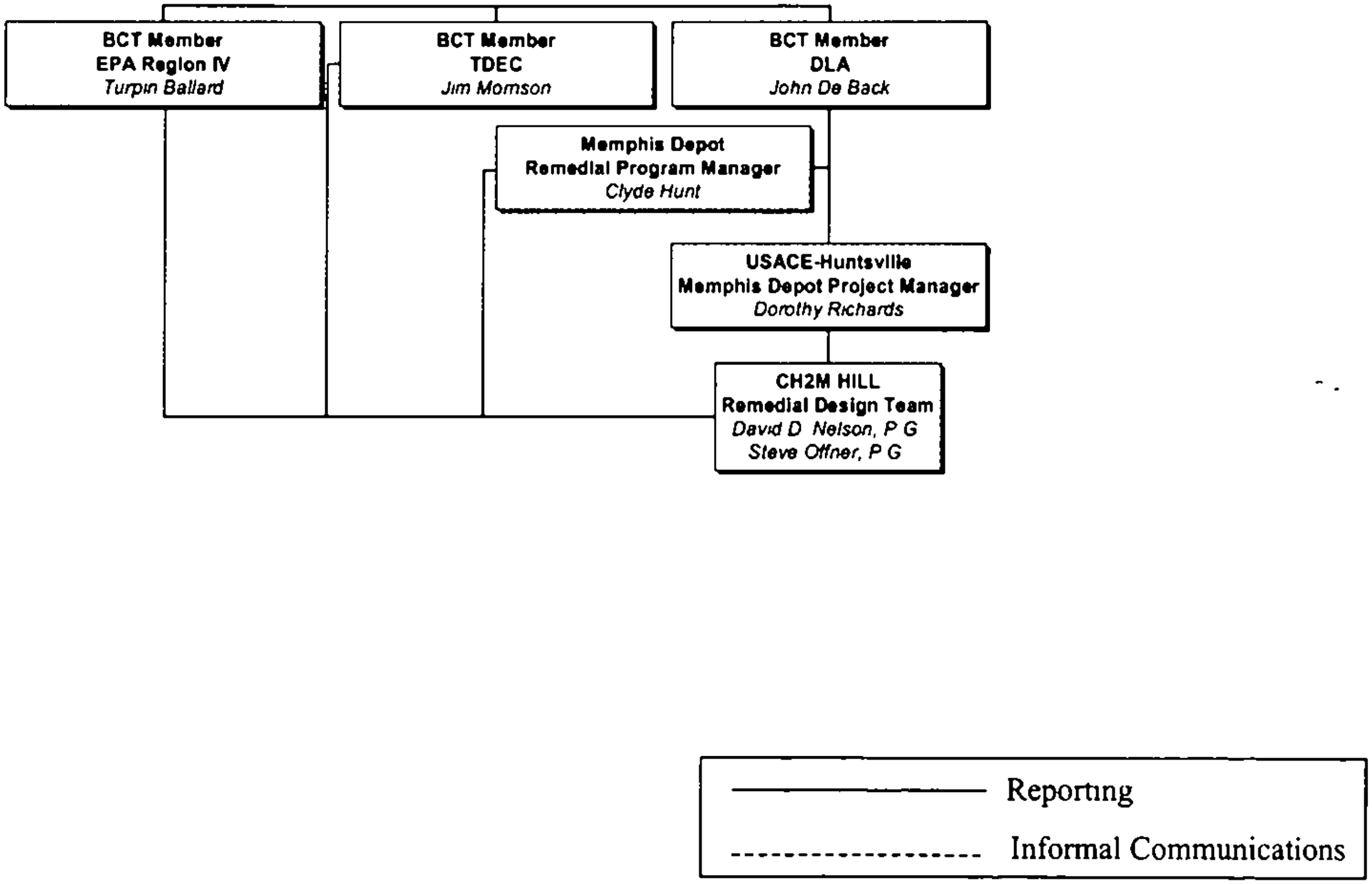


Figure 5-2
Communications and Reporting Matrix
Memphis Depot Main Installation Remedial Design



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Appendix A – Rev. 0 LTOA Technical Memorandum

(The LTOA Technical Memorandum has been temporarily split off from the remainder of the MI RD Workplan based upon a request from CH2M HILL to proceed with the submittal of the Rev 1 MI RD Workplan while discussions on the future of the LTOA investigation are proceeding The request was approved by the BCT during the week of March 25, 2002 The Rev 1 LTOA Technical Memorandum will be submitted along with the final MI RD Workplan at a later date)

Appendix B – Rev. 1 EBT Treatability Study Workplan

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Defense Distribution Center (Memphis)
Main Installation

Enhanced Bioremediation Treatment Treatability Study Workplan

Rev. 1

PREPARED FOR

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Acronyms

BCT	Base Cleanup Team
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAH	chlorinated aliphatic hydrocarbon
°C	degrees Celsius
Cis-1,2-DCE	Cis-1,2-dichloroethene
COC	Chain-of-Custody
COCs	Constituents of concern
cp	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

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

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 post-injection 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.

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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.

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 (µg/L). Average TCE concentrations range from below laboratory detection limit to 79 µg /L In addition, an unusual detection of carbon tetrachloride and chloroform at average concentrations of 122 µg/L and 77 µg/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 (H_2) 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 Mechanisms

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

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
Trichloroethene (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

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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 H_2, resulting in high H_2 levels that persist for only short periods as various H_2-using organisms deplete it. However, lactate may be fermented to propionate, which itself can serve as a more slowly fermentable source of persistent, low H_2 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 H_2 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.

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-1,2-dichloroethene is present. Concentrations of PCE have ranged from an estimated concentration of 2 μg /L to 120 μg /L. TCE concentrations have ranged from an estimated concentration of 2 μg /L to 39 μg /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 μg /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 μg /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 μg/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

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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 µg /L in monitoring well MW-86. The highest concentration of PCE detected was 280 µg/L in MW-86. Average TCE concentrations in these same wells were found to range from below laboratory detection limit to 23 µg /L in monitoring well MW-85. The highest TCE concentration was revealed within MW-85 at 26 µg/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 µg/L in MW-86. Also, carbon tetrachloride was revealed as high as 140 µg/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 off-site 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-to-date 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.

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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.

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 oil-lecithin mixture or sodium lactate, the bromide 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 µg/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 comparison 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, Memphis 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 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.

TABLE 9-1
Sample Numbering Protocol

Sample Event	Type of Sample(s) and Location	Sample Number Description	Example Sample 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 with 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

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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 as-needed basis to maintain the site in a clean and orderly manner. This waste will be containerized and transported to the designated sanitary landfill or collection bin. Acceptable containers will be sealed containers or plastic garbage bags.

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 Transportation-approved 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.

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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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Tables

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Table 3-1
LTOA Diffusion Bag Sample Data - VOCs
November & December 2001
[illegible]

Monitoring Well ID	Monitoring Well Details: Screen Interval Upper (ft BTOC)	Screen Interval Lower (ft BTOC)	Depth to Water (ft BTOC)	Diffusion Sampler Details: Bag 1 Interval Upper (ft BTOC)	Bag 1 Interval Lower	Bag 2 Interval Upper	Bag 2 Interval Lower	Bag 3 Interval Upper	Bag 3 Interval Lower	Bag 4 Interval Upper	Bag 4 Interval Lower	Bag 5 Interval Upper	Bag 5 Interval Lower	Bag 6 Interval Upper	Bag 6 Interval Lower	Bag 7 Interval Upper	Bag 7 Interval Lower	Bag 8 Interval Upper	Bag 8 Interval Lower	Bag 9 Interval Upper	Bag 9 Interval Lower	Bag 10 Interval Upper	Bag 10 Interval Lower	Analytical Lab Data (Sampled on November and December 2001): PCE (ug/L)	TCE (ug/L)	cis-1,2-DCE (ug/L)	trans-1,2-DCE (ug/L)	1,1-DCE (ug/L)	1,1-DCA (ug/L)	1,2-DCA (ug/L)	1,1,2,2-PCA (ug/L)	Chloroform (ug/L)	Carbon Tetrachloride (ug/L)
[illegible]	95.0	116.0	99.87	[illegible]	[illegible]	120.0	102.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	97.0	117.5	99.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	97	[illegible]	81	83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MW-42	90	[illegible]	95.71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MW-43	90	107	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MW-44	[illegible]	110.5	107.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	78.0	90.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MW-47	97.5	117.0	104.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	137	147	142	137	139	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	91.0	111.0	89.6	91.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	111.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5-1
Geochemical Markers of the Fluvial Aquifer Underlying the MI
Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Geochemical Marker	Reported Range*	Background Values	Units	Biodegradation Activity?
Soluble Chloride Ion	11 - 24	10	mg/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	mg/L	Not supportive
Ferric (Fe3+) iron	ND	ND	mg/L	Supportive
Manganese	ND	ND	mg/L	Supportive
Sulfate/Sulfide	4 3 - 18/ND	30/ND	mg/L	Supportive
Methane	0 002142 - 0 005964	0 000067	mg/L	Not supportive
Alkalinity	45 - 90	95	ppm	Supportive
pH	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	mg/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 = millivolts

nm/L = nanometers per liter

ppm = parts per million

su = standard units

C = centigrade

ug/L = micrograms per liter

Table 5-2

Summary of Historical Volatile Organic Compound Data

Monitoring Wells MW-21, MW-22, MW-47, and PZ-04

Rev 1 Memphis Depot MI EBT Treatability Study Workplan

Location ID		PZ04	MW21	MW21	MW21	MW21	MW21	MW21	MW21
Date Collected		11/03/1998	11/18/1993	02/10/1998	06/20/1997	09/27/1997	03/27/1998	10/19/1998	03/24/2000
Parameter Name	Units								
1 1 2 2-TETRACHLOROETHANE	ug/L	0.005 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	4 =
1 1-DICHLOROETHENE	ug/L	0.005 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.2 J
ACETONE	ug/L	0.01 U	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	3 J
CARBON DISULFIDE	ug/L	0.005 U	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
CARBON TETRACHLORIDE	ug/L	0.005 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.4 J
CHLOROFORM	ug/L	0.005 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	8 =
cis-1,2-Dichlorothylene	ug/L	na	na	na	na	na	na	na	1 =
cis-1 3-DICHLOROPROPENE	ug/L	0.005 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
STYRENE	ug/L	0.005 U	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
TETRACHLOROETHYLENE(PCE)	ug/L	110=	48.1=	52=	83=	82=	78=	120=	78=
TOTAL 1,2-DICHLOROETHENE	ug/L	0.005 U	na	0.01 U	0.01 U	0.01 U	0.01 U	2J	na
trans-1 2-DICHLOROETHENE	ug/L	na	0.001 U	na	na	na	na	na	1U
TRICHLOROETHYLENE (TCE)	ug/L	0.005 U	4.42=	8J	14=	12=	18=	31=	38=

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

Location ID		MW22	MW22	MW22	MW22	MW22	MW22	MW22	MW22
Date Collected		11/17/1993	11/17/1993	02/10/1998	06/19/1997	09/25/1997	03/28/1998	10/19/1998	03/23/2000
Parameter Name	Units								
1 1,2 2 TETRACHLOROETHANE	ug/L	0.001 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
1 1-DICHLOROETHENE	ug/L	0.001 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
ACETONE	ug/L	na	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	5 U
CARBON DISULFIDE	ug/L	na	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.3 J
CARBON TETRACHLORIDE	ug/L	0.001 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
CHLOROFORM	ug/L	0.001 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
cis-1,2-Dichlorothylene	ug/L	na	na	na	na	na	na	na	0.5 J
cis-1 3-DICHLOROPROPENE	ug/L	0.001 U	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
STYRENE	ug/L	na	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U
TETRACHLOROETHYLENE(PCE)	ug/L	0.001 U	0.001 U	2J	0.01 U	2J	0.01 U	0.01 U	0.8 J
TOTAL 1 2-DICHLOROETHENE	ug/L	na	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	na
trans-1,2-DICHLOROETHENE	ug/L	0.001 U	0.001 U	na	na	na	na	na	1 U
TRICHLOROETHYLENE (TCE)	ug/L	1.24=	0.001 U	2J	2J	4J	1J	0.01 U	1 =

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

Location ID		MW47	MW47	MW47	MW47	MW47	MW47	MW47	MW47	MW47
Date Collected		02/09/1996	06/22/1997	09/26/1997	03/28/1998	10/19/1998	03/23/2000	03/09/2001	03/09/2001	03/09/2001
Parameter Name	Units									
1 1,2,2 TETRACHLOROETHANE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	0.34 J	0.17 J	1.3 =
1 1-DICHLOROETHENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
ACETONE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	5 U	3 J	2.4 J	2.8 J
CARBON DISULFIDE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
CARBON TETRACHLORIDE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
CHLOROFORM	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
cis-1,2-Dichlorothylene	ug/L	na	na	na	na	na	4 =	1 U	1 U	1 U
cis-1 3-DICHLOROPROPENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
STYRENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 U	1 U	1 U	1 U
TETRACHLOROETHYLENE(PCE)	ug/L	23=	2J	14=	14=	1J	200=	0.57 J	1 U	1 U
TOTAL 1 2-DICHLOROETHENE	ug/L	2J	0.01 U	6J	9J	1J	na	na	na	na
trans-1 2-DICHLOROETHENE	ug/L	na	na	na	na	na	1 U	1 U	1 U	1 U
TRICHLOROETHYLENE (TCE)	ug/L	2J	0.01 U	6J	6J	0.01 U	2 =	1 U	1 U	1 U

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

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Table 5-2a

Summary of Historical Volatile Organic Compound Data

Monitoring Wells MW-25, MW-26, MW-50, and MW-64

Rev 1 Memphis Depot MI EBT Treatability Study Workplan

Location ID		MW25	MW25	MW25	MW25	MW25	MW25
Date Collected		11/13/1993	2/9/1996	6/19/1997	9/25/1997	3/26/1998	10/16/1998
[illegible] Parameter Name [illegible]	Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1 1 2,2 TETRACHLOROETHANE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
1 1-DICHLOROETHENE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
ACETONE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 UJ
CARBON DISULFIDE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
CARBON TETRACHLORIDE	ug/L	0.001 U	0.01 U	0.01 U	1 J	1 J	2 J
CHLOROFORM	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
cis-1,2-Dichlorothylene	ug/L	na	na	na	na	na	na
cis-1 3-DICHLOROPROPENE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
TETRACHLOROETHYLENE(PCE)	ug/L	11.2 =	4 J	4 J	11 =	6 J	9 J
TOTAL 1,2-DICHLOROETHENE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
trans-1 2-DICHLOROETHENE	ug/L	0.001 U	na	na	na	na	na
TRICHLOROETHYLENE (TCE)	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

Location ID		MW26	MW26	MW26	MW26	MW26	MW26
Date Collected		11/9/1993	2/8/1996	6/20/1997	9/26/1997	3/28/1998	10/20/1998
[illegible] Parameter Name [illegible]	Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1 1 2 2 TETRACHLOROETHANE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
1 1-DICHLOROETHENE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
ACETONE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
CARBON DISULFIDE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
CARBON TETRACHLORIDE	ug/L	3.16 =	4 J	4 J	4 J	4 J	4 J
CHLOROFORM	ug/L	0.001 U	1 J	1 J	0.01 U	2 J	1 J
cis-1,2-Dichlorothylene	ug/L	na	na	na	na	na	na
cis-1 3-DICHLOROPROPENE	ug/L	0.001 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
TETRACHLOROETHYLENE(PCE)	ug/L	6.5 =	14 =	12 =	11 =	14 =	18 =
TOTAL 1,2-DICHLOROETHENE	ug/L	na	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
trans-1 2-DICHLOROETHENE	ug/L	0.001 U	na	na	na	na	na
TRICHLOROETHYLENE (TCE)	ug/L	1.29 =	2J	2J	2 J	2 J	2 J

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

Location ID		MW50	MW50	MW50	MW50	MW50	MW64
Date Collected		2/11/1996	6/19/1997	9/24/1997	3/25/1998	10/16/1998	10/25/1998
[illegible] Parameter Name [illegible]	Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1 1 2,2 TETRACHLOROETHANE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	4 J
1 1-DICHLOROETHENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
ACETONE	ug/L	0.048 U	0.01 U	0.01 U	0.01 U	0.01 UJ	0.01 U
CARBON DISULFIDE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 J
CARBON TETRACHLORIDE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	2 J
CHLOROFORM	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	1 J
cis-1 2-Dichlorothylene	ug/L	na	na	na	na	na	na
cis-1 3-DICHLOROPROPENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
TETRACHLOROETHYLENE(PCE)	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	10 =
TOTAL 1,2-DICHLOROETHENE	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
trans-1,2-DICHLOROETHENE	ug/L	na	na	na	na	na	na
TRICHLOROETHYLENE (TCE)	ug/L	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	28 =

(=) Definite detection

J = Estimated detection. Contaminant detected at or below laboratory detection limit.

na = not included in list of analytes

Table 5-3

Summary of LTOA Groundwater Sample Analytical Results - VOCs

Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

	Diffusion Bag Intervals	Analytical Lab Data*									
Monitoring Well ID	Upper to Lower Bag (ft bloc)	PCE (ug/L)	TCE (ug/L)	cis-1,2-DCE (ug/L)	trans-1,2-DCE (ug/L)	1,1-DCE (ug/L)	1,1-DCA (ug/L)	1,2-DCA (ug/L)	1,1,2,2-PCA (ug/L)	Chloroform (ug/L)	Carbon Tetrachloride (ug/L)
MW-85	100 9 to 110 9	**49**	**23**	**28**	**0 7**	< 1	< 1	**1 3**	**1.0**	**64**	**122**
MW-86	99 5 to 115 5	**198**	**20**	**53**	**0 9**	< 1	< 1	**3 6**	< 1	**77**	**77**
MW-88	81 to 97	**10.7**	**2.4**	**1 3**	< 1	< 1	< 1	< 1	< 1	**1 1**	**3 0**
MW 92	98 to 108	**150**	**4 4**	**6 6**	**0 7**	< 1	< 1	**0 1**	< 1	**6 5**	**19**
MW-93	103 to 107	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	**0 8**	< 1
MW-94	108 5 to 110 5	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
MW-96	83 5 to 95 5	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	**0 8**	< 1
MW 97	101 5 to 117 5	< 1	**0 9**	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
MW-98	137 to 147	**4 6**	**0 8**	< 1	< 1	< 1	< 1	< 1	< 1	**0.2**	< 1
MW 99	91 5 to 109 5	< 1	**0 7**	< 1	< 1	< 1	< 1	< 1	< 1	**0 5**	< 1
MW-100	107 5 to 125 5	**50**	**79**	**1 2**	**0.2**	**0 3**	< 1	**0.2**	**0 5**	< 1	< 1
MW-101	NA**	**480**	**0 9J**	**0 3J**	<1	<1	<1	<1	<1	**0 6J**	< 1
MW-102	120 5 to 138 5	< 1	**0 7**	< 1	< 1	< 1	< 1	< 1	**0 6**	< 1	< 1
MW 103	70 to 88	< 1	**4 0**	**0 5**	< 1	**1.2**	**1 3**	**0 3**	< 1	**13**	< 1
MW-104	70 5 to 88 5	< 1	**11**	**0 6**	< 1	**1.1**	**0.5**	< 1	< 1	**12**	< 1
MW-107	NA**	**0 8**	**2.7**	**0 3**	<1	<1	<1	<1	<1	**0.2**	**0 6**
MW-108	NA**	**2 6**	**6**	**0.2J**	<1	<1	<1	<1	<1	**6**	<1

*Detected concentrations are in bold and represent an average concentration for all diffusion bag samplers per monitoring well Details of results per each bag can be found in Table 2 1

**These wells contain multiple screens and therefore were sampled using low-flow sampling methods

ft btoc = feet below top of casing

ug/L = micrograms per liter

J = Estimated detection. Contaminant detected between the MDL and reporting limit

VOCs = Volatile Organic Compounds

Table 5-4
Practicality of Electron Donor Substrates
Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Substrate Type	Substrate Use at Other Sites	Contaminant Concentrations vs. Concentration at Memphis Depot	Aquifer Characteristics vs. Viscosity of Substrate	Equipment Required for Delivery	Success Level
Lactate	MCLB Albany, GA	TCE = 760 mg/L	Laboratory Test	Direct injection	Reduction of contaminant occurred after 0 5 month period
Molasses	AVCO Lycoming Superfund Site	TCE = 67 ug/L, DCE =7 ug/L, VC = <1 ug/L	High permeability aquifer vs Low viscosity substrate	Direct injection through injection wells	TCE and DCE levels below cleanup goals
HRC	Various Sites	Concentrations comparable or greater than at Memphis Depot	Sandy silt aquifers to sand aquifers	Injection through pumping	Contaminant levels vary after injection, some sites show marked decrease and show no decrease
Vegetable Oil	Demo Site, Cape Canaveral, FL,	TCE = 100,000 mg/L, VC = 330 mg/L	Sandy aquifer; viscosity of oil dependent upon mixing	Injection and Recirculation System	After six month period, TCE levels decreased to 160 mg/L Daughter product levels increased along with total VC levels
Hydrogen sparging	AFCEE - Cape Canaveral Air Station	TCE = 48 mg/l, cis-DCE = 140 mg/L	Sandy aquifer; gas - high viscosity substrate	Gas pulsed through three injection points	After one week - extensive biological utilization of hydrogen After 4 months data indicate significant reductions in TCE and cis DCE concentrations compared to a control point (injected with nitrogen only)

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Table 6-1
List of Preliminary Activities of the MI EBT Treatability Study
Rev 1 Memphis 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.

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Table 6-2

Analytical Protocols for EBT Samples

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

*Reported in sequence of sample collection

Table 7-1

Treatability Study Area 1 (MI Southwest Corner) Injection Scenario

Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Well	Oil/Water Mixture		Emulsifier (agent)	Water Flush Amount	Total Volume (gallons)	Final Percent Oil	Screened Interval (feet)	Radius of Influence (feet)	Emulsion Flow Rate (gpm)	Emulsion Injection Time (hours)	Water Flush Flow Rate (gpm)	Water Flush Flow Rate (hours)
	Oil (gallons)	Water (gallons)										
Test Area - Entire Aquifer												
INJ-1	1762	5230	Lecithin	55	7046	25	40	5	3	39.1	3	0.3
INJ-2	1762	5230	Lecithin	55	7046	25	40	5	3	39.1	3	0.3
INJ-3	1762	5230	Lecithin	55	7046	25	40	5	3	39.1	3	0.3
	5285	**15689**		**165**	**21138**					**117.4**		**0.9**

Assumptions

1 An effective porosity of 30 percent for the fluvial aquifer

2 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

Table 7-2

Treatability Study Area 2 (MI Southeast Corner) Injection Scenario

Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

Well	Lactate/Water Mixture		Water Flush Amount	Total Volume (gallons)	Final Percent Lactate	Screened Interval (feet)	Radius of Influence (feet)	Substrate Flow Rate (gpm)	Substrate Injection Time (hours)	Water Flush Flow Rate (gpm)	Water Flush Flow Rate (hours)
	Lactate (gallons)	Water (gallons)									
Test Area- Entire Aquifer											
INJ-4	661	1927	55	2642	15	15	5	3	14.7	3	0.3
INJ-5	661	1927	55	2642	15	15	5	3	14.7	3	0.3
INJ-6	661	1927	55	2642	15	15	5	3	14.7	3	0.3
INJ-7	661	1927	55	2642	15	15	5	3	14.7	3	0.3
	2642	**7707**	**220**	**10569**					**58.7**		**1.2**

Assumptions

1 An effective porosity of 30 percent for the fluvial aquifer

2 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

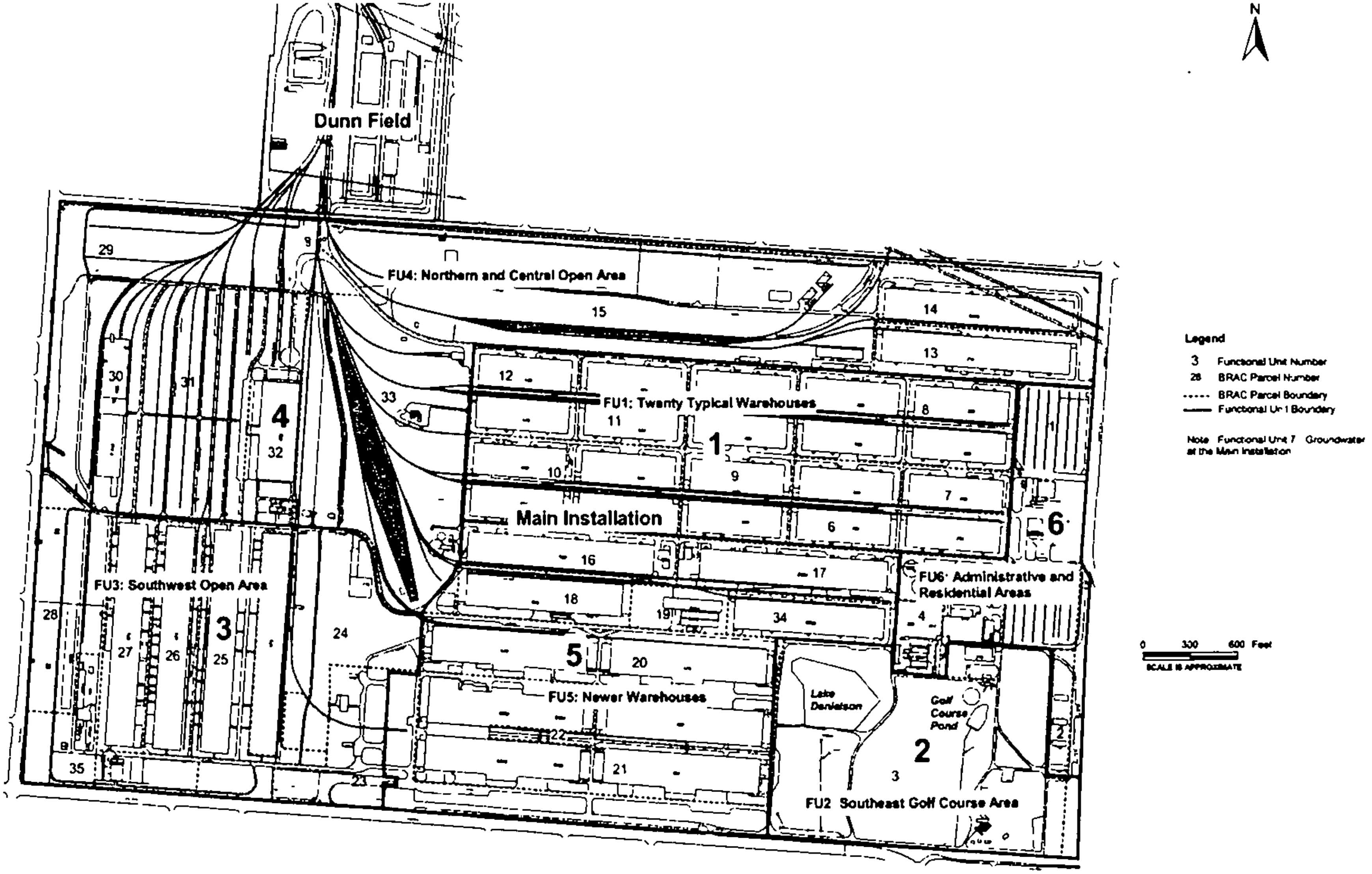

FIGURE 2-1
Functional Units at Main Installation
Rev 1 Memphis Depot Main Installation EBT Treatability Study Workplan

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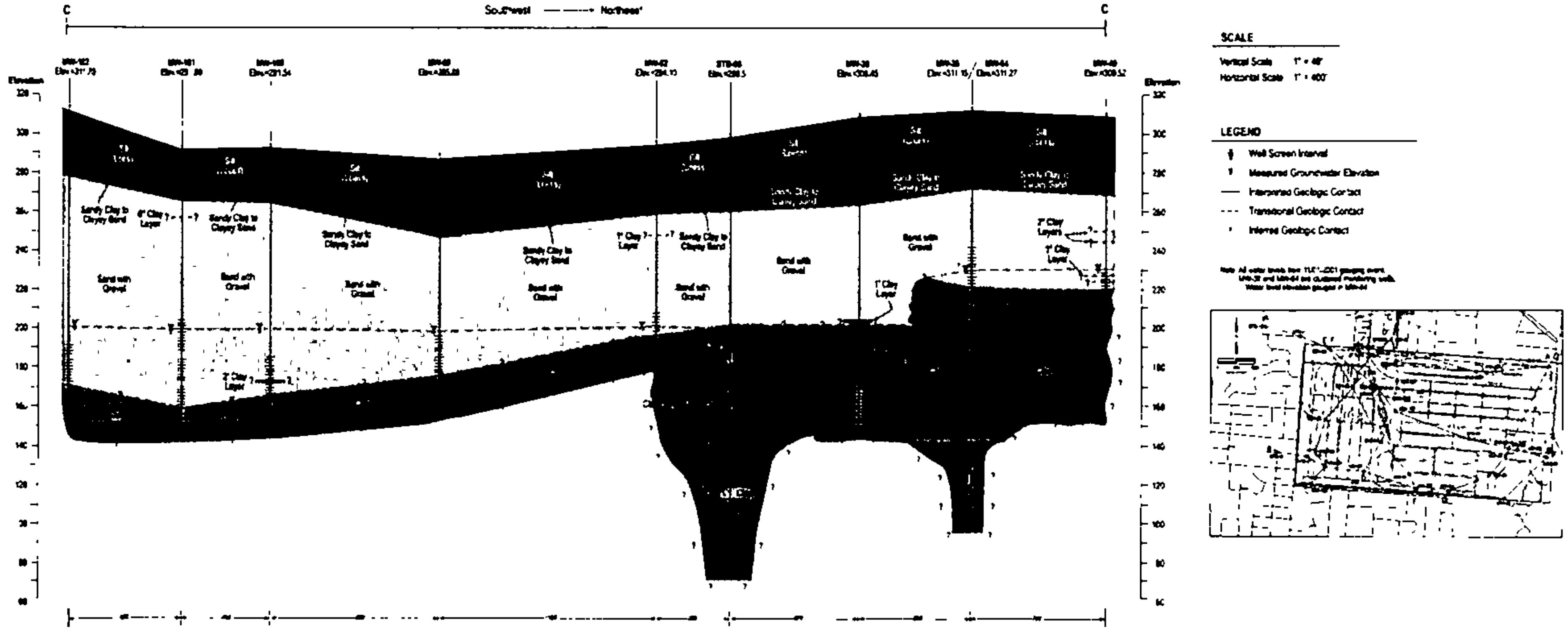

FIGURE 2-2
Lithologic Cross-Section C - C'
Memphis Depot Main Installation EBT Treatability Study Workplan

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Rev 0

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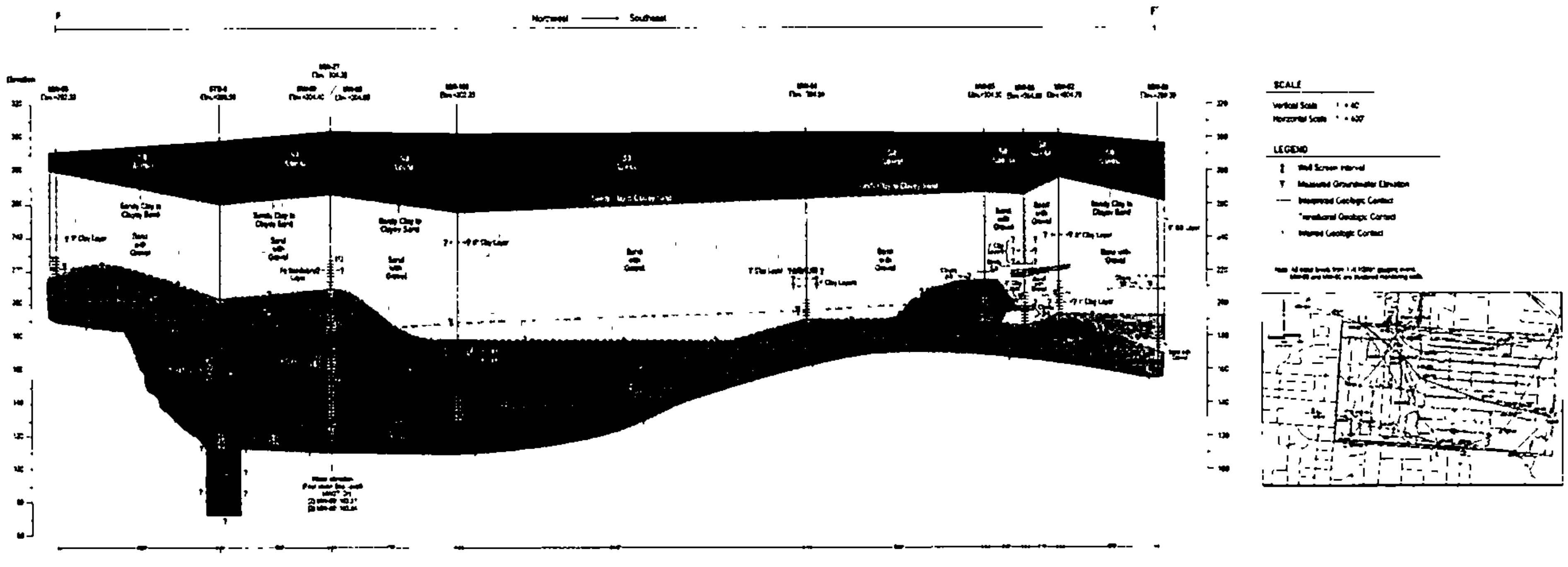

FIGURE 2-3
Lithologic Cross-Section F - F'
Memphis Depot Main Installation EBT Treatability Study Workplan

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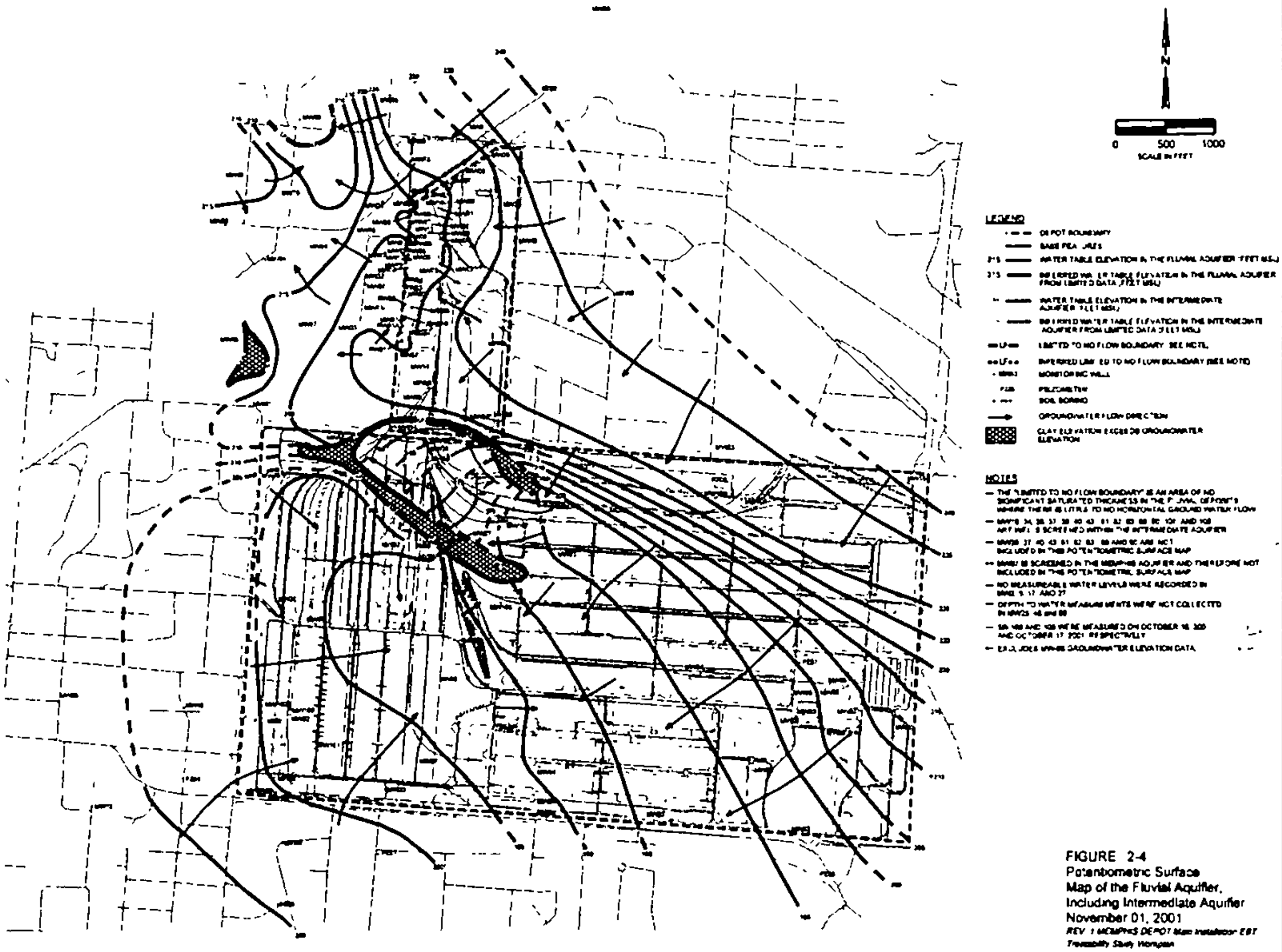
Rev 0

Well ID	Water Level Elevation (feet MSL)
MW03	221.88
MW04	224.84
MW06	224.00
MW07	226.71
MW08	223.88
MW09	229.43
MW10	223.19
MW11	222.80
MW12	224.11
MW13	224.61
MW14	227.22
MW15	224.49
MW16	241.44
MW18	175.20
MW19	200.82
MW20	189.30
MW21	189.86
MW22	220.03
MW23	188.57
MW24	190.82
MW26	203.03
MW27	DRY
MW28	233.88
MW29	233.52
MW30	226.58
MW31	218.34
MW32	221.41
MW33	224.18
MW34	158.80
MW35	222.34
MW36	151.63
MW37	151.12
MW38	189.97
MW39	191.80
MW40	171.05
MW41	217.88
MW42	217.73
MW43	152.75
MW44	212.97
MW45	236.88
MW46	232.05
MW47	203.89
MW49	230.56
MW50	212.21
MW51	234.82
MW52	197.25
MW53	232.67
MW54	213.80
MW55	221.05
MW56	225.81
MW57	224.87
MW58	228.29
MW59	223.82
MW60	224.15
MW61	224.73
MW62	189.71
MW63	187.48

Well ID	Water Level Elevation (feet MSL)
MW64	188.83
MW65	252.85
MW67	151.58
MW68	221.78
MW69	222.44
MW70	223.28
MW71	222.43
MW72	205.91
MW73	223.87
MW74	223.38
MW75	222.88
MW76	217.04
MW77	221.42
MW78	226.11
MW79	212.83
MW80	212.84
MW81	154.87
MW82	151.50
MW83	157.48
MW84	228.48
MW85	204.18
MW86	206.28
MW87	223.70
MW88	224.17
MW89	183.57
MW90	183.84
MW91	223.78
MW92	207.88
MW93	191.83
MW94	189.87
MW95	228.82
MW96	208.20
MW97	198.18
MW98	192.43
MW99	196.73
MW100	198.21
MW101	198.38
MW102	200.88
MW103	231.82
MW104	232.75
MW107	190.48
MW108	188.88
PZ31	202.74
PZ32	241.81
PZ33	191.47
PZ34	203.88
PZ35	198.54
PZ36	229.22
PZ37	206.74
PZ38	204.88
RW04	223.38
RW05	220.82
RW08	219.24
RW09	221.88
SB105	DRY
SB106	DRY



NOTES

- THE "LIMITED TO NO FLOW BOUNDARY" IS AN AREA OF NO SIGNIFICANT SATURATED THICKNESS IN THE FLUVIAL DEPOSITS WHERE THERE IS LITTLE TO NO HORIZONTAL GROUND WATER FLOW
- MW'S 34, 36, 37, 38, 40, 43, 81, 82, 83, 89, 90, 107 AND 108 ARE WELLS SCREENED WITHIN THE INTERMEDIATE AQUIFER
- MW36, 37, 40, 43, 81, 82, 83, 89 AND 90 ARE NOT INCLUDED IN THIS POTENTIOMETRIC SURFACE MAP
- MW67 IS SCREENED IN THE MEMPHIS AQUIFER AND THEREFORE NOT INCLUDED IN THIS POTENTIOMETRIC SURFACE MAP
- NO MEASUREABLE WATER LEVELS WERE RECORDED IN MW5, 17 AND 27
- DEPTH TO WATER MEASUREMENTS WERE NOT COLLECTED IN MW25, 48 and 66
- SB 105 AND 106 WERE MEASURED ON OCTOBER 16, 2001 AND OCTOBER 17, 2001 RESPECTIVELY
- EXCLUDES MW65 GROUNDWATER ELEVATION DATA

FIGURE 2-4
Potentiometric Surface
Map of the Fluvial Aquifer,
Including Intermediate Aquifer
November 01, 2001
REV 1 MEMPHIS DEPOT Main Installation EBT Treatability Study Workplan

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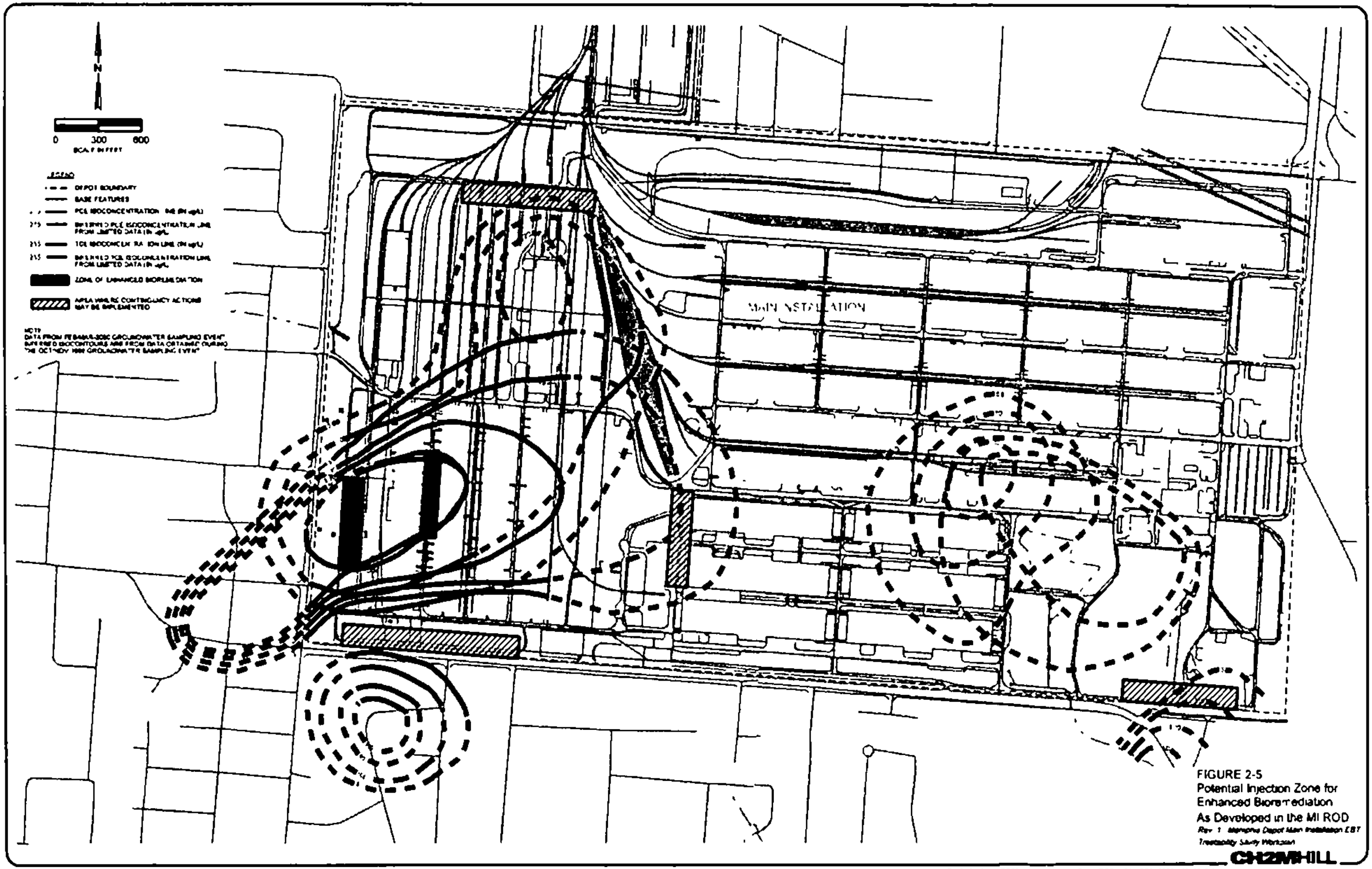

FIGURE 2-5
Potential Injection Zone for
Enhanced Bioremediation
As Developed in the MI ROD

Rev. 1 Memphis Depot Main Installation EBT
Treatability Study Workplan

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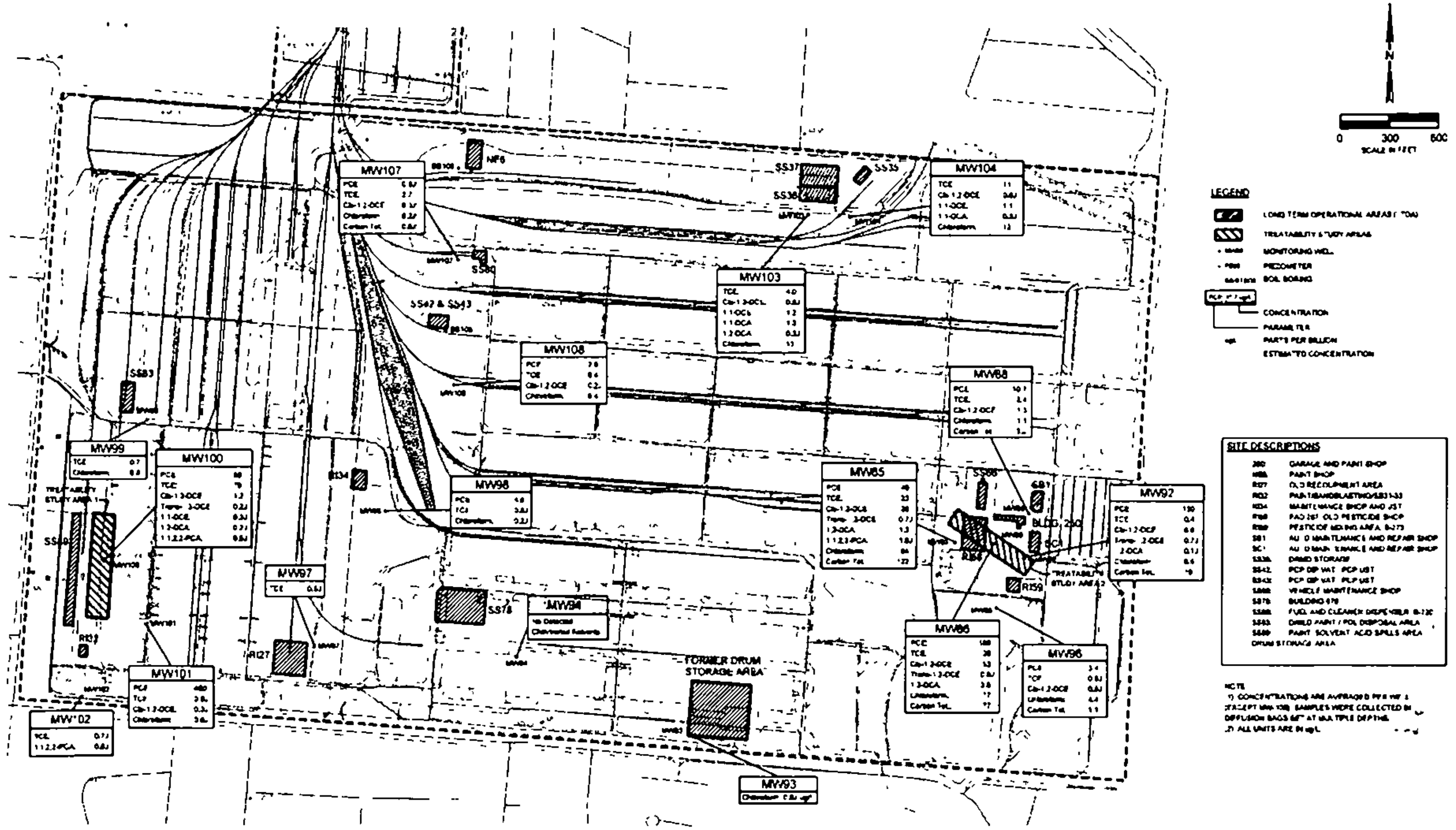

NOTE
1) CONCENTRATIONS ARE AVERAGED PER WELL EXCEPT MW-108; SAMPLES WERE COLLECTED IN DIFFUSION BAGS SET AT MULTIPLE DEPTHS.
2) ALL UNITS ARE IN ug/L.

FIGURE 2-8
CHLORINATED SOLVENT CONCENTRATIONS DETECTED IN GROUNDWATER SAMPLES FROM LTOA INVESTIGATION
Rev 1 - Memphis Depot Main Installation
EBT Study Workplan

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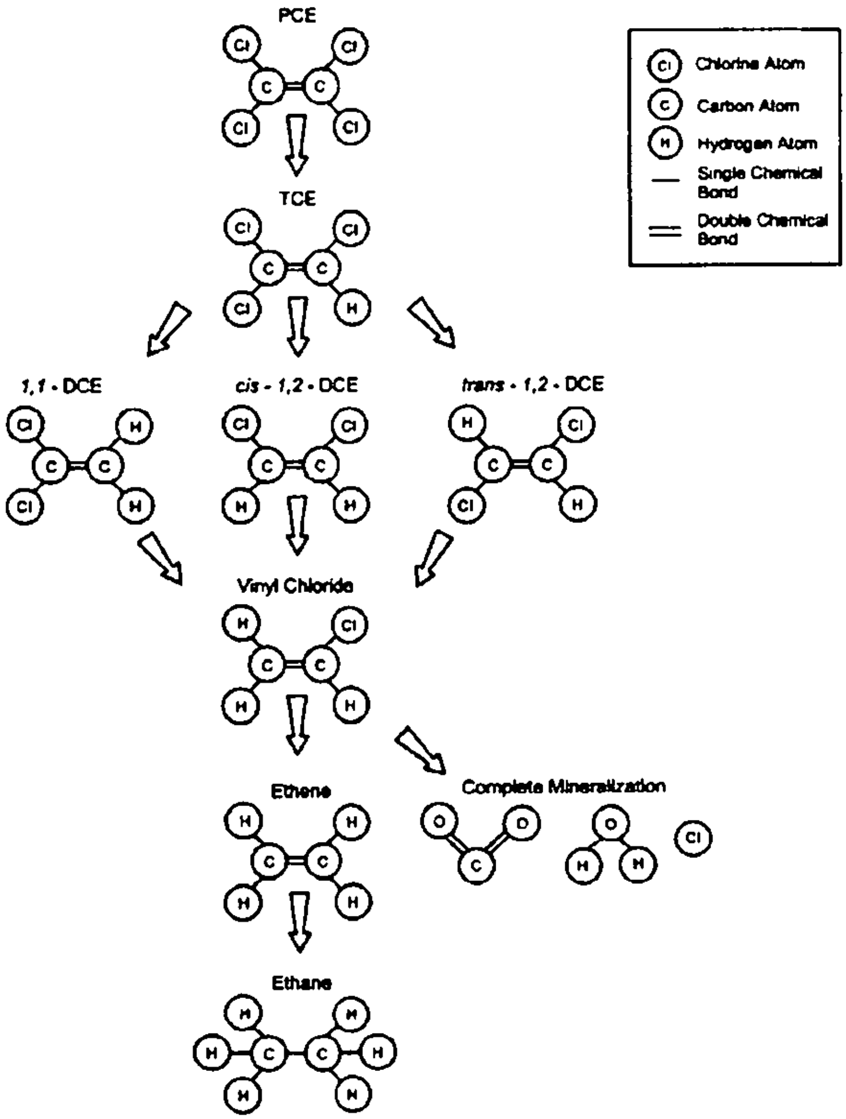

Figure 3-1
Anaerobic reductive dechlorination pathways (Wiedemeier et al 1997).

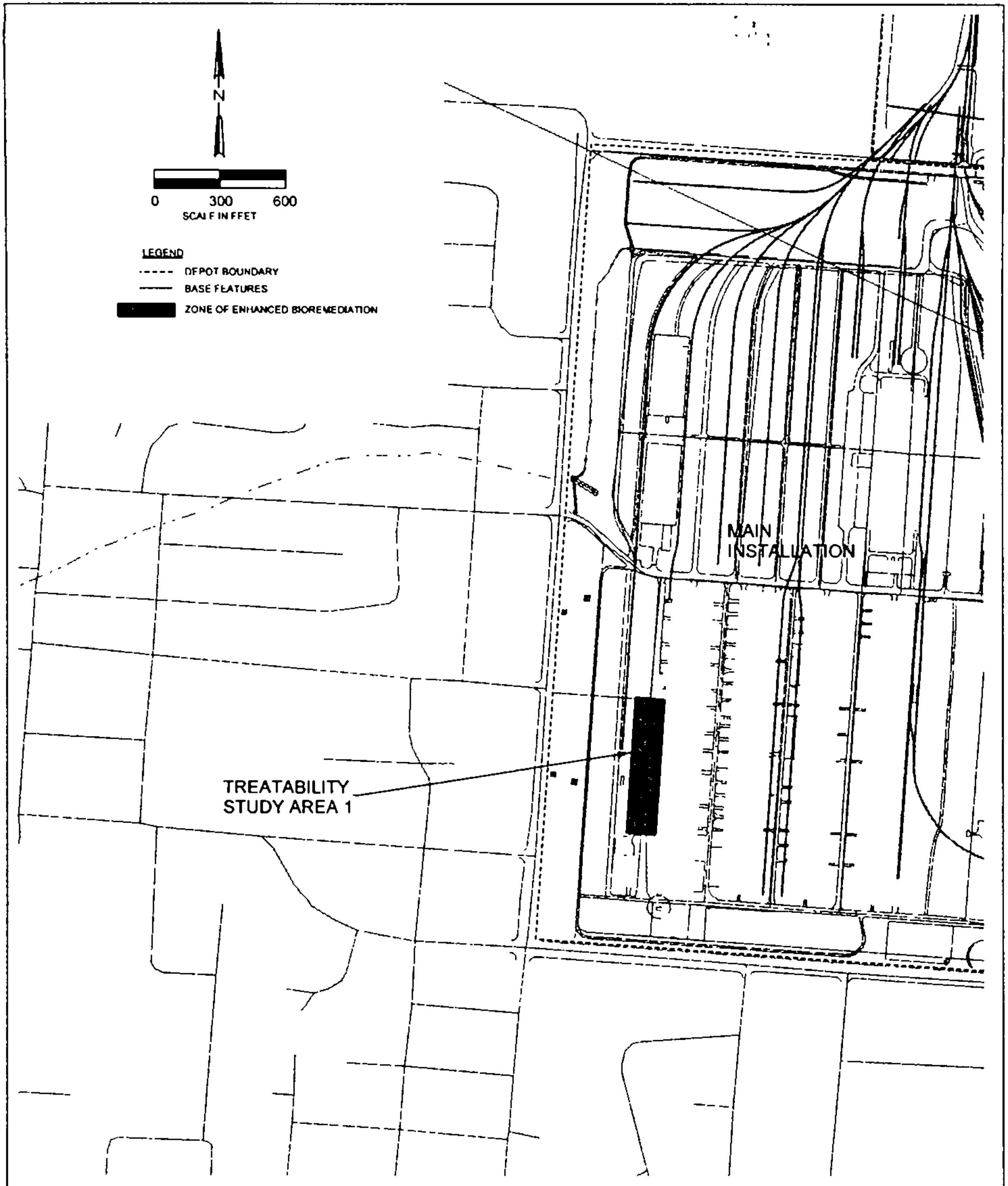

FIGURE 5-1
ENHANCED BIOREMEDIATION
TREATABILITY STUDY AREA 1
Rev 0 - Memphis Depot Main Installation EBT Treatability Study Workplan

CH2MHILL

ATLANTA/CAD1/PROJECTS/147543 MemphisDepot/EBT 12-DEC-2000 7543fig5-1.dgn

FIGURE 5-2
MI MONITORING WELL PIEZOMETER
AND SOIL BORING LOCATION MAP

*Rev.1 Memphis Depot Main Installation EBT
Treatability Study Workplan*

CH2MHILL

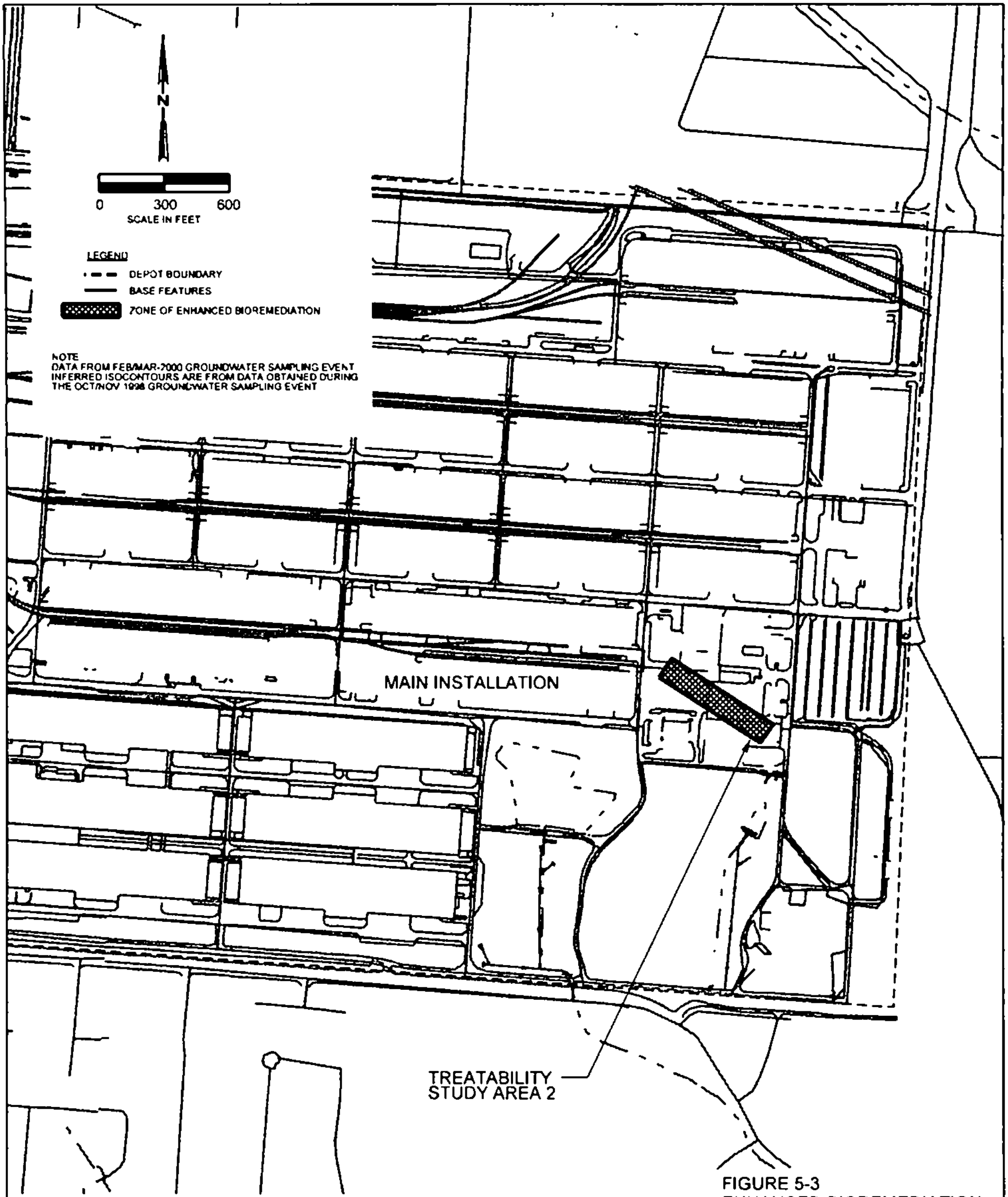

FIGURE 5-3
ENHANCED BIOREMEDIATION
TREATABILITY STUDY AREA 2

Rev 1 - Memphis Depot Main Installation
EBT Study Workplan

CH2MHILL

ATLANTA/CAD1/PROJECTS/147543 MemphisDepot/EBT 04-APRIL-2002 7543fig5-3.dgn

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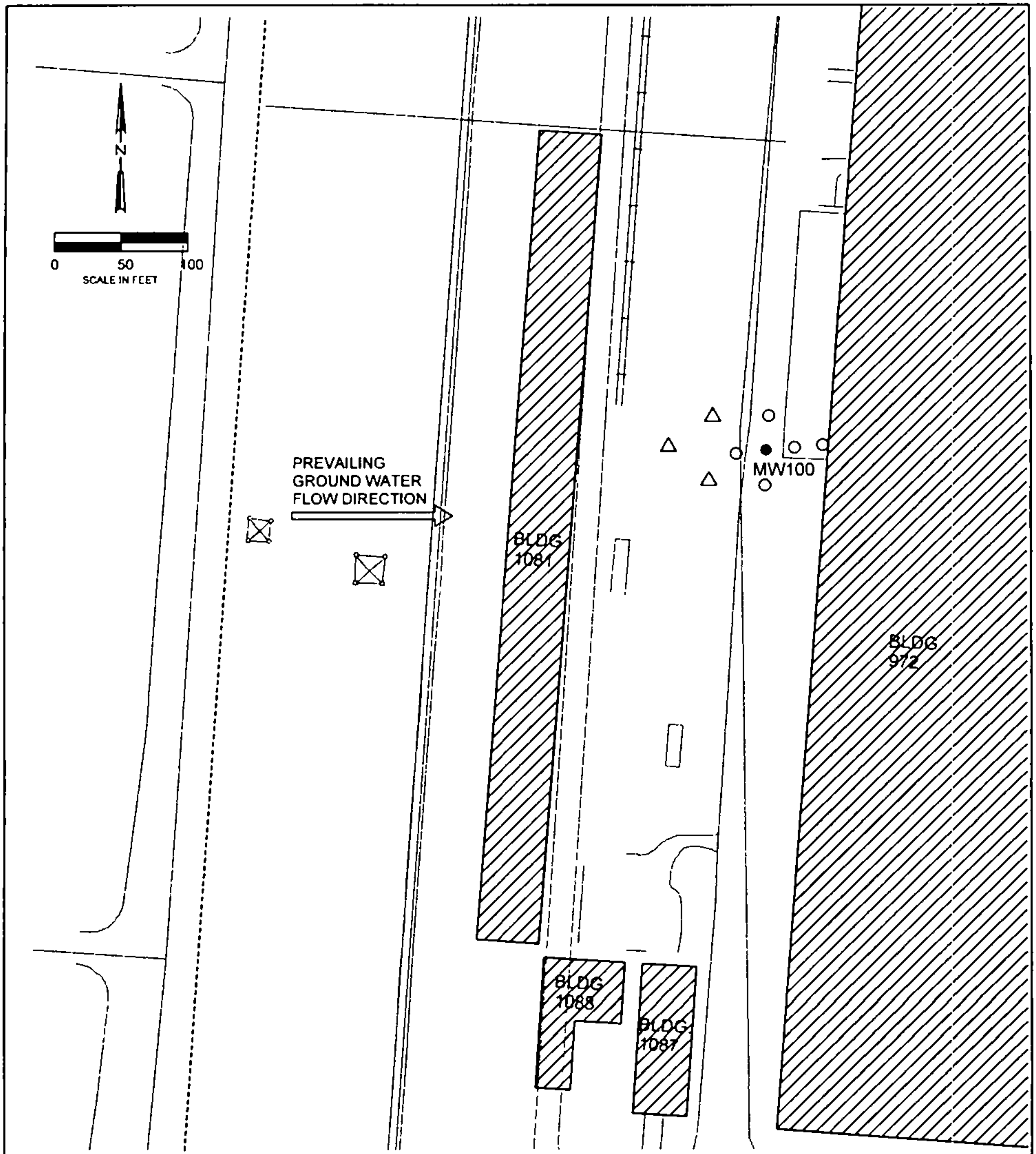


LEGEND

○ = PROPOSED MONITORING WELL LOCATION

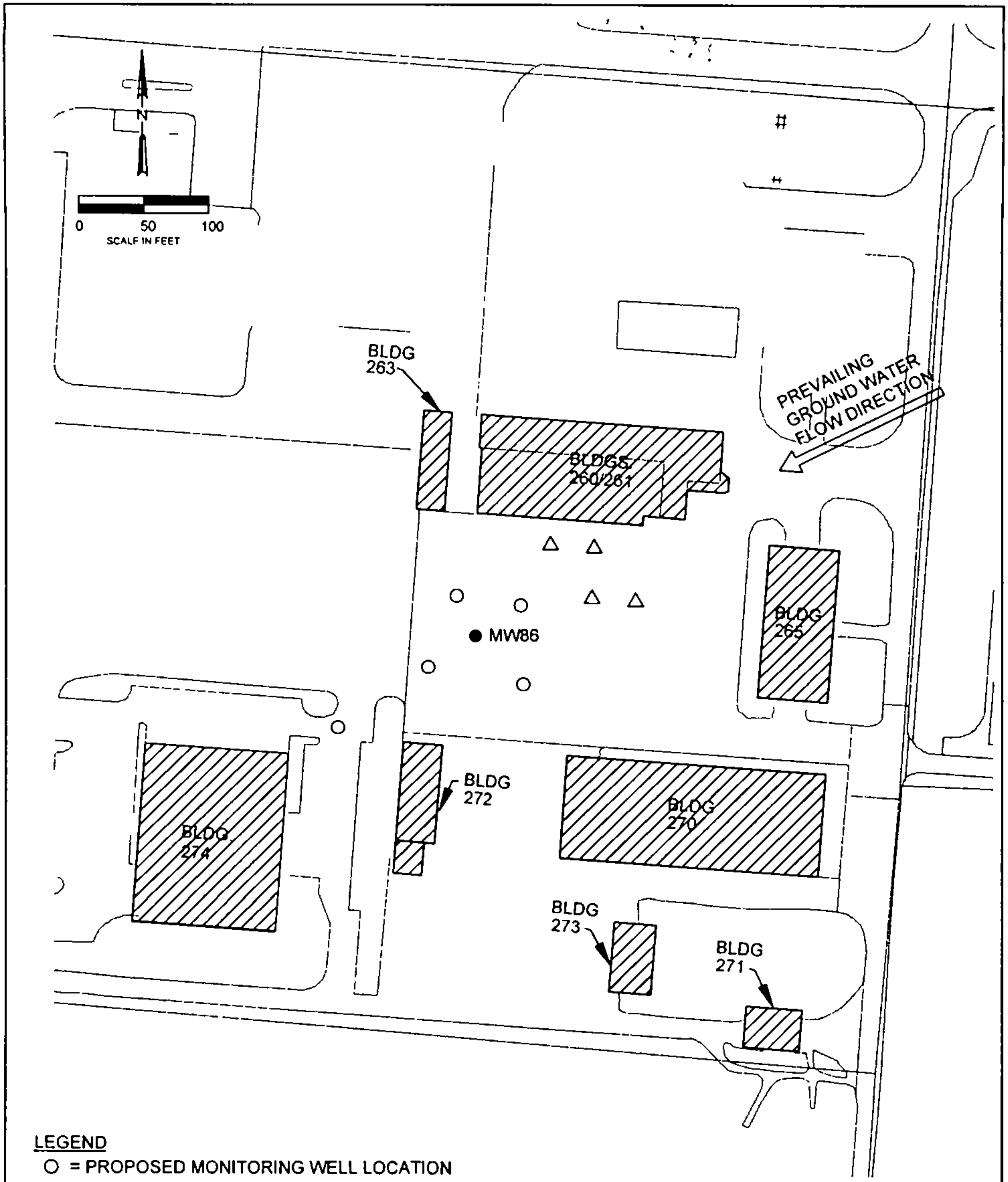
△ = PROPOSED INJECTION WELL LOCATION

● MW100 = EXISTING MONITORING WELL TO BE INCLUDED IN STUDY NETWORK

FIGURE 6-1
TREATABILITY STUDY AREA 1
WELL CONFIGURATION MAP
Memphis Depot Main Installation
EBT Treatability Study

CH2MHILL

ATLANTA/CAD1/PROJECTS/148071 DDMT/LTOA 26-FEB-2002 8071fig4.dgn



LEGEND

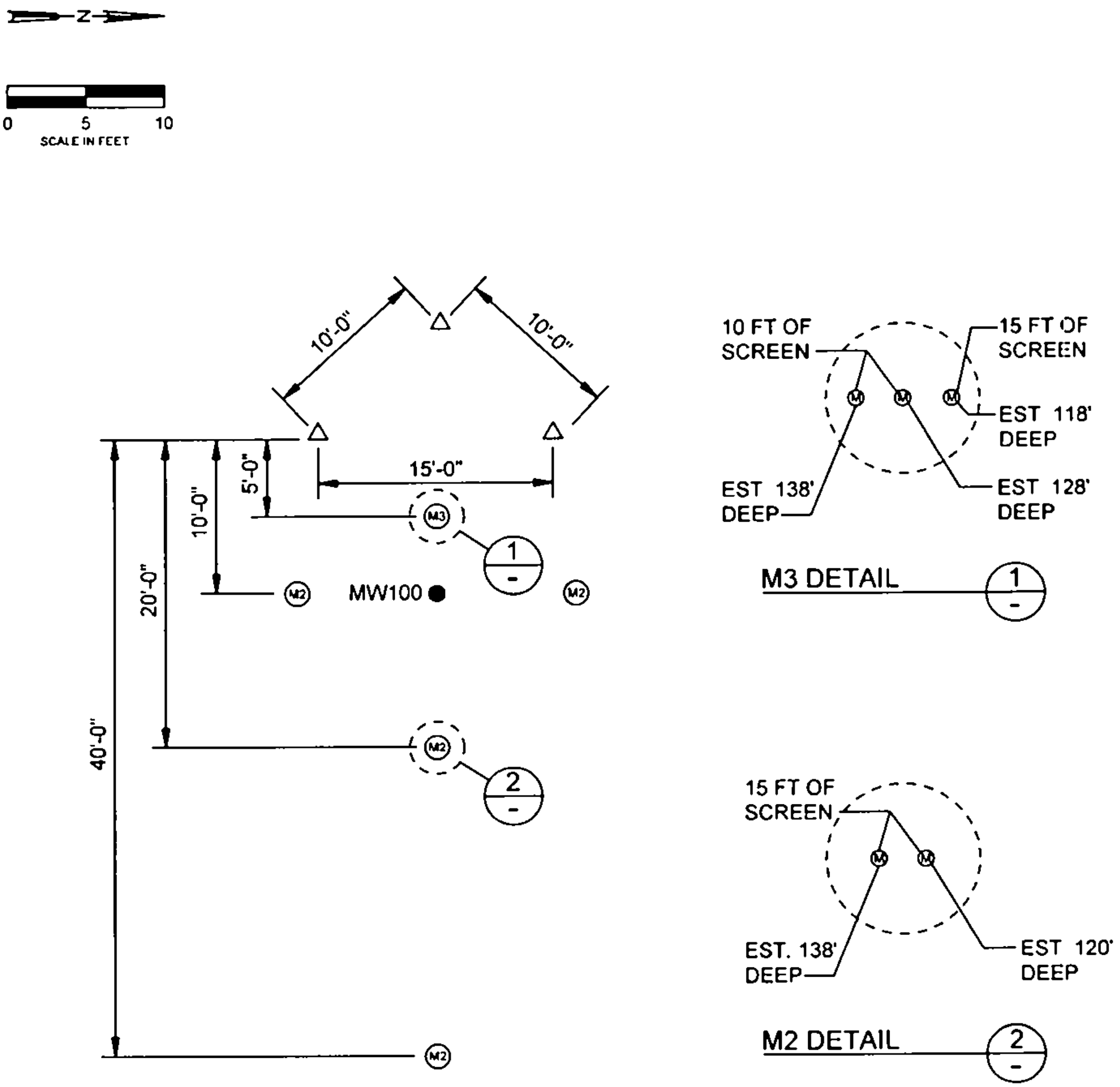
○ = PROPOSED MONITORING WELL LOCATION

△ = PROPOSED INJECTION WELL LOCATION

● MW86 = EXISTING MONITORING WELL TO BE INCLUDED IN STUDY NETWORK

FIGURE 6-2
TREATABILITY STUDY AREA 2
WELL CONFIGURATION MAP
Memphis Depot Main Installation
EBT Treatability Study

CH2MHILL



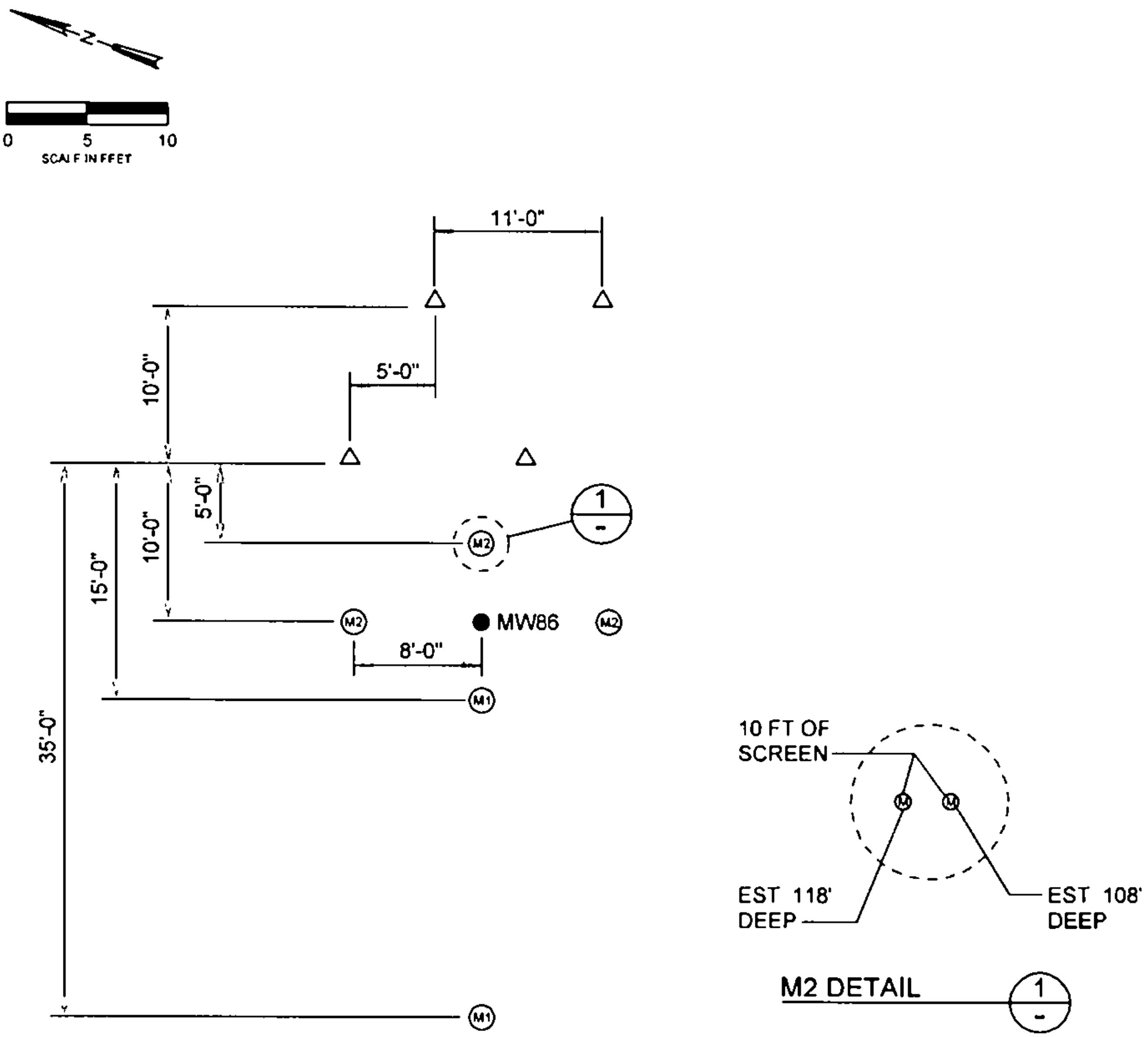
LEGEND

Ⓜ2 = PROPOSED MONITORING WELL LOCATION - 2 WELLS
Ⓜ3 = PROPOSED MONITORING WELL LOCATION - 3 WELLS
△ = PROPOSED INJECTION WELL LOCATION
● MW100 = EXISTING MONITORING WELL TO BE INCLUDED IN STUDY NETWORK

FIGURE 6-3
INJECTION AND MONITORING WELL CONFIGURATION DETAIL MAP
TREATABILITY STUDY AREA 1
Memphis Depot Main Installation
EBT Treatability Study

CH2MHILL

ATLANTA/CAD1/PROJECTS/148071 DDMT/LTOA 04-FEB-2002 8071fig6.dgn



LEGEND

- M1 = PROPOSED MONITORING WELL LOCATION - 1 WELL
- M2 = PROPOSED MONITORING WELL LOCATION - 2 WELLS
- △ = PROPOSED INJECTION WELL LOCATION
- ● MW86 = EXISTING MONITORING WELL TO BE INCLUDED IN STUDY NETWORK

FIGURE 6-4
INJECTION AND MONITORING WELL CONFIGURATION DETAIL MAP
TREATABILITY STUDY AREA 2
Rev 1 - Memphis Depot Main Installation
EBT Study Workplan

CH2MHILL

ATLANTA/CAD1/PROJECTS/148071 DDMT/LTOA 04-APRIL-2002 8071fig7.dgn

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Appendix A - Baseline Groundwater Sampling Plan Technical Memorandum

TECHNICAL MEMORANDUM **CH2MHILL**

Baseline Groundwater Sampling Plan for Main Installation Monitoring Wells

TO.	U.S. Army Engineering and Support Center, Huntsville
COPIES:	Defense Distribution Center (Memphis) U.S. Environmental Protection Agency (USEPA), Region 4 Tennessee Department of Environment and Conservation (TDEC)
FROM:	CH2M HILL
DATE	January 14, 2002

Introduction

This Baseline Groundwater Sampling Plan (BGSP) has been prepared as part of the Enhanced Bioremediation Treatment (EBT) Treatability Study Workplan for the Main Installation (MI) and describes groundwater sampling activities needed in preparation for the EBT study. Recent groundwater sampling events have focused on individual sites within the MI while occurring at different periods, no complete groundwater study has been performed within the MI since October 1998. To develop a comprehensive understanding of the current groundwater contaminant extent, all pertinent monitoring wells (MW) and piezometers (PZ) associated with the MI, both onsite and offsite, will be sampled

Subsequent to the analysis of all samples, the data from this event will be used to formulate the final quantity of electron donor substrate material to inject into the aquifer for the EBT study and other phases of the MI Remedial Design. In addition, the information gained from this sampling event will be used to define long term monitoring needs at the MI.

Objectives of Baseline Groundwater Sampling Plan

The objectives of the BGSP are to:

- Collect groundwater samples from all MW and PZ locations associated with the MI.
- Analyze groundwater samples for volatile organic compound (VOC) content as well as various geochemical parameters required for an understanding of the reductive dechlorination activity in the fluvial aquifer.

The analytical results will be used to: (1) define monitoring well locations for the EBT Treatability Study; (2) provide up-to-date VOC contaminant concentration data for the fluvial aquifer; (3) provide up-to-date geochemical parameter data for the fluvial aquifer; and (4) refine the quantity of nutrient source needed to enhance reductive dechlorination within the fluvial aquifer.

Data Quality Objectives

The data quality objectives (DQOs) are found in Table 1 and have been established to achieve the sampling objectives. Three sampling methods will be used during the sampling event to ensure that the DQOs are satisfied and that the data is usable for the entire RD. These sampling methods have been utilized during other MI groundwater sampling events and have proven effective for data collection. Sample analysis methods are EPA-approved laboratory analytical methods

Twenty-eight monitoring wells and five piezometers will be sampled for VOCs during this event. In addition, eighteen monitoring wells will be sampled for various geochemical parameters. Table 2 lists all MI monitoring wells and piezometers and identifies those that will be included in the baseline sampling event. Figure 1 presents the location of the sampling points Sixteen monitoring wells were sampled for VOCs using diffusion bag samplers during the Long-Term Operational Area (LTOA) investigation (November and December 2001) and this data will be used to supplement information gathered during this baseline event Groundwater samples will be analyzed according to methods described in Table 3.

Field Activities Methodology

Field activity procedures will follow methods described herein. The following site-specific plans should be used for further reference on applicable methods and procedures:

- Operable Units 2, 3, and 4 and Screening Sites Field Sampling Plan Addenda (CH2M HILL, September 1998)
- Operable Unit 2 Field Sampling Plan (CH2M HILL, September 1995)
- Operable Unit 3 Field Sampling Plan (CH2M HILL, September 1995)
- Operable Unit 4 Field Sampling Plan (CH2M HILL, September 1995)
- Screening Sites Field Sampling Plan (CH2M HILL, September 1995)
- Generic Remedial Investigation (RI)/Feasibility Study (FS) Work Plan (CH2M HILL, August 1995)
- Hazardous and Toxic Waste Health and Safety Plan (CH2M HILL, August 1995)
- Generic Quality Assurance Project Plan (QAPP) (CH2M HILL, February 1995)

Groundwater Sampling

The methods and procedures used in the field will adhere as closely as possible to procedures described in the U.S. EPA Region 4 Science and Ecosystems Services Division, *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* (EISOPQAM), dated May 1996 (revised in 1997) as well as sampling and purging procedures presented in *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures* (Puls and Barcelona, 1996), Sections 7 2.2 and 7.3.3.

All VOC samples will be collected through the use of polyethylene diffusion bags. Diffusion bag samplers allow for collection of discrete water samples associated with longer screened wells. Diffusion bag samplers consist of polyethylene bags filled with deionized or distilled water, which are lowered into the well screen interval. The concentration gradient between the VOCs in the well and the water-filled bag results in diffusion of contaminants into the sampler. Diffusion bag samplers will be located in each well as described in Table 2. Construction, installation, and sampling of the diffusion bag samplers will follow guidance developed by the U S. Geological Survey (2001) in *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentration in Wells.* Diffusion bags will remain in each monitoring well for a three week period.

Collection of groundwater samples from piezometers will differ from monitoring wells. The small diameter (0.5 inches) of the piezometer casing necessitates the use of a small diameter bailer instead of a bladder pump. Before sampling, each piezometer will have at least three well volumes purged using the bailer. Field measurements of DO, ORP, turbidity, pH, temperature, and SC will be made during the purging process until stabilization. Piezometers will also be sampled using the same bailers. Each bailer will be discarded after each use

All geochemical samples will be collected using a bladder pump system in order to minimize agitation of the groundwater and sample turbidity. The bladder pump will be equipped with high-density polyethylene (HDPE) tubing lined with Teflon® and the pump will be positioned within selected wells as described in Table 2. Field measurements of DO, ORP, turbidity, pH, temperature, and SC will be made every five minutes. These parameters will be measured using an airtight flow-through cell. Purging will continue until field measurements are stable according to the following standards: plus or minus 0.1 pH, plus or minus ten millivolts ORP, plus or minus 3 percent for specific conductance, and plus or minus 10 percent for turbidity and dissolved oxygen.

All samples will be preserved as required in Table 4 and will be delivered to a laboratory within the appropriate holding period.

In addition to groundwater samples, QA/QC samples will be collected during the field effort. The QA/QC samples include field duplicates, matrix spike/matrix spike duplicate, ambient blanks, equipment blanks, and trip blanks The quantity of QA/QC samples collected at the site will be in accordance with guidelines in Section 5.13.11 and 5.13.12 of the EISOPQAM and as presented in Table 4.

Investigation-Derived Waste (IDW)

Purge water will be contained in drums and transferred to the Groundwater Extraction System located at Dunn Field No drums will be staged on-site.

Logistics

Equipment, supplies, and personnel required to complete the baseline sample event at the MI will mobilize after approval of this BGSP. The Hazardous and Toxic Waste Health and Safety Plan (CH2M HILL, August 1995) for Memphis Depot will be amended prior to the start of field activities.

References

CH2M HILL. February 1995. *Final Generic Quality Assurance Project Plan*. Defense Distribution Depot Memphis, Tennessee. Prepared for the United States Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL, Inc. August 1995 *Generic Remedial Investigation/Feasibility Study Work Plan*. Prepared for U.S. Army Engineering and Support Center Huntsville, Alabama.

CH2M HILL, Inc. August 1995. *Hazardous and Toxic Waste Health and Safety Plan*. Prepared for U.S. Army Engineering and Support Center Huntsville, Alabama.

CH2M HILL September 1995 *Operable Unit 2 Field Sampling Plan*. Defense Distribution Depot Memphis, Tennessee. Prepared for the U.S. Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL. September 1995 *Operable Unit 3 Field Sampling Plan* Defense Distribution Depot Memphis, Tennessee. Prepared for the U.S. Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL. September 1995 *Operable Unit 4 Field Sampling Plan*. Defense Distribution Depot Memphis, Tennessee. Prepared for the U.S Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL. September 1995 *Screening Sites Field Sampling Plan* Defense Distribution Depot Memphis, Tennessee. Prepared for the U.S. Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL September 1998b. *OUs 2, 3, and 4 and Screening Sites Field Sampling Plan Addenda*. Prepared for the U. S. Army Engineering Support Center, Huntsville, Alabama

Puls, R. and Barcelona, M., April 1996. *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures*. Office of Solid Waste and Emergency Response. U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency, Science and Ecosystems Services Division. *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* May 1996 (revised 1997).

U.S. Geological Survey, Vroblesky, D A. *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations In Wells, Part 1: Deployment, Recovery, Data Interpretation, and Quality Control and Assurance*. Water Resources Investigations Report 01-4060. 2001.

Table 1

Sampling, Analysis, and Data Quality Objectives

Memphis Depot Main Installation Baseline Groundwater Sampling Plan

Sampling Method	Associated Well Numbers	Data Quality Objective Category	Data Qauality Objective/Purpose
Diffusion Bag Samplers	MW-16, 19, 20, 21, 22, 23, 24, 26, 34, 36, 38, 39, 47, 50, 52, 53, 55, 62, 63, 64, 66, 72, 81, 82, 83, 84, 89, and 90	Definitive	Quantify VOC contamination in fluvial aquifer by ensuring sampling methods are consistent with recent sampling events Also, provide additional information on the stratification of conaminants in the fluvial aquifer.
Teflon Bailer	PZ-04, 05, 06, 07, and 08	Definitive	Same as previous objective In addition, only productive method for sampling groundwater from piezometers with 0 75 inch ID casing in a water table greater than 33 feet below ground surface.
Low-Flow Techniques (Bladder Pump)	MW-16, 21, 22, 47, 50, 72, 83, 85, 86, 88, 92, 93, 96, 97, 98, 100, 101, and 102	Definitive	Determine current reductive dechlorination activity in fluvial aquifer for EBT study and Remedial Design Acceptable sampling method for geochemical parameters.

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Table 2

Details for Baseline Sampling of Monitoring Wells and Piezometers

Memphis Depot Main Installation Baseline Groundwater Sampling Plan

#	Identification	Total Depth (ft btoc)	Depth to Water (as of 11/01/2001) (ft btoc)	Length of Riser Pipe (ft)	Length of Screen (ft)	Depth to Bottom of Screen (ft btoc)	Water Column within Screened Interval (ft)	Groundwater Sample Parameters										
								VOCs							Geochemical Parameters			
								Yes/No	#	Sample Method	Length of Bag (ft)	Depth to Bottom of Bag (ft btoc)	Length of Sump (ft)	Distance of Bottom of Bag above Bottom of Well (ft)	Yes/No	#	Sample Method	Distance of Pump above Bottom of Well (ft)
1	MW 16	75.00	58.42	57.6	15	72.6	14.2	Yes	1	Diffusion Bag	5	68.0	2.4	7.0	Yes	1	Low Flow/Bladder Pump	8.5
2	MW 19	85.50	89.65	83.1	10	93.1	3.4	Yes	2	Diffusion Bag	2	82.4	2.4	3.1				
3	MW-20	100.50	85.91	83.1	15	98.1	12.2	Yes	3	Diffusion Bag	5	94.5	2.4	6.0				
4	MW 21	109.50	95.05	92.1	15	107.1	12.1	Yes	4	Diffusion Bag	5	103.6	2.4	5.9	Yes	2	Low Flow/Bladder Pump	8.4
5	MW 22	107.80	98.01	95.4	10	105.4	7.4	Yes	5	Diffusion Bag	5	104.2	2.4	3.6	Yes	3	Low Flow/Bladder Pump	6.1
6	MW-23	113.60	100.42	101.2	10	111.2	10.0	Yes	6	Diffusion Bag	5	108.7	2.4	4.9				
7	MW 24	114.70	108.89	97.3	15	112.3	3.4	Yes	7	Diffusion Bag	2	111.6	2.4	3.1				
8	MW 26	110.00	100.64	97.6	10	107.6	6.9	Yes	8	Diffusion Bag	5	106.6	2.4	3.4				
9	MW 34	156.70	143.31	136.6	20	156.6	13.3	Yes	9	Diffusion Bag	5	152.5	0.1	4.2				
10	MW 36	209.40	158.71	192.3	15	207.3	15.0	Yes	10	Diffusion Bag	5	202.3	2.1	7.1				
11	MW 38	155.00	137.48	139.9	15	154.9	15.0	Yes	11	Diffusion Bag	5	149.9	0.1	5.1				
12	MW 39	115.60	104.39	95.5	20	115.5	11.1	Yes	12	Diffusion Bag	5	112.4	0.1	3.2				
13	MW-47	120.00	102.50	110	10	120	10.0	Yes	13	Diffusion Bag	5	117.5	0	2.5	Yes	4	Low Flow/Bladder Pump	5.0
14	MW 50	125.00	86.61	115	10	125	10.0	Yes	14	Diffusion Bag	5	122.5	0	2.5	Yes	5	Low Flow/Bladder Pump	5.0
15	MW-52	104.00	82.01	94	10	104	10.0	Yes	15	Diffusion Bag	5	101.5	0	2.5				
16	MW-53	82.50	73.71	72.5	10	82.5	8.8	Yes	16	Diffusion Bag	5	80.6	0	1.9				
17	MW 55	74.00	71.00	64	10	74	3.0	Yes	17	Diffusion Bag	2	73.5	0	0.5				
18	MW-62	96.00	93.94	86	10	96	2.1	Yes	18	Diffusion Bag	1	95.5	0	0.5				
19	MW-63	134.50	108.60	124.5	10	134.5	10.0	Yes	19	Diffusion Bag	5	132.0	0	2.5				
20	MW-64	112.00	107.38	102	10	112	4.6	Yes	20	Diffusion Bag	2	110.7	0	1.3				
21	MW-66	112.50	80.06	102.5	10	112.5	10.0	Yes	21	Diffusion Bag	5	110.0	0	2.5				
22	MW 72	121.20	89.20	110.7	10	120.7	10.0	Yes	22	Diffusion Bag	5	118.2	0.5	3.0	Yes	6	Low Flow/Bladder Pump	5.5
23	MW-81	211.00	144.95	190	20	210	20.0	Yes	23	Diffusion Bag	5	202.5	1	8.5				
24	MW-82	200.00	140.27	179	20	199	20.0	Yes	24	Diffusion Bag	5	191.5	1	8.5				
25	MW-83	187.00	146.73	176	10	186	10.0	Yes	25	Diffusion Bag	5	183.5	1	3.5	Yes	7	Low Flow/Bladder Pump	6.0
26	MW-84	89.50	82.70	69	20	89	6.3	Yes	26	Diffusion Bag	5	88.4	0.5	1.2				
27	MW-85	111.40	99.97	95.9	15	110.9	10.9	No					0.5		Yes	8	Low Flow/Bladder Pump	6.0
28	MW-86	118.00	98.27	97.5	20	117.5	19.2	No					0.5		Yes	9	Low Flow/Bladder Pump	10.1
29	MW-88	97.50	80.98	82	15	97	15.0	No					0.5		Yes	10	Low Flow/Bladder Pump	8.0
30	MW-89	177.50	120.41	147	30	177	30.0	Yes	27	Diffusion Bag	(2) 5	(1) 155 (2) 172	0.5	(1) 22.5 (2) 5.5				
31	MW 90	145.50	120.25	115	30	145	24.8	Yes	28	Diffusion Bag	(2) 5	(1) 130 (2) 140	0.5	(1) 15.5 (2) 5.5				
32	MW-92	108.50	96.75	93	15	108	11.3	No					0.5		Yes	11	Low Flow/Bladder Pump	6.1
33	MW-93	107.50	102.45	92	15	107	4.6	No					0.5		Yes	12	Low Flow/Bladder Pump	2.8
34	MW-94	111.00	107.07	100.5	10	110.5	3.4	No					0.5					
35	MW-96	96.00	83.02	75.5	20	95.5	12.5	No					0.5		Yes	13	Low Flow/Bladder Pump	6.7
36	MW-97	118.00	101.25	97.5	20	117.5	16.3	No					0.5		Yes	14	Low Flow/Bladder Pump	8.6
37	MW-98	147.50	102.00	137	10	147	10.0	No					0.5		Yes	15	Low Flow/Bladder Pump	5.5
38	MW-99	112.00	89.80	91.5	20	111.5	20.0	No					0.5					
39	MW-100B	128.00	92.95	107.5	20	127.5	20.0	No					0.5		Yes	16	Low Flow/Bladder Pump	10.5
40	MW 101	134.50	93.32	89	15	104	10.7	No							Yes	17	Low Flow/Bladder Pump	20.5 (middle screen int.)
	Middle Interval			5	10	119	10.0	No										
	Lower Interval			5	10	134	10.0	No					0.5					
41	MW 102B*	141.00	110.66	120.5	20	140.5	20.0	No					0.5		Yes	18	Low Flow/Bladder Pump	10.5
42	MW 103	90.50	69.43	70	20	90	20.0	No					0.5					
43	MW-104	91.00	63.01	70.5	20	90.5	20.0	No					0.5					
44	MW 107	158.50	114.43	128	15	143	15.0	No										
	Lower Interval			5	10	158	10.0	No					0.5					
45	MW 108	170.50	113.21	160	10	170	10.0	No					0.5					
1	PZ-04	108.30	98.34	98.3	10	108.3	10.0	Yes	29	Teflon Bailer	NA	NA	0	NA	[illegible]	[illegible]	[illegible]	[illegible]
2	PZ-05	78.10	59.50	68.1	10	78.1	10.0	Yes	30	Teflon Bailer	NA	NA	0	NA	[illegible]	[illegible]	[illegible]	[illegible]
3	PZ-06	99.40	73.52	89.4	10	99.4	10.0	Yes	31	Teflon Bailer	NA	NA	0	NA	[illegible]	[illegible]	[illegible]	[illegible]
4	PZ-07	111.30	98.98	101.3	10	111.3	10.0	Yes	32	Teflon Bailer	NA	NA	0	NA	[illegible]	[illegible]	[illegible]	[illegible]
5	PZ-08	108.20	84.49	98.2	10	108.2	10.0	Yes	33	Teflon Bailer	NA	NA	0	NA	[illegible]	[illegible]	[illegible]	[illegible]

* = Replacement Monitoring Wells for MW 100 and MW 102. Depth-to-water measurements are from MW 100 and MW 102.

Depth-to-water measurement for MW-66 is from the November 12, 1998 gauging event.

NA = Not Applicable

ft btoc = feet below top of casing

ft = feet

Table 3
Analytical Protocols for Samples
Memphis Depot Main Installation Baseline Groundwater Sampling Plan

Matrix and Analytes	Analytical Methods	Field (F) or Analytical (L) Laboratory
Groundwater*		
Redox Potential	Direct-reading meter	F
Dissolved Oxygen	Direct-reading meter	F
pH, turbidity	Direct-reading meter	F
Specific Conductance	Direct-reading meter	F
Temperature	Direct-reading meter	F
VOCs	SW8260B	L
Dissolved Gases (ethene, ethane, and methane)	RSK175	L
Dissolved total organic carbon	SW9060	L
Nitrate, nitrite	SW9056	L
Sulfate	SW9056	L
Sulfide	E376.1	L
Carbon dioxide	CHEMetrics Method 4500	F
Bromide	E320.1	L
Chloride	SW9056	L
Ferrous Iron	SM 3500 FED	L
Manganese	SW6010B	L
Alkalinity	E310.1	L
Metabolic Fatty Acids	E300.0	L

*Reported in sequence of sample collection

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Table 4
Sampling and Analytical Summary
Memphis Depot Main Installation Baseline Sampling Event

Sample Task	Sample Point	Sample Point No	Matrix	Sampling Frequency	Approx Sample No	Duplicate Sample No	Sampling Method	Sampling Equipment	TAT	DQO Level/Data Package Reqrmnt	Required Analysis	Analytical Method	Holding Time	Sample Preservn	Containers
Groundwater Sampling	Monitoring Wells	28	Groundwater	1 per well	30	6	Low-Flow	Diffusion Bag	14 days	DQO Level III	VOCs	8260B	14 days	HCL Cool to 4 degrees C	(3) 40 ml Vial
		13	Groundwater	1 per well	13	2	Low-Flow	Bladder Pump	14 days	DQO Level III	Total Organic Carbon	SW9060	28 Days	H2SO4 Cool to 4 degrees C	250 ml Amber Glass
		13	Groundwater	1 per well	13	2	Low-Flow	Bladder Pump	14 days	DQO Level III	Metabolic Acids	HPLC/UV	7 Days	Cool to 4 degrees C	250 ml Poly
		13	Groundwater	1 per well	26	4	Low-Flow	Bladder Pump	14 days	DQO Level III	Methane Ethane Ethene	RSK 175	7 Days	Cool to 4 degrees C	(2) 40 ml VOA vials
		13	Groundwater	1 per well	13	1	Low-Flow	Bladder Pump	14 days	DQO Level III	Alkalinity	E310 1	14 Days	Cool to 4 degrees C	250 ml Poly
		13	Groundwater	1 per well	13	1	Low-Flow	Bladder Pump	14 days	DQO Level III	Nitrate/Nitrite/Sulfate/ Chloride	SW9056	48 Hours	Cool to 4 degrees C	500 ml Poly
		13	Groundwater	1 per well	13	1	Low-Flow	Bladder Pump	14 days	DQO Level III	Sulfide	E376 1	7 Days	NaOH & Zn(AC) Cool to 4 degrees C	500 ml Poly
		13	Groundwater	1 per well	13	1	Low-Flow	Bladder Pump	14 days	DQO Level III	Dissolved Manganese	SW6010B	6 Months	HNO3 Cool to 4 degrees C	250 ml Poly
		13	Groundwater	1 per well	13	1	Low-Flow	Bladder Pump	14 days	DQO Level III	Dissolved Ferrous Iron	SM 3500 FED	48 Hours	Cool to 4 degrees C	250 ml Poly
											Dissolved Oxygen	Field Screening	NA	NA	NA
											ORP	Field Screening	NA	NA	NA
											Turbidity	Field Screening	NA	NA	NA
											pH	Field Screening	NA	NA	NA
											Temperature	Field Screening	NA	NA	NA
											Specific Conductivity	Field Screening	NA	NA	NA
Groundwater Sampling	Piezometers	5	Groundwater	1 per well	15	3	Bailer	Bailer	14 days	DQO Level III	VOCs	8260B	14 days	HCL Cool to 4 degrees C	(3) 40 ml Vial
		5	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Total Organic Carbon	SW9060	28 Days	H2SO4 Cool to 4 degrees C	250 ml Amber Glass
		5	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Metabolic Acids	HPLC/UV	7 Days	Cool to 4 degrees C	250 ml Poly
		5	Groundwater	1 per well	10	2	Bailer	Bailer	14 days	DQO Level III	Methane Ethane Ethene	RSK 175	7 Days	Cool to 4 degrees C	(2) 40 ml VOA vials
		6	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Alkalinity	E310 1	14 Days	Cool to 4 degrees C	250 ml Poly
		5	Groundwater	1 per well	6	1	Bailer	Bailer	14 days	DQO Level III	Nitrate/Nitrite/Sulfate/ Chloride	SW9056	48 Hours	Cool to 4 degrees C	500 ml Poly
		5	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Sulfide	E376 1	7 Days	NaOH & Zn(AC) Cool to 4 degrees C	500 ml Poly
		6	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Dissolved Manganese	SW6010B	6 Months	HNO3 Cool to 4 degrees C	250 ml Poly
		5	Groundwater	1 per well	5	1	Bailer	Bailer	14 days	DQO Level III	Dissolved Ferrous Iron	SM 3500 FED	48 Hours	Cool to 4 degrees C	250 ml Poly
											Dissolved Oxygen	Field Screening	NA	NA	NA
											ORP	Field Screening	NA	NA	NA
											Turbidity	Field Screening	NA	NA	NA
											pH	Field Screening	NA	NA	NA
											Temperature	Field Screening	NA	NA	NA
											Specific Conductivity	Field Screening	NA	NA	NA
Quality Assurance/ Quality Control Samples	Equipment Blank	4 (est.)	Water	1 per week	4	0	Prepared in Field	Analyte-free water SS funnel	14 days	DQO Level III	VOCs	8260B	14 days	HCL pH<2 Cool to 4 degree C	(3) 40 ml vial
	Ambient Blank	4 (est.)	Water	1 per week	4	0	Prepared in Field	Analyte-free water	14 days	DQO Level III	VOCs	8260B	14 days	HCL pH<2 Cool to 4 degree C	(3) 40 ml vial
	MS/MSD	2 (est.)	Water	1 per 20 samples	2	0	Prepared in Field	Analyte-free water	14 days	DQO Level III	VOCs	8260B	14 days	HCL pH<2 Cool to 4 degree C	(3) 40 ml vial
	Trip Blanks	10 (est.)	Water	[illegible] of VOCs	10	0	Prepared in Lab	NA	14 days	DQO Level III	VOCs	8260B	14 days	HCL pH<2 Cool to 4 degree C	[illegible]

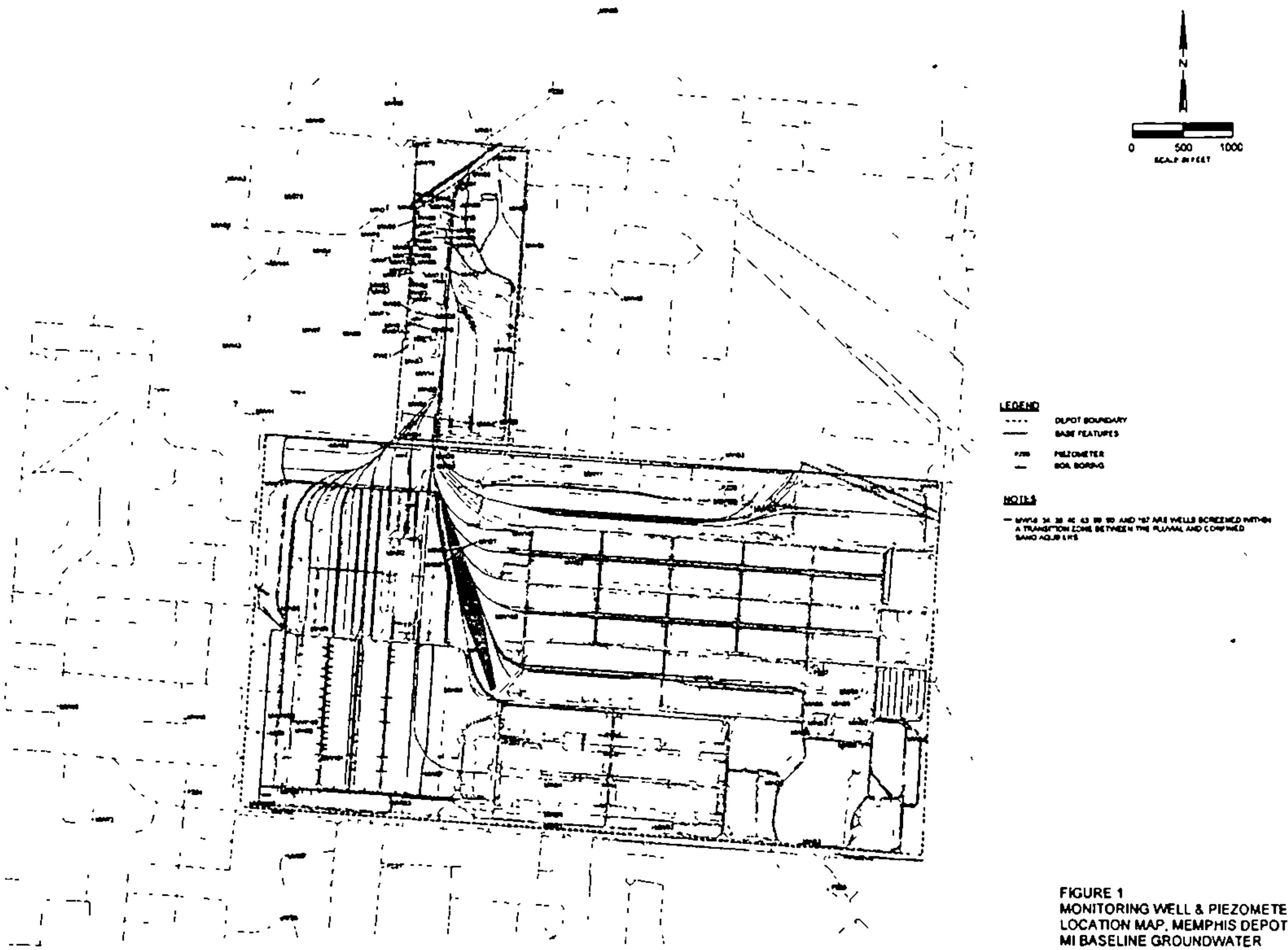

FIGURE 1
MONITORING WELL & PIEZOMETER
LOCATION MAP, MEMPHIS DEPOT
MI BASELINE GROUNDWATER
SAMPLING PLAN

CH2MHILL

ATLANTA/CAD1/PROJECTS/148071/DOMT 29-NOV-2001 8071-mi12.dgn

Appendix B - EBT Treatability Study Monitoring and Injection Well Installation Procedures

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Main Installation EBT Treatability Study Monitoring and Injection Well Installation Procedures

TO:	U S. Army Engineering and Support Center, Huntsville
COPIES:	
FROM.	CH2M HILL
DATE:	April 8, 2002

Introduction

This memorandum has been developed to outline the procedures to be used in the field during monitoring and injection well installation for the EBT Treatability Study within the Main Installation (MI) of the Memphis Depot. Each monitoring and injection well boring will be drilled using rotasonic drilling methods and each well will be constructed according to procedures and specifications described herein

Objectives of Monitoring and Injection Well Installation

The objectives of the installation activities are to:

- Install and complete injection wells for the application of the electron donor substrate into the fluvial aquifer.
- Install and complete monitoring wells downgradient of the anticipated electron donor substrate injection area.
- Incorporate findings of monitoring well installation effort into the EBT Treatability Study Technical Memorandum. The data will be used in conjunction with groundwater sample analysis results within the Intermediate and Prefinal/Final MI Remedial Design documents.

After installation and prior to the application of the electron donor substrate, the monitoring and injection wells will be sampled to represent baseline groundwater conditions. During application of the electron donor substrate, the wells will be sampled during at least seven other events to monitor the effects of the application.

Data Quality Objectives

The data quality objectives (DQOs) detailed below are established to achieve the sampling objectives

Activity	Data Quality Objective Category	Purpose
Monitoring and injection well installation	Definitive	Injection wells will be used during treatability study and, possibly, for future injection events to enhance the reductive dechlorination process Monitoring wells will be used during the entire treatability study testing period for collection of groundwater samples to evaluate the effectiveness of the introduction of electron donor substrate to enhancing reductive dechlorination in the fluvial aquifer.

Monitoring and Injection Well Installation Procedures

Up to 28 monitoring and 22 injection wells will be installed 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 relatively large depth to water (i.e., 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) likely would cause problems with installation of the wells using other drilling methods

Well screen intervals will be positioned at different depths within the fluvial aquifer but will always be located above the clay-confining unit that underlies the aquifer. The estimated depth of the wells ranges from 110 to 135 ft bgs. The final location of these wells will be dependent upon the results of baseline groundwater sampling event, as described in Appendix A to the EBT Treatability Study Workplan.

Installation Procedures

Monitoring and injection well installation will be performed in accordance with US Army Corps of Engineers OE EM 1110-1-4000 and US Environmental Protection Agency Region IV, Science and Ecosystems Services Division *Environmental Investigations Standard Operating Procedures Quality Assurance Manual* (EISOPQAM), May 1996 (revised in 1997).. The wells will be constructed within rotasonic drill casing as the casing is withdrawn from the boring. Borehole diameters will be a minimum of 7 inches The inside diameter of the rotasonic drill casing will be at least 4 inches larger than the outside diameter of the well casing and screen to facilitate proper installation of the well Therefore, the rotasonic drill casing will require an inner annulus that is 6 ¼-inch diameter or larger.

The new wells will be constructed of 2-inch inside diameter (I.D.) PVC casing and screens. Each well will have a filter pack around the screen, a bentonite seal above the filter pack, and cement grout to ground surface installed through the drill casing. The wells will be straight and plumb to allow passage of pumps or sampling devices.

The documentation record and forms will document the following information for each boring:

- Boring or well identification - Begin with well # MW-109
- Purpose of the boring (e g , soil sampling, monitoring well)
- Location in relation to an easily identifiable landmark
- Names of drilling subcontractor and logger
- Start and finish dates and times
- Drilling method
- Types of drilling fluids and depths at which they were used, if applicable
- Diameters of surface casing, casing type, and methods of installation
- Depth at which saturated conditions were first encountered
- Lithologic descriptions and depths of lithologic boundaries
- Sampling-interval depths
- Zones of caving or heaving
- Depth at which drilling fluid was lost and the amount lost
- Changes in drilling fluid properties
- Drilling rate
- Drilling rig reactions (e.g , chatter, rod drops, and bouncing)

Prior to drilling activities and between each well location, all drilling equipment and the rig will be decontaminated using a high pressure steam cleaning wash as described in the Decontamination Section.

Logging of Boreholes

Samples for lithologic description will be collected continuously at 10-foot intervals beginning at the ground surface. Lithologic descriptions of unconsolidated materials encountered in the boreholes will generally be described in accordance with the 1990 American Society for Testing and Materials (ASTM) D-2488-90, *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure). Descriptive information to be recorded in the field will include:

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

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- Maximum particle size or dimension.

Plasticity of fines description include:

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

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

The headspace of soil samples will be screened with a flame ionization detector-organic vapor monitor (e g., FID-OVA). The headspace samples will be brought (if necessary) to a temperature of between 20°C (68°F) and 32°C (90°F), and the reading will be obtained five minutes thereafter. The soil sample will be split into two jars and readings will be made with the FID (unfiltered) on one jar. If the FID reading is greater than 10 parts per million (ppm), a reading will be made on the second jar with an activated charcoal filter on the FID. A total corrected hydrocarbon measurement of the sample will be calculated by subtracting the filtered reading from the unfiltered reading. Analytical instruments must be calibrated in accordance with the manufacturer's instructions. The headspace samples will be collected and analyzed using the following procedure:

1. From the sample location, remove the top 1 to 2 inches of soil using a decontaminated stainless steel spoon
2. Fill ½ of two decontaminated 16-ounce mason jars with soil from the resulting hole using the stainless steel spoon.
3. Cover the jars immediately with aluminum foil and fasten the jar lids.
4. Allow the sample vapors to equilibrate in the jars (approximately 5 minutes).
5 Punch a hole in the aluminum foil with the tip of a calibrated FID.
6 Record the highest reading.
7. If the FID reading is > 10 ppm, repeat Steps 5 and 6 with the active charcoal filter on the calibrated FID to the second jar.

All measurements will be recorded on the logging form at the corresponding depths. The samples will be handled in such a way as to minimize the loss of volatiles Soil cuttings will be examined for their hazardous characteristics. If suspected samples are encountered, they will be noted on the boring log form for reference during investigative derived waste (IDW) sampling.

Casing Requirements

The casing requirements that will be followed include:

- All casing will be new, unused, decontaminated, 2-inch inside diameter, schedule 40 polyvinyl chloride (PVC) with internal flush joined threaded joints.
- The PVC will conform to the ASTM Standard F-480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System).
- Glue or solvent-welded joints will not be used to join casing.

Well Screen Requirements

Well screen requirements are as follows:

- All requirements that apply to casing will also apply to well screen, except for strength requirements.
- Monitoring wells will not be screened across more than one water-bearing unit.
- The screen sections will be factory slotted or wire wrapped with 0 040-inch openings and no less than 10-ft in length.
- A threaded PVC cap or point will be placed at the bottom of the screen will be joined to the screen by threads.

Filter Pack Requirements

The filter pack material will be clean, bagged, sieve sized, silica sand, (supplier certified to be free of contaminants), inert, hard, well rounded (less than 2 percent flat particles), and free from roots, trash, and other deleterious material The sand will be certified free of contaminants by vendor or contractor. The filter pack will extend from the bottom of the hole to at least 2 ft above the top of the well screen. The vendor will be required to use Unimim Filter Seal No. 2.

The filter pack will be installed with a bottom-discharge tremie pipe. The tremie pipe will be lifted from the bottom of the hole at the same rate the filter pack is set. The contractor will record the volume of the filter pack emplaced in the well. Potable water may be used, with the approval of FTL, to emplace the filter pack so long as no contaminants are introduced.

Bentonite Seal Requirements

Following filter pack placement, a minimum 2-foot-thick bentonite seal will be placed above the sandpack. The 100% sodium bentonite seal will consist of 1/4-inch or 3/8-inch diameter dry bentonite pellets or chips. The bentonite seal will be installed by gravity methods The bentonite seal will be allowed to hydrate for a minimum of 4 hours prior to the installation of the cement grout.

Casing Grout Requirements

The casing grout requirements are as follows·

Cement grout will be placed in the annular space above the bentonite seal to ground surface. The grout will be pumped through a side-discharge tremie pipe and the length will be no more than 5 feet from the top of the level of grout at all times. The pumping will continue until grout has returned to the surface No method will be permitted that does not force grout from the bottom of the borehole to the surface. The grout seal will be Type II

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Portland cement or American Petroleum Institute Class A cement with no more than 4 percent bentonite. The grout will be mixed in the following proportions: 94 lbs. of neat cement, not more than 4 lbs. of 100 percent sodium bentonite powder, and not more than 8 gallons of potable water. The grout will have a mixed minimum specific density of 9.4 pounds per gallon (lb/gal) or the manufacturer's recommended density. A mud balance will be used to ensure the density of the mixture conforms to the manufacturer's standards. Prior to installation of the well completions, the boreholes will be topped off with grout to approximately 1 to 2 feet bgs.

Surface Completion Requirements

Wells will be set as flush-mounted completions. The casing will be cut approximately 3 inches bgs and a watertight casing cap will be placed on the well. A small diameter (e.g., 1/4-inch) vent hole will be placed in the upper portion of the casing, or a ventilated well cap will be used. A small notch will be cut in the top of the casing to be used as a measuring point for water levels

A freely draining 10-inch inner diameter manhole cover with a locking lid will be placed over the casing. The top of the casing will be at least 6 inches above the bottom of the box. The manhole will be centered in a 3-foot diameter, 4-inch thick concrete pad that slopes away from the manhole at ¼-inch per foot. The identity of the well will be permanently marked on the concrete pad Where heavy traffic may pass over the well or for other reasons, the concrete pad and valve box/lid assembly will be constructed to meet the strength requirements of surrounding surfaces.

When a well is not installed in a concrete or asphalt drive or parking area, four 3-inch diameter concrete-filled steel guard posts will be installed. The guard posts will be 5 feet in total length and installed at the corners of the well pad. The guard posts must be recessed approximately 2 feet into the ground and set in concrete. Do not install the guard posts in the concrete pad placed at the well base The protective sleeve and guard posts will be painted a high visibility yellow.

Wells will be secured as soon as possible after drilling with corrosion resistant locks. The locks must either have identical keys or be keyed for opening with one master key.

A well completion diagram will be submitted for each monitoring well or injection point installed. It will include the following information.

- Well identification (this will be identical to the boring identification described)
- Drilling method
- Installation date(s)
- Elevations of ground surface and the measuring point notch
- Total boring depth
- Lengths and descriptions of the screen and casing
- Lengths and descriptions of the filter pack, bentonite seal, casing grout, and any back-filled material

- Elevation of water surface before and immediately after development
- Summary of the material penetrated by the boring

The locations and elevations of the monitoring and injection wells will be surveyed by a licensed surveyor upon completion.

Monitoring Well Development

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

Development will continue until clear, sediment free formation water is produced from the well and until pH, conductivity, turbidity, and temperature measurements have stabilized. Stabilization is defined by the pH is within + or - 0.1, the conductivity is + or - 3 %, and the turbidity remains less than 10 NTUs for at least 30 minutes. Parameter measurement and development data will be documented.

Equipment Decontamination Procedures

All downhole drilling equipment as well as other equipment will be decontaminated according to procedures presented in Appendix B of the EISOPQAM. Decontamination of the drill rig, rotasonic drilling equipment, pipes, bits, tools, and all downhole equipment will be conducted between each well installation. Decontamination of development equipment will be performed between each well developed. Decontamination will consist of the following:

- High pressure, low volume steam-cleaning
- Wash and scrub with non-phosphate detergent (Liquinox) and potable water
- Rinse with tap water
- Rinse with deionized (or analyte free) water
- Rinse with laboratory grade isopropyl alcohol (PVC or plastic material will not be rinsed with solvent)
- Rinse with organic free water
- Air dry to the extent practical
- Wrap in plastic sheeting or aluminum foil

Decontamination activities will be conducted on a concrete decontamination pad at the site.

Standard procedures for field equipment are described below.

<u>Well Sounders and Groundwater Measurement Tapes:</u> Decontamination procedures for Teflon™, PVC, stainless-steel, and glass tubing used for groundwater sampling are listed below

- Wash with laboratory detergent and tap water.
- Rinse with tap water.
- Rinse with analyte-free (deionized) water.

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- Wrap equipment in aluminum foil.

Field Parameter Measurement Probes: Field parameter measurement probes, (e.g., pH or specific ion electrodes, geophysical probes, or thermometers) that come in direct contact with the sample will be decontaminated using the procedures listed below, unless manufacturer's instructions indicate otherwise. Probes that make no direct contact (e.g., OVA equipment) will be wiped with clean paper towels.

- Rinse with tap water.
- Rinse with analyte-free (deionized) water.
- Solvent rinse if obvious contamination remains after rinsing and if solvent will not damage probe.
- Rinse with analyte-free (deionized) water.

Sampling Equipment for Organic and Metal Analysis: Teflon™, stainless-steel, glass, or metal sampling equipment used to collect samples for organic and metal analysis will be cleaned between sample locations as listed below

- Wash and scrub equipment thoroughly with laboratory detergent and tap water.
- Rinse thoroughly with tap water.
- Rinse thoroughly with deionized, analyte-free water.
- Rinse with solvent (pesticide-grade isopropanol). Note: Do not rinse PVC or plastic materials with solvent.
- Rinse with organic-free water and allow to air dry as long as possible.
- Wrap with aluminum foil to prevent contamination.

Investigation-Derived Waste (IDW)

All soil cuttings will be placed in roll-off boxes located in a central staging area at the site. Soil cuttings may be temporarily staged at drill location on and covered by plastic sheeting, prior to placement in roll-off boxes. Drilling fluids, development water, and wastewater from equipment decontamination produced during the drilling operation will be containerized in 55-gallon drums approved by Department of Transportation (DOT) (supplied by the Subcontractor). The drums will permanently marked with a weatherproof label, signifying the date, site number, and well number. Drums will be staged at a central location at the site

Representative samples of the IDW will be collected for chemical characterization by the FTL for off-site disposal. Once analytical results of the IDW are available, the IDW will be disposed of off-site in accordance with federal, state, and local regulations. The IDW will be removed from the site within 60 days following of the receipt of analytical results.

Logistics

Equipment, supplies, and personnel required to complete the monitoring well installation effort at the Site will mobilize after approval of the RD workplan and the EBT Treatability Study Workplan. The Hazardous and Toxic Waste Health and Safety Plan (CH2M HILL, August 1995) for Memphis Depot will be amended prior to the start of field activities.

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References

American Society for Testing and Materials (ASTM) D-2488-90 *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure).

CH2M HILL. February 1995. *Final Generic Quality Assurance Project Plan.* Defense Distribution Depot Memphis, Tennessee. Prepared for the United States Army Engineering Support Center, Huntsville, Alabama.

CH2M HILL, Inc. August 1995. *Hazardous and Toxic Waste Health and Safety Plan*. Prepared for U S Army Engineering and Support Center Huntsville, Alabama.

U S. Environmental Protection Agency, Science and Ecosystems Services Division. *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.* May 1996 (revised 1997).

Appendix C – August 1995 Final Generic Quality Assurance Project Plan (amended)

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ADDENDUM SA.03 **CH2MHILL**

Standard Operating Procedures (SOPs) Adopted Since the Completion of the August 1995 Generic Quality Assurance Project Plan (QAPP), Memphis Depot

PREPARED FOR: QAPP (1995)

PREPARED BY: Bryan Burkingstock/ATL

DATE: February 15, 2002

Since the inception of the 1995 QAPP, new protocols have been accepted by BCT members for various Memphis Depot field activities. SOPs located in the following site-specific plans should be used for further reference on applicable methods and procedures:

- *Operable Units 2, 3, and 4 and Screening Sites: Field Sampling Plan Addenda* (CH2M HILL, September 1998)
- *Sampling and Analysis Plan for Evaluation of Biodegradation of VOCs in Groundwater at the Memphis Depot* (CH2M HILL, March 13, 2000)
- *Data Collection Plan for Long-Term Operational Areas (LTOAs), Main Installation, Memphis Depot* (CH2M HILL, June 5, 2001)
- *Well Construction and Sampling Techniques for Long-Term Operational Area (LTOA) Monitoring Wells Associated with SS42/SS43, NE6 (Building T702), and SS80* (CH2M HILL, September 5, 2001)

SOPs included as an Addendum to the 1995 QAPP include:

1) *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures* (Puls and Barcelona, 1996)
2) *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentration in Wells* (USGS 2001)
3) *Standard Operating Procedure for Soil Headspace Field Screening Using an OVA/FID at Dunn Field* (CH2M HILL, May 5, 2000)
4) *Standard Operating Procedure for Collecting Soil Samples for Volatile Organic Compounds (VOCs)* (CH2M HILL, August 16, 2001)
5) *Standard Operating Procedure for Collecting Soil Samples for Volatile Organic Compounds* (CH2M HILL, May 5, 2000)
6) *Standard Operating Procedure for QED® Bladder Pumps* (CH2M HILL, March 10, 2000)
7) *Standard Operating Procedure for Sudan IV Dye Testing* (CH2M HILL, May 5, 2000)

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United States
Environmental Protection
Agency

Office of
Research and
Development

Office of Solid Waste
and Emergency
Response

EPA/540/S-95/504
April 1996

EPA Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by **Robert W. Puls**[1] **and Michael J. Barcelona**[2]

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling

For further information contact: Robert Puls, 405-436-8543, Subsurface Remediation and Protection Division, NRMRL, Ada, Oklahoma.

I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water Large water-bearing units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic *units*. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

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[2] University of Michigan

Technology Support Project

Superfund Technology Support Center for Ground Water

National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
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Technology Innovation Office
Office of Solid Waste and Emergency
Response, US EPA, Washington, DC
Walter W. Kovalick, Jr., Ph.D.
Director

chemical and biological subsurface processes With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquitards* or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today. aquifer heterogeneity and colloidal transport Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g . 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988, Penrose et al., 1990) Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990, McCarthy and Degueldre, 1993; Backhus et al., 1993, U. S EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm The most commonly observed mobile particles include secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria. These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total* mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias *naturally* suspended particle concentrations

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements Detailed soil and geologic data are required prior to and during the installation of sampling points This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended With this information (together with other site characterization data) and a clear understanding of sampling objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;

2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and

3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

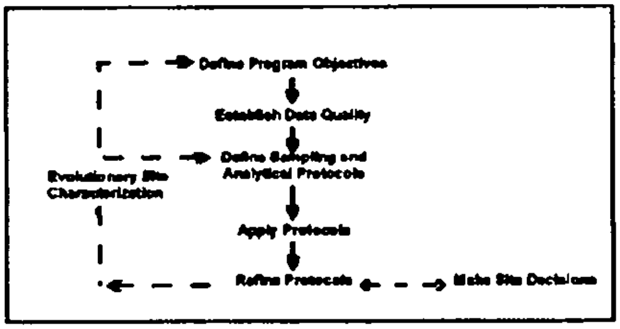

Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0 5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the *mobile* load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;

- reduced stress on the formation (minimal drawdown);
- less mixing of stagnant casing water with formation water,
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time;
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986, Puls and Barcelona, 1989, Puls et. al. 1990, 1992, Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include· mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials This lag time will depend on site conditions and methods of installation but often exceeds one week

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to sampling, it is recommended that an in-line water quality measurement device (e g , flow-through cell) be used to establish the stabilization time for several parameters (e g , pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well,
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

D. Pump Type

The use of low-flow (e.g., 0.1-0 5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site Bailers are inappropriate devices for low-flow sampling.

1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U.S. EPA (1992), Parker (1994) and Thurnblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over <u>any</u> other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 µm filters]) concentrations of major ions and trace metals, 0.1 µm filters are recommended although 0.45 µm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO_2 composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 µm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, ± 3% for conductivity, ± 10 mv for redox potential, and ± 10% for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe^{2+}, CH_4, H_2S/HS^-, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U.S. EPA, 1992] or EPA SW-846 [U.S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

(1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.

(2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.

(3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of the well screen This may require repeated recovery of the water during purging while leaving the pump in place within the well screen

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected, i e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device

A. Low-Permeability Formations (<0.1 L/min recharge)

1. Low-Flow Purging and Sampling with Pumps

a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements) After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.

b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2 Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives

B. Fractured Rock

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum, information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop -- A Workshop Summary" (U. S EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

VII. Notice

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Figure 2. **Ground Water Sampling Log**

Project ______________ **Site** ______________ **Well No.** ____________ **Date** ______________

Well Depth ___________ **Screen Length** _________ **Well Diameter** _________ **Casing Type** ___________

Sampling Device ______________ **Tubing type** __________________ **Water Level** ______________

Measuring Point ________________ **Other Infor** ________________________________

____

Sampling Personnel ____

Time	pH	Temp	Cond.	Dis.O_2	Turb.	[ ]Conc			Notes

Type of Samples Collected

____

Information 2 in = 617 ml/ft, 4 in = 2470 ml/ft· $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3 \pi r^3$

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Figure 3. **Ground Water Sampling Log** (with automatic data logging for most water quality parameters)

Project ______________ **Site** ______________ **Well No.** ____________ **Date** ________________

Well Depth ___________ **Screen Length** _________ **Well Diameter** ________ **Casing Type** __________

Sampling Device ______________ **Tubing type** ____________________ **Water Level** ______________

Measuring Point __________________ **Other Infor** ____

____

Sampling Personnel ____

Time	Pump Rate	Turbidity	Alkalinity	[ ] Conc	Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3\pi r^3$

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USER'S GUIDE FOR POLYETHYLENE-BASED PASSIVE DIFFUSION BAG SAMPLERS TO OBTAIN VOLATILE ORGANIC COMPOUND CONCENTRATIONS IN WELLS

PART 1:
DEPLOYMENT, RECOVERY, DATA INTERPRETATION, AND QUALITY CONTROL AND ASSURANCE

Water-Resources Investigations Report 01-4060

PART 2:
FIELD TESTS

Water-Resources Investigations Report 01-4061

Prepared in cooperation with the
U.S. AIR FORCE
U.S. NAVAL FACILITIES ENGINEERING COMMAND
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DEFENSE LOGISTICS AGENCY
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U.S. Department of the Interior
U.S. Geological Survey

User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells

Part 1: Deployment, Recovery, Data Interpretation, and Quality Control and Assurance

By Don A. Vroblesky

U.S. Geological Survey
Water-Resources Investigations Report 01–4060

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User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells

Part 1: Deployment, Recovery, Data Interpretation, and Quality Control and Assurance

By Don A. Vroblesky

EXECUTIVE SUMMARY

Water-filled passive diffusion bag (PDB) samplers described in this report are suitable for obtaining concentrations of a variety of volatile organic compounds (VOCs) in ground water at monitoring wells. The suggested application of the method is for long-term monitoring of VOCs in ground-water wells at well-characterized sites

The effectiveness of the use of a single PDB sampler in a well is dependent on the assumption that there is horizontal flow through the well screen and that the quality of the water is representative of the ground water in the aquifer directly adjacent to the screen. If there are vertical components of intra-bore-hole flow, multiple intervals of the formation contributing to flow, or varying concentrations of VOCs vertically within the screened or open interval, then a multiple deployment of PDB samplers within a well may be more appropriate for sampling the well.

A typical PDB sampler consists of a low-density polyethylene (LDPE) lay-flat tube closed at both ends and containing deionized water The sampler is positioned at the target horizon of the well by attachment to a weighted line or fixed pipe.

The amount of time that the sampler should be left in the well prior to recovery depends on the time required by the PDB sampler to equilibrate with ambient water and the time required for the environmental disturbance caused by sampler deployment to return to ambient conditions. The rate that the water within the PDB sampler equilibrates with ambient water depends on multiple factors, including the type of compound being sampled and the water temperature The concentrations of benzene, *cis*-1,2-dichloroethene, tetrachlorethene, trichloroethene, toluene, naphthalene, 1,2-dibromoethane, and total xylenes within the PDB samplers equilibrated with the concentrations in an aqueous mixture of those compounds surrounding the samplers under laboratory conditions within approximately 48 hours at 21 degrees Celsius (°C). A subsequent laboratory study of mixed VOCs at 10 °C showed that tetrachloroethene and trichloroethene were equilibrated by about 52 hours, but other compounds required longer equilabration times. Chloroethane, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and 1,1-dichloroethene were not equilibrated at 52 hours, but appeared to be equilibrated by the next sampling point at 93 hours Vinyl chloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane were not equilibrated at 93 hours, but were equilibrated by the next sampling point at 166 hours. Different equilibration times may exist for other compounds Differences in equilibration times, if any, between single-solute or mixed VOC solutions have not yet been thoroughly examined

The samplers should be left in place long enough for the well water, contaminant distribution, and flow dynamics to restabilize following sampler deployment. Laboratory and field data suggest that 2 weeks of equilibration probably is adequate for many applications; therefore, a minimum equilibration time of 2 weeks is suggested. In less permeable formations, longer equilibration times may be required. When applying PDB samplers in waters colder than previously tested (10 °C) or for compounds without sufficient corroborating data, a side-by-side comparison with conventional methodology is advisable to justify the field equilibration time.

suited for project managers, technical personnel, and the regulatory community Part 2 of this report presents case studies of PDB sampler field applications.

INTRODUCTION

The use of PDB samplers for collecting ground-water samples from wells offers a cost-effective approach to long-term monitoring of VOCs at well-characterized sites (Vroblesky and Hyde, 1997; Gefell and others, 1999). The effectiveness of the use of a single PDB sampler in a well is dependent on the assumption that there is horizontal flow through the well screen and that the quality of the water is representative of the ground water in the aquifer directly adjacent to the screen. If there are vertical components of intra-borehole flow, multiple intervals of the formation contributing to flow, or varying concentrations of VOCs vertically within the screened or open interval, then deployment of multiple PDB samplers within a well may be more appropriate for sampling the well

The samplers consist of deionized water enclosed in a LDPE sleeve (fig. 1) and are deployed adjacent to a target horizon within a screened or open interval of a well. The suggested application is for long-term monitoring of VOCs in ground-water wells. Where the screened interval is greater than 10 feet (ft), the potential for contaminant stratification and/or intra-borehole flow within the screened interval is greater than in screened intervals shorter than 10 ft It is important that the vertical distribution of contaminants be determined in wells having 10-ft-long well screens, and that both the vertical distribution of contaminants and the potential for intra-borehole flow be determined in wells having screens longer than 10 ft. For many VOCs of environmental interest (table 1), the VOC concentration in water within the sampler approaches the VOC concentration in water outside of the PDB sampler over an equilibration period. The resulting concentrations represent an integration of chemical changes over the most recent part of the equilibration period (approximately 48 to 166 hours, depending on the water temperature and the type of compound being sampled). The approach is inexpensive and has the potential to eliminate or substantially reduce the amount of purge water removed from the well.

A variety of PDB samplers have been utilized in well applications (fig. 1). Although the samplers vary in specific construction details, a typical PDB sampler consists of a 1- to 2-ft-long LDPE tube closed at both ends and containing laboratory-grade deionized water (fig. 1). The typical diameter for PDB samplers used in a 2-inch-diameter well is approximately 1.2 inches; however, other dimensions may be used to match the well diameter Equilibration times may be longer for larger diameter PDB samplers. On the outside of the PDB sampler, a low-density polyethylene-mesh sometimes is used for protection against abrasion in open boreholes and as a means of attachment at the prescribed depth. The PDB sampler can be positioned at the target horizon by attachment to a weighted line or by attachment to a fixed pipe.

PDB samplers for use in wells are available commercially. Authorized distributors as of March 2001 are Columbia Analytical Services (800-695-7222; www@caslab.com) and Eon Products (800-474-2490; www.eonpro.com). A current list of vendors and PDB-sampler construction details can be obtained from the U.S. Geological Survey Technology Transfer Enterprise Office, Mail Stop 211, National Center, 12201 Sunrise Valley Drive, Reston, Virginia 20192 (telephone 703-648-4344; fax 703-648-4408). PDB samplers employ patented technology (U.S. patent number 5,804,743), and therefore, require that the user purchase commercially produced samplers from a licensed manufacturer or purchase a nonexclusive license for sampler construction from the U.S. Geological Survey Technology Enterprise Office at the above address.

The purposes of this document are to present methods for PDB sampler deployment, and recovery; to discuss approaches for determining the applicability of passive diffusion samplers; and to discuss various factors influencing interpretation of the data. The intended audience for the methodology sections of this report is managers and field personnel involved in using PDB samplers. The discussion of PDB sampler applicability and interpretation of the data is suited for project managers, technical personnel, and the regulatory community. Part 2 of this report presents case studies of PDB-sampler field applications.

Summary of Passive Diffusion Bag Sampler Advantages and Limitations

Advantages

1. PDB samplers have the potential to eliminate or substantially reduce the amount of purge water associated with sampling

2. PDB samplers are inexpensive

3 The samplers are easy to deploy and recover.

4. Because PDB samplers are disposable, there is no downhole equipment to be decontaminated between wells.

5. A minimal amount of field equipment is required.

6. Sampler recovery is rapid. Because of the small amount of time and equipment required for the sampling event, the method is practical for use where access is a problem or where discretion is desirable (that is, residential communities, business districts, or busy streets where vehicle traffic control is a concern).

7. Multiple PDB samplers, distributed vertically along the screened or open interval, may be used in conjunction with borehole flow meter testing to gain insight on the movement of contaminants into and out of the well screen or open interval or to locate the zone of highest concentration in the well. Analytical costs when using multiple PDB samplers sometimes can be reduced by selecting a limited number of the samplers for laboratory analysis based on screening by using field gas chromatography at the time of sample collection.

8. Because the pore size of LDPE is only about 10 angstroms or less, sediment does not pass through the membrane into the bag Thus, PDB samplers are not subject to interferences from turbidity. In addition, none of the data collected suggest that VOCs leach from the LDPE material or that there is a detrimental effect from the PDB material on the VOC sample.

Limitations

1. PDB samplers integrate concentrations over time. This may be a limitation if the goal of sampling is to collect a representative sample at a point in time in an aquifer where VOC-concentrations substantially change more rapidly than the samplers equilibrate. Laboratory results obtained indicate that a variety of compounds equilibrated within 48 hours at 21 °C (Vroblesky and Campbell, 2001). Vinyl chloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane may require between 93 and 166 hours to equilibrate at 10 °C (T.M. Sivavec and S.S. Baghel, General Electric Company, written commun., 2000). The initial equilibration under field conditions may be longer to allow well water, contaminant distribution, and flow dynamics to restabilize following sampler deployment.

2. Water-filled polyethylene PDB samplers are not appropriate for all compounds. For example, although methyl-*tert*-butyl ether and acetone (Vroblesky, 2000; Paul Hare, General Electric Company, oral commun., 2000) and most semivolatile compounds are transmitted through the polyethylene bag, laboratory tests have shown that the resulting concentrations were lower than in ambient water. A variety of factors influence the ability of compounds to diffuse through the polyethylene membrane. These factors include the molecular size and shape and the hydrophobic nature of the compound. Compounds having a cross-sectional diameter of about 10 angstroms or larger (such as humic acids) do not pass through the polyethylene because the largest (transient) pores in polyethylene do not exceed about 10 angstroms in diameter (Flynn and Yalkowsky, 1972; Hwang and Kammermeyer, 1975; Comyn, 1985). The samplers are not appropriate for hydrophilic polar molecules, such as inorganic ions. A detailed discussion of the relation between hydrophobicity and compound transport through polyethylene can be found in Gale (1998). Unpublished laboratory test data (D.A. Vroblesky, U S. Geological Survey, written commun., 1998) of semi-volatile compounds in contact with PDB samplers showed a higher concentration of phthalates inside the PDB sampler than outside the PDB sampler, suggesting that the polyethylene may contribute phthalates to the enclosed water. Thus, the samplers should not be used to sample for phthalates.

3. PDB samplers rely on the free movement of water through the well screen. In situations where ground water flows horizontally through the well screen, the VOC concentrations in the open interval of the well probably are representative of the aquifer water in the adjacent formation (Gillham and others, 1985; Robin and Gillham, 1987; Kearl and others, 1992; Powell and Puls, 1993; Vroblesky and Hyde, 1997). In these situations, the VOC concentration of the water in contact with the PDB samplers, and therefore, the water within the diffusion samplers, probably represents local conditions in the adjacent aquifer. However, if the well screen is less permeable than the aquifer or the sandpack, then under ambient conditions, flowlines may be diverted around the screen. Such a situation may arise from inadequate well development or from iron bacterial fouling of the well screen. In this case, the VOC concentrations in the PDB samplers may not represent concentrations in

The following steps should be used for deploying PDB samplers in wells:

1 Measure the well depth and compare the measured depth with the reported depth to the bottom of the well screen from well-construction records. This is to check on whether sediment has accumulated in the bottom of the well, whether there is a nonscreened section of pipe (sediment sump) below the well screen, and on the accuracy of well-construction records. If there is an uncertainty regarding length or placement of the well screen, then an independent method, such as video imaging of the well bore, is strongly suggested.

2. Attach a stainless-steel weight to the end of the line. Sufficient weight should be added to counterbalance the buoyancy of the PDB samplers This is particularly important when multiple PDB samplers are deployed. One approach, discussed in the following paragraphs, is to have the weight resting on the bottom of the well, with the line taut above the weight. Alternatively, the PDB sampler and weight may be suspended above the bottom, but caution should be exercised to ensure that the sampler does not shift location. Such shifting can result from stretching or slipping of the line or, if multiple samplers are attached end-to-end rather than to a weighted line, stretching of the samplers.

3. Calculate the distance from the bottom of the well, or top of the sediment in the well, up to the point where the PDB sampler is to be placed. A variety of approaches can be used to attach the PDB sampler to the weight or weighted line at the target horizon. The field-fillable type of PDB sampler is equipped with a hanger assembly and weight that can be slid over the sampler body until it rests securely near the bottom of the sampler When this approach is used with multiple PDB samplers down the same borehole, the weight should only be attached to the lowermost sampler. An additional option is to use coated stainless-steel wire as a weighted line, making loops at appropriate points to attach the upper and lower ends of PDB samplers. Where the PDB sampler position varies between sampling events, movable clamps with rings can be used. When using rope as a weighted line, a simple approach is to tie knots or attach clasps at the appropriate depths. Nylon cable ties or stainless-steel clips inserted through the knots can be used to attach the PDB samplers. An approach using rope as a weighted line with knots tied at the appropriate sampler-attachment points is discussed below.

(a) For 5-ft-long or shorter well screens, the center point of the PDB sampler should be the vertical midpoint of the saturated well-screen length. For example, if the well screen is at a depth of 55 to 60 ft below the top of casing, and the measured depth of the well is 59 ft, then the bottom of the well probably has filled with sediment. In this case, the midpoint of the sampler between the attachment points on the line will be midway between 55 and 59 ft, or at 57 ft. Thus, for a 1.5-ft-long sampler, the attachment points on a weighted line should be tied at distances of 1 25 ft (2 ft – 0.75 ft) and 2.75 ft (2 ft + 0 75 ft) from the top of the sediment in the well, or the bottom of the well, making adjustments for the length of the attached weight. When the PDB sampler is attached to the line and installed in the well, the center of the sampler will be at 57-ft depth. If, however, independent evidence is available showing that the highest concentration of contaminants enters the well from a specific zone within the screened interval, then the PDB sampler should be positioned at that interval.

(b) For 5- to 10-ft-long well screens, it is advisable to utilize multiple PDB samplers vertically along the length of the well screen for at least the initial sampling (fig. 2). The purposes of the multiple PDB samplers are to determine whether contaminant stratification is present and to locate the zone of highest concentration. The midpoint of each sampler should be positioned at the midpoint of the interval to be sampled. For 1.5-ft-long samplers, at each sampling depth in the screened interval, make two attachment points on the weighted line at a distance of about 1.5 ft apart. The attachment points should be positioned along the weighted line at a distance from the bottom end of the weight such that the midpoint between the knots will be at the desired sampling depth along the well screen. Sampler intervals are variable, but a simple approach is to use the top knot/loop of one sampler interval as the bottom knot/loop for the overlying sampler interval.

5. When using PDB samplers without the protective outer mesh, the holes punched at the ends of the bag, outside the sealed portion, can be used to attach the samplers to the weighted line. Stainless-steel spring clips have been found to be more reliable than cable ties in this instance, but cable ties also work well.

6. Lower the weight and weighted line down the well until the weight rests on the bottom of the well and the line above the weight is taut. The PDB samplers should now be positioned at the expected depth. A check on the depth can be done by placing a knot or mark on the line at the correct distance from the top knot/loop of the PDB sampler to the top of the well casing and checking to make sure that the mark aligns with the lip of the casing after deployment

7. Secure the assembly in this position. A suggested method is to attach the weighted line to a hook on the inside of the well cap. Reattach the well cap The well should be sealed in such a way as to prevent surface-water invasion. This is particularly important in flush-mounted well vaults that are prone to flooding

8. Allow the system to remain undisturbed as the PDB samplers equilibrate.

PASSIVE DIFFUSION BAG SAMPLER AND SAMPLE RECOVERY

The amount of time that the samplers should be left in the well prior to recovery depends on the time required by the PDB sampler to equilibrate with ambient water and the time required for environmental disturbances caused by sampler deployment to return to ambient conditions. The rate that the water within the PDB sampler equilibrates with ambient water depends on multiple factors, including the type of compound being sampled and the water temperature The concentrations of benzene, *cis*-1,2-dichloroethene (*c*DCE), tetrachlorethene (PCE), trichloroethene (TCE), toluene, naphthalene, 1,2-dibromoethane (EDB), and total xylenes within the PDB samplers equilibrated with the concentrations in an aqueous mixture of those compounds surrounding the samplers under laboratory conditions within approximately 48 hours at 21 °C (Vroblesky and Campbell, 2001). A subsequent laboratory study of mixed VOCs at 10 °C showed that PCE and TCE were equilibrated by about 52 hours, but other compounds required longer equilibration times (T M. Sivavec and S S. Baghel, General Electric Company, written commun., 2000). Chloroethane, *c*DCE, *trans*-1,2-dichloroethene, and 1,1-dichloroethene were not equilibrated at 52 hours, but appeared to be equilibrated by the next sampling point at 93 hours. Vinyl chloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane were not equilibrated at 93 hours, but were equilibrated by the next sampling point at 166 hours. Different equilibration times may exist for other compounds. Differences in equilibration times, if any, between single-solute or mixed-VOC solutions have not yet been thoroughly examined.

Under field conditions, the samplers should be left in place long enough for the well water, contaminant distribution, and flow dynamics to restabilize following sampler deployment The results of borehole dilution studies show that wells can recover to 90 percent of the predisturbance conditions within minutes to several hours for permeable to highly permeable geologic formations, but may require 100 to 1,000 hours (4 to 40 days) in muds, very fine-grained loamy sands, and fractured rock, and may take even longer in fractured shales, recent loams, clays, and slightly fractured solid igneous rocks (Halevy and others, 1967).

In general, where the rate of ground-water movement past a diffusion sampler is high, equilibration times through various membranes commonly range from a few hours to a few days (Mayer, 1976; Harrington and others, 2000). One field investigation showed adequate equilibration of PDB samplers to aquifer trichloroethene (TCE) and carbon tetrachloride (CT) concentrations within 2 days in a highly permeable aquifer (Vroblesky and others, 1999). In other investigations, PDB samplers recovered after 14 days were found to be adequately equilibrated to chlorinated VOCs (Obrien & Gere Engineers, Inc., 1997a, 1997b; Hare, 2000); therefore, the equilibration period was less than or equal to 14 days for those field conditions. Because it appears that 2 weeks of equilibration probably is adequate for many applications, a minimum equilibration time of 2 weeks is suggested. When applying PDB samplers in waters colder than previously tested (10 °C) or for compounds without sufficient corroborating field data, a side-by-side comparison with conventional sampling methodology is advisable to justify the field equilibration time.

In less permeable formations, longer equilibration times may be required. It is probable that water in the well bore eventually will equilibrate with the pore-water chemistry; however, if the rate of chemical change or volatilization loss in the well bore exceeds the rate of exchange between the pore water and the well-bore water, then the PDB samplers may under-

6. If a comparison is being made between concentrations obtained using PDB samplers and concentrations obtained using a conventional sampling approach, then the well should be sampled by the conventional approach soon after (preferably on the same day) recovery of the PDB sampler. The water samples obtained using PDB samplers should be sent in the same shipment, as the samples collected by the conventional approach for the respective wells. Utilizing the same laboratory may reduce analytical variability.

7. Any unused water from the PDB sampler and water used to decontaminate cutting devices should be disposed in accordance with local, state, and Federal regulations.

DETERMINING APPLICABILITY OF PASSIVE DIFFUSION BAG SAMPLERS AND INTERPRETATION OF DATA

When attempting to determine whether the use of PDB samplers is appropriate at a particular well, a common approach is to do a side-by-side comparison with a conventional sampling method during the same sampling event. This approach is strongly suggested in wells having temporal concentration variability. In a well having relatively low temporal concentration variability, comparison of the PDB-sampler results to historical concentrations may provide enough information to determine whether the PDB samplers are appropriate for the well. In general, if both PDB and conventional sampling produce concentrations that agree within a range deemed acceptable by local, state, and Federal regulatory agencies and meet the site-specific data-quality objectives, then a PDB sampler may be approved for use in that well to monitor ambient VOC concentrations. If concentrations from the PDB sampler are higher than concentrations from the conventional method, it is probable that concentrations from the PDB sampler adequately represent ambient conditions because there usually is a greater potential for dilution from mixing during sampling using conventional methods than during sampling using PDB samplers

If, however, the conventional method produces concentrations that are significantly higher than those obtained using the PDB sampler, then it is uncertain whether the PDB-sampler concentrations represent local ambient conditions In this case, further testing can be done to determine whether contaminant stratification and/or intra-borehole flow is present. Multiple sampling devices can be used to determine the presence of contaminant stratification, and borehole flowmeters can be used to determine whether intra-borehole flow is present. When using flowmeters to measure vertical flow in screened boreholes, however, the data should be considered qualitative because of the potential for water movement through the sand pack. Borehole dilution tests (Halevy and others, 1967; Drost and others, 1968; Grisak and others, 1977; Palmer, 1993) can be used to determine whether water is freely exchanged between the aquifer and the well screen.

Once the source of the difference between the two methods is determined, a decision can be made regarding the well-specific utility of the PDB samplers. Tests may show that VOC concentrations from the PDB samplers adequately represent local ambient conditions within the screened interval despite the higher VOC concentration obtained from the conventional method. This may be because the pumped samples incorporated water containing higher concentrations either from other water-bearing zones induced along inadequate well seals or through fractured clay (Vroblesky and others, 2000), from other water-bearing zones not directly adjacent to the well screen as a result of well purging prior to sampling (Vroblesky and Petkewich; 2000), or from mixing of chemically stratified zones in the vicinity of the screened interval (Vroblesky and Peters, 2000)

The mixing of waters from chemically stratified zones adjacent to the screened interval during pumping probably is one of the more important sources of apparent differences between the results obtained from PDB sampling and conventional sampling because such stratification probably is common. Vertical stratification of VOCs over distances of a few feet has been observed in aquifer sediments by using multilevel sampling devices (Dean and others, 1999; Pitkin and others, 1999), and considerable variation in hydraulic conductivity and water chemistry has been observed in an aquifer in Cape Cod, Massachusetts, on the scale of centimeters (Wolf and others, 1991; Smith and others 1991; Hess and others, 1992). Multiple PDB samplers have been used to show a change in TCE concentration of 1,130 (μg/L over a 6-ft vertical screened interval in Minnesota (Vroblesky and Petkewich, 2000). Tests using PDB samplers in screened intervals containing VOC stratification showed that the PDB-sampler data appeared to be point-specific, whereas the pumped sample integrated water over a larger interval (Vroblesky and Peters, 2000).

concentrations that may differ from VOC concentrations obtained from PDB samplers because the methodologies sometimes are influenced in different ways by aquifer hydraulic and chemical heterogeneity. This section examines potential sources of concentration differences between traditional methodologies and the PDB methodology.

The purge-and-sample approach to ground-water monitoring differs from the diffusion-sampler approach primarily because the area of the screened or open interval that contributes water to the purged sample typically is greater than for the PDB sampler, and the potential for mixing of stratified layers is higher. When pumping three or more casing volumes of water prior to collecting a sample, chemical concentrations in the discharging water typically change as the well is pumped (Keely and Boateng, 1987; Cohen and Rabold, 1988; Martin-Hayden and others, 1991; Robbins and Martin-Hayden, 1991; Reilly and Gibs, 1993; Barcelona and others, 1994; Martin-Hayden, 2000), due to mixing during pumping and other factors, such as the removal of stagnant water in the casing and changing patterns of inflow and outflow under ambient and pumping conditions (Church and Granato, 1996). The induction of lateral chemical heterogeneity during pumping also may produce variations in the sampled concentrations. The amount of mixing during purging can be highly variable (Barber and Davis, 1987; Church and Granato, 1996; Reilly and LeBlanc, 1998; Martin-Hayden, 2000), and may result in concentrations that are not locally representative (Reilly and Gibs, 1993) Substantial vertical hydraulic gradients, even in shallow homogeneous aquifers, have been observed to bias sampling using conventional purging because the majority of the pumped water may come from a particular horizon not related to the contaminated zone and because the intra-well flow that intruded the aquifer may not be adequately removed during purging (Hutchins and Acree, 2000). Thus, differences may be observed between concentrations obtained from a pumped sample and from a PDB sample in a chemically stratified interval if the pumped sample represents an integration of water collected from multiple horizons and the PDB sampler represents water collected from a single horizon.

Low-flow purging and sampling (Barcelona and others, 1994, Shanklin and others, 1995) disturbs the local ground water less than conventional purge-and-sample methods. Thus, samples obtained by PDB samplers are likely to be more similar to samples obtained by using low-flow purging than to those obtained by using conventional purge-and-sample methods. Even under low-flow conditions, however, purging still can integrate water within the radius of pumping influence, potentially resulting in a deviation from VOC concentrations obtained by PDB sampling. One investigation found that in low hydraulic conductivity formations, low-flow sampling methodology caused excessive drawdown, which dewatered the screened interval, increased local ground-water velocities, and caused unwanted colloid and soil transport into the ground-water samples (Sevee and others, 2000). The authors suggest that in such cases, a more appropriate sampling methodology may be to collect a slug or passive sample from the well screen under the assumption that the water in the well screen is in equilibrium with the surrounding aquifer.

Isolating a particular contributing fracture zone with straddle packers in an uncased borehole allows depth-discrete samples to be collected from the target horizon (Hsieh and others, 1993; Kaminsky and Wylie, 1995). Strategically placed straddle packers often can minimize or eliminate the impact of vertical gradients in the sampled interval. However, even within a packed interval isolating inflowing fracture zones, deviations between VOC concentrations in water from PDB samplers and water sampled by conventional methods still may occur if the conventional method mixes chemically stratified water outside the borehole or if the packed interval straddles chemically heterogeneous zones.

The use of multilevel PDB samplers and other types of multilevel samplers (Ronen and others, 1987; Kaplan and others, 1991; Schirmer and others, 1995; Gefell and others, 1999; Jones and others, 1999) potentially can delineate some of the chemical stratification. Diffusion sampling and other sampling methodologies, however, can be influenced by vertical hydraulic gradients within the well screen or the sand pack. When vertical hydraulic gradients are present within the well, water contacting the PDB sampler may not be from a horizon adjacent to the PDB sampler. Rather, the water may represent a mixing of water from other contributing intervals within the borehole. In a screened well, even multilevel samplers with baffles to limit vertical flow in the well cannot prevent influences from aqueous mixture of those compounds surrounding the samplers under laboratory conditions within approximately 48 hours at 21 °C. A subsequent laboratory study of mixed VOCs at 10 °C showed that tetrachloroethene and trichloroethene were equilibrated by about 52 hours, but other compounds required longer equilabration times. Chloroethane, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and 1,1-dichloroethene were not equilibrated at 52 hours, but appeared to be equilibrated by the next sampling point at 93 hours. Vinyl chloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane were not equilibrated at 93 hours but were equilibrated by the next sampling point at 166 hours Different equilibration times may exist for other compounds. Differences in equilibration times, if any, between single-solute or mixed-VOC solutions have not yet been thoroughly examined.

The samplers should be left in place long enough for the well water, contaminant distribution, and flow dynamics to restabilize following sampler deployment Laboratory and field data suggest that 2 weeks of equilibration probably is adequate for many applications. Therefore, a minimum equilibration time of 2 weeks is suggested. In less permeable formations, longer equilibration times may be required. When deploying PDB samplers in waters colder than previously tested (10 °C) or for compounds without sufficient corroborating data, a side-by-side comparison with conventional methodology is advisable to justify the field equilibration time.

Following the initial equilibration period, the samplers maintain equilibrium concentrations with the ambient water until recovery. Thus, there is no specified maximum time for sampler recovery after initial equilibration. PDB samplers have routinely been left in ground waters having concentrations of greater than 500 ppm of TCE for 3 months at a time with no loss of bag integrity, and at one site, the PDB samplers were left in place in VOC-contaminated ground water for 1 year with no reported loss of sampler integrity. The effects of long-term (greater than 1 month) PDB-sampler deployment on sampler and sample integrity have not yet been thoroughly tested for a broad range of compounds and concentrations. In some environments, development of a biofilm on the polyethylene may be a consequence of long-term deployment. Investigations of semipermeable membrane devices (SPMDs) have shown that the transfer of some compounds across a heavily biofouled polyethylene membrane may be reduced, but not stopped. If a heavy organic coating is observed on a PDB sampler, it is advisable to determine the integrity of the sample by comparing sampler results to a conventional sampling method concentrations before continuing to use PDB samplers for long-term deployment in that well.

PDB methodology is suitable for a broad variety of VOCs, including chlorinated aliphatic compounds and petroleum hydrocarbons. The samplers, however, are not suitable for inorganic ions and have a limited applicability for non-VOCs and for some VOCs. For example, although methyl-*tert*-butyl ether and acetone and most semivolatile compounds are transmitted through the polyethylene bag, laboratory tests have shown that the resulting concentrations were lower than in ambient water. The samplers should not be used to sample for phthalates because of the potential for the LDPE to contribute phthalates to the water sample.

When attempting to determine whether the use of PDB samplers is appropriate at a particular well, a common approach is to do a side-by-side comparison with a conventional sampling method. This approach is strongly suggested in wells having temporal concentration variability. In a well having relatively low temporal concentration variability, comparison of the PDB-sampler results to historical concentrations may provide enough information to determine whether the PDB samplers are appropriate for the well. In general, if the two approaches produce concentrations that agree within a range deemed acceptable by the local, state, and Federal regulatory agencies, then use of a PDB sampler in that well will provide VOC concentrations consistent with the historical record. If concentrations from the PDB sampler are higher than concentrations from the conventional method, then it is probable that the concentrations from the PDB sampler are an adequate representation of ambient conditions If, however, the conventional method produces concentrations that are substantially higher than the concentrations found by using the PDB sampler, then the PDB sampler may or may not adequately represent local ambient conditions. In this case, the difference may be due to a variety of factors, including mixing or translocation due to hydraulic and chemical heterogeneity of the aquifer within the screened or open interval of the well and the relative permeability of the well screen.

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TECHNICAL MEMORANDUM **CH2MHILL**

Standard Operating Procedure for Soil Headspace Field Screening Using an OVA/FID at Dunn Field

TO:	U.S. Army Engineering and Support Center, Huntsville
COPIES:	Memphis Depot Caretaker (MDC) U.S. Environmental Protection Agency (USEPA), Region 4 Tennessee Department of Environment and Conservation (TDEC)
FROM:	CH2M HILL
DATE:	May 5, 2000

This memorandum describes the use of the Organic Volatile Analyzer (OVA)/ Flame Ionization Detector (FID) headspace method for performing field soil screening.

Collecting Soil Samples

1. Calibrate the FID per the manufacture's procedures.
2. Place latex gloves on hands for protection and to reduce cross-contamination.
3. Open the 5 foot core sampler and extract the two 2.5-foot clear liners and cap each end of the liner. Label the top and bottom of each liner with the associated depths and boring ID.
4. Visually and physically characterize the soil core by collecting small samples from each end of the liner remembering to only remove the end caps briefly. Determine if any abrupt changes in soil lithology exists (i.e. sand to clay, gravelly sand to sandy clay).
5. If no change in soil lithology exists, the headspace sample should be collected (skip to #11) where the two liners connect (center point of the 5-foot interval).

   If one or more lithological changes occur, then proceed to #6.
6. Mark the outside of the liner with a permanent pen were the change occurs.
7. Label the sample bags with the appropriate sample ID.
8. Cut the liner approximately 4 inches above the marked soil change and separate the two sections of the liner. (The area of concern is the higher permeability soil immediately above the lower permeability layer.)
9. Immediately place a cap on the cut end of liner section containing the area of concern and the soil change. (This section of the liner could be sampled later for laboratory analysis.)
10. Use the end of the other section that was cut to collect soil for headspace readings.
11. Quickly fill 2 quart sized sealable plastic bags at least 1/2 full with soil using a stainless steel sampling spoon.

742.154

12. Immediately seal the bags.
13. * For liners that contain soil lithology changes* Label the liner that contains the area of concern with the appropriate ID.
14. Repeat steps #6 through #11 for each lithological change. For areas where multiple low permeability layers are concentrated, only the soil above the upper layer will be considered important.
15. Place the liners out of the sun and protected from the environment.
16. Allow the soil in the bags to reach room temperature or warmer [20°C (68°F) to 32°C (90°F)].
17. While the FID organic vapor analyzer is running, insert the OVA/FID probe through the side of the first bag after the temperature has equilibrated (typically after 5 minutes).
18. Record the highest reading on the gauge; this is the unfiltered concentration. If the unfiltered measurement is non-detect, do not proceed to line 9. Record the reading in the logbook as the total hydrocarbon measurement for that sample.
19. Attach an activated charcoal filter onto the OVA/FID .
20. While the FID organic vapor analyzer is running, insert the OVA/FID probe with the attached charcoal filter through the side of the second bag.
21. Record the highest reading on the gauge; this is the filtered concentration.
22. Subtract the filtered reading from the unfiltered reading for the total corrected hydrocarbon measurement.

Attachment II.
Standard Operating Procedure for Collecting Soil Samples for Volatile Organic Compounds (VOCs)

TO:	U.S. Army Engineering and Support Center, Huntsville
COPIES:	Memphis Depot Caretaker (MDC)
	U.S. Environmental Protection Agency (EPA), Region 4
	Tennessee Department of Environment and Conservation (TDEC)
FROM:	CH2M HILL
DATE:	August 16, 2001

Standard Operating Procedure

This memorandum describes the use of pre-weighed VOC vials for collection of discrete sample aliquot to be analyzed for VOCs using EPA SW-846 Method 5035. Importantly, using this method, two vials must be prepared for each sample submitted.

Collecting Soil Samples

1. Place nitrile gloves on hands for protection and to prevent cross-contamination.
2. Open the package containing the pre-cut syringe sample-collection device.
3. Open the vial that will be receiving the soil.
4. Retract the plunger of the cut-off syringe to between 5 or 6; mark on the syringe tube.
5. Insert the syringe into the soil.
6. Remove the syringe and the "slug" of soil into a pre-weighed vial. Replace the cap on the vial.
7. Label the vial with the sample ID and date sampled.
8. Repeat the steps above for the second sample vial.
9. Make sure that the preservative in the vial mixes with the slug of soil by shaking, if necessary.
10. Place vials into cooler with wet ice for shipment.

TECHNICAL MEMORANDUM **CH2MHILL**

Standard Operating Procedure for Collecting Soil Samples for Volatile Organic Compounds

TO:	U.S. Army Engineering and Support Center, Huntsville
COPIES:	Memphis Depot Caretaker (MDC) U.S. Environmental Protection Agency (USEPA), Region 4 Tennessee Department of Environment and Conservation (TDEC)
FROM:	CH2M HILL
DATE.	May 5, 2000

Standard Operating Procedure

This memorandum describes the use of an EnCore sampler to collect a discrete sample aliquot to be analyzed for volatile organic compounds (VOCs). The confirmation samples will be analyzed for TCL volatile organics by SW-846 Method 8260B.

Collecting Soil Samples

1. Place latex gloves on hands for protection and to reduce cross-contamination.
2. Open the EnCore reusable package and remove the core device and cap.
3. Twist the piston on the EnCore sampler, so that the piston is unlocked and can move freely.
4. Place the core device into the T-handle.
5. Open the soil-core sampler (e.g , split spoon) containing the soil core.
6. Using a stainless steel spoon, scrape off the initial soil touching the soil-core sampler.
7. Push the EnCore core device into the soil core.
8. Twist the T-handle, and pull the encore sample free of the soil. The sampler should now be full of soil. If not, repeat this step until the encore is full of soil.
9. Remove excess soil from the sides of the sampler, and place the cap onto the sampler. (Make sure both sides of the cap lock into place)
10. Twist the piston 90 degrees, so that it is locked.
11. Label and reseal in the original package.
12. Place into cooler with wet ice for shipment.

Standard Operating Procedure for QED® Bladder Pumps

PREPARED FOR: Steve Offner/ATL

PREPARED BY. Johannah Rogers

DATE: March 10, 2000

Advantages for using bladder pumps from the MicroPurge® Website on Well Wizard® Bladder Pumps.

1. Low-flow groundwater monitoring system with rates as low as 100 mL/minute or less, does not increase turbidity, and does not alter samples.
2. EPA accepted for low-flow sampling.
3. Pneumatic bladder pumps operate with a timed on/off cycle of compressed air alternately squeezing the flexible bladder to displace water out of the pump and release it to allow the pump to refill by submergence.
4. The bladder prevents contact between the pump drive air and the sample.

Standard Operating Procedure

This memorandum describes techniques used for low-flow purging and intrinsic sampling of groundwater monitoring wells. Low-flow purging techniques are used to reduce purge volumes and sampling time. It also allows for the collection of more representative field parameters (for example, dissolved oxygen and redox potential).

Low-flow purging techniques have the following advantages:

- Avoids lowering the water table and sampling static water in well (pulls in formation water),
- reduces sample aeration, and
- reduces groundwater turbidity (important in the collection of total metals samples).

Purging Procedure

1. Measure depth to groundwater.
2. Measure total depth of well.
3. Calculate purge volume.
4. Place pump intake approximately in the center of the screen interval that is submerged for wells screened across the water table. In fully submerged wells, place pump intake

approximately 1 foot below the top of screen. Rather than lowering the pump to the bottom of the well and pulling it up to the desired level, the pump should be slowly and carefully lowered to the target screen zone (measure pump tubing as it is lowered). This will prevent siltation of the groundwater.

5. Start the air compressor engine. If a gasoline powered compressor is used, place as far from the well as possible, in the down wind direction.
6. Connect the appropriate hoses for the air supply.
7. Set the length of the on/off cycle for pressurizing and venting. This will control the length of time that the pump discharges and refills the bladder. The length of the cycle is dependent on the rate of recharge of the well. It should be adjusted to prevent drawdown of the well. Consult the pump manual for recommendations on cycle times.
8. Increase the pressure on the air compressor.
9. Install a water level indicator above the pump to monitor drawdown during purging.
10. Purge wells slowly, at a rate that does not lower that water table significantly (less than 10% of the screen length). Well Wizard® Bladder Pumps can be run at rates less than 100mL/minute or less. The purging rate should be carefully controlled and can be measured using a graduated bucket. A minimum of three well volumes should be purged prior to sampling.
11. Consult the pump manual for detailed instructions and recommendations.

Stabilization Criteria

1. Measure field parameters (pH, conductivity, dissolved oxygen (DO), oxidation-reduction potential (redox), turbidity [visual or turbidimeter], and temperature) using a calibrated YSI 600XL (or equivalent) and a flow cell. Record parameters every quarter well volume. The depth to groundwater should also be recorded on the purging form to monitor the water table drawdown.
2. Purge monitoring wells until field parameters have stabilized to within the ranges presented below. Purging with the QED® Well Wizard® Bladder Pump should produce representative formation water without increasing turbidity or altering the parameters.
3. Typically, dissolved oxygen will be elevated at the start of purging (for example, 7 mg/L), and should decrease as pumping proceeds. Contaminated wells typically have a low DO (less than 1 mg/L) and a negative redox. If the DO begins to rise during purging, it is an indication that artificial aeration is occurring and the pumping rate should be reduced.
4. If the water table begins to drop more than 1 foot, adjust the length of the on/off cycle. If a well is purged dry, purging will be considered complete. A replacement well should be selected for intrinsic sampling adjacent to the original well in the same zone of contamination (clean upgradient, in contaminated plume, or downgradient).
5. Position the pump lower (approximately 2 to 3 feet) in wells that have historically low recharge rates. Slowing the pumping rate down to match the recharge rate may help avoid pumping a well dry.

Field Parameter/General Order of Stabilization:	Stabilization Criteria:
1. pH	± 0.1
2 Temperature	± 10%
3. Conductivity	± 3%
4. Redox potential	± 10 mV
5. DO and turbidity	± 10%

Sample Collection

1. Collect groundwater samples following stabilization directly out of the pump discharge.
2. Sample collection order is based on the approximate order of susceptibility to artificial aeration and should be consistent between all wells sampled: volatile organics (benzene, toluene, ethylbenzene, and xylenes [BTEX] and trimethyl benzene [TMB]), carbon dioxide [CO_2], total organic carbon (TOC), methane [CH_4], sulfide [SO_3], alkalinity, sulfate [SO_4], nitrate [NO_3], extractable lead [Pb], and ferrous iron (filtered). Note that nitrate has a 48 hour holding time.
3. Use an in-line filter to field filter dissolved metals (ferrous iron). If total metals (extractable lead) samples are turbid (silty), delay sample collection for approximately 3 to 4 hours, at which time a bailer can carefully be lowered into the uppermost portion of the water column (in wells screened across the water table) to collect the sample.

TECHNICAL MEMORANDUM **CH2MHILL**

Standard Operating Procedure for Sudan IV Dye Testing

TO: U.S. Army Engineering and Support Center, Huntsville

COPIES: Memphis Depot Caretaker (MDC)
U S. Environmental Protection Agency (USEPA), Region 4
Tennessee Department of Environment and Conservation (TDEC)

FROM. CH2M HILL

DATE: May 5, 2000

Standard Operating Procedure

This memorandum describes the use of Sudan IV dye as a preliminary screening technique used for detecting the presence of DNAPL in groundwater and soil samples. Sudan IV is a hydrophobic dye which turns bright red in the presence of DNAPL.

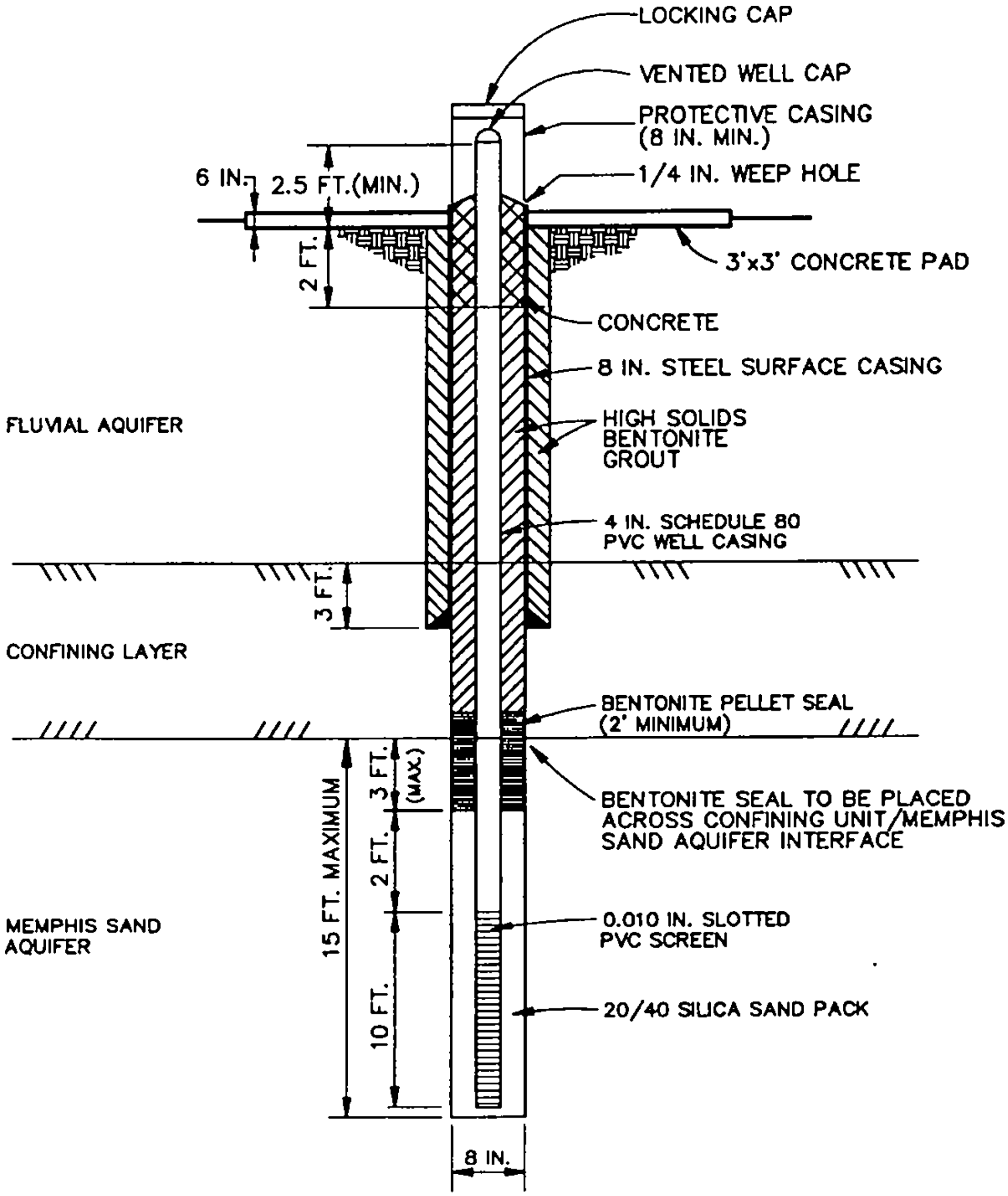
Testing Soil Samples

1. Collect soil samples from the soil core extracted by the sampler.
2. Place an aliquot of soil from the area(s) exhibiting the highest PID reading(s) into a 4 ounce glass or plastic jar or other appropriate receptacle.
3. Fill approximately one-half of the container with the sampled soil.
4. Manually disperse the soil in the jar to minimize clumping.
5. Fill the remaining volume of the container with distilled water.
6. Add a very small amount (2 to 4 milligrams – an amount that would rest on the edge of a toothpick) of Sudan IV dye (in powder form) to the container using extra care not to expose the dye to any parts of the body. [*Sudan IV is an irritant and possible mutagen with which skin or eye contact should be avoided. Gloves should always be worn when handling the Sudan IV dye.*]
7. After the dye has been added, seal the container and shake the soil/distilled water/dye mixture for approximately 30 seconds.
8. Note the presence or absence of bright red staining indicative of DNAPL in the logbook. Is there a presence of bright red staining? If yes, this indicates the presence of DNAPL in the sample.

Testing Groundwater Samples

1. DO NOT purge monitoring well prior to sample collection.
2. Collect groundwater samples from the bottom of each monitoring well using a bottom filling, 3 foot disposable Teflon bailer.

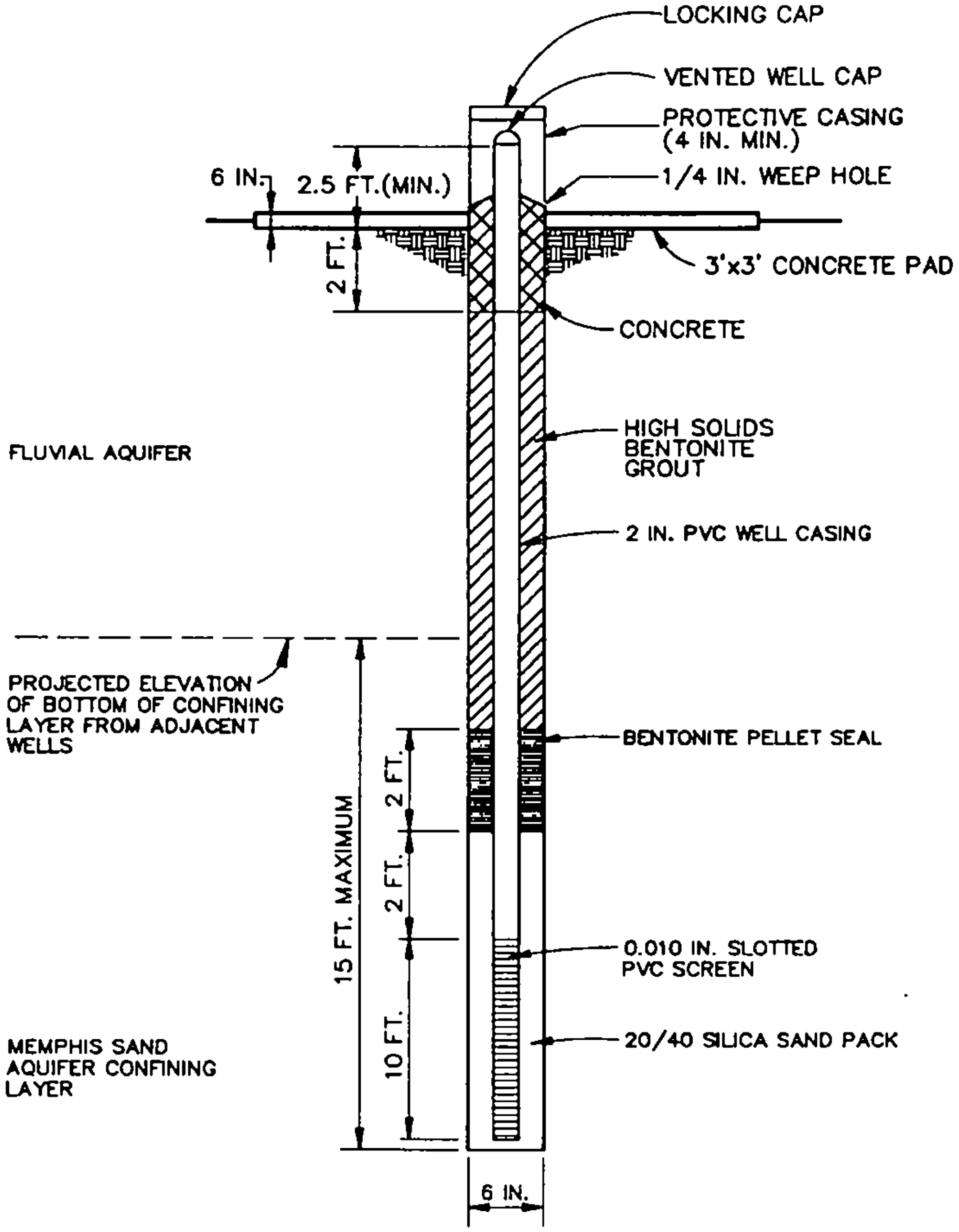
3. Pour an aliquot of the liquid from the bottom of the bailer into a 4 ounce glass jar or other appropriate receptacle.
4. Add a very small amount (2 to 4 milligrams – an amount that would rest on the edge of a toothpick) of Sudan IV dye (in powder form) to the container using extra care not to expose the dye to any parts of the body. [*Sudan IV is an irritant and possible mutagen with which skin or eye contact should be avoided. Gloves should always be worn when handling the Sudan IV dye.*]
5. After the dye has been added, seal the container and shake the groundwater/dye mixture for approximately 30 seconds.
6. Note the presence or absence of bright red staining indicative of DNAPL in the logbook. Is there a presence of bright red staining? If yes, this indicates the presence of DNAPL in the sample.



NOTE:
3-2" DIAMETER GUARD POSTS ARE REQUIRED (EQUAL SPACINGS) AROUND PROTECTIVE CASING. EXTEND POSTS 3'-6" ABOVE TOP OF PAD. SEE FIGURE 5-2 FOR FLUSHMOUNT INSTALLATION.

FIGURE 5-4
MEMPHIS SAND AQUIFER MONITORING WELL WITH CONFINING UNIT
Defense Depot Memphis, Tennessee

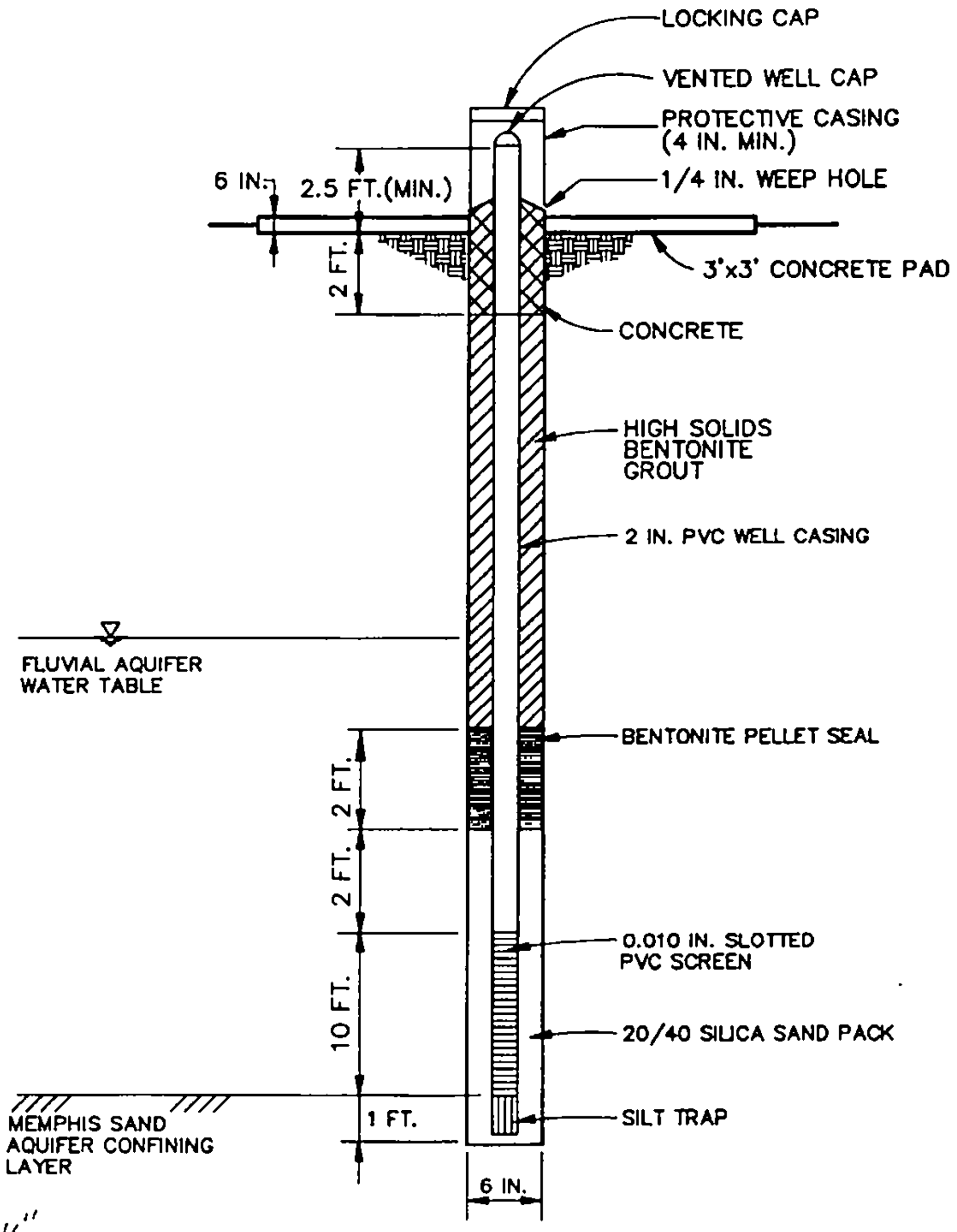
CH2M HILL



NOTE:
3-2" DIAMETER GUARD POSTS ARE REQUIRED (EQUAL SPACINGS) AROUND PROTECTIVE CASING. EXTEND POSTS 3'-6" ABOVE TOP OF PAD. SEE FIGURE 5-2 FOR FLUSHMOUNT INSTALLATION.

FIGURE 5-3
MEMPHIS SAND AQUIFER MONITORING WELL
WITHOUT CONFINING UNIT
Defense Depot Memphis, Tennessee

742 164



NOTE:
4 ~~3-2"~~ 4" DIAMETER GUARD POSTS ARE REQUIRED (EQUAL SPACINGS) AROUND PROTECTIVE CASING. EXTEND POSTS 3'-6" ABOVE TOP OF PAD.

FIGURE 5-1
TYPICAL STICKUP MONITORING WELL
Defense Depot Memphis, Tennessee

CH2M HILL

110479 QP

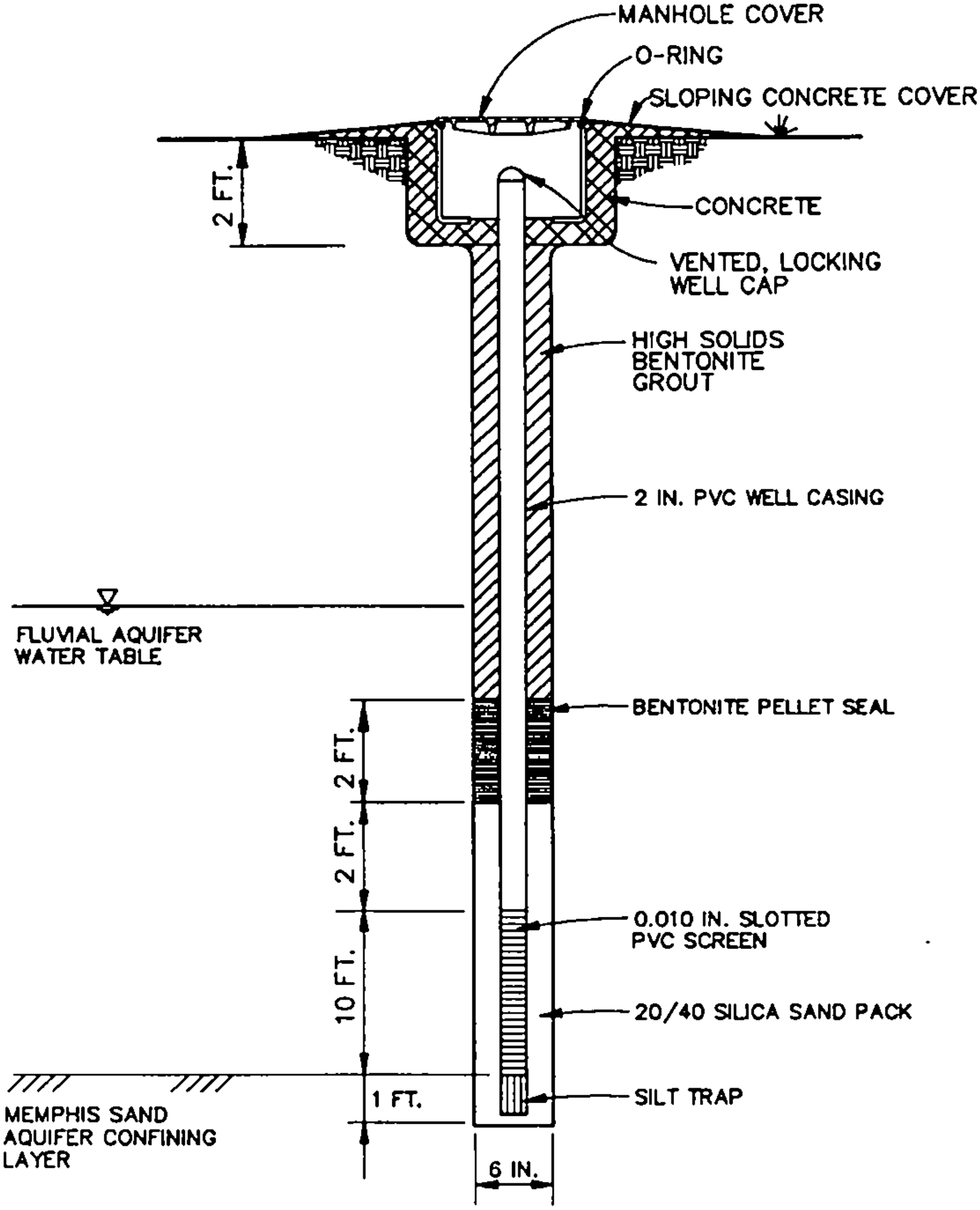


FIGURE 5-2
TYPICAL FLUSHMOUNT MONITORING WELL
Defense Depot Memphis, Tennessee

CH2M HILL

MQP-0001.DWG 9-6-95

742 166

Generic
Quality Assurance
Project Plan

for

Defense Distribution Depot Memphis

Prepared for

Huntsville Division Corps of Engineers
Huntsville, Alabama

Prepared by

CH2M HILL
2567 Fairlane Drive
Montgomery, Alabama 36116

110479.QP

9/7/95

Executive Summary

Introduction

In October 1992, the Defense Depot Memphis, Tennessee (DDMT), was placed on the National Priorities List (NPL) by the U.S. Environmental Protection Agency (EPA). Therefore, DDMT must fulfill requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and National Contingency Plan. A remedial investigation/feasibility study (RI/FS) must be prepared to determine the nature and extent of contamination, to evaluate the risk to human health and the environment, and to screen potential cleanup actions. The *Generic RI/FS Work Plan* was prepared to show how the investigation and study would be accomplished. This *Quality Assurance Project Plan* (QAPP) was prepared as a supplement to the *Generic RI/FS Work Plan* to describe the general sampling, laboratory, monitoring well installation, soil boring installation, and quality assurance/quality control (QA/QC) procedures that will be used during the RI/FS at DDMT.

Site Background and Location

DDMT covers 642 acres of land in Memphis, Shelby County, Tennessee, in the extreme southwestern portion of the state. The installation contains approximately 110 buildings, 26 miles of railroad track, and 28 miles of paved streets. Approximately 5.5 million square feet of storage space is open. Stored items include food, clothing, electronic equipment, petroleum products, construction materials, and industrial, medical, and general supplies.

Description of Operable Units (OUs)

DDMT is divided into four OUs for evaluation purposes. Dunn Field is designated OU-1. The Main Installation is divided into three areas: the southwestern quadrant, OU-2; the southeastern lakes and golf course area, OU-3; and the north-central area, OU-4. Substances found in OU-1 probably resulted from use of the area for landfill operations, mineral stockpiles, pistol range use, and pesticides storage. Potential contamination of OU-2 could have resulted from spills or releases from the hazardous material storage and repouring area, sandblasting and painting activities, or both. Storage of polychlorinated biphenyls (PCBs) and the use of pesticides and herbicides are potential sources of contamination for OU-3. Principal contamination in OU-4 probably resulted from a wood treatment operation and hazardous material storage.

Description of QAPP

This QAPP was prepared as a supplement to the *Generic RI/FS Work Plan* to provide quality assurance and quality control requirements for sampling activities, and other types of field analyses and tests that generate data as part of the activities performed during the RI/FS process at DDMT. The goal of this plan is to provide data of known quality to the project team to support the project decision-making process. The requirements of this plan apply to the primary contractor, as well as to subcontractors.

This plan addresses the following:

- QA/QC objectives for the project
- Discussion of the QC levels and applicability of each
- Specific QA/QC procedures that will be implemented to achieve these objectives
- Project team organization and responsibility

The contractor's internal QA programs will control other project aspects, such as engineering analysis and report preparation. Laboratory activities (either onsite or fixed-base analytical laboratories) will be covered by the Laboratory Comprehensive Quality Assurance Manual.

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Acronyms

ASTM	American Society for Testing and Materials
bgs	Below ground surface
BRA	Baseline risk assessment
CEHND	Corps of Engineers, Huntsville Division
CEMRD	Corps of Engineers Missouri River Division
CEWES	Corps of Engineers Waterways Experiment Station
CFR	*Code of Federal Regulations*
CLP	Contract Laboratory Program
COC	Chain-of-Custody
COE	Corps of Engineers
CompQAM	Comprehensive Quality Assurance Manual
CPR	Cardiopulmonary resuscitation
CSL	Close support laboratory
DDIS	Detailed Data Inventory Sheet
DDMT	Defense Depot Memphis, Tennessee
DE	Disposable equipment
DOT	Department of Transportation
DQE	Data quality evaluation
DQO	Data quality objective
DRMO	Defense Reutilization and Marketing Office
E-Data	Electronic data
EMIS	Environmental Management Information System
EPA	U.S. Environmental Protection Agency
FID	Flame ionizing detection
FSP	Field Sampling Plan
FTL	Field team leader
GC	Gas chromatograph
GC/MS	Gas chromatograph/mass spectrometer
HSA	Hollow stem auger
HASP	Health and Safety Plan
HW	Hazardous waste
ID	Inside diameter
IFF	Interchange File Format
MLGW	Memphis Light, Gas, and Water
MR	Mud rotary
MS/MSD	Matrix spike/matrix spike duplicate
MW	Monitoring well
NCP	National Contingency Plan
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NSF	National Sanitation Foundation
OSHA	Occupational Safety and Health Administration
OU	Operable unit

Acronyms (cont'd)

OVA/PID	Organic vapor analyzer/photoionization detector
PAH	Polycyclic aromatic hydrocarbon
PARCC	Precision, accuracy, representativeness, completeness, and comparability
PCB	Polychlorinated biphenyl
PCP	Pentachlorophenol
PM	Project Manager
PPE	Personal protective equipment
ppm	Parts per million
psi	Pounds per square inch
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RD	Rotasonic drilling
RFA	RCRA Facility Assessment
RI/FS	Remedial investigation/feasibility study
RPD	Relative percent difference
RTL	Review team leader
SDG	Sample delivery group
SOP	Standard operating procedure
SOW	Statement of Work
SSC	Site safety coordinator
STB	Stratigraphic test boring
STP	Sample Tracking Program
SVOC	Semivolatile organic compound
TAL	Target analyte list
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TCL	Target compound list
TCLP	Toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TIC	Tentatively identified compounds
VOC	Volatile organic compound
WR	Water rotary

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1.0 Objectives of the Quality Assurance Project Plan

The purpose of this Defense Depot Memphis, Tennessee (DDMT) Generic Quality Assurance Project Plan (QAPP) is to describe the general sampling, laboratory, monitoring well installation, soil boring installation, and quality assurance/quality control (QA/QC) procedures that will be used during the Remedial Investigation/Feasibility Study (RI/FS) at DDMT. The procedures have been developed for the chemical data collection activities to provide data of sufficient quality and quantity to support the objectives of the RI/FS, and to provide careful planning of data collection and analysis activities to meet the stated data quality objectives that are consistent with the intended data uses.

The QAPP has been written in accordance with the current RI/FS guidance (ref. 21), the *Data Quality Objectives for Remedial Response Activities* (ref. 26), the *Guidelines and Specifications for Preparing Quality Assurance Plans* (ref. 27), and *EPA Region IV, Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM)* (ref. 31) to address aspects of the field investigations to be conducted as a part of the site characterization activities that are common to all operable units (OUs) at DDMT. References used for QAPP development are provided as Appendix A.

1.1 Project Objectives

The overall objectives of the RI/FS are to determine the nature and extent of the release of hazardous substances to the underlying aquifer system as a result of past disposal activities at DDMT, to identify the sources of release, and to evaluate the effectiveness of proposed remedies. The ultimate goal is to select cost-effective and implementable remedies that mitigate threats and provide protection for public health and the environment. During the RI, the data and data collection processes will be evaluated to monitor the support of the RI/FS objectives. That is, the data must be of sufficient quality and quantity that the distribution and migration of contaminants can be determined to satisfy the objectives of the RI. The data and conclusions drawn during the RI must support the screening and in-depth analyses of the remedial alternatives to be evaluated during the FS. To accomplish these tasks, confidence in field sampling procedures; data collection, analysis, management, and validation procedures; and QA activities are vitally important. Because these items are so important to the remedial decision-making process, a carefully considered approach to detailed QA procedures is necessary for success.

To characterize the sites and potential releases, DDMT will implement an extensive field sampling effort to identify and delineate the contaminants (in the groundwater, soil, surface water, and sediments) that may have resulted from past practices at sites where hazardous or toxic wastes were managed or disposed. A laboratory that has been validated by the Corps of Engineers' Missouri River Division (CEMRD) and that is a

Program (CLP) will be selected to perform the required chemical analyses. Split samples will be routinely provided to the CEMRD to comply with Corps of Engineers (COE) quality-control requirements and to the EPA- and Tennessee Department of Environment and Conservation (TDEC)-designated laboratories to meet EPA's requirements.

1.2 Objectives of Site Investigation Activities

The primary objective of this RI is to characterize the nature and extent of contaminants in soil, surface water, sediment, and groundwater. Additional data will be collected to supplement the previous RI/FS completed in 1990 by Law Environmental Inc., to evaluate the extent of groundwater contamination in the Fluvial Aquifer and to assess the potential for contaminant migration to the Memphis Sands Aquifer. This investigation will provide additional information for the baseline risk assessment (BRA) and the selection of appropriate remedial alternatives. Other general objectives of the RI include the following:

- Understand site geology and hydrogeology sufficiently to evaluate groundwater movement and to identify potentially affected aquifers.
- Collect a sufficient number of samples from areas surrounding the site unaffected by earlier activities to adequately evaluate background concentrations of target analytes.
- Collect samples that are representative of actual site conditions.
- Provide data of known quality by using approved sampling and analytical methods.

Specific site investigation details, along with sampling and analysis objectives, are discussed in the Field Sampling Plans (FSPs) for the OU in which the site is located.

1.3 Site Characterization Activities

Field investigations will be conducted under the guidance of this QAPP, the Health and Safety Plan (HASP), and the OU-specific FSPs, as well as any addendum that may be required for these plans. Proposed sample locations are identified in the FSPs and in site maps prepared for the particular OU to be investigated. Data management, field

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sampling, and field and laboratory QA/QC activities will be conducted in accordance with the procedures outlined in the QAPP. The following field activities will be conducted:

- Install monitoring wells and soil borings.
- Collect and analyze soil, groundwater, surface water, sediment samples, and the appropriate QA/QC samples.

2.0 Project Organization and Responsibilities

2.1 Project Team Organization

The project team will be organized into contractor, COE, and offsite laboratory work groups. The contractor's group will consist of a project manager, a project hydrogeologist, a project environmental engineer, a project chemist, a review team leader, a database manager, and various support staff. The COE's group will consist of a project manager, a project engineer, a project geologist, a project industrial hygienist, a project environmental engineer, and a project chemist, who will develop work plans and scopes of work, oversee field performance, and review technical documents. The contractor group at the field site will consist of the field team leader (FTL), who will be onsite for all phases of the project; the field geologists; the safety officer and sampling team; and various support technicians. The laboratory work groups include the technical staff and QA/QC personnel at the laboratories. Additional project organization information will be provided upon selection of a contractor.

2.2 Key Personnel Qualifications and Responsibilities

2.2.1 Contractor Work Group

The personnel selected for the RI/FS will have the necessary qualifications to complete this complex project. Additional information will be provided later concerning specific qualifications.

In full compliance with the training requirements of Occupational Safety and Health Administration (OSHA) regulations (29 *Code of Federal Regulations* [CFR] 1910.120), all field personnel have received at least 40 hours of health and safety training, including first aid and cardiopulmonary resuscitation (CPR), and a minimum of 3 days actual field experience under the direct supervision of a trained experienced supervisor. The personnel positions and responsibilities listed below will be involved in the RI/FS.

Program Manager—The program manager is a senior level management person who coordinates all the project efforts for DDMT. As the direct contact between the COE and other program and project staff, the program manager will be responsible for negotiating and communicating contractual obligations, including program objectives, technical requirements, schedules, budgets, and deliverables. The program manager will coordinate all administrative and financial reporting, provide the COE with progress and financial reports, review all deliverables, and provide day-to-day coordinating with the COE.

Project manager (PM)—Responsible for overall activities for a specific project. The PM is responsible for cost and schedule control and for technical quality; in addition, he or she will develop the work plan and monitor task order activities to ensure compliance with project objectives and scope. The PM also will communicate with the client and, as appropriate, other designated parties regarding project progress.

The PM has ultimate responsibility within CH2M HILL for producing deliverables that are technically adequate, satisfactory to the client, and cost-effective. To accomplish this, the PM assists the review team leader (RTL) in developing an internal project review schedule, provides written instructions and frequent guidance to the project team, and monitors budgets and schedules.

Review Team Leader—The RTL is generally a technical resource with experience in the various technical aspects involved in a complex project. The RTL coordinates internal QA/QC review for technical validity and adherence to both internal CH2M HILL policy and project-specific criteria. The RTL assists the PM in selecting an internal QA/QC review team and in coordinating review efforts, and works with the project team in addressing review comments and adjudicating technical disagreements.

Lead Hydrogeologist—This person is a technical specialist who is responsible for the technical aspects of the project concerning hydrogeology and who provides technical review and continuity of work between project tasks. His/her role includes selection of methodology, field procedures, and review of data analysis and reporting. He/she will be present at major meetings on decision points. The lead hydrogeologist will work closely with the lead engineer to develop and implement a field program that addresses the project objectives and provides technically sound data.

Lead Chemist—The lead chemist assists with the preparation of the project scoping documents, provides an interface between the laboratory and the project team, supervises the analytical data quality evaluation, and participates in preparing deliverables to the client. The lead chemist communicates regularly with the project team and the analytical laboratory during the field activities. The lead chemist also is responsible for monitoring project-specific laboratory activities (including checking laboratory invoices and reports) and may audit the laboratory at the PM's direction.

The lead chemist monitors so that specific QA and primary technical operations are coordinated effectively for the project. The lead chemist is responsible for the following:

- Performance and system audits of laboratory operations to evaluate compliance with the QAPP
- System audits of field operations to evaluate compliance with the QAPP
- Provision of guidance and coordination to rapidly resolve any QA/QC problems

- Independent review of QA/QC information to evaluate the quality of all deliverables or outputs from the project team
- Interaction and communication with COE QA personnel to resolve QA/QC problems specific to the project

Lead Risk Assessor—The lead risk assessor provides guidance and input into the RI/FS planning implementation stages, and directs the human health and ecological risk assessments for the project.

Remedial Design Engineer—The remedial design engineer will evaluate the data collected from the RI and direct sampling to be conducted for the FS activities. The remedial design engineer also will conduct a cost-benefit analyses and other FS activities to aid in evaluating remedial alternatives for the contaminated sites at the facility.

Lead Data Manager—Responsible for the structure, organization, format, implementation, and operation of the project database. The lead data manager supervises the data management team and provides direction to the database manager. The lead data manager, in conjunction with the PM, may decide to establish separate databases for each project task. The lead data manager is responsible for the following:

- Coordinating efforts between the project team and the database, including setting up the sample tracking program and providing instruction to field team members in its operation.
- Importing the analytical data into the project database.
- Doing a QC review of the data input into the database.
- Assisting project team members in using the database.
- Preparing the electronic deliverables to the client.

Database Manager—Works with the database on a daily basis and provides normal deliverables (for example, data summary tables) to the project team.

Field Team Leader (FTL)—Reports to the PM and will be responsible for the coordination of field efforts, provides for the availability and maintenance of sampling equipment and materials, and provides shipping and packing materials. The FTL will supervise completion of all chain-of-custody records, supervise the proper handling and shipping of samples, and be responsible for accurate completion of the field notebook. As the lead field representative, the FTL will be responsible for consistently implementing program QA/QC measures at the site and for performing field activities in accordance with approved work plans, policies, and field procedures.

Site Safety Coordinator (SSC)—The SSC oversees the administration of the project HASPs in the field. The SSC will assist in conducting site briefings and perform all final

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safety checks. The SSC is responsible for stopping any investigation-related operation that threatens the health and safety of the field team or surrounding populace. Additional responsibilities are detailed in the HASP.

2.2.2 Laboratory Work Group

The selected laboratories will be responsible for screening and analysis of groundwater, soil, sediment, and surface water samples obtained during RI activities.

The chemical analysis supervisor serves as a liaison between field and laboratory operations and is responsible for the following:

- Receipt of sample custody from the field team members, verification of sample integrity, and transfer of sample fractions to the appropriate analytical departments
- Coordination of sample analyses to meet project objectives
- Preparation of analytical reports
- Review of laboratory data for compliance with method requirements
- Review of any QC deficiencies reported by the analytical department manager
- Coordination of any data changes resulting from review by the project QA supervisor or the PM
- Response to questions from the project team during the data quality evaluation process

2.3 Project Communication

One of the most critical elements in performing the RI/FS is to establish and maintain lines of communication among all project personnel. Some work groups will meet at least weekly to review the status of the project and to discuss technical and safety issues. When necessary, other meetings will be scheduled or the FTL will meet individually with field personnel or the subcontractors to resolve problems. The FTL will prepare a weekly report detailing project progress.

The FTL will be in regular telephone contact with the all work groups. When significant problems or decisions requiring additional authority occur, the FTL can immediately contact the PM or project hydrogeologist for assistance.

Daily and weekly reports, boring logs, QA reports, and other project information will be delivered by the field supervisor or other personnel on a daily basis or several times during the week.

All communications with DDMT will be channeled through the DDMT project manager, who will be informed of field activities being conducted on a daily basis.

All communications with the COE will be channeled through the Corps of Engineers, Huntsville Division (CEHND) project manager. The contractor will prepare monthly progress reports and submit telephone conversation records to the COE throughout the contract period.

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3.0 Data Quality and Quality Assurance Objectives for Sampling

3.1 Introduction

This section presents the data quality objectives (DQOs) and QA objectives for the RI/FS sampling activities. DQOs are quantitative and qualitative statements that specify the quality of the data required to support decisions during the remedial response activities. They are based on the end uses of the data to be collected. The basis on which these objectives were established are discussed in the following sections. The criteria for evaluating data quality, precision, accuracy, representativeness, comparability, and completeness are presented in this section, along with the mechanisms that will be used to determine if they are met.

3.2 Establishing Data Quality Objectives

Objectives for data quality reflect the expected uses of the data, the expected levels of contamination, and the available analytical and sampling resources.

3.2.1 Data Uses

The primary uses of the data to be gathered during the DDMT RI sampling activities are as follows:

- Contaminant Characterization—Data will be used to describe the nature and extent of contaminants in the soil and groundwater at the site.
- Health and Safety—Air monitoring within the RI/FS work zones will be used to establish the level of protection needed for workers during the RI activities.
- Risk Assessment—Data will be used to evaluate the threat posed by the site to public health and the environment via the soil, groundwater, surface water, and air pathways.
- Evaluation of Alternatives—Soil chemistry and physical data will be collected and used to evaluate the feasibility of various remedial technologies.
- Engineering Design of Alternatives—Data such as preliminary volume estimates for contaminated soil and groundwater will be used for engineering design purposes and to determine the cost and performance of various remedial technologies.

3.2.2 Data Quality Levels

Data must be of sufficient quality to support the decision-making process. A tiered approach to sampling and analysis (including screening) will be used so that the field team can adjust the sampling effort to accommodate site-specific conditions. The tiered approach will be accomplished by screening a large number of samples for potential contamination using Level 2 data quality; then a selected number of samples will be submitted to an analytical laboratory for confirmation. Screening data will be used to provide sufficient sampling to evaluate the potential presence of target compounds at each site and to accomplish quantitation.

Four categories of data will be collected as part of this field effort, with each category having a different level of supporting QA/QC documentation. The four categories, or levels, correspond to QC levels 1, 2, 3, and 4. Level 1 includes field monitoring activities such as pH, temperature, conductivity, and total organic vapor monitoring. Level 2 screening activities and Level 3 analysis provide confirmation by an analytical laboratory. Level 4 analysis provides legally defensible data, if needed. For each QC level, the potential measures and methods to be used, as well as the applicable data package deliverables, are outlined below. For each site, the use and applicability for each of the available measures and methods will be evaluated and appropriate measures and methods selected. For example, the pH and conductivity of groundwater samples from all the screening sites will be measured; however, only soil samples from selected sites will be tested for VOCs.

3.2.2.1 Level 1—Field Surveys

Level 1 encompasses field monitoring activities and does not require formal data package deliverables. Level 1 activities are focused on easily measured bulk characteristics of a sample such as total organic vapors, or pH, temperature, and conductivity. Level 1 activities also include screening samples using immunoassay field methods for classes of compounds such as polycyclic aromatic hydrocarbons (PAHs) or polychlorinated biphenyl (PCBs) in soils.

CH2M HILL typically uses the data generated from field monitoring to make decisions about the execution of the investigation, such as approximating the relative degree and extent of contamination to assist the investigation activities, or providing a general sample screening before analysis by the analytical laboratory.

Immunoassay screening provides a yes/no approach to screening: either the target compound(s) is present at, or above, the reporting limit or it is not. These tests will be used to identify potential sources of contamination and may be used to estimate approximate areas for vertical and horizontal extent of contamination. Immunoassay screening kits use an antibody that is developed to have a high degree of sensitivity to the target compounds. This antibody's high specificity is coupled with a sensitive colorimeteric reaction that provides a visual result. Immunoassay screening tests consist of four steps:

- **Sample Extraction**—An aliquot of soil is weighed and extracted with methanol.
- **Dilution of Sample and Standard**—The sample extract is diluted to the required detection level.
- **Immunoassay**—The sample and enzyme conjugate are introduced into antibody tubes and allowed to stand; then the tubes are washed, coloring agent is added, and the color is allowed to develop
- **Measurement and Interpretation**—The color of the sample is measured using the spectrophotometer and the sample results are compared to the standard results. This comparison provides an accurate semi-quantitative measurement of the specific contaminant of interest.

Immunoassay kits that will be used in the field for Level 1 screening include PCBs, PAHs, total petroleum fuel contamination, pentachlorophenol (PCP), and dioxins (2,3,7,8-Tetrachlorodibenzo-p-dioxin [TCDD]). Each of the immunoassay kits is described briefly below:

- **PCBs**—Recognizes all commercial Aroclors; the more highly chlorinated and most common (1260, 1254, and 1248) are detected at lower concentrations, as summarized in Table 3-1.

Table 3-1
Detection Limits for Aroclors in Soil
Defense Depot Memphis, Tennessee

Aroclor	mg/kg in soil
1260	0.4
1254	0.4
1248	1.0
1242	2.0
1232	4.0
1016	4.0

- **Total Petroleum Fuel Contamination**—This immunoassay responds to a selected subset of the chemical components in fuels, primarily aromatic and aliphatic compounds with fewer than 15 carbons. Because this test responds to "petroleum products," it cannot be used to distinguish individual types or sources of fuel. Reporting limits for various fuels using this screening test are summarized in Table 3-2.

Table 3-2
Reporting Limits for Various Fuels Using the Total Petroleum Fuel Contamination Screening Test
Defense Depot Memphis, Tennessee

Fuel	Reporting limit in mg/kg
Gasoline	10
Diesel fuel, #2	15
Jet A fuel	15
Jet fuel, JP-4	15
Kerosene	15
Fuel oil, #2	15

- **PAHs**—This test is used to screen for 3- and 4-ring PAHs, which are indicative of petroleum contamination. The overall detection limit is 1 mg/kg.

- **PCP**—This test recognizes pentachlorophenol only and has a reporting limit of 0.5 mg/kg.

- **Dioxin**—This test is used to detect the presence of 2,3,7,8-TCDD only and has a reporting limit of 10 picograms/kg. The extraction for this screening test is more complex than the simple methanol extraction used for the other analyses; therefore, samples for dioxin screening will be sent to the analytical laboratory for extraction and screening.

Monitoring results, as well as pertinent data concerning the sampling event, are documented in a bound field book. Level 1 documentation will consist of the following:

- Instrument identification
- Calibration information (standards used and results)
- Date and time of calibration and sample measurement
- Sample results

The logbooks will be reviewed by the FTL daily for completeness and correctness. No additional documentation or data quality evaluation is required.

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3.2.2.2 *Level 2–Screening Data*

Level 2 screening data will be used by the project team to make informed decisions in the field concerning implementation and execution of the work plan, as well as to evaluate whether a release has occurred and to estimate the extent of contamination. Level 2 data differ from Level 1 data in that Level 1 is used to measure "bulk" characteristics of a sample, while Level 2 analyses are used to estimate the concentrations of selected individual compounds.

Level 2 data quality will be used on this project to collect cost-effective (lower cost than Level 3) quality data for use in decision making and in the risk assessment. The level 2 data quality will be evaluated as outlined in Section 8 and the sample results will be confirmed using Level 3 data.

EPA-approved methods will be used to analyze Level 2 samples. Level 2 data quality samples will be analyzed using the same analytical techniques as Level 3 data. The difference between Level 2 and Level 3 will be the frequency and target acceptance windows for laboratory QA/QC samples. The same QA/QC samples will be analyzed for Level 2 as Level 3; however, the QA/QC samples may be analyzed less frequently with broader acceptance limits than with Level 3. For example, for VOCs or SVOCs by GC/MS, for Level 2 an instrument tune check sample will be analyzed once every 24 hours rather than once every 12 hours as required for Level C. A comparison of the Level 2 and Level 3 QA/QC requirements is provided as Appendix B.

Formal data package deliverables are not required for this level of data quality; however, all instrument calibration and sample analysis activities must be documented and this information retained by the laboratory. Data package deliverables may require summaries of laboratory performance information (such as calibration), but the laboratory must maintain all the corresponding documentation for at least 7 years. Data package deliverables will include instrument calibration, sample, method blank results, and matrix spike results. Example data packages will be included in the subcontractor documentation.

Confirmation is critical for samples that are determined by field screening to contain concentrations near the action levels. Approximately 10 percent of the samples will be submitted to an analytical laboratory for additional Level 3 confirmatory testing.

3.2.2.3 *Level 3–Laboratory Analyses*

The purpose of Level 3 data is to provide the basis for evaluating Level 2 data and for making decisions for further action, if needed, at each of the areas of investigation and to broaden the characterization of contaminants. The TCL has been designed to fully evaluate the potential for contamination from past site activities and to support a preliminary risk evaluation. Only EPA-approved methods from *SW-846, Test Methods for Evaluating Solid Waste* or EPA CLP methods will be used to analyze samples for

Levels 3 or 4. Level 3 data package deliverables include all the CLP-type QC summary forms, but none of the unreduced experimental data, (summarized in Table 7-1). Therefore, during the data quality evaluation process, it is possible to evaluate the effect of the overall analytical process on the usability of the data; however, it is not possible to recreate the details of the analytical process or sample calculations.

TCLs and reporting limits for Levels 2 and 3 data quality are included in Section 7.

Many of the OU-specific FSPs refer to Level 3 analyses as "TAL/TCL." This is a common usage way of referring to the CLP SOWs lists for organic and inorganic compounds. For this project, "TCL/TAL" refers to VOCs, SVOCs, pesticides, PCBs, metals, and cyanide, but does not refer to dioxins. For TCL/TAL analyses, the CLP target compound lists and reporting limits will be used.

3.2.2.4 Level 4—Laboratory Analyses

Level 4 analytical methods are the same as Level 3; the difference between the levels is in the data package deliverables. Level 3 deliverables include only the QC summary information (typically provided on the CLP QC summary forms or functional equivalents). Level 4 deliverables include the summary forms and all the unreduced, experimental data. Therefore, it is possible for Level 4 data to completely recreate the entire analytical process and recalculate all of the calibration and sample results. For Level 3, this information is summarized on the data sheets and used to evaluate laboratory performance and potential matrix interferences.

There is a potential for Level 4 data to be required in the future at this facility. Samples analyzed using Level 4 QC are analyzed using the same analytical methods as Level 3 samples, but different data package deliverables are provided, as discussed in this section. Confirmatory samples will be analyzed using Level 3 QC, and no Level 4 is proposed at this time. However, if in the future Level 4 information becomes necessary, this information will be requested from the analytical laboratory.

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4.0 Field Sampling Procedures

4.1 General Sampling Requirements

The following general sampling requirements will be maintained:

- Prior notification of facility to obtain entry permits for personnel.
- Field sampling teams will consist of a minimum of two individuals. One person will collect the sample as the other monitors adherence to sampling procedures, records any difficulty encountered, and documents other information pertinent to the investigation.
- To the extent feasible during sampling episodes, sampling activities in each medium will be conducted so that the sampling order will be from the area of least contamination to the area of most contamination.
- The preferred order of sample collection will be specified in the OU-specific FSP.
- Sample collection for chemical analysis will be performed with either disposable sampling devices or decontaminated, stainless steel or Teflon® devices. When composite samples are required, the sample will be homogenized in stainless steel bowls. All sampling equipment will be decontaminated in accordance with the procedures outlined later in this plan.
- Samples collected for VOC analysis will not be homogenized.
- Precleaned sample containers will be provided by the analytical laboratory except for the stainless steel sleeves used for soil sampling, which will be decontaminated onsite. All sample container records will be maintained by the analytical laboratory and will be available upon request.
- A sample that is representative of the matrix being sampled will be collected.
- Sample integrity will be maintained from the time of sample collection to receipt by the laboratory.

All field notes will be recorded in indelible ink on standard forms in bound notebooks. A daily field log will be completed by the FTL. This log will be signed and dated daily. Significant events occurring during the day will be recorded and reported to the PM. Daily communication is essential to evaluate whether timely corrective actions are necessary. The field notebook(s) must provide a place for the field team members to sign and date the entries. The FTL must review all field notes.

4.2 Sample Blanks and Field Duplicates

The number of environmental and field QC samples to be collected are discussed in the OU-specific FSP. The three types of sample blanks–travel (trip) blanks, equipment (rinsate) blanks, and field blanks–along with field duplicates and split samples, are discussed below.

4.2.1 Trip Blanks

Trip blanks are to be analyzed for VOCs only, and consist of sample bottles filled in the laboratory with American Society for Testing and Materials (ASTM) Type II water; the sample bottles are then sent to the sampling location with sampling kits. The specified number of trip blanks are returned from the sampling location with every shipment of groundwater samples and analyzed for VOCs. One of these trip blanks will accompany split VOC samples to the COE QA laboratory.

4.2.2 Equipment Blanks

Rinsate blanks for the groundwater samples are processed by rinsing decontaminated sampling equipment with ASTM Type II water obtained from the laboratory. The rinse water is collected in sample bottles, preserved, and handled in the same manner as the samples. Split equipment blank samples of the rinsate will be sent to the COE QA laboratory. Equipment blanks will be collected once a day for the equipment used during sampling procedures.

4.2.3 Field Blanks

Field blanks are samples of source water used for decontamination and are used to monitor the potential for contamination from the source water. Field blanks will be collected once a week from each water source.

4.2.4 Field Duplicates

Field duplicate samples are collected to measure the precision of the sampling process. The FTL will choose at least 10 percent of the total number of sample locations previously known to contain moderate contamination, and will collect duplicate samples from these locations. The source information will be recorded in the field notes, but not on the chain-of-custody (COC) form prepared by the field team at the time of sample collection. The identity of the duplicates will not be given to the analysts. The source information will be forwarded to the QA reviewer to aid in the review and validation of

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the data. The source of the field duplicate for the QA samples will be clearly identified on the COC form sent to the QA laboratory.

4.2.5 Split Samples

Split samples are used to calculate the precision of the sampling and analytical processes by providing a measure of comparability between laboratories. Split samples will be submitted to the contractor's laboratory as QC samples and to the COE and EPA/TDEC Laboratories as QA samples. Split samples will be collected from 5 percent of the samples collected at DDMT for the purpose of a quality control check by the Corps of Engineers' laboratory in Missouri. Also, TDEC reserves the right to collect split samples and to analyze these samples by the State of Tennessee laboratory. The contact person at the COE laboratory will be notified at least 2 weeks in advance of the sampling event at (402) 444-4304. The samples will be sent to the following address:

COE Laboratory
Missouri River Division
420 South 18th Street
Omaha, Nebraska 68102

4.2.6 Matrix Spike/Matrix Spike Duplicate (MS/MSD)

MS/MSD samples will be collected and shipped to the laboratory for spike analyses. Five percent of the samples collected will be accompanied by spike samples. However, if a spike sample has not been collected in a 14-day time period, a spike sample will be collected and sent for analyses.

4.2.7 Other Sample Blanks

Samples of the bentonite, sand, and mud used in the drilling process will be collected and retained for future analysis, if necessary.

4.3 Field Documentation

Bound field log books will be maintained by the FTL and other team members to provide a daily record of significant events, observations, and measurements during sampling events. All entries will be signed and dated. All information pertinent to sampling will be recorded in bound log books. Entries in the log book must include at least the following:

- Name and title of author, date and time of entry, and weather/ environmental conditions during field activity
- Location of sampling activity

- Name and title of field crew
- Name and title of any site visitors
- Sample media (for example, groundwater)
- Sample collection method
- Number and volume of sample(s) taken
- Date and time of collection
- Sample identification number(s)
- Sample distribution (for example, laboratory)
- Water level measurement data
- Field observations
- Any field measurements made, such as pH, temperature, and conductivity
- All sample documents such as:
    - Bottle lot numbers
    - Dates and method of sample shipments
    - COC forms
- Sample handling (preservation)

All original data recorded in field log books, sample labels, and COC forms will be written with waterproof, black, indelible ink. None of these accountable, serialized documents are to be destroyed or thrown away, even if one is illegible or contains inaccuracies requiring document replacement. If an error is made on an accountable document assigned to one individual, that individual should make all corrections simply by crossing a line through the error, initialing and dating the correction, and entering the correct information. The erroneous information should not be obliterated. Any subsequent error discovered on an accountable document should be corrected by the person who made the entry. All subsequent corrections will be initialed and dated.

4.4 Sample Numbering and Containers

The FTL is responsible for proper sampling, labeling of samples, preservation, and shipment of samples to the laboratory to meet required holding times. Table 4-1

Table 4-1
Required Sample Containers, Preservation, and Holding Times
Defense Depot Memphis, Tennessee

Analyses	Sample Matrix*	Container†	Quantity	Preservative**	Holding Time
Volatile Organic Compounds (SW8240)	W	40-mL VOA vials††	3	Cool 4°C, HCl, pH <2	14 days
	S	4-oz Glass	1	Cool 4°C	14 days
Semivolatile Organic Compounds	W	1-L amber glass	2	Cool 4°C	7/40 days***
Pentachlorophenol (8151)	S	1-L amber glass	2	Cool 4°C	7/40 days
BNAs (8270/3520)	S	4-oz Glass	1	Cool 4°C	40 days
PAHs (8310/3520)	W	1-L amber glass	2	Cool 4°C	7/40 days***
Pesticides/PCBs (8080/3520)	W	1-L amber glass	2	Cool 4°C	7/40 days***
	S	4-oz Glass	1	Cool 4°C	40 days
Organopesticides (8150/3520)	W	1-L amber glass	2	Cool 4°C	7/40 days***
Thiodyglycol (U109)	W	40-mL vials††	2	Cool 4°C	40 days
(LL09)	S	8-oz Glass	1	Cool 4°C	7/40 days***
Metals (Total) (6010, 7000)	W	1-L polyethylene	1	Cool 4°C, HNO_3, pH <2	6 months
	S	8-oz Glass	1	Cool 4°C	6 months
Metals (Dissolved) (6010, 7000)	W	1-L polyethylene	1	Cool 4°C, HNO_3, pH <2	6 months
Mercury (7470)	W	1-L polyethylene	1	Cool 4°C, HNO_3, pH <2	28 days
	S	8-oz Glass	1	Cool 4°C	28 days
Chromium VI (7196)	W	1-L polyethylene	1	Cool 4°C, HNO_3, pH <2	24 hours
	S	4-oz Glass	1	Cool 4°C	24 hours
Total Dissolved Solids (160.1)	W	1-L polyethylene	1	Cool 4°C	7 days

*Sample matrix: S = Surface soil, subsurface soil, sediment;
W = Groundwater, surface water
†Glass containers will be sealed with Teflon®-lined screw caps.
**All samples will be stored promptly at 4°C in insulated chest.
††VOC vials will be sealed with Teflon®-septa secured screw caps.
***Extraction: 7 days for water, 40 days for analysis.

Source: RI Report, 1990

identifies the proper containers, preservation techniques, and maximum holding times according to EPA SW-846.

4.5 Sampling Numbering System

A sample numbering system will be used to identify each sample collected during the field investigation and for all blanks. The numbering system will provide a tracking procedure to allow retrieval of information about a particular location and to monitor that each sample is uniquely numbered. The FTL will maintain a list of sample numbers.

4.6 Sample Chain-of-Custody

Sample custody and documentation procedures described in this section will be followed throughout all sample collection at DDMT. Components of sample custody procedures include the use of field log books, sample labels, custody seals, and COC forms. Examples of these are present in Figures 4-1 and 4-2. Each person involved with sample handling will be trained in COC procedures before the implementation of the field program. The COC form will accompany the sample during shipment from the field to the laboratory. If samples are split and sent to different laboratories, a copy of the COC form will accompany each split sample.

The information provided on the COC form will include the following:

- The project name
- The sampling station number or sample number
- Date and time of collection
- Grab or sample designation
- A brief description of the type of sample and sampling location
- Signature of individuals involved in the sample transfer
- The time and date they receive the sample
- Sample matrix
- The analytical methods required

COC records initiated in the field will be placed in a plastic cover and taped to the inside of the shipping containers used for sample transport from the field to the laboratory. This record will be used to document sample custody transfer from the field sampler to the laboratory.

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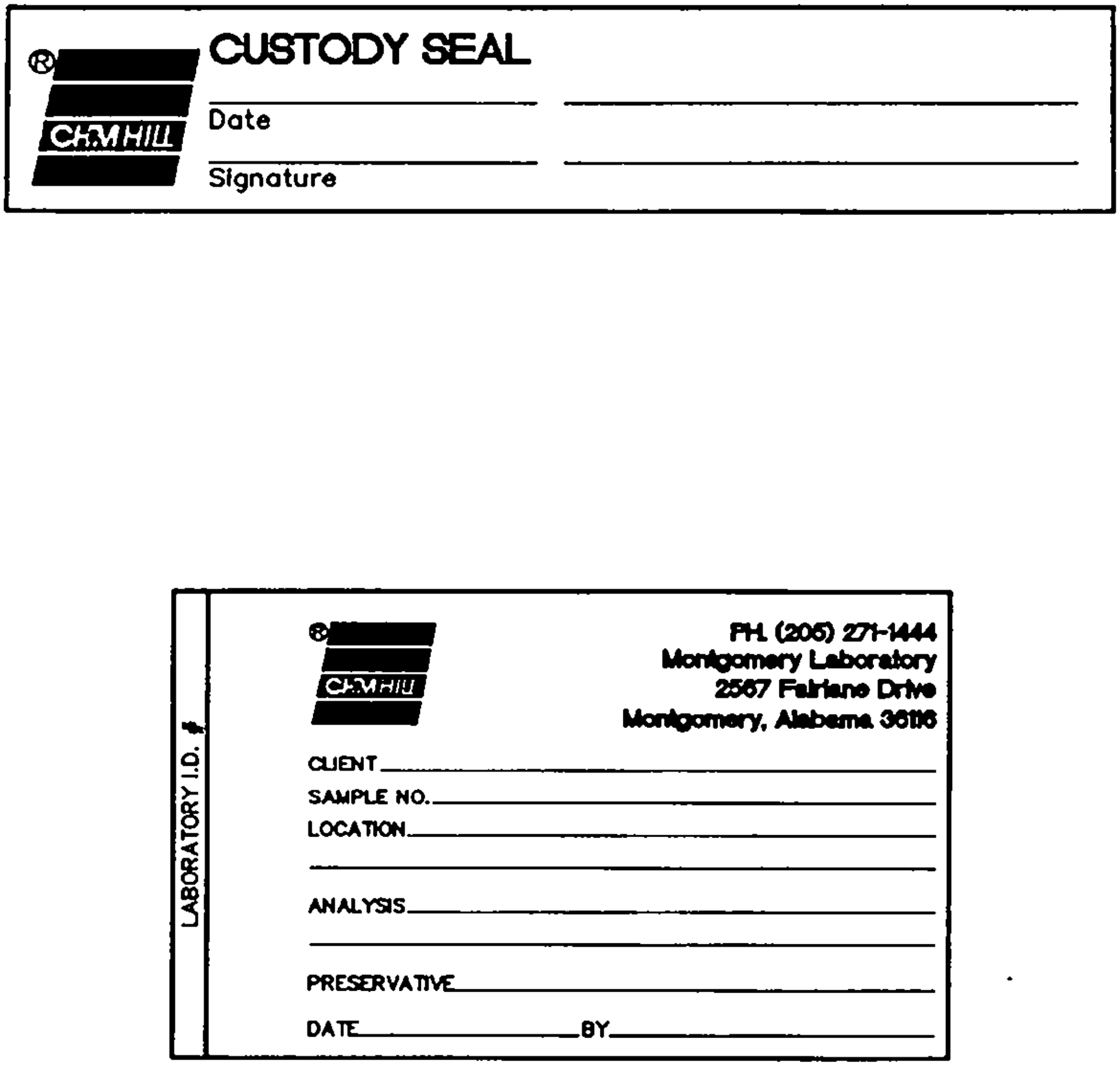


CUSTODY SEAL

Date ______________________ ______________________

Signature ______________________ ______________________

LABORATORY I.D. #

PH. (205) 271-1444
Montgomery Laboratory
2567 Fairlane Drive
Montgomery, Alabama 36116

CLIENT ______________________

SAMPLE NO. ______________________

LOCATION ______________________

____

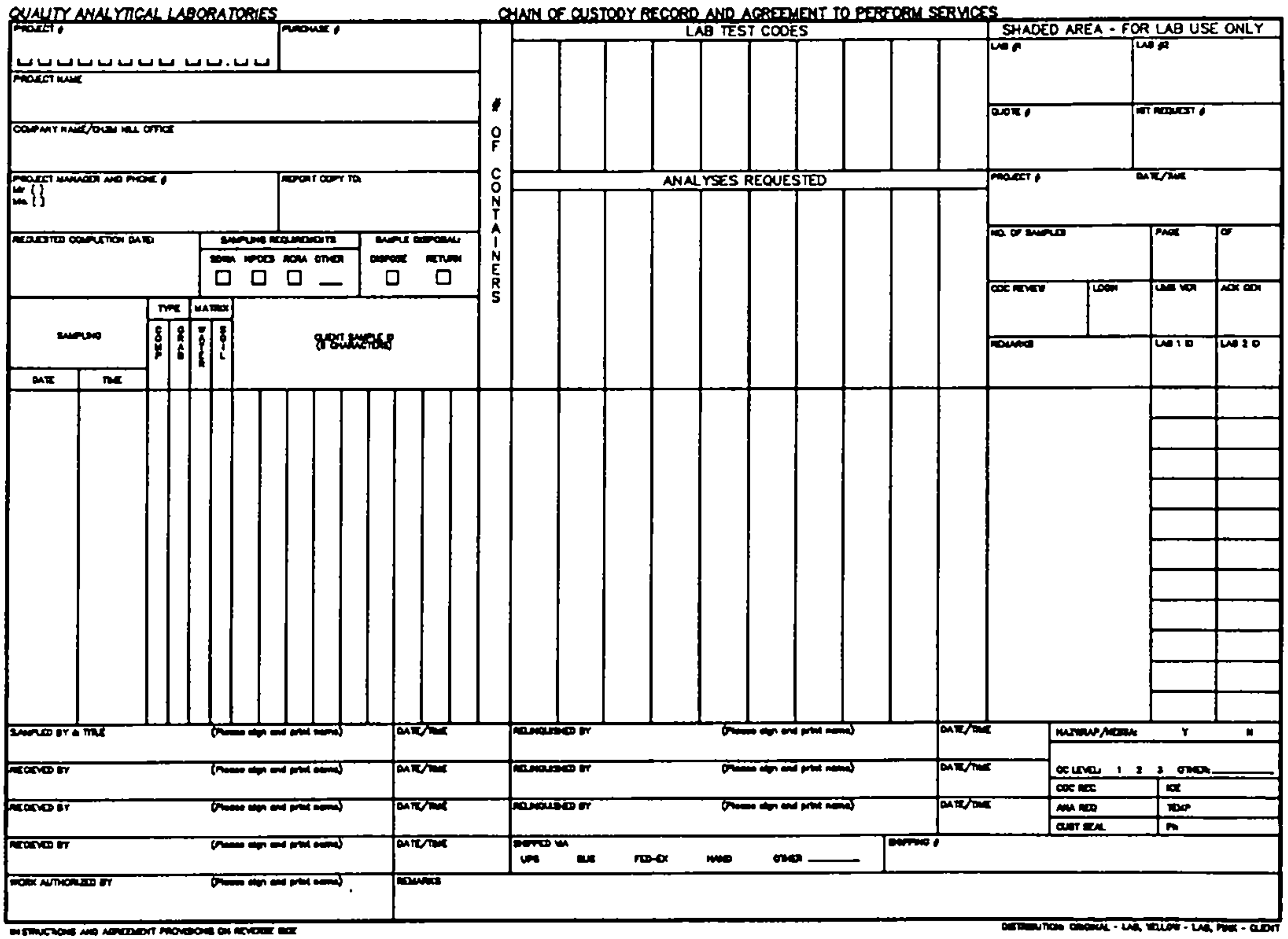
ANALYSIS ______________________

____

PRESERVATIVE ______________________

DATE ______________ BY ______________

FIGURE 4-1
EXAMPLE CUSTODY SEAL AND SAMPLE CONTAINER LABEL
Defense Depot Memphis, Tennessee



QUALITY ANALYTICAL LABORATORIES

CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

PROJECT #
PURCHASE #
PROJECT NAME
COMPANY NAME/CH2M HILL OFFICE
PROJECT MANAGER AND PHONE #
Mr ( )
Ms ( )
REPORT COPY TO:
REQUESTED COMPLETION DATE
SAMPLING REQUIREMENTS: SDWA ☐ NPDES ☐ RCRA ☐ OTHER ___
SAMPLE DISPOSAL: DISPOSE ☐ RETURN ☐
SAMPLING: DATE, TIME
TYPE: COMP, GRAB
MATRIX: WATER, SOIL
CLIENT SAMPLE ID (8 CHARACTERS)
OF CONTAINERS
LAB TEST CODES
ANALYSES REQUESTED

SHADED AREA - FOR LAB USE ONLY
LAB #
LAB #2
QUOTE #
KIT REQUEST #
PROJECT #
DATE/TIME
NO. OF SAMPLES
PAGE
OF
COC REVIEW
LOGIN
LIMS VER
ACK GEN
REMARKS
LAB 1 ID
LAB 2 ID

SAMPLED BY & TITLE (Please sign and print name) DATE/TIME
RELINQUISHED BY (Please sign and print name) DATE/TIME
RECEIVED BY (Please sign and print name) DATE/TIME
RELINQUISHED BY (Please sign and print name) DATE/TIME
RECEIVED BY (Please sign and print name) DATE/TIME
RELINQUISHED BY (Please sign and print name) DATE/TIME
RECEIVED BY (Please sign and print name) DATE/TIME
SHIPPED VIA: UPS BUS FED-EX HAND OTHER ______
SHIPPING #
WORK AUTHORIZED BY (Please sign and print name)
REMARKS
HAZWRAP/NESSA: Y N
QC LEVEL: 1 2 3 OTHER: ______
COC REC
ICE
ANA REQ
TEMP
CUST SEAL
Ph

INSTRUCTIONS AND AGREEMENT PROVISIONS ON REVERSE SIDE

DISTRIBUTION: ORIGINAL - LAB, YELLOW - LAB, PINK - CLIENT

FIGURE 4-2
EXAMPLE CHAIN OF CUSTODY RECORD
Defense Depot Memphis, Tennessee

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MQP-0006 DWG 02-21-95

4.6.1 Sample Custody

A sample is under custody under the following conditions:

- It is in your actual possession; or
- It is in your view, after being in your physical possession; or
- It was in your physical possession and then you locked it up to prevent tampering; or
- It is in a designated and identified secure area.

4.6.2 Sample Custody in the Field

The following procedures will be used to document, establish, and maintain custody of field samples:

- Sample labels will be completed for each sample, with waterproof ink, making sure that the labels are legible and affixed firmly on the sample container (see Figure 4-1).
- All sample-related information will be recorded in the project log book.
- The field sampler will retain custody of the samples until they are transferred or properly dispatched.
- During the course of and at the end of the field work, the field supervisor determines whether these procedures have been followed, and whether additional samples are required.

4.7 Sample Shipment

Samples will be delivered to the designated laboratory. During sampling and sample shipment work, the FTL (or a designee) will contact the appropriate laboratory daily to inform it of shipments. Hard plastic ice chests or coolers with similar durability will be used for shipping samples. The coolers must be able to withstand a 4-foot drop onto solid concrete in the position most likely to cause damage. Styrofoam or bubble wrap will be used as packing material to protect the samples from breakage during shipment. All water VOC vials will be shipped in the same cooler. After packing is complete, the cooler will then be taped shut with COC seals affixed across top and bottom joints. Each container will be clearly marked with "THIS END UP" arrows on all four sides and a sticker containing the originator's address. Figure 4-3 provides a schematic for proper labeling of the cooler.

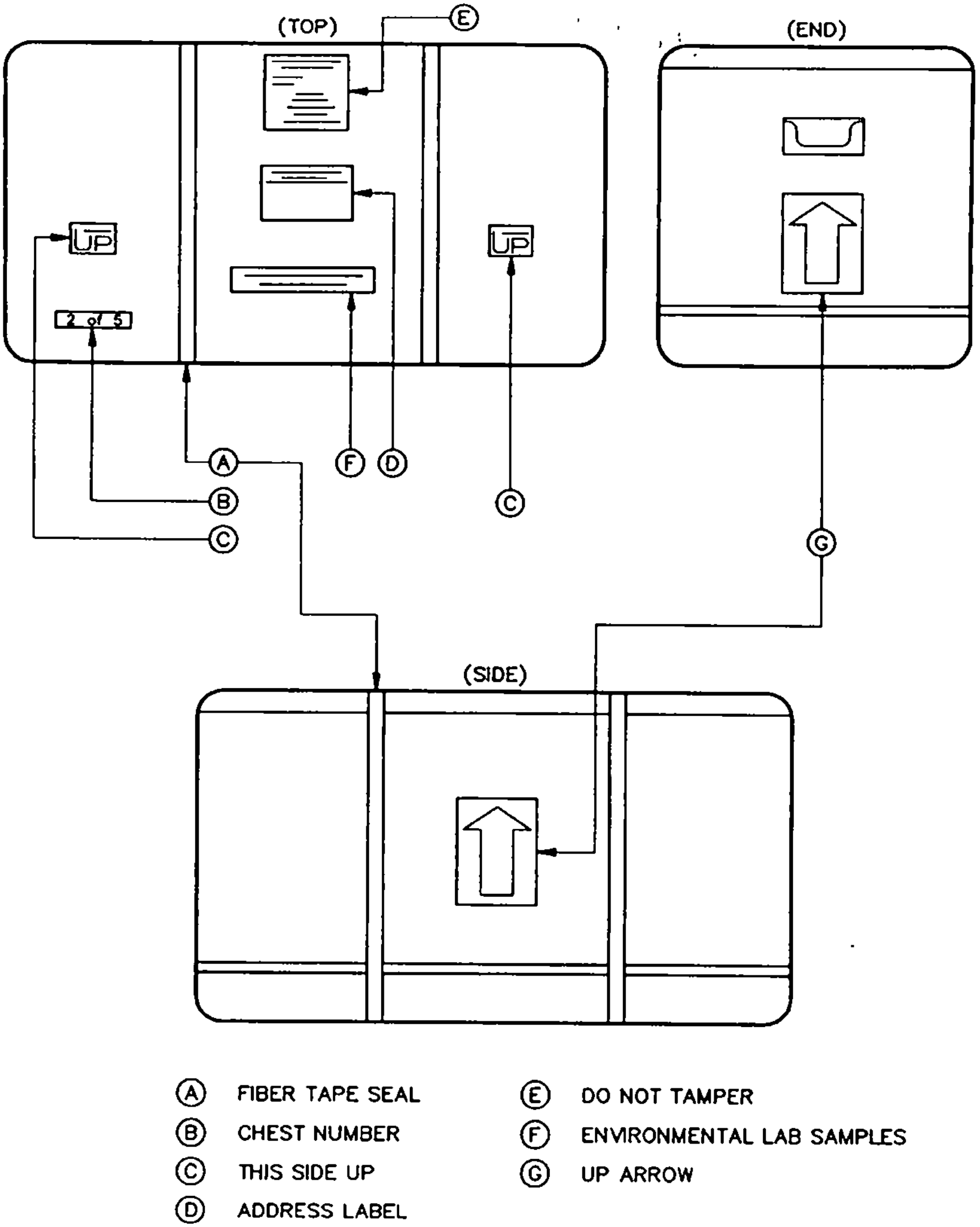

FIGURE 4-3
PROPER LABELING OF AN ICE CHEST
FOR LOW LEVEL SAMPLES
Defense Depot Memphis, Tennessee

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The following procedures will be used when transferring the samples for shipment:

- Samples are accompanied by a COC form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents transfer of custody of samples from the field sampler to another person, or to the laboratory. Overnight carriers will be treated as a single entity and a single signature will be required when the samples are delivered to the laboratory.

- Samples will be properly packaged for a shipment and dispatched to the appropriate laboratory for analysis with a separate signed COC form enclosed in each sample box or cooler.

- Whenever samples are split with a government agency, a separate COC form will be prepared for those samples and marked to indicate with whom the samples are being split.

- All packages will be accompanied by a COC form showing identification of the contents. The original record will accompany the shipment, and a copy will be retained by the FTL.

4.8 Laboratory Sample Custody

The FTL will notify the laboratory of upcoming field sampling activities and the subsequent transfer of samples to the laboratory. This notification will include information concerning the number and type of samples to be shipped, as well as the expected date of arrival.

The following procedures will be used by the laboratory sample custodian in maintaining the COC once the samples have arrived at the laboratory:

- The laboratory will designate a sample custodian who is responsible for maintaining custody of the samples and for maintaining all associated records documenting that custody.

- Upon receipt of the samples, the custodian will check the original COC and request-for-analysis documents and compare them with the labeled contents of each sample container for corrections and traceability. The sample custodian signs the COC and records the date and time received. The sample custodian also will assign a unique laboratory sample number to each sample.

- Care is exercised to annotate any labeling or descriptive errors. In the event of discrepancies in the documentation, the laboratory will immediately contact the FTL as part of the corrective action process. A qualitative assessment of each sample container is performed to note any anomalies, such as broken or leaking bottles. This assessment is recorded as part of the incoming COC procedure.
- If all data and samples are correct, and there has been no tampering with the custody seals, the "received by laboratory" box is signed and dated.
- The samples are stored in a secured area and at a temperature of approximately 4°C, if necessary, until analyses are to begin.
- Samples are accompanied by a COC form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents transfer of custody of samples from the field sampler to another person, or to the laboratory.
- A laboratory COC form accompanies the sample or sample fraction through final analysis for control.
- Copies of the COC and request-for-analysis forms will accompany the laboratory report and will become a permanent part of the project records.

4.9 Disposal of Derived Wastes

In the following sections, the disposal of derived wastes is discussed.

4.9.1 Purged/Development Water and Decontaminating Fluids

Development and purged water will be collected, stored, and analyzed (if required). The discharge will be conducted in accordance with the DDMT industrial discharge permit application (currently being applied for). The processed water will be collected in a storage tank for disposal to the City of Memphis sanitary sewer system (consistent with the permit). Solids will be allowed to settle out of the water before being transferred to the treatment system.

4.9.2 Storage, Analysis, Treatment, and Disposal of Investigation-derived Wastes

All monitoring well and soil boring cuttings will be collected and placed in DOT-approved drums. A label will be affixed to each drum clearly indicating the boring number and depth interval from which the cuttings originated. The site geologist will

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maintain a log detailing the disposition of cuttings from each hole. The drums will be stored in the permitted Resource Conservation and Recovery Act (RCRA) storage area pending the results of the chemical analysis (toxicity characteristic leaching procedure [TCLP]), which will determine the disposition of the contents (if they are determined to be hazardous or nonhazardous by the toxicity characteristic).

4.9.2.1 Soil Waste

Analytical sample results from the investigation will be reviewed to evaluate whether any of the soil waste might exceed TCLP criteria. Upon completion of the data evaluation, a letter report will be submitted to DDMT detailing the drums that contain cuttings that are nonhazardous and may be disposed of onsite as fill. The sample from each drum will be collected using a stainless steel scoop and will be obtained immediately below the surface material in each drum. No attempt will be made to obtain depth-integrated samples from within the drums because of the homogenization expected during filling of the drums. Analysis of these samples will be at DQO analytical Level 3. Upon completion of laboratory analysis, a report will be submitted to DDMT detailing those drums containing cuttings that the should be considered hazardous waste (HW). The report will identify options for treatment and disposal of the HW in accordance with applicable federal and State of Tennessee regulations. The contents of the drums will be identified with a composite representative analytical sample. Of particular concern are cuttings with metals (primarily arsenic, chromium, and lead) contamination. The RI Report (ref. 7) reported widespread occurrence of metals concentrations in both surface and subsurface soils. A number of these samples were obtained from areas with no known source of metals contamination.

Soil and cuttings from the decontamination basin will be collected in drums. The site geologist will record the well number(s) from which decontamination sediments were added to the drum. Labeling and handling of the drums from decontamination will follow the same procedures as the drums of drill cuttings.

4.9.2.2 Classification and Disposal of Soil Waste

If the analysis of a soil sample indicates that organic compounds or metals exceed either federal or state TCLP limits (whichever is more stringent), then the drum(s) associated with that sample will be considered HW and will be disposed in accordance with federal and state requirements through the Defense Reutilization and Marketing Office (DRMO) at DDMT. Drums containing cuttings that were recommended to be considered nonhazardous will be disposed only upon specific written instructions from DDMT.

4.9.2.3 Personal Protective Equipment and Disposable Equipment Waste

All disposable personal protective equipment (PPE) waste (gloves, coveralls, decontamination supplies, protective coverings, respirator canisters, booties, and splash suits) and disposable equipment (DE) waste (plastic ground and equipment covers, Teflon® tubing, conduit pipe, and aluminum foil) used during the study will be collected and double bagged. PPE and DE wastes are generally classified as nonhazardous wastes (ref. 31) and will be disposed in dumpsters at DDMT. This procedure is in accordance with Ref. 31.

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5.0 Field Procedures

5.1 Groundwater

Groundwater sampling efforts will be conducted to identify and evaluate contaminants in the groundwater beneath and around DDMT. A summary of the quantity of samples to be collected and the parameters to be tested during chemical analysis is provided in the OU-specific FSP. Table 4-1 provides minimum laboratory QC sample requirements, including container type, container quantities, preservatives, holding times, SW-846 Methods, and extraction and preparation methods for each parameter.

5.1.1 Groundwater Sample Locations and Rationale

Groundwater samples will be collected for chemical analysis from both existing and newly constructed monitoring wells at DDMT. Collection and analysis of groundwater samples are planned for selected Memphis Light, Gas, and Water (MLGW) monitoring wells in the Allen Well Field. These samples will be collected if groundwater analysis from any of the optional wells (along Elvis Presley Boulevard) show that the contamination has migrated from Dunn Field to the wells on Elvis Presley Boulevard. In the event that recent groundwater data are not available from MLGW, efforts will be coordinated with MGLW to obtain the necessary approval to collect and chemically analyze groundwater samples from the Allen Well Field monitoring wells. Groundwater samples from the wells will be analyzed for several reasons: to characterize sites and to evaluate the nature of releases from disposal sites at DDMT; to evaluate the vertical and horizontal extent of a potential contaminant plume in the Fluvial Aquifer; to evaluate whether contaminants in the Fluvial Aquifer pose a threat to the Memphis Sand Aquifer; and to obtain background water quality data (offsite and upgradient wells) for comparative study. The specific rationale for collecting groundwater samples from each location will be provided in the OU-specific FSP. Additional samples to be analyzed will include equipment blanks, field duplicates, and samples of water from the wells. Split field duplicates and split equipment blanks will routinely be sent to the CEMRD.

5.1.2 Groundwater Sampling Procedures

Before groundwater sample collection, static water levels in the monitoring wells will be measured to calculate groundwater purge volumes. Water level measurements collected for this purpose will be obtained within 24 hours of purging the monitoring well.

Groundwater levels used to construct a groundwater potentiometric surface map will be collected within a 24-hour time frame, provided that barometric conditions remain essentially the same. This will be determined by using a barometer during water level measurements. The intent of this requirement is to obtain water levels during a short time frame during which no significant barometric variations occurred (all readings within 0.25-inch mercury), and not to obtain water levels within a 24-hour period when significant barometric variations did occur (readings greater than 0.25-inch mercury). All water levels will be measured using a decontaminated, electronic water level indicator with an accuracy of plus or minus 0.1 foot. Monitoring well sampling will generally proceed from the potentially least contaminated well to the most contaminated well, according to existing data.

To prevent contamination of sampling equipment by surface soils when the wells are being purged or sampled, a plastic ground cloth will be placed beneath all sampling equipment. Purging will be accomplished through the use a decontaminated stainless steel submersible pump or Teflon® bailer. The discharged water will be monitored for pH, temperature, and specific conductivity. Purging will continue until three to five well volumes have been removed and the pH, temperature, and conductivity are stabilized (three successive measurements are within 5 percent of one another).

The amount of purged fluid will be measured by filling graduated buckets or by using a stopwatch and noting the flow rate of the pump versus elapsed times. All water purged from the wells will be permitted for discharge to the city sewer. Wells will be sampled immediately after purging, if possible, but no later than 6 hours after purging. Wells that recharge slowly will be purged dry and allowed to recharge to at least 80 percent of initial well volume before sampling. If excessive time (greater than 10 hours) is required for the slow recharging wells to recharge to 80 percent, it will be documented by the FTL in the field log. To monitor that data is consistent, all wells will be sampled within a 14-day time frame.

Clean disposable vinyl gloves will be used to handle all samples and equipment used for purging and sample collection. Each well will be sampled with a Teflon® bailer decontaminated according to procedures described previously. Precleaned bailers will be wrapped in aluminum foil for transportation to DDMT. A clean, braided nylon cord will be used to lower each bailer into the well and will be discarded after each use. Care will be taken to prevent contact between the bailer and line and the ground.

Samples will be collected in accordance with the guidelines furnished in the *Practical Guide for Ground Water Sampling* (ref. 1) and the *EPA Region IV ECBSOPQAM* (ref. 31). In accordance with EPA's Environmental Services Division guidelines, care will be taken to avoid aeration of the sample. The sample will be poured in a slow, steady stream from the bailer to the prepared sample containers. The process will be repeated as necessary to fill each container to the required volume. Field measurements of pH, specific conductance, and temperature will be conducted and recorded using instruments that have been calibrated daily and decontaminated before each use. Temperature will be measured immediately upon pouring the sample from the bailer into a glass beaker.

Samples to be analyzed for VOCs will be collected first, to minimize the effects of volatilization caused by disturbance of the water surface in the well. VOC sample containers will be filled completely to the top of the container, leaving no air space above the liquid. Before transport to the laboratory for analysis, samples will be preserved in accordance with the guidelines in Table 4-1. Trip blanks will be included with each container holding samples to be analyzed for VOCs. Groundwater samples also will be collected by EPA and state regulators on a regular basis throughout the project.

5.2 Soil

5.2.1 Surface Soil

Surface soil samples will be collected and analyzed to identify and to delineate contaminants in the surface soils at sites and at some offsite locations (for background sampling). A summary of the quantity of samples to be collected and the parameters to be tested during chemical analysis is provided in the OU-specific FSP. Container type, container quantities, preservatives, holding times, SW-846 Methods, and extraction and preparation methods for each parameter are provided in Table 4-1. This section of the QAPP identifies the general requirements and purposes for collection of surface samples, including the field QA/QC methods.

5.2.2 Surface Soil Sampling Procedures

Surface soil samples will be collected using a clean stainless-steel hand auger or scoop to retrieve soil from zero to 12 inches below ground surface (bgs). Any VOC samples will be placed in the appropriate jars immediately upon collection. The remaining sample will be thoroughly mixed in a stainless-steel mixing bowl before being transferred to the appropriate sample containers. Surface cover (grass and weeds) and debris (such as broken glass and rocks) will be removed from the sample prior to placing in sample containers.

5.2.3 Subsurface Soils

Subsurface soil samples from soil borings will be collected for chemical analyses from both soil and monitoring well borings installed for this study. Samples will generally be selected on the basis of historical data results, field screening during sampling, or both. The overall purpose of this sampling effort will be to characterize the subsurface conditions by providing soil samples for chemical analysis to determine the nature and extent of releases of hazardous substances to the environment from waste disposal sites on DDMT, as well as the vertical and horizontal extent of such contamination in the subsurface soils; to evaluate soil lithology and subsurface stratigraphy; and to help characterize the potential hydraulic interconnection between the Fluvial Aquifer and the Memphis Sand Aquifer on the Main Installation. Soil samples also will be collected for geotechnical lab analyses. Locations and justifications for sample collection, including background samples and offsite locations, are provided in the OU-specific FSPs. Additional samples to be analyzed include equipment blanks and field duplicates (to fulfill QA/QC requirements) and samples from soil cuttings to determine disposal requirements. Split field duplicates and equipment blanks will routinely be sent to the CEMRD laboratory. Trip blanks will be included with each container holding samples to be analyzed for VOCs.

5.2.4 Subsurface Soil Sampling Procedures

Three types of subsurface soil samples will be collected—vertical (shallow) soil borings, vertical (deep) soil borings. The specific number of samples for chemical analysis and depths of collection are discussed in the OU-specific FSPs. However, in general, one soil sample will be collected from the first 12 inches for all borings, from an intermediate depth based on field screening, and from the saturated zone of some vertical (deep) borings for geotechnical analyses. Soil samples will collected on the basis of visual or organic vapor analyzer/photoionization detector (OVA/PID) field screening. Soil samples will be stored in airtight containers and shipped daily to the laboratory for analysis. Geotechnical sample collection and analyses are discussed in Section 5.4. The general analyses include grain size, moisture content, and Atterberg limits. Grain size analysis will be performed on the aquifer material. Atterbergs will be performed on the fine silty to clay material. If the confining layer at the base of the Fluvial Aquifer is penetrated, Atterberg limits will be performed on the retrieved sample to evaluate the condition and character of the clay. The final decision to collect a sample from a certain zone will be at the discretion of the field geologist. This decision will be documented in the field log.

5.3 Surface Water and Sediment Samples

Surface water samples will be collected and analyzed to determine whether storm waters are contributing to the degradation of the Golf Course Pond and Lake Danielson and to determine if sites at DDMT are affecting the quality of storm water runoff waters leaving the installation. Specific location criteria and analysis will be identified in the appropriate OU FSP. Sediment samples will be collected from the same location as surface water samples to the extent possible. Collecting sediment and surface water samples from the same location will be easily accomplished at Lake Danielson and at the Golf Course Pond. However, it may not be possible for some of the storm water drainage channels. The samples will be taken from various locations around DDMT and will be used to further define sites previously identified in the RI Report (ref. 7) and the RFA (ref. 25) and to help characterize any possible sources for contaminants found in Lake Danielson, in the Golf Course Pond, and in storm water drainage channels.

5.3.1 Surface Water Sampling Procedures

After a rainstorm with at least 0.2 inches of precipitation, when quantities of surface water/runoff are sufficient for collection, samples will be collected for chemical analysis. Sampling locations are identified in the OU-specific FSPs, which are considered representative of surface water runoff from the installation. These samples will be used to determine whether storm waters are contributing to the degradation of the lakes and runoff waters leaving the installation. Samples may be collected from storm drainage

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ditches will be a single grab sample taken at mid-depth from the center of the channel. Samples collected from Lake Danielson and from the Golf Course Pond. If so, they will be collected from the estimated deepest point of the lake or pond and, with the exception of the volatile sample, will consist of single vertical composite (depth integrated) samples. The vertical composite samples will be taken using a decontaminated stainless steel Kemmerer sampler or bailer. The physical water quality parameters of specific conductivity, temperature, pH, and dissolved oxygen will be measured at each sampling point. Specific conductivity, temperature, dissolved oxygen, and pH will be measured with an electronic meter. The first draw of sample will placed into the VOC containers immediately if a bailer or Kemmerer sampler is being used. An aliquot will be placed in each container from each subsequent draw until the bottles are filled.

Samples will be collected from the surface directly into the container where the column of water is less than 1 foot deep and when no preservatives are required in the sampling bottle. Samples requiring preservatives will be collected in a spare bottle that has been rinsed twice in the water to be sampled. The sample collected will then be transferred to the appropriate container. Sediment samples will be collected at the location of all surface water samples unless the sample is obtained from a concrete-lined drainage ditch with no accumulated sediment. If sediment samples are also to be collected, the surface water samples will be collected first. Care will be taken to prevent disturbance of the sediments in the stream, lake, or pond.

5.3.2 Sediment Sampling Procedures

Samples of sediment from the drainage ditches will be collected using a stainless steel scoop. The samples will be collected when there is no flow in the ditch or when the flow allows wading to the sample location. Field judgment will be exercised when collecting sediment samples. The depth of sampling will be limited to zero to 12 inches for surface sediments. Smaller intervals may be used to limit sampling to sediments rather than native soil. The sampling interval will be documented in the field logbook. If there is flow in the stream, the sample location will be approached from downstream of the point facing into the current. All non-purgeable organic samples will be thoroughly mixed in a stainless steel mixing bowl before being transferred to the appropriate sample container. Sediment samples that are to be analyzed for VOCs will be immediately placed in the appropriate sample container and filled completely. No head space will remain in the sample container.

5.4 Soil Boring and Monitoring Well Drilling Procedures

5.4.1 Permitting and Design of Monitoring Wells

The design and construction of monitoring wells will follow (as closely as practical) the design criteria presented in the *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells* (ref. 37) and *EPA Region IV ECBSOPQAM* (ref. 31). Diagrams of typical well construction details are shown in Figures 5-1 and 5-2. Drilling and field personnel will have all applicable state and local certification required for drilling. DDMT will be responsible for obtaining the required entry permits for offsite locations. Additionally, Figures 5-3 and 5-4 show the construction details of the proposed Memphis Sand Aquifer Monitoring Well (Section 4.6 of the OU-4 FSP).

5.4.2 Installation of Monitoring Wells and Soil Borings

The procedures described below will be followed for monitoring well installation and soil borings.

5.4.2.1 General Requirements

The drilling contractor will provide all drilling equipment, materials, and personnel required to install the monitoring wells and soil borings. A qualified geologist or geotechnical engineer will be onsite for all drilling, installation, development, and testing activities.

5.4.2.2 Protection of Water-yielding Zones

Water will be used during drilling only when absolutely necessary for successful installation of the well. During the drilling of wells at DDMT for the RI/FS, a zone of flowing sand was encountered in some boreholes. This zone made removal of the auger from the hole difficult, especially when it was left in overnight. In such an instance, water or an additive may be necessary to keep the hole open. If water is required during drilling or well installation, only non-chlorinated potable water will be used. If an additive is required, only pure bentonite will be used. Any proposed use of water or bentonite will be cleared through the CEHND Contracting Officer before use. Grease or oil on drill rod joints will not be permitted; neither will dispersing agents such as phosphates or acids. Toxic and contaminating substances will be prohibited during any part of the drilling, well installation, or well development activities. No attempt will be made to chemically disinfect the well.

All drilling activities and methods will be performed to prohibit the introduction of contaminants from one zone to another, particularly from the Fluvial Aquifer to the Memphis Sand Aquifer. Monitoring well borings intended to penetrate the Memphis Sand Aquifer will be completed with an isolation casing that will be pressure-grouted to approximately 3 ft into the confining layer. The grout will be allowed to set for a minimum of 24 hours before advancing the borehole and installing a monitoring well.

When material is removed from the confining unit for confirmation or laboratory testing from a soil boring, the base of the borehole will be backfilled using tremie pipe to pump pure bentonite containing at least 20 percent solids to the top of the confining unit.

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5.4.2.3 Drilling Techniques

Drilling techniques will be followed as described below.

Soil Borings. The DDMT soil borings and monitoring wells will be installed using hollow stem auger (HSA), mud rotary (MR), water rotary (WR), rotosonic, or another EPA-approved alternative drilling technique.

It is acknowledged that the HSA technique is preferable for installation of the monitoring wells and will be used whenever possible. As stated previously, a zone of flowing sand has been encountered during previous drilling operations at DDMT. If the auger becomes ineffective in the sands, a center plug will be used. If the center plug is ineffective, WR will be used. MR will be used only as a last resort. The drill rigs will install a minimum 7-inch-diameter borehole to facilitate installation of 2-inch inside diameter (ID) casing and screens for the Fluvial Aquifer monitoring wells. If soil borings and monitoring wells are to be installed in the Memphis Sand Aquifer, a larger diameter boring will be drilled for installation of the isolation casing. The drill rig will have the capability to collect split-spoon samples according to ASTM procedures. At a minimum, the rig will be equipped with a cathead-operated, 140-pound hammer with a 30-inch draw.

Hollow Stem Auger Technique. When a boring is advanced using HSA, the following protocol will be followed to install the well casing and screen in the shallow wells:

- Install the 2-inch screen and riser through the HSAs with enough riser pipe to extend the well casing about 2 ft above the ground surface.
- Install an artificial sand pack through the annular opening, using a tremie pipe. Water in small amounts may be used to prevent bridging of the sand in the annulus.
- Remove hollow stem augers in increments as the annulus space fills with sand.
- Continue installing sand pack until it reaches at least 2 ft above the top of the well screen.
- Install a minimum 2-foot pure bentonite seal of at least 20 percent solids using a tremie pipe.
- Remove HSAs from boring.
- Grout boring annulus to within 2 ft of ground surface using a tremie pipe and high solids pure bentonite grout. Install steel security cap and a 3-foot by 3-foot by 6-inch concrete pad with protective posts if the well is in a high-traffic

area. The grout will be allowed to set a minimum of 48 hours before developing the well.

Water Rotary Technique. When a boring is advanced using WR, the following protocol will be followed to install the well casing and screen the shallow wells:

- After termination of boring, all drilling rods will be removed.
- Install the 2-inch screen and riser, with enough riser pipe to extend about 2 ft above the ground surface. Centralizers may be necessary to center the pipe in the borehole.
- Install the sand pack with a tremie pipe from the bottom of the boring until at least 2 ft above the well screen.
- Install a minimum 2-foot pure bentonite seal with at least 20 percent solids.
- Grout boring annulus to within 2 ft of the ground surface using a tremie pipe and high solids, pure bentonite grout. Install steel security cap and a 3-foot by 3-foot by 6-inch concrete pad with protective posts if the well is in a high-traffic area. The grout will be allowed to set a minimum of 48 hours before developing the well.

Mud Rotary Technique. When a boring is advanced using MR, the protocol described below will be followed to install the well casing and screen in the shallow wells:

- After termination of boring, all drilling rods will be removed.
- Install the 2-inch screen and riser, with enough riser pipe to extend about 2 ft above the ground surface. Centralizers may be necessary to center the pipe in the borehole.
- Remove the mud cake from the boring well by pumping potable water through the well riser and screen.
- Install the sand pack with a tremie pipe from the bottom of the boring until at least 2 ft above the top of the well screen.
- Install minimum 2-foot bentonite seal.
- Grout boring annulus to within 2 ft of ground surface using a tremie pipe and high solids pure bentonite grout. Install steel security cap and a 3-foot by 3-foot by 6-inch concrete pad with protective posts. The grout will be allowed to set a minimum of 48 hours before developing the well.

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Rotasonic Drilling (RD) Technique. When a boring is advanced using RD, the following protocol will be followed to install the well casing, screen, and cover for the shallow wells:

- At the termination depth of the boring, the inner drill pipe and core barrel containing the soil sample (typically up to 10 ft in length) are removed.
- Install the 2-inch monitoring well casing and screen through the outer drill pipe (usually 6- or 8-inch ID) using enough casing (riser) that the well extends about 2 feet above the ground surface.
- Install an artificial sand pack through the annular opening using a 1- or 1.5-inch tremie line. The drill pipe and well casing can be vibrated to minimize the potential for bridging of the sand in the annulus. Water in small amounts may also be used to minimize the potential for bridging.
- Remove the outer drill pipe in increments and allow the annular space to fill with sand. Repeat this process until the sand extends at least 2 feet above the top of the well screen.
- Install a minimum 2-foot bentonite slurry seal containing at least 20 percent solids into the annular space using a tremie pipe. Granular bentonite (pellets or chips) may be slowly poured into the annular space as an alternative to the bentonite slurry. If granular bentonite is used, the drill pipe and well casing can be vibrated to minimize the potential for bridging. Potable water should be used to hydrate the pellets or chips if the bentonite interval occurs above the water table. A minimum of 4 hours should be allowed for the bentonite to hydrate before grouting the remaining annular space.
- Grout annulus to within 2 feet of ground surface using a tremie pipe to pump a neat cement-bentonite sealant in the annular space. During the placement of the grout above the bentonite seal, the outer drill casing is incrementally removed, allowing this material to completely fill the annular space.
- Install a locking steel security cover within a 3-foot by 3-foot by 6-inch concrete pad. A minimum of three high-visibility steel protective posts will be installed around the concrete pad if the well is in a high-traffic area. The grout within the annular space of each monitoring well will be allowed to cure a minimum of 48 hours before beginning well development.

5.4.2.4 Borehole Abandonment Procedures

Upon completion of each borehole, or if for any reason a well must be abandoned during drilling, the abandonment will follow the procedure as outlined in Section E.8.1 of EPA's *ECBSOPQAM* (ref. 31).

5.4.2.5 *Well Design*

Well Riser and Screen. The OU-specific FSP will dictate the requirements for each specific proposed monitoring well. In general, the risers and screens used in well construction will be made of polyvinyl chloride (PVC) (meeting National Sanitation Foundation [NSF] Standard 14). PVC is preferred to stainless steel where possible because all of the existing monitoring wells at DDMT have PVC screens and risers. To have comparable results, wells that will be installed should be constructed with similar materials.

Additionally, previous analytical results from existing monitoring wells at DDMT indicate that contamination is not affecting well materials. There has been no indication of degradation of the well materials resulting in well failure or leaching of organics from the well materials. Thus, the sample and data quality will not be adversely affected by using PVC.

Continued use of PVC for well construction materials will provide water samples that will be consistent with samples from the existing monitoring wells without sacrificing data quality. This approach is consistent with technical information provided in Ref. 33, an EPA report concerning the selection well materials and contaminants, and Ref. 34, a COE report documenting surface changes in well casing pipes exposed to high concentrations of organic compounds. However, if DNAPL concentrations are detected during drilling operations or if contaminants are present in concentrations that degrade PVC well casing materials (ref. 41), then stainless steel will be used as the well construction material in the area of DNAPL concentration.

Riser. Wells installed in the Fluvial Aquifer will be constructed of new threaded, flush joint, PVC pipe with a nominal 2-inch diameter. Well risers will conform to the requirements of ASTM-D 1785 Schedule 40 pipe and NSF Standard 14 PVC, and will be clearly identified as such. Any Memphis Sand Aquifer wells will consist of new threaded, flush joint, Schedule 80 PVC pipe with a nominal 4-inch diameter and will conform to NSF Standard 14.

Screen. The well screens will be a minimum of 10 ft long and will be constructed of ink- and printing-free PVC material similar to the well riser. The screens will be non-contaminating, factory-constructed, continuous wrap or mill-slot design, with a slot size of 0.010 inch to minimize the volume of silt and sand entering the well. This slot size is compatible with the results of the sieve analysis of existing wells shown in Appendix C of the RI Report (ref. 8). The mean grain size for the samples from the Fluvial Aquifer ranged from 0.0075 to 0.11 inches, with most samples in the range of 0.012 to 0.032 inches. Most of the wells had a coefficient of uniformity less than 3 and a curvature of less than 2. The screens in the existing wells are also of the same slot size. The wells have functioned satisfactorily. A 20/40 filter pack will be used in the well installations. This screen and filter pack combination will minimize the sediment entering the well, while allowing adequate flow for rapid purging and sampling of the monitor wells. To

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confirm the compatibility between the screen and the aquifer material, sieve analysis will be performed on at least one representative sample of the aquifer in which the screen is placed. The sieve analysis will be conducted in accordance with ASTM-C 117 and C 136. The results will be submitted in the field boring logs.

Screen Location. Wells will be constructed so that base of the screen is near the top of the confining unit between the Fluvial and Memphis Sand aquifers. The proposed screen length is 10 feet. The placement of well screens near the base of the Fluvial Aquifer is consistent with the nature of the contaminants of concern. Floating constituents have not been encountered and are not expected during this project. The potential contaminants of concern include solvents such as 1,1,2,2-Tetrachloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethene; carbon tetrachloride; and trichloroethene, as well as metals such as arsenic, barium, lead, chromium, and nickel. None of these substances occur or are expected to occur as a floating product or dense layers within the aquifer.

Joining Screen and Riser. Screen and riser sections will be joined by threaded, flush-joint couplings to form watertight unions that retain 100 percent of the strength of the screen. Solvent glue will not be used at any time in construction of the wells. The bottom of the deepest screen or casing section will be sealed with a threaded cap or plug of inert, non-corroding material similar in composition to the screen.

Well Plumbness and Alignment. All risers and screens will be set plumb and true to line. The monitoring well screen and riser pipe will be held in the center of the hole by the augers during the installation of the annular materials. Centralizers will be used where necessary to calculate plumbness and alignment of the wells (generally for wells that exceed 80 ft in depth). It can be assumed that centralizers will be used for wells in the Memphis Sand Aquifer. Centralizers will not be attached to the well screen. The lowest centralizer attachment will be a minimum of 10 ft above the top of the well screen.

Filter Pack. Silica sand will be used as the filter pack material. Only clean, inert silica sand of 20/40 or similar gradation will be used to construct a uniform and continuous filter pack. This filter pack is slightly finer than would be typically used in material with the reported grain size distribution of the Fluvial Aquifer. However, this difference will not alter the well efficiency and will provide an effective connection with the aquifer. The pack will be designed to prevent migration of fines into the screen. The existing wells are constructed of similar-sized material. The filter pack will be placed by tremie pipe from the base of the boring to approximately 2 ft above the well screen. If the boring penetrates the confining layer, bentonite will be used to backfill the portion of the confining layer penetrated by the auger.

Bentonite Seal and Grout. A minimum 2-foot bentonite pellet seal will be placed into the annular space between the riser and the boring wall at the top of the filter pack. The bentonite will be tremied in place to prevent "bridging." A bentonite grout mixture, consisting of a coarse-grained, high solids bentonite grout of at least 20 percent solids pure bentonite (Baroid Benseal, American Colloid, Volclay, or equal), will be placed from the top of the bentonite seal to within 2 feet of ground surface. The grout will contain a minimum of 20 percent solids and be mixed in the field with clear water in accordance with manufacturer's specifications. The upper 2 feet of the annulus will be filled with cement grout, as shown in Figures 5-1 and 5-2.

Soil Sampling for Geotechnical Analysis. During drilling, soil samples will be collected and geotechnical analysis will be performed as outlined below:

- Soil samples will be taken continuously for the first 10 ft, and then at 5-foot intervals thereafter.
- Sampling will be done with a split-spoon sampler (ASTM-D 1586-67) or thin wall sampler (ASTM-D 1587-74) using standard sampling techniques.
- Samples will be stored in labeled, air-tight plastic or glass containers until such time as they are needed for testing or the contract is complete.
- All soil samples will be visually classified by the Unified Soil Classification System. The field classification will be verified by laboratory analyses consisting of the following:
    - Shelby tube samples will be collected from specific wells and borings identified in the OU-specific FSPs. These samples will be collected and tested using Standard Triaxial Permeability methods developed by the COE (Engineering Manual 1110-2-1906, 1986) (ref. 39) to determine if the confining unit is capable of allowing contaminants to migrate to the lower aquifer:

        a. Grain-size distribution (ASTM-D 421 and 424)
        b. Atterberg limits (ASTM-D 423 and 424)
        c. Moisture content (ASTM-D 2216)
        d. Triaxial permeability (EM 1110-2-1906, 1986)

    - Specific depths for samples to be tested will be determined by the field geologist after reviewing the boring logs.

Protection of Well and Surface Completion. Precautions will be taken to prevent tampering with monitoring wells or the entrance of foreign material into the well. Upon the completion of each well, a vented cap will be installed to prevent material from entering the well. A protective steel casing will be placed around the well riser. The steel casing will be equipped with a cap and lock and will be between 24 inches and 36 inches above ground level. It will be taller than the enclosed well. Depending on the location (offsite versus onsite), wells may be set in a protective casing much closer to the ground (flush-mounted) to reduce the attraction for vandalism. At a minimum, a 3-foot-square, 4-inch-thick concrete pad will be constructed around the protective casing at

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ground level and sloped away from the well. The portion of the pad around the well will be set a minimum of 3 inches in the ground. Three, 2-inch or larger diameter steel posts will be equally spaced around the protective casing and embedded in the concrete pad. There will be no openings in the protective casing wall below its top. The top of the well riser, as opposed to the well casings, will be notched on the north side, which will be the point where the elevation is established. The elevation will be to the closest 0.01 foot. All outside casing will be permanently identified with the well number. A survey marker will be permanently placed in each pad. Each survey marker will be stamped with the identifying number according to the directions of the survey section in this QAPP. Protective casings and steel posts will be primed and painted with two coats of traffic yellow paint.

Temporary Capping. Any well that is to be temporarily removed from service, or left incomplete because of delay in construction, will be capped with a watertight cap and equipped with a vandal-proof cover.

5.4.2.6 Field Logs

The field geologist or geotechnical engineer will maintain suitable field logs detailing drilling and well construction activities. One copy of each field log, including the required color slides, will be submitted to the Contracting Officer not longer than 10 calendar days after each well is completed. Information provided in the logs will include the following, as a minimum:

- Reference point for all depth measurements
- Depth of each change of stratum
- Thickness of each stratum
- Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard nomenclature, as necessary
- Depth interval from which each formation sample was taken, and condition of sample (such as wet or dry)
- Depth at which hole diameter (bit sizes) change
- Depth at which groundwater is first encountered
- Depth to the static water level
- Total depth of completed well
- Depth or location of loss of drilling fluids (if used)

- Location of any fractures, joints, faults, cavities, or weathered zones
- Depth and thickness of grouting or sealing
- Nominal hole diameters
- Amount of cement used for grouting or sealing
- Depth and type of well casing
- Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screen(s)
- Any sealing-off of water-bearing strata
- Static water level upon completion of the well and after well development
- Drilling date or dates
- Construction details of monitoring well
- Well development notes

Final Logs. Photocopies of the original field logs will be included in an Appendix of the final report. Additionally, the field logs will be edited (for spelling and grammar) and drafted for inclusion into the final report.

5.4.2.7 Well Development

After each well has been constructed, but no sooner than 48 hours after grouting is completed, the well will be developed by pumping or surging, without the use of acids, dispersing agents, or explosives. Development will continue for a minimum of 4 hours or until groundwater removed from the well is clear and free of sand and drilling fluids, and parameters (such as pH, temperature, and conductivity) are stabilized to less than 5 percent fluctuation between three successive readings. Other than formation water from the particular well, no other liquid will be introduced into the well. After final development of the well, approximately 1 liter of water will be collected (from the well) in a clear glass jar and photographed in front of a standard color chart with 35-mm color slide film. The jar will be shaken immediately before being photographed to display any suspended solids. The photograph will have enough close-up lighting to show the clarity or turbidity of the water. The slides will be submitted as part of the well log.

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5.4.2.8 *In-Situ Permeabilities*

The hydraulic conductivity of the water-bearing zone in which each monitoring well is screened will be estimated using a rising head pneumatic slug test method. This slug test method will allow testing to be performed quickly, and nearly instantaneous removal of the pneumatic slug will eliminate much of the noise in the very-early-time data that is often present in manual slug test methods in transmissive aquifers.

5.4.2.9 *Decontamination Procedures*

A stringent decontamination and inspection program will be followed to prevent the introduction of any contaminants into the subsurface during drilling. A decontamination area for the cleaning of drilling equipment will be set up away from the drill site. After cleaning and decontaminating, all drilling equipment and sampling tools will remain off the ground on metal racks, metal sawhorses, or plastic sheeting until ready for use.

Drill Rig and Tools. All the drilling rigs and drilling equipment will be steam cleaned in the designated cleaning/decontamination area before entering the drill site. In addition, all downhole drilling, sampling, and associated equipment will be cleaned and decontaminated by the following procedure:

- Steam clean using a steam cleaner capable of generating a pressure of at least 2,500 pounds per square inch (psi) and producing a steam of at least 20°F. All equipment that is hollow or that has holes to transmit water or drilling fluids will be cleaned inside and outside.
- Rinse with potable tap water.
- Rinse with de-ionized water from a stainless steel container.
- Rinse with pesticide grade isopropanol from a stainless steel container.
- Air dry.
- Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.

All cleaning and decontamination will be conducted in a designated area lined with heavy-duty plastic. A catch basin will be used or constructed to contain all runoff until it can be placed into containers. The cleaning of drilling equipment (drill pipe, auger, and tools) will be conducted above the plastic sheeting on saw horses or other appropriate means.

All of the drilling equipment, including the drill rig, will be inspected before entering the site to monitor whether there are fluids leaking and whether all gaskets and seals are intact. No oil or grease will be used to lubricate drill stem threads or any other drilling equipment being used over the borehole or in the borehole without prior approval.

Soil and Sediment Sampling Equipment Decontamination. All the soil and sediment sampling equipment not associated with the drill rig and drilling will be decontaminated by personnel wearing disposable latex gloves or vinyl gloves and using the following procedure:

- Wash with tap water and laboratory grade, non-phosphate detergent, using a brush if necessary to remove particulate matter and surface films.
- Rinse with tap water.
- Rinse with de-ionized water.
- Rinse twice with pesticide grade isopropanol.
- Rinse with organic-free water (not deionized or distilled water).
- Air dry.
- Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.
- Water used in decontamination operations will be disposed of as is purge water.

Surface Water Sampling Equipment Decontamination. All of the surface water sampling equipment will be decontaminated by personnel wearing disposable latex gloves or vinyl gloves and using the following procedure:

- Wash with tap water and laboratory grade, non-phosphate detergent, using a brush if necessary to remove particulate matter and surface films.
- Rinse with tap water.
- Rinse with de-ionized water.
- Rinse twice with pesticide grade isopropanol.
- Rinse with organic-free water (not deionized or distilled water).
- Air dry.
- Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.

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- Water used in decontamination operations will be disposed of as is purge water.

Groundwater Sampling Equipment Decontamination. With the following exceptions, all groundwater sampling will be conducted with disposable sampling equipment (such as disposable bailers and disposable rope) that requires no decontamination.

Elevation tapes will be decontaminated using the following procedure:

- Wash with tap water and laboratory grade, non-phosphate detergent, using a brush if necessary to remove particulate matter and surface films.
- Rinse with tap water.
- Rinse with de-ionized water.
- Air dry.
- Wrap with aluminum foil or seal in a plastic bag.

Submersible pumps and hoses used to purge groundwater wells will be decontaminated using the following procedures:

- Flush the hose using laboratory grade, non-phosphate detergent, followed by scrubbing the exterior of the hose with a brush.
- Rinse the exterior of the hose with tap water followed by pumping tap water through the hose.
- Rinse the exterior of the hose and pump with de-ionized water.
- Place equipment in a polyethylene bag to prevent contamination.

5.5 Geophysical Survey and Logging

5.5.1 Natural Gamma Logs

Although MW-36 and MW-37 are double cased, there is a concern that they may represent a pathway for migration of potentially contaminated water. Either a dual density (gamma-gamma) or an acoustic velocity log will be conducted in the two wells currently screened in the Memphis Sand Aquifer (MW-36 and MW-37) to measure the density of the grout, to determine the location of the filter pack relative to the confining unit (the filter pack will have a lower density than the bentonite seal), and to determine if the grout is effectively sealing the upper aquifer from the lower aquifer.

Gamma-gamma and acoustic velocity are the only geophysical methods available to determine the soundness of the grout inside a small borehole with a 2-inch-diameter well casing. Because of the accuracy and the lack of a nuclear source, the acoustical method is the preferred method. However, because the probe used in the acoustical method has a diameter of 1 1/16 of an inch, the well casing must be perfectly round and free of any interior abnormalities (such as scaling or ridges). If interior abnormalities are encountered, the gamma-gamma method will have to be employed.

Geophysical logging service companies must maintain licenses from the Nuclear Regulatory Commission (NRC) to operate and transport a nuclear source. Part of their license requirements includes preparing a company health and safety plan. This plan includes safe handling training for their employees, quarterly testing of their equipment, and training regarding safe shipment of the sources. Part of the employee training includes provisions that do not allow untrained personnel to operate or be near a source when it is onsite. When implementing the health and safety plan, the area where the source is used is roped off and untrained personnel are not allowed within that exclusion zone. The service company's health and safety plan will be followed when that company is onsite, as described in Section 10 of DDMT's HASP.

In addition to the precautions that service companies take to maintain their license, they are subject to an audit from the NRC (or from the agreement state that implements the NRC rules) while they are onsite.

Natural gamma logging will be performed on six existing wells to help identify the depth to the Jackson/Claiborne confining unit. Because the existing monitoring wells are constructed with 2-inch-diameter PVC, natural gamma logging is the only applicable logging method. Other viable alternatives require a larger diameter casing. These logs will be prepared by lowering a natural gamma radiation detector into the well or borehole and recording the amount of naturally occurring gamma radiation present as a function of depth. Clay minerals commonly contain the isotope potassium-40, which is typically the source of gamma radiation. Natural gamma logs will be used in determining the proportion of clay present and the depth to formation interfaces.

The six existing wells to be logged are the two wells into the Memphis Sand Aquifer (MW-36 and 37) and four Fluvial Aquifer wells (MW-19, 34, 38, and 39) in the north-central area of DDMT in the vicinity of the depression into the confining unit (see the Generic RI/FS WP, ref. 38), for a discussion of this depression). The two Memphis Sand wells will provide a clear profile of the natural gamma characteristics of the confining unit. The four Fluvial Aquifer wells may provide added information on clay formations in the vicinity of the confining unit. New wells will be logged on a case-by-case basis. The logging of the well will be conducted by qualified personnel. All the necessary equipment, personnel, and safety procedures will be provided by the selected contractor. A copy of the log, along with a letter report indicating the findings, will be submitted as an appendix to the RI report.

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5.5.2 Electromagnetic and Magnetic Surveys

Electromagnetic and magnetic surveys were performed in Dunn Field in the vicinity of known burial sites. The survey was performed in June 1993 by the Corps of Engineers Waterways Experiment Station (CEWES). The purpose was to confirm locations of buried pits and trenches that might be burial sites of hazardous and toxic waste that could be contributing to groundwater contamination in Dunn Field. The results of the investigation are being analyzed and will be included as an appendix to the RI/FS report. Magnetometers will be used before drilling to clear drill sites of any buried metal and utilities.

5.6 Surveying

5.6.1 Control Monuments

Control monuments, monitoring wells, and soil and stratigraphic borings will be surveyed for their locations and elevations by a State of Tennessee certified land surveyor. Permanent survey markers will be installed at each control monument and monitoring well. Documentation, tabulation, and mapping of the final coordinates and elevations will be submitted in the RI Report appendixes.

Three permanent control monuments with a 3½-inch-diameter domed, brass, bronze, or aluminum alloy cap will be set in accessible locations within or immediately adjacent to the project area. These monuments will be set no closer than 500 ft to each other. Coordinates (1:10,000) and elevations (1:5,000) to Third Order accuracies or better will be established to the closest 0.01 foot for each monument. The coordinates will be referenced to the State Plane Coordinate System, and the elevations will be referenced to the 1929 North American Vertical Datum. Each survey marker and monument will be stamped with the following data by using steel dies that are a minimum of 1/8 inch tall: *COE, Huntsville, Alabama Identification Number Month and Year Established.*

5.6.2 Location Surveys

Coordinates and elevations will be established for each of the following items: all new monitoring wells, stratigraphic test borings, and the corners of the geophysical survey area. The coordinates will be to the closest 1.0 foot and referenced to the State Plane Coordinate System. The elevation will be determined for both the top of the well casing (at the water-level measuring point) and the top of the survey marker. All elevations will be referenced to the North American Vertical Datum of 1929. A 3½-inch-diameter domed brass, bronze, or aluminum alloy cap will be permanently set in the concrete pad surrounding each well. The marker will be stamped as indicated above. In addition to the coordinates, the elevations to the closest 0.01 foot will be provided for the survey marker and top of casing for the pump test well, the piezometers, and all new monitoring wells.

5.6.3 Documentation

A tabulated list of the coordinates and elevations for the corners of the geophysical survey, stratigraphic test borings, monitoring wells, and control monuments will be prepared and submitted. The tabulation will consist of the designated name or number of the corner, boring, well, or monument; the X and Y coordinates; and all of the required elevations. Elevations will be determined for both the top of casing and the top of the survey monument at each monitoring well. This information will be used to generate a map plotted at a scale of 1 inch = 300 ft or larger showing the location, identification, coordinates, and elevations of the geophysical survey, soil borings, wells, and monuments. The tabulated list of coordinates and the map will be submitted, along with all field books and computation sheets, no later than when the Draft RI Report for this project is submitted.

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6.0 Calibration Procedures

6.1 Field Instruments

Field instruments will be calibrated daily before beginning sampling activities. Standards used to calibrate the field survey instruments will be traceable to NIST Standards. The method and frequency of calibration for the instruments used for each field activity are described in this section.

6.1.1 HNu Calibration

The meter will be calibrated according to manufacturer's instructions. The manufacturer will be contacted regarding recommendations for the most appropriate calibration procedure to be used for the contaminants of interest. General instructions are included in the HASP. On a daily basis, the meter will be calibrated to isobutylene. The HNu will be zeroed to background levels each hour and at each new location. Calibration records will be kept in the field log book by field personnel.

6.1.2 Organic Vapor Analyzer Calibration

The primary calibration of the OVA is performed at the factory to 100 parts per million (ppm) methane gas. Secondary calibration will be performed according to manufacturer's specifications at the beginning of each sampling activity. Those specifications are included in the HASP. In addition, the manufacturer will be contacted regarding recommendations for the most appropriate calibration procedure to be used for the contaminants of interest. The meter will be zeroed to background levels on a daily basis by field personnel.

6.1.3 Soil Boring Drilling

While drilling either borings or wells, an OVA or an HNu will be used to screen the soil samples and to monitor the ambient air. The calibration procedures outlined in Section 6.1.1 will be followed during the soil boring activities.

6.1.4 Groundwater Sampling

Several instruments will be used during the collection of groundwater samples. Initial monitoring of the ambient air for volatile organic vapors around the wellhead will be performed using an HNu meter. The meter will be calibrated to isobutylene each day and will be zeroed to ambient air at each well location before opening the well. During well evacuation, pH and specific conductance will be measured. The meters will be calibrated in the field before use at each well, following manufacturer's specifications. The calibration procedures are described below and will be carried out by field personnel.

6.1.5 pH Meter Calibration

The pH meters will be calibrated against two sets of standard pH solutions, either 4.0 standard units (SU) and 7.0 SU or 7.0 SU and 10.0 SU, depending on whether previous pH measurements have been less than or greater than 7.0 SU, respectively. Both the Cole-Parmer and Beckman meters automatically recognize pH standards and adjust the span and offset readings accordingly. Both pH meters also measure and display temperatures and automatically compensate pH readings accordingly. At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water.

6.1.6 Specific Conductivity Meter Calibration

The specific conductivity meters will be standardized by immersing the decontaminated conductivity probe into a standard solution of conductivity buffer. The conductivity of the standard solution will be within the same order of magnitude as the water sample. The meter reading will be manually adjusted to the buffer solution value. The Markson conductivity meter is automatically temperature-compensated to 20°C, while the Hanna meter requires manual adjustment of a temperature compensation knob. After calibrating, the probe will be triple rinsed with distilled water.

The pH and conductivity meters will be decontaminated before use at each well. The probes will be rinsed three times with distilled water before storage each day. The meters will be checked for battery charge and physical damage each day. The meters, pH standard solutions, and conductivity buffers will be stored in a cool, dry environment. Standard solutions will be discarded on their expiration dates.

6.2 Laboratory Equipment

The contracted laboratory will provide the project chemist and QA supervisor with a copy of the appropriate Comprehensive Quality Assurance Manual (CompQAM) for review and approval. The Laboratory CompQAM will outline in detail procedures for instrument calibration control.

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Section 7.0
Analytical Procedures

Samples will be analyzed using EPA-approved methods. Before the field effort begins, the analytical laboratory will provide the lead chemist with a copy of its CompQAM for review and approval.

7.1 Data Packages

Level 1 and 2 data package deliverables were detailed in Section 3.2.2. Level 3 data package deliverables are summarized in Table 7-1. Level 4 deliverables are the same as Level 3 with the addition of all the unreduced experimental data.

7.2 Reporting Limits

Method target compound lists and reporting limits are summarized in Table 7-2. Because of the use of similar analytical techniques for Levels 2 and 3, the target reporting limits presented in Table 7-2 are applicable for both data quality levels.

7.3 Special Analyses

The reporting limits are based on the Contract Laboratory Program Contract Required Detection Limits, which are equal to PQLs for this project.

Ten VOC compounds, three SVOC compounds, and one pesticide have MCLs lower than the standard reporting limits for the analytical methods chosen, as summarized in Table 7-3. Groundwater samples from areas not affected by site activities will initially be analyzed using the normal VOC and SVOC methods (CLP). However, sample locations that meet both of the following criteria may be resampled and reanalyzed using the low-level method presented below:

- None of the method target compounds can be present in concentrations greater than 25 μg/L (upper linear calibration range for the CLP).
- At least one of the target compounds was detected above its MCL but below the method reporting limit.

Also, for compounds where the CLP reporting limits do not meet the MCL or other preliminary remediation goal, the intent is to reanalyze the sample using a method with lower detection limits, if feasible. The decision to reanalyze samples using lower detection limits will be made on a case-by-case basis.

Table 7-1
Level 3 Data Package Deliverables
Defense Depot Memphis, Tennessee

Page 1 of 2

CLP Form	Purpose
Organic Compounds by GC/MS	
1	Data summary form
2	Surrogate spike recovery
3	MS/MSD recovery
4	Method blank summary
5	Instrument performance check summary
6	Initial calibration data
7	Continuing calibration check
8	Internal standard area and retention time summary
Organic Compounds by GC (Pesticides, PCBs, Herbicides)	
1	Data summary form
2	Surrogate spike recovery
3	MS/MSD recovery
4	Method blank summary
6D	Initial calibration retention time summary
7E	Continuing calibration summary
8C	Analytical sequence—evaluation of retention time shift for the internal standard
10	Compound identification summary
Inorganic Compounds	
1	Data summary form
2	Initial and continuing calibration verification
3	Blanks
4	ICP Interference check samples

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Table 7-1
Level 3 Data Package Deliverables
Defense Depot Memphis, Tennessee

Page 2 of 2

CLP Form	Purpose
5A	Spike sample recovery
5B	Post-spike sample recovery
6	Duplicates
7	Laboratory control sample
8	Method of standard addition results
9	ICP serial dilution results
10	Instrument detection limit
11A & B	ICP inter-element correction factors (annually)
12	ICP linear ranges (quarterly)
13	Preparation logs
14	Analysis run logs

Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

Page 1 of 7

Target Compound	Water (µg/L)	Soil (µg/kg)
Volatile Organic Compounds		
Chloromethane	10	10
Bromomethane	10	10
Vinyl chloride	10	10
Chloroethane	10	10
Methylene chloride	10	10
Acetone	10	10
Carbon disulfide	10	10
1,1-Dichloroethene	10	10
1,1-Dichloroethane	10	10
1,2-Dichloroethene (total)	10	10
Chloroform	10	10
1,2-Dichloroethane	10	10
2-Butanone	10	10
1,1,1-Trichloroethane	10	10
Carbon tetrachloride	10	10
Bromodichloromethane	10	10
1,2-Dichloropropane	10	10
cis-1,3-Dichloropropene	10	10
Trichloroethene	10	10
Dibromochloromethane	10	10
1,1,2-Trichloroethene	10	10
Benzene	10	10
trans-1,3-Dichloropropene	10	10
Bromoform	10	10
2-Hexanone	10	10
4-Methyl-2-pentanone	10	10

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Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

Page 2 of 7

Target Compound	Water (µg/L)	Soil (µg/kg)
Tetrachloroethene	10	10
1,1,2,2-Tetrachloroethane	10	10
Toluene	10	10
Chlorobenzene	10	10
Ethyl benzene	10	10
Styrene	10	10
Xylenes (total)	10	10
Semivolatile Organic Compounds		
Phenol	10	330
bis(2-Chloroethyl)ether	10	330
2-Chlorophenol	10	330
1,3-Dichlorobenzene	10	330
1,4-Dichlorobenzene	10	330
1,2-Dichlorobenzene	10	330
2-Methylphenol	10	330
2,2'-oxybis(1-Chloropropane)	10	330
4-Methylphenol	10	330
N-Nitroso-di-n-propylamine	10	330
Hexachloroethane	10	330
Nitrobenzene	10	330
Isophorone	10	330
2-Nitrophenol	10	330
2,4-Dimethylphenol	10	330
bis(2-Chloroethyoxy)methane	10	330
2,4-Dichlorophenol	10	330
1,2,4-Trichlorobenzene	10	330

Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

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Target Compound	Water (μg/L)	Soil (μg/kg)
Naphthalene	10	330
4-Chloroaniline	10	330
Hexachlorobutadiene	10	330
4-Chloro-3-methylphenol	10	330
2-Methylnaphthalene	10	330
Hexachlorocyclopentadiene	10	330
2,4,6-Trichlorophenol	10	330
2,4,5-Trichlorophenol	25	830
2-Chloronaphthalene	10	330
2-Nitroaniline	25	830
Dimethylphthalate	10	330
Acenaphthylene	10	330
2,6-Dinitrotoluene	10	330
3-Nitroaniline	25	830
Acenaphthene	10	330
2,4-Dinitrophenol	25	830
4-Nitrophenol	25	830
Dibenzofuran	10	330
2,4-Dinitrotoluene	10	330
Diethylphthalate	10	330
4-Chlorophenyl-phenylether	10	330
Fluorene	10	330
4-Nitroaniline	25	830
4,6-dinitro-2-methylphenol	25	830
N-Nitrosodiphenylamine	10	330
4-Bromophenyl-phenylether	10	330
Hexachlorobenzene	10	330

Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

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Target Compound	Water (µg/L)	Soil (µg/kg)
Pentachlorophenol	5	165
Phenanthrene	10	330
Anthracene	10	330
Carbazole	10	330
Di-n-butylphthalate	10	330
Fluoranthene	10	330
Pyrene	10	330
Butylbenzylphthalate	10	330
3,3'-dichlorobenzidine	10	330
Benzo(a)anthracene	10	330
Chrysene	10	330
bis(2-Ethylhexyl)phthalate	10	330
Di-n-octylphthalate	10	330
Benzo(b)fluoranthene	10	330
Benzo(k)fluoranthene	10	330
Benzo(a)pyrene	10	330
Indeno(1,2,3-cd)pyrene	10	330
Dibenz(a,h)anthracene	10	330
Benzo(g,h,i)perylene	10	330
Thiodyglycol	12.1	4200
2,4-Dinitrotoluene	10	330
Pesticides and PCBs		
alpha-BHC	0.050	1.7
beta-BHC	0.050	1.7
delta-BHC	0.050	1.7

Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

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Target Compound	Water (μg/L)	Soil (μg/kg)
gamma-BHC (Lindane)	0.050	1.7
Heptachlor	0.050	1.7
Aldrin	0.050	1.7
Heptachlor epoxide	0.050	1.7
Endosulfan I	0.050	1.7
Dieldrin	0.10	3.3
4,4'-DDE	0.10	3.3
Endrin	0.10	3.3
Endosulfan II	0.10	3.3
4,4'-DDD	0.10	3.3
Endosulfan sulfate	0.10	3.3
4,4'-DDT	0.10	3.3
Methoxychlor	0.50	17
Endrin ketone	0.10	3.3
Endrin aldehyde	0.10	3.3
Toxaphene	5.0	170
Aroclor-1016	1.0	33
Aroclor-1221	2.0	67
Aroclor-1232	1.0	33
Aroclor-1242	1.0	33
Aroclor-1248	1.0	33
Aroclor-1254	1.0	33
Aroclor-1260	1.0	33
alpha-Chlordane	0.05	1.7
gamma-Chlordane	0.05	1.7

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Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

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Target Compound	Water (µg/L)	Soil (µg/kg)
Herbicides		
2,4-D	2.5	50
Silvex (2,4,5-TP)	0.5	10
2,4,5-T	0.5	10
Dinoseb	0.5	10
Dioxins and Furans		
Tetrachlorodibenzodioxins	0.005	0.005
Pentachlorodibenzodioxins	0.005	0.005
Hexachlorodibenzodioxins	0.005	0.005
Tetrachlorodibenzofurans	0.005	0.005
Pentachlorodibenzofurans	0.005	0.005
Hexachlorodibenzofurans	0.005	0.005
Metals		
Aluminum—ICP	200	40,000
Antimony-ICP	60	12
Arsenic-GFAA	10	2
Barium—ICP	200	40,000
Beryllium-ICP	5	1
Cadmium-ICP	5	1
Calcium—ICP	5,000	1,000,000
Chromium-ICP	10	2
Cobalt—ICP	50	10,000
Copper-ICP	25	5
Iron—ICP	100	20,000
Lead-GFAA	3	0.6
Magnesium—ICP	5,000	1,000,000
Manganese—ICP	15	3,000

Table 7-2
Target Compound Lists and Reporting Limits
Defense Depot Memphis, Tennessee

Page 7 of 7

Target Compound	Water (µg/L)	Soil (µg/kg)
Mercury-CVAA	0.2	0.1
Nickel-ICP	40	8
Potassium–ICP	5,000	1,000,000
Selenium-GFAA	5	1
Silver-ICP	10	2
Sodium–ICP	5,000	1,000,000
Thallium-GFAA	10	2
Vanadium–ICP	5,000	1,000,000
Zinc-ICP	20	4

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Table 7-3
Comparison of Organic Compounds with MCLs and Method Reporting Limits
Defense Depot Memphis, Tennessee

Target Compound	Analysis	MCL (μg/L)	Normal CLP Method Reporting Limit (μg/L)	Special Method Reporting Limit (μg/L)
Vinyl chloride	VOC	2	10	1[a]
Methylene chloride	VOC	5	10	2[a]
1,1-Dichloroethene	VOC	7	10	1[a]
1,2-Dichloroethane	VOC	5	10	1[a]
Carbon tetrachloride	VOC	5	10	1[a]
1,2-Dichloropropane	VOC	5	10	1[a]
Trichloroethene	VOC	5	10	1[a]
1,1,2-Trichloroethene	VOC	5	10	1[a]
Benzene	VOC	5	10	1[a]
Tetrachloroethane	VOC	5	10	1[a]
Hexachlorobenzene	SVOC	1	10	0.2[b]
Pentachlorophenol	SVOC	1	50	0.5[c]
bis (2-ethylhexyl)phthalate	SVOC	6	10	5
Aldrin	Pesticide	–	0.05	0.02[b]

[a] Low Level Contract Laboratory Program
[b] Method 8080
[c] Method 8151

8.0 Data Quality Evaluation

8.1 Level 1—Field Survey Data

Field instruments used by CH2M HILL to collect temperature, pH, and conductivity are direct reading, thus making field calculations and subsequent data reduction unnecessary. All field data will be recorded in the site log books by appropriate trained field personnel. Field data will include the following:

- Instrument identification
- Calibration information (standards used and results)
- Date and time of calibration and sample measurement
- Sample results
- Supporting information (for example, temperature for pH reading)

If QC samples are used as part of the overall immunoassay tests, the results of these analyses also will be included in the field log. The FTL will provide a summary of the immunoassay results to the project chemist as well as to the FTL for review.

All data will be reviewed the FTL, who is responsible for the collection and verification of all field data while in the field. Data initially will be accepted or rejected by the FTL before leaving the sampling site. Extreme readings (readings that appear significantly different from other readings at the same site) will be accepted only after the instrument has been checked for malfunction and the readings verified by retesting. In addition, extreme or spurious readings will be recorded in the field log book, along with the rationale for accepting or rejecting the data.

Field documentation, sample data, instrument calibrations, and QC data will be reviewed by the PM (or a designee) before being included in the project files. QC checks will be reviewed by the project chemist, as well.

8.2 Level 2—Field Screening Data

The field screening laboratory will be required to provide a limited data package that includes instrument calibration, results for field samples, method blanks, and QC samples. This data package will be defined in detail in the subcontracting documents.

The project chemist will review the QC supporting information on a weekly basis and will provide a summary report to the PM at the end of the field effort. Areas of review will include the following:

- Instrument Calibration—Correct frequency for initial and continuing calibration, initial calibration linear range, and continuing calibration within the method target acceptance limits
- Sample Results—Results within the linear calibration range
- Laboratory Method Blanks—Potential for field sampling or laboratory contamination
- QC Sample Results—Replicate sample precision and spiked sample recovery (where applicable)
- Matrix Spike Results—Will be used to evaluate the effect of the sample matrix on the overall analytical results, as well as to provide an estimate for analytical accuracy and precision.

In addition to the methods outlined above, samples will be submitted to the fixed-base analytical laboratory for Level 2 screening. The laboratory will use the same analytical approach as outlined in the EPA-approved method; however, for Level 2 the frequency of QC will be decreased and no supporting QA/QC documentation will be included in the data package deliverables. There will not be any changes in the method target compound lists and reporting limits. For example, samples will still be analyzed for the same list of VOCs; however, for Level 2 samples, fewer MS/MSD samples will be analyzed and only sample results and method blank results will be submitted for the data package deliverables.

8.3 Level 3—Laboratory Analyses

Data quality evaluation will be performed by the CH2M HILL project chemists. The data quality evaluation process is used to assess the effect of the overall analytical process on the usability of the data. The two major categories of data evaluation are laboratory performance and matrix interferences. Evaluation of laboratory performance is a check for compliance with the method requirements and is a straight-forward examination; either the laboratory did, or did not, analyze the samples within the limits of the analytical method. Evaluation of the matrix interferences is more subtle and involves examination of several results including surrogate spike recoveries, matrix spike recoveries, and duplicate sample results.

Level 3 data package deliverables are summarized in Table 7-1 and will be detailed in the laboratory subcontractor documents. Before the analytical results were released by the laboratory, both the sample and QC data were carefully reviewed to verify sample identity, instrument calibration, detection limits, dilution factors, numerical computations, accuracy of transcriptions, and chemical interpretations. Additionally, the QC data were reduced and spike recoveries were included in control charts, and the resulting data were reviewed to ascertain whether they were within the laboratory defined limits for accuracy and precision. Any non-conforming data were discussed in the data package cover letter and case narrative. The laboratory will retain all the analytical and QC documentation associated with each data package. Such retained documentation need not be hard (paper) copy, but can be available on other storage media such as magnetic tape. However, the laboratory must be able to produce a hard copy of all the retained information upon request.

The data package will be reviewed by the project chemists using the process outlined in the EPA guidance document, *Functional Guidelines for Evaluating Data Quality* (EPA, 1991) (ref. 40). This overall process is used regardless of whether the samples were analyzed using CLP methods or not. The data review and validation process is independent of the laboratory's checks. It focuses on the usability of the data to support the project data interpretation and decision-making process. Areas of review include data package completeness, holding time compliance, initial and continuing calibration, spiked sample results, method blank results, and duplicate sample results. A data review worksheet will be completed for each data package. Acceptance criteria for each area of review are specified in the analytical method. For example, acceptance criteria for initial and continuing calibration are specified in each analytical method; any non-conformances will be noted on the data review worksheets and the effect of the non-conformance on the overall usability of the data will be evaluated as part of the overall data quality evaluation.

Samples that do not meet the acceptance limit criteria will be indicated with a qualifying flag, which is a one or two-letter abbreviation that indicates a problem with the data. Flags used in the text may include the following:

U	Undetected. Analyte was analyzed for but not detected above the detection limit.
J	Estimated. The analyte was present, but the reported value may not be accurate or precise.
UJ	Reporting limit estimated. The analyte was not detected above the method detection limit, but the actual detection limit may be estimated.
R	Rejected. The data were rejected because the corresponding QC data were not within the method-specified limits.

It is important to note that laboratory qualifying flags are included on the data summary forms (Form I) which are submitted to the project by the laboratory. However, during the data review and validation process, the laboratory qualifying flags are evaluated and replaced with validation flags.

Once each of the data packages has been reviewed, and the data review worksheets completed, then the entire data set will be evaluated for overall trends in data quality and usability. Information summarized as part of the data quality evaluation may include chemical compound frequencies of detection, dilution factors that might affect data usability, and patterns of target compound distribution. The data set will also be evaluated to identify potential data limitation or uncertainties in the laboratory. Additional areas of review are discussed below.

8.3.1 Field and Laboratory Blank Contamination

Review includes the appearance and concentration of target compounds in field and laboratory blanks as well as of environmental samples. Common field sampling and laboratory contaminants detected in blank include acetone, methylene chloride, and phthalates. Acetone and methylene chloride are used to extract samples in the laboratory and hence are common laboratory contaminants. Phthalates are used as plasticizers, the most common of which is bis(2-ethylhexyl)phthalate, and are often introduced during sample handling.

According to the EPA Functional Guidelines, concentrations of these common contaminants detected in samples at less than 10 times the maximum concentration in the blanks can be attributed to field sampling and laboratory contamination rather than to environmental contamination from site activities. As a note, concentrations of common contaminants such as acetone, methylene chloride, and phthalates detected in both the sample and the corresponding blanks use the 10X rule. Concentrations of less common contaminants are multiplied by five rather than 10, as required by the EPA Functional Guidelines.

8.3.2 Surrogate Spike Recoveries

Surrogate spike recoveries are compounds for each of the organic analytical methods. For gas chromatograph/mass spectrometer (GC/MS) analyses, surrogate spike compounds are the structural homologs of target compounds, often with deuterium substituted for hydrogen, and are therefore are expected to behave in a similar manner during analysis. For GC analyses, surrogate spike compounds, are structurally similar (but not identical) to target compounds and again, should behave in a similar manner during analysis. Surrogate spike recoveries are used to monitor both laboratory performance and matrix interferences. Surrogate spike recoveries from field and laboratory blanks are used to evaluate laboratory performance because these blanks represent an ideal sample matrix. Surrogate spike recoveries for field samples are used to evaluate the potential for matrix interferences. When surrogate spike recoveries for field samples fall outside the method target acceptance windows, the samples are re-analyzed. If the surrogate spike recovery is still outside the acceptance window for the re-analyzed sample, then the sample results are qualified as affected by matrix interferences.

8.3.3 Matrix Spike Recoveries

For this QC measure, three aliquots of a single sample are analyzed—one native and two spiked with the same concentration of matrix spike compounds. Unlike the surrogate spike compounds, matrix spike compounds are found on the method target compound list. Spike recovery is used to evaluate potential matrix interferences as well as accuracy. The duplicate spike results are compared to evaluate precision.

8.3.4 Duplicate Sample Results

Typically, one duplicate field sample will be collected for every 10 field samples. Both the native and duplicate samples are analyzed for the same parameters. Target compounds that are detected in both the native and duplicate samples can be compared and precision for the sample results calculated.

8.4 Level 4—Laboratory Analyses

Data quality evaluation of Level 4 data will be executed using the same process descirbed for Level 3 data; however, calculations for calibration, spike recovery, and sample results will be recreated using the raw data. These example calculations will be included with the data review worksheets.

8.5 Reconciliation with Data Quality Objectives

The final activity of the data quality evaluation is an assessment of whether the data meets the DQOs. The goal of this assessment is to demonstrate that a sufficient number of representative samples were collected and the resulting analytical data can be used to support the project decision-making process. The following precision, accuracy, representativeness, completeness, and comparability (PARCC) measures are used:

- **Precision**—is the agreement between duplicate results and can be estimated by comparing duplicate matrix spike recoveries and field duplicate sample results.
- Accuracy—is a measure of the agreement between an experimental determination and the true value of the parameter being measured. For organic analyses, each of the samples is spiked with a surrogate spike compound and for inorganic analyses, each sample was spiked with a known reference material before digestion. Each of these approaches provides a measure of the matrix effects on the analytical accuracy.

Accuracy can be estimated from the analytical data and cannot be measured directly.

- **Representativeness**—is a qualitative measure of the degree to which sample data accurately and precisely represent a characteristic environmental condition. Representativeness is a subjective parameter and is used to evaluate the efficacy of the sampling plan design. Representativeness is demonstrated by providing full descriptions of the sampling techniques and the rationale used for selecting sampling locations in the project scoping documents.
- **Completeness**—is defined as the percentage of measurements that are judged to be valid compared to the total number of measurements made. Typically, a goal of 95 percent usable data is desired.
- **Comparability**—is another qualitative measure designed to express the confidence with which one data set may be compared to another. The following factors affect comparability: sample collection and handling techniques, sample matrix type, and analytical method. Comparability is limited by the other PARCC parameters because data sets can be compared with confidence only when precision and accuracy are known. Data from one phase of an investigation to another can be compared when the same EPA-approved methods are used and data package deliverables are similar.

9.0 Performance and System Audits

Performance and systems will be audited to verify documentation and implementation of the project work plan, to identify any nonconformances, and to verify correction of identified deficiencies.

9.1 Assessments and Response Actions

Assessment activities may include surveillance, inspections, peer review, management system review, readiness review, technical systems audit, performance evaluation, and data quality assessment. The CH2M HILL project chemist or PM will be responsible for initiating audits, for selecting the audit team, and for overseeing audit implementation.

The project chemist or PM will evaluate the need for a performance audit independently, or by recommendation of the PM or the client. Performance audits are used to quantitatively assess the accuracy of analytical data through the use of performance evaluation and blind check samples. Laboratory performance will be audited by the PM, project chemist, or a designee.

The FTL is responsible for supervising and checking that samples are collected and handled in accordance with the approved project plans and that documentation of work is adequate and complete. The PM is responsible for seeing that project performance satisfies the QA/QC objectives. Reports and technical correspondence will be peer reviewed by an assigned qualified individual, otherwise external to the project, before being finalized.

9.2 Field Team Performance and System Audits

The FTL or a designated representative will conduct weekly informal audits of the field activities. The weekly audit for completeness will include the following items:

- Sample labels
- COC records
- Field notebooks
- Sampling operations
- Document control

The first three items above will be checked for completeness. Sampling operations will be reviewed to determine if they are performed as stated in the project-specific work plan, or as directed by the FTL. The informal document control audit will consist of checking each document for completeness, including such items as signatures, dates, and project numbers.

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A systems audit of field operations may be required by the project-specific work plan and will be used to review the total data generation process, which includes onsite review of the field operational system, physical facilities for sampling, and equipment calibrations. A performance audit may be conducted by the PM and the FTL during the first week of sampling if it is deemed necessary by the PM, FTL, project chemist, or client. The audit may focus on verifying that proper procedures are followed so that subsequent sample data will be valid. Before the audit, a checklist will be prepared by the PM and the FTL, and will serve as a guide for the performance audit. The audit may verify the following:

- Collection of samples follows the available written procedures.
- COC procedures are followed for traceability of sample origin.
- Appropriate QC checks are being made in the field and documented in the field log book.
- Specified equipment is available, calibrated, and in proper working order.
- Sampling crews are adequately trained.
- Record-keeping procedures are being followed and appropriate documentation is maintained.
- Corrective action procedures are followed.

An audit report summarizing the results and corrections will be prepared and filed in the project files.

9.3 Laboratory Performance and Systems Audits

The analytical laboratory will conduct both internal and external QC checks. External QC checks include participation in EPA's certification and performance evaluation programs. The results of quarterly performance evaluation samples will be made available to the PM on request. Internal QC checks (duplicates, blanks, and spiked samples) will be performed in accordance with the approved methods.

Laboratory systems will be audited annually and as required by specific projects. Contracted laboratories are required to submit a laboratory QAPP and relevant SOPs before the field effort begins. If, during data evaluation and data use, any problems are noted, specific corrective actions will be implemented on a case-by-case basis. An additional systems audit may be requested by the CH2M HILL project chemist or PM, if warranted.

Depending on the project objectives, the laboratory may be required to perform the following:

- Monthly project review of 10 percent of all projects done by the QA department
- Audits performed by the laboratory QA manager at a frequency greater than specified in the lab CompQAM
- Special audits by the project chemist or corporate management when a problem is suspected

10.0 Preventive Maintenance

10.1 Field Instruments

All equipment used by CH2M HILL will be maintained in accordance with the manufacturer's instructions. Preventive maintenance activities for field equipment are listed in Table 10-1. Routine maintenance and all equipment repairs will be documented in the site log book. Whenever a piece of equipment fails to operate properly, the instrument either will be repaired in-house (if possible) or will be sent out for repairs and another instrument equivalent to the original substituted (if possible).

Table 10-1
Field Equipment Preventive Maintenance
Defense Depot Memphis, Tennessee

Instrument	Activity	Frequency
pH meter	Battery replacement or electrode cleaning	As needed (indicated by LCD display) or as specified in instrument manual
Conductivity Meter	Battery replacement or probe cleaning	As needed (indicated by LCD display) or as specified in instrument manual

10.2 Analytical Laboratory Instruments

Preventive maintenance for laboratory instruments is discussed in detail in the laboratory CompQAM.

11.0 Calculation of Data Quality Indicators

11.1 Quality Control Measures

The QC measures described below are incorporated into Levels 2, 3, and 4 analytical methods.

Method Blanks—A method blank is a sample of analyte-free water that is treated as a sample in that it undergoes the same analytical process as the corresponding field samples. Method blanks are used to monitor laboratory performance and contamination introduced during the analytical procedure. Typically, one method blank is required per 10 or 20 samples (depending on the analytical method) or one per batch, whichever is more frequent.

Matrix Spikes—For inorganic analyses, a single sample is split and one portion is spiked with a known amount of reference material. For organic analyses, three aliquots of a single sample are analyzed—one native and two spiked with matrix spike compounds. Unlike the surrogate spike compounds, matrix spike compounds are found on the method TCL. Spike recovery is used to evaluate potential matrix interferences as well as accuracy. The duplicate spike results are compared to evaluate precision. The matrix spike compounds and method target acceptance ranges are summarized for each analytical method. Typically, one matrix spike (inorganic) or matrix spike/matrix spike duplicate (MS/MSD) sample (organic) is analyzed for every 20 samples of the same matrix.

Surrogate Spikes Recoveries—This QC measure is applicable only to organic analyses. Surrogate compounds are the structural homologs of target compounds, often with deuterium substituted for hydrogen, and are therefore expected to behave in a similar manner during the analysis. Surrogate spike recoveries were used to monitor both laboratory performance and matrix interferences. Surrogate spike recoveries from field and laboratory blanks were used to evaluate laboratory performance because the field blanks represent an "ideal" sample matrix. Surrogate spike recoveries for field samples were used to evaluate the potential for matrix interferences. For field samples, when the surrogate spike recoveries fall outside the method target acceptance windows, the samples are re-analyzed. If the surrogate spike is still outside the acceptance window for the re-analysis, then the sample results are qualified as affected by matrix interferences.

11.2 Formulas for Calculating Accuracy, Precision, and Completeness

Precision is a measure of the agreement or repeatability of a set of replicate results obtained from duplicate analyses made under the same conditions. Precision will be estimated from analytical data and cannot be measured directly. The precision of a duplicate determination can be expressed as the relative percent difference (RPD), as calculated from the equation:

$$RPD\ IX_1 - X_2I/(X_1 + X_2)\ X\ 200$$

where X_1 and X_2 are the duplicate values.

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured. Accuracy is estimated through the use of known reference materials or matrix spikes. Accuracy is calculated from analytical data and is not measured directly. Spiking of reference materials into an actual sample matrix is the preferred technique because it provides a measure of the matrix effects on the analytical accuracy. Accuracy, defined as percent recovery (P), is calculated by the following equation:

$$P = (SSR - SR)/SA]\ x\ 100$$

where SSR is the spiked sample result, SR is the sample result (native), and SA is the spike added.

Completeness is defined as the percentage of measurements judged to be valid compared to the total number of measurements made. Completeness is calculated using the formula:

$$\text{Completeness} = \frac{\text{Valid Measurements}}{\text{Total Measurements}}\ \text{x}\ 100$$

12.0 Corrective Actions

12.1 Field Activities Corrective Actions

The PM is responsible for initiating corrective actions. Corrective action steps include problem identification, investigation responsibility assignment, investigation, action to eliminate the problem, increased monitoring of the effectiveness of the corrective action, and verification that the problem has been eliminated.

Documentation of the problem is important to the overall management of the study. A corrective action request form for problems associated with sample collection is completed by the person discovering the QA problem. This form identifies the problem, establishes possible causes, and designates the person responsible for action. The responsible person will be either the project manager or the FTL.

The correction action request form (Figure 12-1) includes a description of the corrective action planned and has space for follow-up. The PM verifies that the initial action has been taken and appears to be effective and, at an appropriate later date, checks to see if the problem has been resolved fully. The PM receives a copy of all corrective action request forms and enters them into the corrective action log. This permanent record aids the PM in follow-up and assists in resolving the QA problems.

Examples of corrective action include, but are not limit to, correcting COC forms, analysis reruns (if holding time criteria permit), recalibration with fresh standards, replacement of sources of blank contamination, or additional training in sampling and analysis. Additional approaches may include the following:

- Resampling and re-analyzing.
- Evaluating and amending sampling and analytical procedures.
- Accepting the data and acknowledging the level of uncertainty or inaccuracy by flagging the validated data and providing an explanation for the qualification.

12.2 Laboratory Activities Corrective Actions

The laboratory department supervisors review the data generated to verify that all QC samples have been run as specified in the protocol. Laboratory personnel are alerted that corrective actions may be necessary under the following conditions:

- QC data are outside the warning or acceptable windows for precision and accuracy established for laboratory samples.

Originator: ______________________ Date: __________

Person responsible for replying: ______________________

Description of problem and when identified: ______________________

____

Sequence of Corrective Action (CA): (Note, if no responsible person is identified, submit this form directly to the project manager)

State date, person, and action planned:

____

____

____

____

____

CA initially approved by: ______________________ Date: __________

Follow-up date: ______________________

Final CA approval by: ______________________ Date: __________

Information copies to:

Responsible Person: ______________________

Field Team Leader: ______________________

Project Manager: ______________________

FIGURE 12-1
CORRECTIVE ACTION REQUEST FORM
Defense Depot Memphis, Tennessee

CH2MHILL

MQP-0005.DWG 21-Feb-1995

- Blanks contain contaminants at concentrations above the levels specified in the laboratory QAPP for any target compound.

- Undesirable trends are detected in matrix spike recoveries or RPD between matrix spike duplicates.

- There are unusual changes in detection limits.

- Deficiencies are detected by the laboratory QA director during internal or external audits, or from the results of performance evaluation samples.

If nonconformances appear in analytical methodologies, QC sample results are identified by the bench analyst, and corrective actions are implemented immediately. Corrective action procedures are handled initially at the bench level by the analyst, who reviews the preparation or extraction procedure for possible errors; and checks the instrument calibration, spike and calibration mixes, instrument sensitivity, and so forth. The analyst immediately notifies his/her supervisor of the problem that is identified and the investigation being made. If the problem persists or cannot be identified, the matter must be referred to the laboratory supervisor and QA/QC officer for further investigation. Once resolved, full documentation of the corrective action procedure must be filed with the laboratory supervisor, and the QA/QC officer must be provided with a corrective action memorandum for inclusion into the project file if data are affected.

Corrective actions may include, but are not limited to, the following:

- Re-analyzing suspect samples
- Resampling and analyzing new samples
- Evaluating and amending sampling and analytical procedures
- Accepting data with an acknowledged level of uncertainty
- Recalibrating analytical instruments
- Qualifying or rejecting the data

After the implementation of the required corrective action measures, data that is deemed unacceptable may not be accepted by the PM, and follow-up corrective actions may be explored. Details of laboratory corrective actions are provided in the laboratory CompQAM.

13.0 Quality Assurance Reports

The purpose of QA reports is to document implementation of the QAPP. These reports include periodic assessments of measurement data accuracy, precision, and completeness; the results of performance audits; the results of system audits; and identification of significant QA problems and recommended solutions.

The analytical laboratory will be responsible for submitting monthly progress reports to the client as requested.

The final QA report will be attached as an appendix to the project report and may include the following:

- Data quality assessment in terms of PARCC, and the method detection limits
- The degree to which DQOs were met
- Limitations of the measurement data; usability of the data
- Applicability of the data to site conditions
- Laboratory QC activities, including a summary of planned versus actual laboratory QC activities, explanations for deviations, and an evaluation of data quality for each analysis for each media
- Field QC activities, including a summary of planned versus actual field QC activities, explanations for deviations, and an evaluation of the data quality of field QC samples/activities and estimated effect on sample data
- Data presentation and evaluation, including an assessment of sampling and analysis techniques, data quality for each analysis and each media, and data usability

A final report will be submitted to the client after comments from the client and any regulatory agencies have been incorporated.

14.0 Sample and Database Management

14.1 General Information

The project database will be EDMS-A (environmental data management system in Access) and an environmental management information system (EMIS) deliverable will be submitted to the client. EMIS is similar to Interchange File Format (IFF) typically used by EPA, and the two formats are compared in Table 14-1. The few fields in IFF that do not correspond to an EMIS field include data that are not normally collected or are represented in EMIS in another field (LTHAN in Table 14-1 is represented in the flag qualifiers in EMIS).

The data management team consists of the PM, database manager, and data manager. The team will be responsible for the execution of the Data Management Plan. All documentation relating to the development and execution of the Data Management Plan will be kept in the project data management file, which will be stored in a central location accessible to all members of the data management team. The data manager will be responsible for maintenance of the data management file.

The data management file will consist of the following sections:

- Internal correspondence
- External correspondence
- Field correspondence
- Data management meeting notes
- Work plan information
- Project instructions
- Status reports
- E-Data documentation from lab
- Import description and exception reports
- Front-end QC description and exception reports
- Intermediate QC description and exception reports
- Back-End QC description and exception reports
- E-Data resubmittal requests
- Internal deliverable review comments
- External deliverable review comments
- Standard procedures

All electronic files associated with the project data management task will be kept on the network file server. Examples of these files are memos, plans, instructions, spreadsheets with station data, and the database itself. Backups of this data will be made according to that office's daily, system-wide backup routine.

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Table 14-1
Parameters
Defense Depot Memphis, Tennessee

[illegible]	Format	Description	[illegible]	COMMENTS
LOCATION KEY	[A22]	(1-16 SiteID) (17-21 Solid Wst Mgt ID) (22 Program Status Indicator - VVL)	SAMP_LOC - LOC_ID	
			SAMP_LOC - SITE_ID	
SAMPLE KEY	[A15]	Unique field sample ID	SAMPLE_DATA - SAMPLE_NO	
PARAMETER KEY	[A15]	Unique lab sample ID	SAMPLE_PREP - LABSAMP_ID	
CASE NUMBER	[A5]	Batch identifier	SAMPLE_PREP - SDG	
PARAMID	[A12]	Parameter identifier	ANAL_RES - PARAM_LABEL	
REPLNUM	[XXXX]	Replicate number. Identifies results as which number replicate	None	
LABQUALIF	[A2]	Lab qualifier - VVL	ANAL_RES - LAB_QUAL	
REVIEWQUALIF	[A2]	Project qualifier - VVL	ANAL_RES - DATA_QUAL	
WHO_REVIEW	[A4]	Name and organization of reviewer	ANAL_RES - VALCOMP - VVL	
VALUE	[XXXXXXX.XXXX]	Analytical result of chemical	ANAL_RES - CONCENTRATION	
LTHAN	[A2]	[ND] for non detects or blank for detects	None	like lab and proj qualifiers
UNITS	[A6]	Units	ANAL_RES - UNIT_MEAS	
AMETHOD	[A40]	Analytical method used to find VALUE	ANAL_RES - ANAL_METH	
EMETHOD	[A40]	Extraction method used (SV, Pesticide/PCB etc)	SAMPLE_PREP - EXTRACT_METH	
ADATE	[YYMMDD]	Analysis date	SAMPLE_PREP - ANALYSIS_DATE	
CDATE	[YYMMDD]	Collection date	SAMPLE_DATA - COLLECT_DATE	
RDATE	[YYMMDD]	Date recieved at lab	SAMPLE_PREP - RECEIVED	
EDATE	[YYMMDD]	Extraction date	SAMPLE_PREP - EXTRACT_DATE	
MATRIX	[A5]	Sample matrix (SOIL, WATER, AIR, OTHER)	SAMPLE_DATA - MATRIX	
DILUTION	[XXXXXXXX]	Dilution factor	ANAL_RES - DILUTE	

mgm95-DDMT-WP2/028.xls

Table 14-1
Parameters
Defense Depot Memphis, Tennessee

[illegible]	[illegible]	Description	[illegible]MIS[illegible]	[illegible] COMMENTS [illegible]
REPLIMIT	[XXXXXXX.XXXX]	Lab reporting limit	ANAL_RES - DETECT_LIM	
DETECT_LIMIT	[XXXXXXX.XXXX]	Method detection limit	None	
PQL	[XXXXXXX.XXXX]	Practical quantification limit for the specified analysis	None	
LAB	[A40]	Name of lab perfoming analysis	SAMPLE_PREP - LAB_ID	
Comment	[A80]	Additional information	ANAL_RES - COMMENTS	

14.2 Hard Copy Data Management

Management of hard copy data packages is the responsibility of the data manager. As data packages are received, the data manager will enter the sample delivery group (SDG) number and date received in the database, and pass the data package to the data quality evaluation manager.

A cursory review of each hard copy data package will be performed by the data quality evaluation manager. Under the direction of the data quality evaluation manager, the data received will be compared to the COC to confirm that hard copies of all expected results are received. The SDG number for each analysis requested (for example, volatiles, semivolatiles, total metals, filtered metals, and dioxins) will be recorded in the Detailed Data Inventory Sheet (DDIS). Data packages will be prepared for data quality evaluation and filed in a central data storage area.

After all data packages are received, the DDIS will be reviewed for completeness by the data quality evaluation (DQE) team as part of the data quality evaluation process. The finalized DDIS will be included as part of the data quality evaluation technical memorandum delivered to the client.

14.3 Field Data Management

A sample tracking program (STP) will be used to manage data collected by the field team. STP is a subsystem of the EMIS implementation of the Microsoft Access-based Environmental Data Management System (EDMS/A-EMIS), developed to manage the flow of information from the field sampling team to the laboratory and to internal/external clients. STP is used for entry of field-originating information (such as station locations, lithologic descriptions, well completion information, sample collection dates/times, analyses requested, and field measurements), and to produce sample bottle labels, COC forms, electronic files containing COC information, and daily and weekly sampling summary reports.

STP will be updated by the database manager to include codes for EMIS-specific data reporting requirements (such as site location type, sample matrix, and analytical method) in accordance with the November 1994 EMIS Data Dictionary. Queries will be developed to aid the field team in calculating sample collection statistics and in verifying stations sampled and analyses requested against the work plan. All software modifications and support will be the responsibility of the database manager.

Before field mobilization, all STP modifications will be reviewed. All November 1994 EMIS Data Dictionary codes applicable to the project will be verified by data entry personnel. A data inventory table of all analytical methods to be requested and the corresponding analytes to be received from the laboratory will be verified by the data manager and sent to the laboratory for verification. All sampling location information (such as well identification and site identification) will be verified against historically used location information by the data manager. If historical names are not available, location information will be provided by the client's data manager. A table of location information and the corresponding analyses to be requested will be sent to the client's data manager for independent verification.

Testing of STP modifications will consist of running STP through the normal daily routine performed in the field using an example data set that will be representative of planned field sampling activities. A daily sample summary report will be printed. Sample labels will be generated for all planned analytical combinations. Sample collection times will be entered and a COC will be printed. An electronic file containing COC information will be generated and sent via modem to the analytical laboratory for import into its data management system. Finally, an example weekly summary report will be produced and compared against the example data set.

The data manager will coordinate the implementation of STP during the field investigation during the mobilization period. Implementation will include the setup of all necessary computer hardware and software, setup of electronic communication systems, installation of the database, and STP usage training for the two-person sample management team. After the initial training, the data manager will provide support to the sample management team, as needed, for the duration of the field sampling event.

During the field sampling event, all station location, lithologic description, well completion, groundwater level, and sampling-related data will be entered by one field sample management team member and checked by the other team member against the original data forms (for example, purging forms, sampling forms, soil boring logs, and well completion logs) using the manual data entry verification procedure described below.

One of the sample management team members will be designated as the field data manager and will assume responsibility for setting up samples, generating labels, logging samples and generating COCs, generating electronic files containing COC information and transferring them via modem to the analytical laboratory, and entry of field-related information. The field data manager is also responsible for verifying that samples with QA Levels 3 and 4 collected on the same day will be shipped to the laboratory on separate COCs. The other sample management team member will be responsible for setting up sample coolers in the morning for the sampling teams to take out, checking in coolers after sample collection throughout the day, confirming that the sample preservation is adequate, shipping the sample coolers from the field to the laboratory, and verifying field-related information entered into the database against the hard copy. QA Level 2 (screening) samples and analyses will not be tracked by STP or reported in EMIS format.

The FTL will notify the data manager or database manager of any unusual occurrences relating to field sampling that affect the field or laboratory data that are to be processed by the data management team. Examples of unusual occurrences are assigned samples that were not collected, omission of field-generated data from the database, or breaking of sample bottles during transport to or processing at the laboratory. This information will be documented as appropriate in the database and the data management file under "Field Correspondence."

After log-in of the SDG from the field, the laboratory will acknowledge receipt of the samples by faxing the following items to both the field data manager and the DQE team:

- COC
- Exception Report—noting any problems with the sample shipment
- Sample Receipt Summary Report—containing data entered into the laboratory's database for each sample (including SDG, sample identification, location identification, analysis requested, data collected, and date received by laboratory)

The field data manager will use this information to verify all field-related information (sample identification, location identification, analysis requested, and date collected) at the laboratory, using the manual data entry verification procedure described in this section. The date received by the laboratory and the SDG number assigned by the laboratory to each sample will be entered into STP by the field sample management team from the Detailed Laboratory Summary Report.

The field data manager will generate a weekly sample status report. This report will be delivered to the FTL for review and delivery to the client. The field data manager will fax a copy of the finalized weekly sample status report to the data manager, who will add it to the data management file under "Status Reports."

Data from STP will be transmitted via modem or disk from the field team to the data manager on a weekly basis. The time and method of transmittal will be coordinated by the field data manager and the data manager. The data manager will check the STP data for correctness, completeness, and consistency. The data manager will alert the FTL of any errors or omissions contained in the STP data.

STP data will be contained in the STP file EDMSDATA.MDB and will be "imported" into the data management team copy of EDMS/A-EMIS by renaming the existing file in the appropriate EDMS subdirectory to EDMSDATA.MXX (where XX is the two-digit number of the field effort's week) and copying the new EDMSDATA.MDB file into that same directory. The goal is to have one EDMSDATA.MDB file for every week of the field effort, each containing data up to that week, with the most current file using the .MDB extension.

14.4 Management of Laboratory Electronic Data Deliverables

Electronic data (E-Data) deliverables will be sent as compressed (PKZIP 2.04) files to the data manager. A copy of the E-Mail cover letter, which includes a list of the file(s) transmitted and the date and time of transmittal, will be printed and stored in the data management file under "E-Data Documentation from Lab."

E-Data will be imported into EDMS/A-EMIS, using an EMIS-specific import program. The import program reads the data into EDMS/A-EMIS and performs a series of QC and data validation checks, based on the requirements specified in the November 1994 EMIS Data Dictionary. The checks and the rules they are based on are documented in the data management file under "Import Description and Exception Reports."

If the import program encounters any exceptions to the QC checks described above, the exception will be listed in the Import Exceptions Report. The Import Exceptions Report will contain the information necessary to identify the import file and line, and an explanation of the exception. Exceptions serious enough to jeopardize the integrity of the database will be reported as "ERRORS," and the offending line will not be imported. Less critical exceptions will be reported as "WARNINGS," and the offending line will be imported.

The data manager will evaluate each item in the Import Exceptions Report and determine what action, if any, needs to be taken. If the appropriate action is a manual data change to the laboratory-provided E-Data files by the data management team, the change will be verified and the laboratory will be notified of the change via E-Mail. If the appropriate action is to request a resubmission of the electronic data from the laboratory, the resubmission will be requested.

Once the appropriate action to be taken is completed, the action taken for each item in the Import Exceptions Report will be noted, initialed, and dated. Once all items listed on the Import Exceptions Report are resolved, the report will be added to the data management file under "Import Exceptions Reports."

During the data management process, manual changes may be made to the EDMS/A-EMIS database that create discrepancies with data stored in files at the laboratory. The data manager will notify the laboratory of the discrepancies so that laboratory records can be updated.

14.5 Front-end Data Content Verification

After the import of laboratory electronic data into the EDMS/A-EMIS database and resolution of all Import Exceptions, a series of queries will be performed to verify the content of and relationships between data. Content queries will confirm that all specific data codes used are correct as defined by the November 1994 EMIS Data Dictionary. Relationship queries will verify that relationships between certain data elements are correct and logical. For example, queries will verify that for a single sample, the Collection Date is an earlier date than the Analysis Date. The front end QC queries will be reviewed and modified as needed to check for valid values specific to this project.

If a database record does not satisfy the conditions specified by the query, the exception will be listed in the Front-End Exceptions Report. The Front-End Exceptions Report will contain the name of the query, the information necessary to identify the database record, and an explanation of the exception. The data manager will evaluate each item in the Front-End Exceptions Report and determine what action, if any, needs to be taken. If the appropriate action is a manual data change, it will be verified. If the appropriate action is to request a resubmission of the electronic data from the laboratory, the resubmission will be requested. If the action taken affects information received from the laboratory in its deliverables, the laboratory will be notified of the changes made via E-Mail.

Some items in the Front-End Exceptions Report may be acceptable. For example, the Front-End Exceptions Report may identify a matrix spike that is reported with a Sample Location ID of "FIELDQC." The Location ID of "FIELDQC" is only appropriate for equipment blanks, field blanks, and trip blanks; matrix spikes normally are not taken from blanks. Evaluation of the database record reveals that the matrix spike was taken by the laboratory to satisfy its own internal QC procedures, and that the parent sample from which the matrix spike was taken was an equipment blank. Therefore, the Sample Location of "FIELDQC" is acceptable.

Once the appropriate action to be taken is completed, the query will be re-run to confirm that the exception has been corrected, and the item in the Front-End Exceptions Report will be initialed and dated. If the item is acceptable, it will be noted as such and explained as necessary on the Front-End Exceptions Report, initialed, and dated. Once all items listed on the Front-End Exceptions Report are resolved, the report will be added to the data management file under "Front-End QC Descriptions and Exceptions Reports."

14.6 Data Quality Evaluation Flag Entry

The data manager is responsible for the entry of the data quality evaluation flags into the database after the completion of data quality evaluation by the DQE team. The DQE team will notify the data manager when the data quality evaluation is completed. Using data entry forms in EDMS/A-EMIS, laboratory qualifiers and/or concentration values changed on the Form I by the DQE team will be entered into the database in the validation flag and/or concentration fields. If the laboratory qualifier and/or concentration values were not changed by the DQE team, no entry will be made in the validation flag and/or concentration fields. After the completion of data entry, the data manager will update the validation flag field as appropriate with data from the laboratory qualifier field for validation flag values that were not changed during the data quality evaluation process. This update will occur for all non-surrogate parameters associated with normal environmental samples, field duplicates, dilutions, or re-extractions. This update will not occur for surrogate parameters or for parameters associated with equipment blanks, trip blanks, field blanks, matrix spike/spike duplicates, inorganic laboratory replicates, or laboratory blanks.

After completion of the process described above, Replicate Form Is will be generated from the database and printed. The Replicate Form Is will be verified against the original validated (marked-up) Form Is using the manual data entry verification procedure. If errors are discovered, the error will be corrected in the database, and a new Replicate Form Is will be generated, printed, and verified against the original marked-up Form I. This process is repeated until no errors remain. When the verification process is completed, the Replicate Form Is will be filed with the original validated (marked-up) Form Is according to SDG number. An entry will be made in the history data table to document that the data quality evaluation flag field values have been entered and verified.

14.7 Intermediate Data Completeness Verification

After entry of the data quality evaluation flags, a series of queries will be performed to verify the content of, correctness of, and relationships between the data. This intermediate data completeness verification will consist of the complete set of front-end data content validation queries (with results evaluated and documented), and additional intermediate queries that will further evaluate the database. The intermediate QC queries will be reviewed and modified as needed to meet the requirements of this project.

Content and relationship queries involving the data quality evaluation flag field will be evaluated. For example, queries will be performed confirming that all the data quality evaluation flags are valid and that all analytical result records with a QA level other than "N" have non-null values in the data quality evaluation flag field. In addition, queries will be performed confirming that the one-to-many relationships between Sample Data, Sample Preparation Data, and Analytical Results are intact and correct. Queries will confirm that all Analytical Results records have associated Sample Preparation Data records, and that all Sample Preparation Data records have associated Sample Data records. Conversely, queries will confirm that no Sample Data records exist without associated Sample Preparation Data records, and that no Sample Preparation Data records exist without associated Analytical Results records.

If a database record does not satisfy the conditions specified by the query, the exception will be listed in the Intermediate QC Exceptions Report. The Intermediate QC Exceptions Report will contain the name of the query, the information necessary to identify the database record, and an explanation of the exception. The data manager will evaluate each item in the Intermediate QC Exceptions Report and determine what action, if any, needs to be taken. If the appropriate action is a manual data change, it will be verified. If the appropriate action is to request a resubmission of the electronic data from the laboratory, the resubmission will be requested.

Once the appropriate action to be taken is completed, the query will be re-run to confirm that the exception has been corrected, and the item in the Intermediate QC Exceptions Report will be initialed and dated. If the item is acceptable, it will be noted as such and explained as necessary on the Intermediate Exceptions Report, initialed, and dated. Once all items listed on the Intermediate Exceptions Report are resolved, the report will be added to the data management file under "Intermediate QC Descriptions and Exceptions Reports." If the action taken affects data provided by the laboratory in its electronic deliverables, the laboratory will be notified via E-Mail of the changes made.

14.8 Generation of EMIS-like Access Tables

Two weeks before each deliverable deadline (draft/final), and provided that the necessary data are complete, the database manager will generate the EMIS-like Access tables. These tables follow the exact field name, count, type, length, and order of the EMIS tables deliverables. For the project, seven tables will be generated: SAMP_LOC, WELL_COMP, LITH_DES, SAMPLE_DATA, WATER_LEVEL, SAMPLE_PREP, and ANAL_RES. These tables are the source and final repository of the data for the draft and final deliverables.

The database manager will establish the structure of the tables manually in EDMS/A-EMIS, according to the EMIS November 1994 Data Dictionary specifications. The tables will be populated by running queries that pull the appropriate data from various EDMS/A-EMIS tables and place them in the corresponding fields in the EMIS-like Access tables. In addition to bringing in the data, the queries also format the data as necessary (for example, date as DD-MMM-YY, number of digits beyond the decimal point, and so forth).

Following the generation of the EMIS-like Access tables, a series of queries will be performed to verify the content of, correctness of, and relationships between the data. These queries, known as the back-end data content verification queries, will consist of appropriate front-end and intermediate data verification queries modified to analyze the EMIS template tables and their respective field names. The back-end QC queries will be reviewed and modified, if needed, to check for valid values specific to this project.

If a database record does not satisfy the conditions specified by a query, the discrepancy will be listed in the Back-End QC Exceptions Report. The Back-End QC Exceptions Report will contain the name of the query, the information necessary to identify the database record, and an explanation of the exception. The data manager will evaluate each item in the Back-End QC Exceptions Report and determine what action, if any, needs to be taken. If the appropriate action is a manual data change, it will be verified. If the appropriate action is to request a resubmission of the electronic data from the laboratory, the resubmission will be requested.

Once the appropriate action to be taken is completed, the query will be re-run to confirm that the exception has been corrected, and the item in the Back-End QC Exceptions Report will be initialed and dated. If the item is acceptable, it will be noted as such and explained as necessary on the Back-End QC Exceptions Report, initialed, and dated. Once all items listed on the Back-End QC Exceptions Report are resolved, the report will be added to the data management file under "Back-End QC Descriptions and Exceptions Reports."

Depending on the action taken to resolve items in the Back-End QC Exceptions Report, the EMIS-like Access tables may have to be regenerated and the process described above repeated. When all issues are resolved, generation of draft/final deliverables will proceed.

14.9 Generation of Deliverables

After completion of the EMIS-like Access table generation, the EMIS deliverables will be generated by the data manager. The source for these deliverables will be the EMIS-like tables in EDMS/A-EMIS. Microsoft Excel (v.5.0) will be the primary tool used to manipulate and format the data contained in the EMIS-like tables. Using Excel macros, data will be extracted directly from the EMIS-like tables in EDMS/A-EMIS. The data will then be inserted into Excel worksheets modeled after the EMIS Lotus 123 (v.2.2) templates provided by the client's data manager. The filled Excel worksheets are then saved as Lotus 123 spreadsheets. Once completed and reviewed, these Lotus 123 spreadsheets serve as the final deliverables.

The EMIS Lotus 123 templates have three purposes. First, the templates specify the column (field) order in which the data is to be organized. Second, they specify the field type for each field. Third, they help the client's data manager view the data.

Hard copies of the SAMP_LOC, WELL_COMP and LITH_DESC EMIS files will be generated and given to the site geologist for review using guidelines that will include a checklist of project-specific, acceptable entries and the November 1994 EMIS Data Dictionary. The site geologist will fill out a Review Comments Form that will be returned to the data manager along with the marked-up hard copy.

Hard copies of the WATER_LEVEL and SAMPLE_DATA EMIS files will be generated and given to the FTL for review using guidelines that will include a checklist of project-specific, acceptable entries from the November 1994 EMIS Data Dictionary. The FTL will fill out a Review Comments Form that will be returned to the data manager along with the marked-up hard copy.

The draft submission of SAMPLE_DATA to the client will include normal environmental and field duplicate samples only. The final submission of SAMPLE_DATA will contain all sample types.

Hard copies of at least three sets of SAMPLE_PREP and ANAL_RES records for each SAMPLE_PREP fraction (volatiles, semivolatiles, pesticides, and so forth) will be generated and given to a representative of the DQE team for review using guidelines that will include a checklist of project-specific acceptable entries (previously agreed upon with the client data manager) and the November 1994 EMIS Data Dictionary. The reviewer will fill out a Review Comments Form that will be returned to the data manager along with the marked-up hard copy.

An electronic backup of the database will be made and stored as the current working version. After backup, the DQE team reviewer will be given access to the original electronic EDMS/A-EMIS database for electronic review of the EMIS template tables. The data management team will provide queries incorporating appropriate joins between the key fields of the EMIS template tables. Queries will be performed by the DQE reviewer using the guidelines described above. Comments will be noted on a Review Comments Form and returned to the data manager.

The data management team will determine what action, if any, is necessary to address the Review Comments for each EMIS deliverable. Actions taken will be noted on the Review Comments Form, initialed, and dated. The Review Comments Form and marked-up hard copies will be added to the data management file under "Internal Deliverable Review Comments." Depending on the nature of the comments and their resolution, the EMIS template tables may have to be regenerated and reviewed again.

If subsequent reviews are necessary, the data manager will return the marked-up hard copy, the Review Comments Form, and the corrected hard copy to the reviewer. The review process will continue until all exceptions identified in Review Comments Forms are resolved and verified.

After resolution of all internal review comments, the draft EMIS tables (Lotus 123 v.2.2 templates) will be placed on one or more 3.5-inch high density disk(s) (formatted using MS-DOS) with the files in a self-extracting compressed format (PKZIP 2.04). Each disk will be labeled with the following information:

- Name of Facility: DDMT
- Contractor Name:

A. Executable File Name:

- EMIS File Name(s): EMIS_SL, EMIS_WC, EMIS_LD, EMIS_SD, EMIS_WL, EMIS_SP, EMIS_AR1, EMIS_AR2...etc.
- Date of Submission:

A transmittal letter will accompany each data submission and will specify Contractor name, Contract number, Subcontractor point of contact, and a list of the files submitted. Additional explanation regarding the procedure for uncompression of the files will also be indicated. Unless directed otherwise, disk(s) containing draft and final EMIS files will be transmitted by the data manager via overnight delivery to the client's data manager.

The client's data manager should notify the PM immediately if any problems are encountered loading the draft EMIS electronic data deliverable into EMIS. This will allow the data management team to take any corrective actions needed and to include a corrected file(s) in the final EMIS electronic data deliverable.

The client's data manager will provide the PM with a hard copy of review comments. The data management team will determine what action, if any, is necessary to address the comments. Actions taken will be noted and explained to the extent necessary on the hard copy Comment Response Form, initialed, and dated. The client's data manager's Review Comments Form will be added to the data management file under "External Deliverable Review Comments." Depending on the nature of the comments and their resolution, the EMIS template tables may have to be regenerated and checked again.

After resolution of the client's data manager's comments, the final EMIS deliverables will be packaged and transmitted as described above for the draft deliverable. Copies of the final deliverables sent to the client will be archived by the data manager.

14.10 Postmortem

Any manual changes made to the electronic data by the client's data manager after the transmission of the final electronic deliverable will be documented as appropriate in the database and in the data management file to ensure that the data contained in the EDMS/A-EMIS database is identical to that in the client's database.

An archive of all the data on both file servers will be made to tape in a standard format (QIC-80, 8mm, etc) and stored with other project documentation, according to existing guidelines. The data will then be kept on both network file servers for 6 months. At the end of that period, a second archive will be made as described above and stored. At that time, unless the data is being actively used or modified, it will be removed from both network file servers.

If any subsequent changes need to be made to the data, it will be restored from the latest tape, modified, archived as indicated above, and removed from the network file servers. Unless problems occur with data restoration, the primary source for non-database and database files will be the archives. All laboratory deliverables (either hard copy or electronic) will be retained by the laboratory for a period of 7 years.

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DDMT ACRONYMS

Acronym	**Meaning/Explanation**
72-C	LMG designation for non-CLP Pesticide standard mixture of single component pesticides and surrogates (22 components)
BFB	Bromofluorobenzene
CCB	Continuing Calibration Blank
CCC	Calibration Check Compounds
CCV	Continuing Calibration Verification
CDA	Comma Delimited ASCII
CLP	USEPA Contract Laboratory Program
COC	Chain of Custody
CRDL	Contract Required Detection Limit - defined in CLP SOW for Inorganics
CRQL	Contract Required Quantitation Limit - defined in CLP SOW for Organics
CVAA	Cold-Vapor Atomic Absorption
% D	Percent Difference
DEM	Degradation Evaluation Mixture (LMG designation for 8080 work), measures Endrin and 4,4'-DDT degradation)
DFTPP	Decafluorotriphenylphosphine
EDL	Estimated Detection Limit
EMIS	Environmental Management Information System
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectrometry
GFAA	Graphite Furnace Atomic Absoption
ICB	Initial Calibration Blank
ICP	Inductively Coupled Plasma
ICSA/ICSAB	Interference Check Samples (ICP)
ICV	Initial Calibration Verification
CV	Initial Calibration Verfication
IDL	Instrument Detection Limit
IEC	Inter-Element Correction Factor (ICP)
INDA	Pesticide single component mixture A - compounds and concentration defined in CLP SOW The 3 levels are named INDAL, INDAM, and INDAH (as specified in SOW)
INDB	Pesticide single component mixture B - compounds and concentration defined in CLP SOW. The 3 levels are named INDBL, INDBM, and INDBH (as specified in SOW)
IR	Infrared Spectrophotometer
IS	Internal standard
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LIMS	Laboratory Information Management System
LMG	QAL Montgomery Lab
MDL	Method Detection Limit
MS/MSD	Matrix Spike and Matrix Spike Duplicate
MSA	Method of Standard Addition
PCB	Polychlorinated biphenyl
PCB LOC	PCB Locator = mixture of aroclors 1221, 1248, and 1260 - which contain most PCB congener peaks This standard is used to provide all necessary peaks to identify aroclors in samples
PEM	Performance Evaluation Mixture - compounds, concentrations, and criteria (degradation and RF) defined in CLP SOW
PIBLK	Pesticide/PCB instrument blank - CLP nomenclature
% R	Percent Recovery
RESC	Resolution Check Mixture - compounds, concentration , and criteria defined in CLP SOW
F	Response Factor
RL	Lab Reporting Limit

DDMT ACRONYMS

Acronym	Meaning/Explanation
RPD	Relative Percent Difference
RRF	Relative Response Factor
RRT	Relative Retention Time
RSD	Relative Standard Deviation
RT	Retention Time
RT window	Retention Time window
SOP	Standard Operating Procedures
SOW	CLP Statement of Work. We are currently following OLM01.9 for Organics and ILM02 1 for Inorganics
TAL	Target Analyte List - as defined in Inorganic CLP SOW
TCL	Target Compound List - as defined in Organic CLP SOW
TEF	Toxicity Equivalent Factor
TIC	Tentatively Identified Compound

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PROJECT: MEMPHIS DEFENSE DEPOT
GENERAL CHEMISTRY

	LEVEL 2	LEVEL 3
NO PROCEDURAL CHANGES IN SAMPLE PREPARATION		
Instrument Calibration	1/day	1/day
Method Blank	1/batch of 20 or less Target Analyte < Reporting Limit (RL)	1/batch of 20 or less Target Analyte < Reporting Limit (RL)
Initial Calibration/ICV	1/day EPA Methods 90-100% CLP-Cyanide: 85-115%	1/day EPA Methods: 90-110% CLP-Cyanide: 85-115%
Continuing Calibration	Same as above	Same as above
MS/DUP	Recovery 80%-120% RPD <20% TSS DUP Only	Recovery 80%-120% RPD <20% TSS DUP Only
LCS	1/batch Recoveries Cyanide 85-115% Roveries EPA Methods 90-110%	1/batch Recoveries Cyanide 85-115% Recoveries EPA Methods 90-110%
Reporting Levels	Water Soil CN 10.0µg/L 1.0 mg/Kg TSS 4.0 mg/L -NA- F 0.10 mg/L 1.0 mg/kg I 2.0 mg/L 20 mg/Kg Br 2.0 mg/l 20 mg/Kg I (IC) 0.1 mg/L 1 mg/Kg Br (IC) 0.1 mg/L 1 mg/Kg	Water Soil CN CRDL 10 ug/L 1.0 mg/kg TSS 4.0 mg/L -NA- F 0.10 mg/L 1.0 mg/kg I 2.0 mg/L 20 mg/Kg Br 2.0 mg/L 20 mg/Kg I (IC) 0.1 mg/L 1 mg/Kg Br(IC) 0.1 mg/L 1 mg/Kg
Dilutions	If Linear Range is Exceeded	If Linear Range is Exceeded
Report	LIMS Report	CLP Report
Review	Peer or Supervisor	Peer or Supervisor
Price		

pH (EPA 150.1)
Cyanide (CLP-SOW)
Total Suspended Solids (EPA 160.2)
Fluoride (EPA 340.2)
Iodide (EPA 345.1), Titrametric **(Phospholine Iodide)**
Iodine (EPA 300.0), Ion Chromatography (IC)
Bromide (EPA 320.1), Titrametric
Bromide (EPA 300.0), Ion Chromatography (IC)

PROJECT: MEMPHIS DEFENSE DEPOT
CATIONS

	LEVEL 2	LEVEL 3
NO CHANGE IN SAMPLE PREPARATION		
Instrument Tune	ICP Scan No GFAA Hg - by CVAA	CLP/SOW Criteria CLP ICP + GFAA+CVAA
Instrument Blank	Target Analytes <5xCRDL	Target < CRDL
Method Blank	1:20/Target Analytes <5xCRDL	1:20 CLP Criteria
Initial and Continuing Calibration	CCV/CCB 1:20 CCV 70 - 130% recoveries Calibration: ICP Blank + 1 standard Hg Blank + 3 standards	Calibration: CLP Criteria CLP ICV % Recovery 90-110% ICP, GFAA 80-120% Hg 85-115% CN CRA/CRI @ 1/run 2/run ICP
Interference Check	ICSA Beginning 1 ICSAB End 1 70-130%	ICSA/ICSAB 80-120% 1 set/ICP run
MS/DUP	Post Spike 1:20 MS/DUP 1:20 or as requested	1 MS 1:20 1 DUP 1:20 GFAA Post Spikes 85-115% (every sample)
LCS	1:20; Soil - EPA Criteria (0287) Recovery 70-130% H_2O	1:20; Soil - EPA Criteria (0287) % Recovery 80-120% H_2O
Reporting Levels	As 100 ICP & Hg Pb 50 Same as CRDL Se 60 Ti 60 (See Attachment)	CLP Criteria
Dilutions	Any sample response 10% above Linear Range	CLP Criteria
Report	LIMS Form I	CLP Criteria
Review	Analyst 100% Technical Review 10%	CLP Criteria
Price		

OC Pesticides and PCBs by GC/ECD

Quality Control	DOQ Level 2 Criteria (Screen)	DOQ Level 3 Criteria (CLP SOW OLM01.9)
nstrument blanks	As needed. Targets < 5 x RL	At CLP SOW specified frequency Targets < 1/2 CRQL
Method blanks	Targets < 5 x CRQL	Targets < CRQL
MS/MSD	Frequency = 1 set / 20 samples Use lab generated limits as advisory Recovery outside of limits will be investigated for possible explanation.	Frequency = 1 set / 20 samples Use CLP limits - CLP does not require corrective action.
Surrogate spikes	Use lab generated limits as advisory Recovery outside of limits will be investigated for possible explanation	Use CLP limits - CLP does not require corrective action.
LCS (a blank spike is prepped with every MS/MSD for internal QC & control charting)	No criteria	Not required by CLP SOW
Initial calibration	DEM - Endrin and 4,4'-DDT degradation must each be ≤30% 3 point of single-component pesticides (22-C mix) should produce correlation coefficient ≥ 0 95 or 25%RSD (linearity check) PCB LOC at RL (to be used for identification) Toxaphene/Chlordane at RL	Standard CLP requirements RESC - check resolution PEM - check degradation (Endrin and 4,4'-DDT each ≤ 20%, combined ≤ 30%) All multi-component targets at CRQL (single pt) 3 levels of single-component pesticides to demonstrate instrument linearity (INDA/INDB)
Continuing calibration	Mid-level 22-C - should be ≤25%D from initial. Then recalibrate with this as single point. Frequency = after every 20 samples (approximately every 12 hours)	CLP specified standards and frequency. PIBLK/PEM and PIBLK/INDAM/INDBM alternating to bracket 12 hour blocks RF < 25% from initial and degradation criteria same as initial
	Mid-level multi-component standard of any hit in a sample - should be run within 48 hours of sample This single point will be used to calculate.	Multi-component targets found in any samples will be run within 72 hours of sample (for identification) Calc. from initial single point
Retention time windows	No defined RT windows Analyst will compare RT and/or RRT to nearby applicable standards when targets are tentatively identified	CLP specified RT windows
Internal standards	Internal standard quantitation will be used. No quantitative criteria for IS response.	As specified in CLP SOW, only external standard quantitation will be used.
Cleanup (Sulfur removal with Hg for all Pesticides/PCBs)	Pest. and Pest/PCB will go through CLP approved lots of florisil PCBs will be partitioned against sulfuric acid (which is a very effective cleanup)	Cleanups will be performed as specified in CLP SOW with CLP criteria Florisil for all samples and GPC for all soils.
Second-column confirmation	Second column confirmation will be done as needed and will have same criteria as primary But as long as criteria is met on one column, analysis will continue.	As required by SOW - dual column analysis with same criteria for both columns. CLP SOW does not designate primary and confirmation
Reporting limits - may vary depending on chromatographic data	CLP SOW CRQLs	CLP SOW CRQLs
Dilutions	As needed to provide accurate quantitation Single component pesticides will be within initial curve range Multi-component targets are calculated from single point and will be diluted to be within approximately 20%-200% of standard. (this is the typical range of 5 point curve for 8080. CLP has no criteria for dilution of PCBs or Tox)	Per CLP SOW
Report	Form Is	CLP Forms
EData	CDA	

Herbicides by GC/ECD

Quality Control	DOQ Level 2 Criteria (Screen)	DOQ Level 3 Criteria (8150/8151)
istrument blanks	Optional. As needed Targets < 5 x RL	Optional Analyzed as needed Targets < RL
Method blanks	Targets < 5 x RL	Targets < CRQL
MS/MSD	Frequency = 1 set / 20 samples Use lab generated limits as advisory Recovery outside of limits will be investigated for possible explanation	Frequency = 1 set / 20 samples Use lab generated limits
Surrogate spikes	Use lab generated limits as advisory. Recovery outside of limits will be investigated for possible explanation and corrective action	Use lab generated limits
LCS (a blank spike is prepped with every MS/MSD for internal QC & control charting)	No criteria	Frequency = 1 per MS/MSD Use lab generated acceptance limits if MS/MSD does not meet criteria.
Initial calibration	3 point of all targets and surrogates. Curve should ≥ 0 95 correlation coefficient or 25%RSD	5 point of all targets and surrogates Curve ≥ 0.995 correlation coefficient or 20% RSD Establish initial RT windows
Continuing calibration	Mid-level injected after every 20 samples (approximately every 12 hours). Criteria ≤25%D from initial. Then recalibrate with this as single point.	Mid -level injected after every 10 samples Criteria: ≤ 15% D from initial RT windows can be updated once a day
Retention time windows	No defined RT windows. Analyst will compare RT and/or RRT to nearby applicable standards when targets are tentatively identified	RT windows are based upon actual retention time variation measured in accordance with Method 8000 published in SW-846. Test Methods for Evaluating Solid Waste, Third Edition, Nov 1986 Can be updated once per day
iternal standards	Internal standard quantitation will be used. No quantitative criteria for IS response	Internal standard quantitation will be used No quantitative criteria for IS response.
Cleanup	Cleanups will be performed as described in lab SOPs..	Cleanups will be performed as described in lab SOPs .
Second-column confirmation - will be done as needed	Same criteria as primary. But as long as criteria is met on one column, analysis will continue	Same criteria as primary. But as long as criteria is met on one column (and confirmation of any compound exceeding limits is not needed) analysis will continue.
Reporting limits - may vary depending on chromatographic data	Typical lab RL (attached)	Typical lab RL (attached)
Dilutions	As needed to provide accurate quantitation Dilutions will be performed so that targets are within initial curve range.	As needed to prevent target compounds from exceeding instrument calibration range
Report	Form Is	CLP-like forms
EData	CDA	

PNAs (Polynuclear Aromatic Hydrocarbons) by GC/FID

Quality Control	DOQ Level 2 Criteria (Screen)	DOQ Level 3 Criteria (8100)
Instrument blanks	Optional As needed Targets < 5 x RL	Optional. Analyzed as needed Targets < RL
Method blanks	Targets < 5 x RL	Targets < CRQL
MS/MSD	Frequency = 1 set / 20 samples Use lab generated limits as advisory Recovery outside of limits will be investigated for possible explanation	Frequency = 1 set / 20 samples Use lab generated limits
Surrogate spikes	Use lab generated limits as advisory Recovery outside of limits will be investigated for possible explanation and corrective action	Use lab generated limits
LCS (a blank spike is prepped with every MS/MSD for internal QC & control charting)	No criteria	Frequency = 1 per MS/MSD Use lab generated acceptance limits if MS/MSD does not meet criteria
Initial calibration	3 point of all targets and surrogates Curve should ≥ 0.95 correlation coefficient or 25%RSD	5 point of all targets and surrogates. Curve ≥ 0.995 correlation coefficient or 20% RSD Establish initial RT windows
Continuing calibration	Mid-level injected after every 20 samples (approximately every 12 hours) Criteria: ≤25%D from initial. Then recalibrate with this as single point	Mid -level injected after every 10 samples Criteria: ≤ 15% D from initial RT windows can be updated once a day
Retention time windows	No defined RT windows Analyst will compare RT and/or RRT to nearby applicable standards when targets are tentatively identified	RT windows are based upon actual retention time variation measured in accordance with Method 8000 published in SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Nov 1986 Can be updated once per day.
Internal standards	Internal standard quantitation will be used No quantitative criteria for IS response	Internal standard quantitation will be used No quantitative criteria for IS response
Cleanup	Cleanup necessity and technique will depend on matrix	Cleanups will be performed as described in lab SOPs .
Second-column confirmation - will be done as needed.	Same criteria as primary But as long as criteria is met on one column, analysis will continue	Same criteria as primary. But as long as criteria is met on one column (and confirmation of any compound exceeding limits is not needed) analysis will continue.
Reporting limits - may vary depending on chromatographic data	Typical lab RL (attached)	Typical lab RL (attached)
Dilutions	As needed to provide accurate quantitation. Dilutions will be performed so that targets are within initial curve range	As needed to prevent target compounds from exceeding instrument calibration range
Report	Base level (spreadsheet) or Level 1 Form Is	CLP-like forms
EData	CDA	

PROJECT: MEMPHIS DEFENSE DEPOT
GC/MS

	LEVEL 2	LEVEL 3
NO PROCEDURAL CHANGES IN SAMPLE PREPARATION		
Instrument Tune or Tune Verification	1/24 Hrs. Full Method Compliance	Every 12 Hours Full Method Compliance
Method Blank	1/day/instrument or 1/batch or as needed Target Analytes <5 x RL	1/20 or 1/Batch Common Contaminants - CLP Guidelines
Initial Calibration	3 Levels (VOA 10-200) (SVO 20-160) RSD ≤50%; Minimum RF - None Select List of Compounds (CCC)	5 Levels (VOA 10-200) (SVO-20-160) Method Criteria
Continuing Calibration	Mid Point: 1/day RPD ≤50% Select List (CCC + SPCC)	Method Criteria
MS/MSD	1 pair/20 samples or as requested Method Specified List %R within ± 20% D from Method Criteria	1/20 Per Matrix Method Specified List Method Criteria
Surrogates	All samples. Reanalyze if <10% - >200% of method specified recoveries 1 out each fraction VOA, B/N, A/E	All samples CLP Criteria
Internal Standards	Every injection +150%, -75% up to 2 out Analyst's discretion	Every injection Method Limits (+100%, -50%)
Second Vendor Standard	None	Analyze after each new stock calibration mix
Sample Screening	As needed	As needed
Sample Cleanup	If needed	CLP Guidelines
Reporting Levels	CLP/CRDL	CLP/CRDL
Dilutions	20% above the highest standard Analysts' discretion	CLP Guidelines
Report	Form I; E-Data - CDA	QAL Level 2
Review	Analyst 100% Tech Review 5%	Analyst 100% Forms 100% Tech Review 100%
Price		

TRIANGLE LABS
DIOXINS/FURANS
GC/MS

	LEVEL 2	DLFM01.1 (CLP)
NO PROCEDURAL CHANGES IN SAMPLE PREPARATION		
Instrument Tune	Same	Verified prior to each sample, per method and instrument specifications
Method Blank	1/20 or batch, target analytes <IDL	1/20 or batch . Target analytes < 2% of internal standard
Initial Calibration	Same	5 point RSD <15%
Continuing Calibration	Same	Midpoint 1/12 hours %D < 30%
MS/DUP	Same	1 Pair/20 Samples, method analyte, % recoveries 50-150% RPD < 50%
LCS/LCSD	Same	When MS/DUP not requested same analytes & criteria
Surrogates/Internal Standards	Same	All samples: % recoveries 25-150%, some out - analyst discretion
Recovery Standards	Same	All samples: signal to noise > 10 1: retention time within 10 sec of calibration
Sample Screening	If needed	If needed
Sample Cleanup	Same	As per method
Reporting Levels	Same	EDL's. Soil Water Tetra 1 ppb or 10 ppt Penta Hepta 2-5 ppb or 25 ppt Octa 5 ppb 50 ppt
Dilutions	On saturated peaks exceeding linear range.	On analytes greater than calibration range at client request (chargeable rerun)
Report	Formaster (Form I): Case Narrative, Sample Documentation	Full CLP package.
Review	Data Review: Peer Review/QC	Data Review, Peer Review/QC, Quality Assurance Review
Second Column Confirmation	No	If TEF> 7ppt (water) or 0 7 ppb (soil)

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ADMINISTRATIVE RECORD

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