THE MEMPHIS DEPOT
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Defense Distribution Center (Memphis)
Dunn Field

Intermediate Aquifer Investigation Work Plan

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PREPARED FOR

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Contents

Figures

Tables

Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BCT	BRAC Cleanup Team
bgs	Below Ground Surface
BRAC	Base Realignment and Closure
°C	Degrees Celsius
CD	Compact Disc
CEHNC	U.S. Army Engineering and Support Center, Huntsville, Alabama
cm/sec	Centimeter(s) per Second
CSM	Conceptual Site Model
CVOC	Chlorinated Volatile Organic Compound
DLA	Defense Logistics Agency
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DQO	Data Quality Objective
DRC	Depot Redevelopment Corporation
EB	Equipment Blank
EDMS	Environmental Data Management System
EISOPQAM	*Environmental Investigation Standard Operating Procedures and Quality Assurance Manual* (EPA)
EPA	U.S. Environmental Protection Agency
FID	Flame Ionization Detector
FB	Field Blank
ft	Foot or Feet
ft/d	Feet per Day
ft/ft	Foot per Foot
g	Gram(s)
gpm	Gallon(s) per Minute
GW	Groundwater
HASP	Health and Safety Plan
IAI	Intermediate Aquifer Investigation
IDW	Investigation-Derived Waste
MCL	Maximum Contaminant Level
Memphis Depot	(former) Defense Distribution Center (Memphis)
mL	Milliliters
MLGW	Memphis Light, Gas & Water
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Monitoring Well
ORP	Oxidation-Reduction Potential
OVA	Organic Vapor Analyzer
1,1,2,2-PCA	1,1,2,2-Tetrachloroethane
POTW	Publicly Owned Treatment Works
PVC	Polyvinyl Chloride

QA	Quality Assurance
RA SAP	Remedial Action Sampling and Analysis Plan
RD	Remedial Design
RI	Remediation Investigation
SVOC	Semivolatile Organic Compound(s)
TB	Trip Blank
TCE	Trichloroethene
TCL	Target Compound List
TDEC	Tennessee Department of Environment and Conservation
TM	Technical Memorandum
TOC	Total Organic Carbon
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	United States Geological Survey
VOC	Volatile Organic Compound(s)

1.0 Introduction

As part of the Off-Depot Groundwater Remedial Design (RD) effort for Dunn Field of the former Defense Distribution Center (Memphis) (hereafter referred to as the Memphis Depot), additional geochemical and hydrogeologic data will be collected from the fluvial and intermediate aquifers. CH2M HILL prepared this work plan for the U.S. Army Engineering and Support Center, Huntsville, Alabama (CEHNC) and the Defense Logistics Agency (DLA). Once approved by the Memphis Depot Base Realignment and Closure (BRAC) Cleanup Team (BCT), consisting of personnel from DLA, the U.S. Environmental Protection Agency (EPA), and the State of Tennessee Department of Environment and Conservation (TDEC), CH2M HILL and its subcontractors will implement the activities described herein.

The objectives for the work are:

- Improve the conceptual site model (CSM) of Dunn Field with respect to groundwater flow and hydraulic interconnectivity of the fluvial, intermediate, and Memphis Sand aquifers.
- Assess the vertical hydraulic connections between the aquifers and test for vertical contaminant migration.
- Use new site-specific and regional hydrologic information to recalibrate and revise the groundwater model.
- Assess the indigenous microbial population in the fluvial aquifer and define whether the population can degrade site-specific contaminants and associated daughter products under engineered reducing conditions.

The work will include the following activities:

- Install additional onsite and offsite (west of Dunn Field) wells in the intermediate aquifer.
- Install additional offsite (west of Dunn Field) wells within suspected geologic "windows" – areas of direct connection between the sands of the fluvial and intermediate aquifers to support the CSM and expansion of the groundwater flow model grid.
- Collect groundwater samples from select wells for laboratory analysis.
- Collect fluvial aquifer sediments for analysis of existing microbial community.
- Collect fluvial aquifer sediments for a microcosm study to assess the degradation of 1,1,2,2-tetrachloroethane (1,1,2,2-PCA) and trichloroethene (TCE).
- Collect samples of the clay at the bottom of the fluvial aquifer to measure its organic carbon content and permeability using laboratory methods.

- Obtain regional information about Memphis Sand aquifer from previously developed Memphis Light, Gas & Water (MLGW) and University of Memphis groundwater models.
- Combine new site information and regional information to update the groundwater flow model.
- Perform a microcosm study of enhanced reductive dechlorination. The microcosm study will assess biodegradation kinetics, substrate preference, and necessity and effectiveness of bioaugmentation.

CH2M HILL will document the methods used and the data collected in this effort in a technical memorandum (TM) that will include, as a minimum:

- Description of the investigation procedures
- Field measurement methods and data collected
- Summary of field and laboratory analytical data presented in graphs, tables, and/or figures
- Boring logs from all new injection and monitoring wells
- Variances to field procedures performed
- Overall impact on the Dunn Field Off-Depot RD
- Appendices containing laboratory results and data validation narrative

This work plan contains the following sections:

- **Section 1 Introduction** presents the work plan structure, objectives, and organization.
- **Section 2 Background Information** presents information about Dunn Field that explains the context for the work.
- **Section 3 Intermediate Aquifer Investigation (IAI) Activities** describes the activities and procedures that will be performed during the IAI.
- **Section 4 Sampling and Analysis Plan** describes field sampling, waste characterization, and sampling and analysis activities during the IAI.
- **Section 5 Data Management, Analysis, and Interpretation** describes procedures for recording observations, capturing field or laboratory results, and procedures to analyze and interpret data from the IAI.
- **Section 6 Community Relations** describes community relations activities performed in conjunction with the IAI.
- **Section 7 Reporting** describes the TM documenting the results of the IAI.
- **Section 8 Works Cited** lists documents cited in this work plan.

2.0 Background Information

This section presents information on the hydrogeology and contaminant plumes at Dunn Field to provide background for the work to be performed. A thorough description of the operational and regulatory history of Dunn Field is provided in the *Dunn Field Remedial Investigation Report* (CH2M HILL, 2002), *Dunn Field Five -Year Review* (CH2M HILL, 2003a), and *Dunn Field Feasibility Study* (CH2M HILL, 2003b).

2.1 Hydrogeologic Setting

2.1.1 Geology

The vadose zone at Dunn Field consists of two distinct geological units: (1) a layer of relatively low-permeability loess, and (2) a thicker unit of relatively high-permeability alluvium composed of sand and gravel with discontinuous layers of silt and clay that collectively are referred to as the "fluvial deposits." The loess, a semi-cohesive eolian deposit of silt, silty clay, and silty sand, extends from the ground surface to a depth of about 30 feet (ft) below ground surface (bgs). Underlying the loess are several ft of sandy clay, followed by 30 to 75 ft of fluvial deposits.

The upper 10 ft of the fluvial deposits represents a transition zone between the silt-dominated loess and the sand and gravel of the fluvial deposits. Underneath the western boundary of Dunn Field, the lower portion of the fluvial deposits is about 40 ft thick. The fluvial deposits are sand grading downward into gravel with sand. Clay lenses that range from thin laminations to lenses up to 1 ft thick are interbedded within the sand and gravel layers.

A clay unit of variable thickness and horizontal extent occurs at the bottom of the fluvial aquifer as the formation transitions to the Jackson Formation/Upper Claiborne Group. Typically, this orange to yellow clay unit is stiff to dense silty clay that ranges from 4 to 8 ft thick. Typically, the unit directly overlies the gray, stiff, dense, silty clay of the Jackson Formation/Upper Claiborne Group. The two clay layers are distinguishable by their different colors and the lesser amount of silt in the Jackson Formation. In some instances, the sands of the fluvial aquifer are reportedly in direct contact with sand units of the Jackson Formation/Upper Claiborne Group, which contains the intermediate aquifer. Examples of this transitional contact are found at monitoring well (MW)-43 and at MW-185/MW-186.

The Jackson Formation/Upper Claiborne Group is composed of loosely consolidated interbedded sand, silt, clay, and lignite (Kingsbury and Parks, 1993). In the vicinity of Dunn Field, the unit varies in thickness from approximately 80 to 220 ft. Within the Jackson deposits is the intermediate aquifer. Beneath the Jackson are the clay-rich sediments of the Upper Claiborne Group that act as an aquitard between the intermediate aquifer and the lower Memphis Sand aquifer.

Additional site geology details are presented in the following documents:

- *Dunn Field RI Report* (CH2M HILL, 2002)
- *Report of Offsite Design-Related Investigation* (MACTEC, 2005a)
- *Results of the Memphis Depot – Dunn Field Remedial Design Investigation* (CH2M HILL, 2006a)

2.1.2 Hydrogeology

The water table occurs within the fluvial deposits. Depth to water is approximately 75 ft bgs. Recharge is primarily from the infiltration of rainfall. Soil cores indicate that a perched groundwater layer with limited areal extent exists seasonally in the loess. The base of the fluvial aquifer is the uppermost clay in the Jackson Formation/Upper Claiborne Group. The saturated thickness of the fluvial aquifer is variable and controlled by the elevation of the clay at Dunn Field and the area west of Dunn Field. In this area, the saturated thickness of the fluvial aquifer generally ranges between 5 and 30 ft.

Beneath the fluvial aquifer is the intermediate aquifer, which has been the subject of less study than the fluvial aquifer at Dunn Field. The intermediate aquifer is typically composed of sand and silt layers interbedded within the Jackson Formation/Upper Claiborne Group. At the Memphis Depot, those borings that have penetrated into the intermediate aquifer have indicated that this aquifer is composed of a fine to medium-grained grey sand ranging from 2 to 30 ft thick. These sand units may transition back to a predominantly clay unit above the Memphis Sand aquifer. Graham and Parks (1986) noted that the thick intervals of clay or interbedded clay and fine sand typically representing the base of the Jackson Formation/Upper Claiborne Group or the upper part of the Memphis Sand are highly variable and may interfinger with sand in the main body of the Memphis Sand aquifer within short lateral distances. Beneath the intermediate aquifer is the Memphis Sand aquifer, the principal source of water supply for Shelby County. The Memphis Sand aquifer is 500 to 890 ft thick, has a transmissivity of 2,700 to 45,000 square ft per day, and a storativity of 1E10-4 to 6E10-4.

The potentiometric surface of the fluvial aquifer is shown on Figure 2-1. In general, groundwater in the fluvial aquifer flows west, which is also the direction of the local dip of the basal clay unit. Water-level measurements within the fluvial, intermediate, and underlying Memphis Sand aquifers indicate downward hydraulic gradients across the entire area. Water-level measurements at Dunn Field collected by the United States Geologic Survey (USGS) during pumping of the Memphis Sand show interconnectivity between the Memphis Sand and the intermediate aquifer. Investigations in Shelby County have also shown hydraulic interconnection between the fluvial and the intermediate aquifers, and the fluvial and Memphis Sand aquifers (Graham and Parks, 1986; Kingsbury and Parks, 1993; Parks et al., 1995; Garner et al., 2003; Larsen et al., 2003). Additional site hydrogeology details are presented in the *Dunn Field RI Report* (CH2M HILL, 2002).

Aquifer tests conducted at Dunn Field during the Remedial Investigation (RI) indicate an average hydraulic conductivity for the fluvial aquifer of 7.8×10^{-3} centimeters per second (cm/sec). The groundwater velocity in the fluvial aquifer beneath Dunn Field is estimated to range from 0.13 foot per day (ft/d) to 1.7 ft/d based on a hydraulic gradient that ranges from 0.0017 foot per foot (ft/ft) to 0.023 ft/ft along the western boundary of Dunn Field and an effective porosity of 0.3.

CH2M HILL conducted additional aquifer tests (rising head slug tests) during pre-design studies of the offsite area (CH2M HILL, 2006b). These results indicate that higher hydraulic conductivities and groundwater velocities occur in portions the offsite areas. The elevated groundwater velocities are typically encountered between the western property boundary of Dunn Field and the area south of the MLGW substation. These higher flow rates suggest that the offsite chlorinated volatile organic compound (CVOC) plume should be migrating faster than has been observed.

2.1.3 Groundwater Model

The groundwater flow model of the site is a three-dimensional, multi-layer model constructed using the MODFLOW groundwater flow modeling package. Solute transport simulations were performed using the MT3DMS contaminant transport model that links directly to the MODFLOW model output. The primary model layers correspond, from top to bottom, to the fluvial aquifer, the intermediate aquitard, the intermediate aquifer, the Memphis aquitard, and the Memphis Sand aquifer. Layers 2 through 4 collectively represent sediments of the Jackson/Upper Claiborne Group. Boundary conditions include constant head boundaries located around the model perimeter in layers 1, 3, and 5, a specified flux boundary at the top of layer 1 representing the deep percolation of precipitation, and a no-flow boundary at the base of layer 5.

The hydraulic conductivity assumed for the aquifer sediments ranges from 11 to 94 ft/d in the fluvial aquifer, 7.5 ft/d in the intermediate aquifer, and 50 ft/d in the Memphis Sand aquifer. The vertical hydraulic conductivity of the aquitards was 0.0028 ft/d ($1x10^{-6}$ cm/s) except where "holes" in the aquitards exist. At these locations, hydraulic conductivity values more representative of the underlying aquifer properties were assumed (7.5 ft/d for the window above the intermediate aquifer and 97.5 ft/d for the window above the Memphis Sand aquifer).

Groundwater flow modeling simulations suggest that groundwater moving off Dunn Field in the fluvial aquifer flows in a westerly direction. Groundwater hydraulic gradients and flow velocities decrease west of the railroad tracks that cross the CVOC plume, where the aquifer transmissivity is believed to increase, and the presence of gaps in the underlying aquitard results in the vertical movement of groundwater into the deeper intermediate aquifer. The vertical permeability of the aquitard units at the site has not been directly studied and is a key uncertainty regarding the magnitude of contaminated groundwater in the fluvial aquifer that moves vertically into the intermediate aquifer.

Contaminant transport simulations suggest that vertical migration of contamination between the fluvial and underlying intermediate aquifer occurs through the aquitards both in the source areas on Dunn Field and near the downgradient distal end of the contaminant plume offsite. Further, more extensive migration is also forecast to occur through the higher permeability "windows" in the aquitard units located northwest and southwest of the site boundary. Lastly, model simulations suggest a more rapid rate of contaminant migration into downgradient areas than has been observed historically at the site. This may be due to the presence of attenuation mechanisms acting on site contamination that are not included in the model simulations, the result of a greater magnitude of vertical contaminant migration into the intermediate aquifer than is currently simulated, or the influence of remaining data gaps on the accuracy of the model.

The field investigation tasks described in this work plan will provide the necessary data to improve understanding of these key site parameters. Additional groundwater model details are provided in the *Pre-Final Off-Depot Groundwater Remedial Design* (CH2M HILL, 2007).

2.2 Dunn Field CVOC Plumes

Plume characterization efforts have shown that the CVOC plumes originating at Dunn Field extend to the west and northwest in the offsite areas (Figure 2-2 shows the total CVOC plume). Based on the groundwater model output and the date of the release, the CVOC plumes should be longer than current data suggest. In addition, the plume extent depicted in current maps does not match the groundwater seepage rates, especially for a plume that may be 50 years old.

Based on the November 2005 CVOC data, Figure 2-3 shows a significant concentration change just downgradient of MW-152. The current plume configuration and apparent loss of CVOC mass at the distal end of the plume may be due to a change in apparent degradation rates and/or downward leakage of contaminants into the intermediate aquifer.

This proposed investigation will be conducted to evaluate whether CVOC mass is present in the intermediate aquifer due to downward vertical migration of the plume and to assess the hydraulic connectivity of the shallow and intermediate aquifers. The new data will allow CH2M HILL to improve the CSM of Dunn Field with respect to groundwater flow and hydraulic interconnectivity of the fluvial, intermediate, and Memphis Sand aquifers and to use new site-specific and regional hydrologic information to recalibrate and revise the groundwater model.

3.0 Intermediate Aquifer Investigation Activities

This section describes the activities and procedures required to complete the IAI. The activities include land surveying, monitoring and extraction well installation and sampling, aquifer testing, microcosm testing, and review of existing models of the Memphis Sand aquifer. Drilling activities are scheduled to begin in August 2007. Groundwater sampling and aquifer testing will occur in August and September 2007.

3.1 Preliminary Activities

Preliminary activities associated with the implementation of the IAI include:

- Preparation of the Site Health and Safety Plan (HASP)
- Acquisition of subcontractors
- Submission of applications for drilling permits, as necessary
- Survey of proposed well locations
- Coordination with Memphis Depot personnel to locate utilities
- Designation of areas for temporary storage of equipment and material
- Planning for site-specific security and safety concerns

CH2M HILL will acquire specialty subcontractors to perform the work, including drilling, surveying, and laboratory services. The drilling subcontractor will be responsible for obtaining drilling permits, as necessary to install the wells. CH2M HILL will prepare a HASP based on the work scope and activities described in this work plan. Equipment, supplies, and personnel for the work will be mobilized after approval of this plan and the HASP.

CH2M HILL will host a site coordination meeting with its subcontractors before mobilization. Personnel from DLA, EPA, TDEC, CEHNC, and the Depot Redevelopment Corporation (DRC) may also participate in the coordination meeting, which will include discussions of Depot regulations, data quality objectives (DQOs), field procedures, work schedules, and review of the HASP.

3.1.1 Land Surveying and Utility Locating

CH2M HILL will provide maps, showing the proposed locations of wells, to a professional land surveyor registered in the State of Tennessee. The surveyor will use the maps to stake the well locations. As necessary, Memphis Depot and DRC representatives will approve all locations, and a professional utilities locating service will mark all utilities prior to the start of drilling. The proposed well locations are shown on Figures 3-1 and 3-2 but final locations will be based on the utility locations and access restrictions.

3.2 Well Installation

3.2.1 Intermediate Pumping and Monitoring Wells

As shown on Figure 3-1, six new intermediate wells (IW-1 to IW-6) will be installed no deeper than 200 ft bgs to assess the quality of the intermediate aquifer beneath the fluvial aquifer CVOC plumes and conduct aquifer tests. IW-3 and IW-5 will be used as pumping wells during the aquifer test (see Section 3.3). These wells will be 6-inch diameter; the other four intermediate aquifer wells will be 2-inch diameter.

If the clay unit is encountered at the base of the fluvial deposits, the 14-inch boring will be advanced an additional 10 ft and temporarily halted so that surface casing may be installed. Six-inch and 10-inch diameter casings will be installed for the 2-inch diameter monitoring wells and 6-inch diameter pumping wells, respectively. The surface casings will be welded sections of carbon steel or threaded Schedule 80 polyvinyl chloride (PVC), with the bottom section containing a seal and check valve. After placing the surface casing, the driller will then lower a galvanized or PVC injection pipe connected to a grout pumping unit through the inner annulus of the casing and connect it to the check valve. The driller will pump grout through the injection pipe until the grout returns to the ground surface. If the grout does not return to ground surface, the driller will stop pumping after injecting a quantity sufficient to fill the volume of the entire borehole between the top of the clay unit and the bottom of the borehole. Following the grouting effort, and as a preventive measure in case of valve failure, potable water will be pumped into the inner annulus of the casing. The grout will cure for 24 hours before continuing to advance the borehole. Water present in the inner annulus of the casing will be pumped to a holding tank before the borehole is advanced. The boring will be completed to the first significant (>20-ft foot thickness) sand layer within the Jackson Formation/Upper Claiborne Group.

If clay is not encountered at the base of the fluvial deposits or within the Jackson Formation/Upper Claiborne Group, the well will be drilled to a depth of 200 ft bgs where the well screen will be installed.

Continuous soil sampling will be conducted using rotasonic coring methods. The sampling interval will not be greater than 10 ft. This sampling technique is expected to provide relatively undisturbed samples of the fluvial deposits and intermediate sands for archiving, and the basal clay for total organic carbon (TOC), CVOC, and permeability analyses.

The wells will be constructed within the rotasonic drill casing in accordance with the *Remedial Action Sampling and Analysis Plan Volume I: Field Sampling Plan and Volume II: Quality Assurance Project Plan* (MACTEC, 2004). The field geologist will select the screen interval, which may be up to 25 ft long, based on lithology observations. After placing the screen and casing, the driller will fill the annular space with the filter pack, bentonite seal, and grout as the rotasonic casing is withdrawn from the borehole in accordance with the Remedial Action Sampling and Analysis Plan (RA SAP) (MACTEC, 2004).

All wells will be completed with flush-mount wellhead protection pads and developed in accordance with the RA SAP (MACTEC, 2004). CH2M HILL will collect groundwater samples in accordance with Section 4 after the wells are developed.

3.2.2 Fluvial Monitoring Wells

As shown on Figure 3-1, one monitoring well will be installed north of MW-32 to provide another fluvial monitoring location for the aquifer testing. As shown on Figure 3-2, two additional monitoring wells will be installed north of MW-32 (aquifer test monitoring), north of MW-43 and MW-182/MW-183, and another also north of MW-185/MW-186 to further refine the CSM for the fluvial and intermediate aquifers in the western and northwestern Off-Depot areas. These wells will also be used to collect additional data to support the expansion of the groundwater flow model grid.

Each well will be no deeper than 150 ft bgs and will be installed. The drill casing will be advanced until at least 10 ft of continuous clay is encountered within the intermediate aquifer or to the prescribed maximum depth. No more than 10 ft of screen will be used in each well. Final placement of the well west-northwest of MW-185/MW-186 will be a function of site access, lithologic findings of nearby monitoring wells, estimates of the potentiometric surface, and hydrogeologic and other field conditions.

Well installation and development procedures for the new fluvial monitoring wells will be the same as those described for the 2-inch intermediate wells in Section 3.2.1, except that no outer surface casing will be used. CH2M HILL will collect groundwater samples in accordance with Section 4 after the wells are developed.

3.3 Aquifer Testing

Aquifer tests will be conducted to assess the hydraulic connectivity of the fluvial and intermediate aquifers. The tests will also provide storage and transmissivity properties of the intermediate aquifer, including estimates of the directional transmissivity. As discussed below, step-down and 72-hour constant rate tests will be conducted at two pumping wells.

3.3.1 Pre-Testing Activities

Pre-test activities will consist of notifying DLA and MLGW and other adjacent property owners about the aquifer test, collection of water levels from wells within the vicinity of each test (see Figure 3-1), and performance of a step-drawdown tests on the pumping wells. Measurements will be recorded from the wells shown on Figure 3-1 and listed below.

Test Well	Observation Wells	Aquifer	Distance from Test Well (ft)
IW-3	MW-32	Fluvial	100
	MW-73 (background)		500
	MW-164		140
	MW-184		130
	New MW		10
	IW-1 (background)	Intermediate	450
	IW-2		40
	MW-37		100
IW-5	MW-73 (background)	Fluvial	1,200
	MW-151		120
	MW-155		180

Test Well	Observation Wells	Aquifer	Distance from Test Well (ft)
IW-5 (cont.)	MW-158A	Fluvial	120
	MW-159		10
	MW-166		90
	MW-166A		90
	IW-1 (background)	Intermediate	1,150
	IW-4		40
	IW-6		80

The observation wells were selected based on the following factors.

- Water levels in intermediate aquifer wells will be monitored to determine the hydraulic properties of that aquifer. Water levels in fluvial aquifer wells will be monitored to determine the degree of vertical connection between the two aquifers. Due to the limited number, all intermediate aquifer wells near the pumping well will be used as observation wells. Wells in the fluvial aquifer will be located at various radial distances from the pumping well because the degree of vertical connection is unknown.
- Water levels in wells far from the pumping well (background wells) will be monitored to account for aquifer response to changes in atmospheric pressure.

Prior to conducting the constant rate test, a step-drawdown test will be performed on the extraction wells. Data from the tests are necessary to select the optimum pumping rate during the aquifer test. The data also provide an estimate of well efficiency and preliminary values of hydraulic conductivity.

To perform the step-drawdown tests, IW-3 will be equipped with a submersible pump and an automated data logger (miniTROLL® or equivalent) positioned below the pump. The test will begin at a low constant discharge rate until the drawdown in the well stabilizes or after 1 hour of pumping. The pumping rate will then increase to a higher constant rate and will continue for the same duration as used in the first run. This process will be repeated through at least five steps of equal duration. Flow rates will be measured at least every 4 hours using a flow meter, or by recording the time needed to fill a 5-gallon bucket, or other appropriate method. Groundwater pumped from the aquifer during these tests will be processed as described in Section 3.3.2. Following the conclusion of the step test, the water levels in IW-3 will be allowed to stabilize for 24 hours; the field team leader will evaluate whether more or less time is required to meet the DQOs. The step test will then be repeated at IW-5. The step test data will be analyzed using Aquifer^WIN32 TM^ or equivalent software.

3.3.2 Constant-Rate Pumping Tests

Prior to beginning the constant rate test, water levels in observation wells near the pumping well will be measured manually. After the manual measurements are completed, automated data loggers will be placed in the observation wells. The data loggers will be in place at least 72 hours before pumping starts to record baseline groundwater fluctuations and will remain in the wells during the entire test period. Manual water-level measurements will be collected every 6 hours to verify the water levels recorded by the data loggers.

The first test will be conducted at IW-3 and will include the following steps.

1. Automated data loggers will be installed in the test well and in the fluvial and intermediate observation wells listed above.

2. In accordance with the City of Memphis Publicly Owned Treatment Works (POTW) discharge permit, if the intermediate aquifer groundwater has CVOC concentrations above their respective maximum contaminant levels (MCLs), the pumped water will be temporarily contained in one 21,000-gallon frac tank. The water will be treated with an air-stripping unit and then discharged directly to the POTW[1]. Pre- and post-treatment groundwater samples will be collected once during the step-drawdown tests and once per day during the constant-rate drawdown tests. Each sample will be analyzed for CVOCs.

   If CVOC concentrations from the new intermediate wells IW2 to IW6 all have concentrations below MCLs, then the extracted groundwater will be discharged to the POTW without treatment.

3. The flow rate will remain constant for the entire test duration. An in-line flow meter will be used to measure the flow rate and total discharge. The pump discharge line will be fitted with a ball valve to regulate the flow. Flow rates will be manually verified every 4 hours, adjusted as necessary, and recorded in the test logbook.

4. The pumping test will last 72 hours. During the test, data from the data loggers in the intermediate observation wells will be downloaded and plotted to observe the shape of the drawdown curve over time. The drawdown data are anticipated to show effects of delayed yield. Therefore, the test will not be terminated until the drawdown values are tracking on the late-time portion of the Hantush-Jacob theoretical curve.

5. When the drawdown data indicate that the late time response of the aquifer has been recorded, the pumping will be halted and the recovery phase will start. The attendant will reset the data loggers to record the water levels at the start of the recovery period. The recovery period will last until water levels in the pumped well have returned to 95 percent of the pre-test level.

These test procedures will be repeated at IW-5.

3.3.3 Post-Test Activities

The pump and data loggers will be removed after the test is completed. Data will be transferred from the loggers to computer for analysis using pump-test software. Groundwater produced during the test will be handled as described in Section 3.2.3.

3.4 Decontamination

Onsite activities will require decontamination of personnel exiting the work area, especially in cases where a release of contaminants has been detected by the monitoring instruments. Typical decontamination procedures are described in Section 4 of the November 2001 EPA Science and Ecosystem Services Division *Environmental Investigation Standard Operating*

[1] Written permission for pumping the treated water to the POTW was received from the office of Mr. Akil Al-Chockachi, City of Memphis, Sewer Division, in January 2007.

Procedures and Quality Assurance Manual (EISOPQAM). The decontamination of personnel will follow procedures in the contractor's HASP.

All down-hole drilling and testing equipment will be decontaminated using procedures consistent with Appendix B of the EISOPQAM (EPA, 2001) and the RA SAP (MACTEC, 2004). All wash and decontamination water will be managed in accordance with Section 3.5. All disposable personnel protective clothing and articles will be contained in drums for offsite disposal as trash.

3.5 Well Installation Waste Management

All soil cuttings will be placed in roll-off boxes or, temporarily, in drums located in a central staging area west of Dunn Field. Soil cuttings may be staged temporarily in drums at drill locations or covered by plastic sheeting prior to placement in roll-off boxes or drums. Drilling fluids, development water, and soil and wastewater from decontamination will be contained temporarily in 55-gallon drums approved by the U.S. Department of Transportation. The drums will be permanently marked with a weatherproof label, signifying the date the drum was filled, site number, and well number, as appropriate.

Representative samples of the investigation-derived waste (IDW) will be collected for chemical characterization prior to onsite or offsite disposal. Once analytical results of the IDW are available, all IDW will be managed and disposed of in accordance with federal, state, and local regulations. The IDW will be removed from the site within 60 days following the receipt of analytical results. During past investigation activities at Dunn Field, IDW water was disposed of in the sanitary sewer after a temporary permit had been obtained from the City of Memphis POTW. The basis for the permit is that the IDW water contained concentrations of contaminants similar to the effluent from the Dunn Field groundwater extraction system, which discharges into the City's sewer system.

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

3.6 Health and Safety

A site-specific HASPs will be developed and submitted to CEHNC for review and approval prior to mobilization. All hazards related to the groundwater and soil investigation will be discussed in the HASP. These hazards may include, but not be limited to, the following:

- **Drilling and Well Installation:** The installation of wells at Dunn Field will require the use of rotasonic equipped drill rigs. The use of this equipment has inherent hazards, including rotating mechanical equipment, potential hazardous atmospheres, noise, and potential slips, trips, and falls. Drill returns (soil and groundwater) may be contaminated with solvents and their degradation products.
- **Groundwater Sampling: Use of Pumping Equipment**. Equipment used to obtain samples includes air-operated bladder-type pumps, electrical generators, tubing, diffusion bags,

and portable direct-reading instruments. The work will require effort around potentially hazardous environments and will require controls on ambient air hazards.

3.7 Site Security/Erosion Control

Access controls (i.e., orange safety fencing) and erosion control measures will be maintained around all drilling, stockpiles, and other areas disturbed by their operations. Open holes will be barricaded with orange safety fence. All work areas will be kept clean and neat.

3.8 Microcosm Study

A microcosm study is being performed by SiREM in Guelph, Ontario, to evaluate 1,1,2,2-PCA and TCE degradation rates using multiple carbon substrates, site sediments, and groundwater, and a commercially available dehalorespiring microbial consortia (WBC-2™) that is capable of completely dechlorinating 1,1,2,2-PCA. The study will provide information to address the following questions relevant to the Off-Depot groundwater RD:

- *Can target compounds be biodegraded under current site conditions?*
- *What site amendments will increase degradation rates?*
- *What are the expected degradation rates of target compounds?*
- *What are the degradation by-products?*
- *What are the maximum concentrations that can be degraded?*
- *What are the synergies/inhibitions?*

Microcosm construction, incubation, sampling and analysis, and schedule are discussed below.

3.8.1 Microcosm Construction

Anaerobic treatment microcosms were constructed on January 3, 2007, to assess the rate and extent of reductive dechlorination that can be achieved by the indigenous microbial populations under natural in situ conditions (intrinsic controls) and through the addition of both soluble and slow release electron donors (biostimulation). The potential to enhance biodegradation through bioaugmentation is also being evaluated with the addition of a WBC-2™ to several of the microcosms. As such, the microcosm study includes the tests (all treatments were prepared in triplicate) listed in Table 3-1.

Microcosms were constructed by filling 250-milliliter (mL) (nominal volume) glass bottles with approximately 150 to 200 mL of site groundwater and 60 grams (g) of site geologic material leaving a nominal headspace for gas production (e.g., ethene, carbon dioxide, methane) under anaerobic conditions. CH2M HILL collected the groundwater used in the microcosm study from MW-77 on December 18, 2007; the geologic materials were collected from an adjacent soil boring using rotasonic drilling technology (drilling techniques are detailed in Section 4). Microcosms were sealed with Mininert™ valves to allow repetitive sampling of each microcosm and allow addition of amendments to sustain metabolic/biodegradation activities.

To maintain anaerobic conditions, the microcosms were constructed in a disposable anaerobic glove-bag and are being stored and sampled in an anaerobic chamber. Geologic materials added to the anaerobic sterile control microcosms were autoclaved, and the groundwater used in these microcosms were amended with mercuric chloride and sodium azide to inhibit microbial activity.

One replicate of each test was amended with resazurin to monitor redox conditions. Resazurin is a non-toxic, water-soluble, redox-sensitive dye that changes from its blue/non-fluorescent state to pink/highly fluorescent upon reduction to resorufin via exposure to oxygen. Resazurin in viable cells may become reduced via an unknown mechanism in the cells. Resazurin thus may be used in a simple yet quantitative method to measure cell proliferation, viability, and cytotoxicity.

3.8.2 Microcosm Incubation, Sampling, and Analysis

The microcosms are being incubated up to 8 months. The actual study timeframe depends on intrinsic activity, starting 1,1,2,2-PCA concentrations, potential lag time due to groundwater geochemistry, and initial 1,1,2,2-PCA concentration (high concentration may extend the timeframe).

SiREM collects aqueous samples from the control and test microcosms every 2 to 3 weeks for analysis of CVOCs and dissolved hydrocarbon gases (e.g., ethane, ethene, and methane). The microcosms amended with slow-release electron donor will also be sampled twice for analysis of volatile fatty acids (lactate, pyruvate, formate, and butyrate, acetate, and propionate). Other routine analyses include the measurement of pH, methane, and anions (e.g., nitrate, chloride, and phosphate).

3.8.3 Microcosm Study Results

The preliminary microcosm study results are presented in the *Pre-Final Off-Depot Groundwater Remedial Design* (CH2M HILL, 2007).

3.9 Review of Memphis Sand Aquifer Model(s)

CH2M HILL will contact pertinent organizations, including the USGS, MLGW, and the University of Memphis Ground Water Modeling Center, that may currently hold data referencing hydrogeological characteristics of the Jackson Formation/Upper Claiborne Group and the Memphis Sand aquifer. Specifically, CH2M HILL will attempt to collect the following information:

1. Regional stratigraphic information that includes the area of Dunn Field and Allen Well Field, at a minimum. This includes the thickness of the fluvial, intermediate, and Memphis Sand aquifers along with the interlayered aquitards (especially areas where the aquitards are absent).
2. Hydraulic properties of the aquifers and aquitards (i.e., aquifer transmissivity and aquitard vertical hydraulic conductivity).
3. Regional pumping rates from well fields in the area, along with the specific capacities of the production wells.
4. Estimates of the spatial distribution of the rate of deep percolation of rainfall/applied water.

5. Groundwater contour maps and/or historical water level information for monitoring wells in the area.

The effort to collect these data was begun on April 19, 2007, through TDEC. The information will be used to support expansion of the existing groundwater flow model to encompass the Allen Well Field. Once the groundwater model grid is expanded, CH2M HILL will need to assign hydraulic properties to the aquifer units in that area and define the water budget in the new areas of the model. The information described above will support these model refinement activities.

4.0 Sampling and Analysis

Sampling and analysis procedures associated with the activities required for this investigation effort are outlined below. This section includes information regarding locations, frequency, and analyses for soil and groundwater to be collected during the investigation, as well as analyses required for disposal characterization for IDW.

4.1 Data Quality Objectives

The DQOs detailed in Table 4-1 are established to achieve the objectives outlined in Section 1.

4.2 Soil Sampling

During the drilling of each well, 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-ft length. The core samples will be cut open and examined for geologic characteristics immediately upon return to the surface.

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

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

Plasticity of fines description includes:

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

Soil will be identified using the Unified Soil Classification System (USCS) group symbol. Additional information to be recorded includes depth to the water table, caving or sloughing of the borehole, changes in drilling rate, and other noteworthy observations or conditions, such as the locations of geologic boundaries.

Headspace field screening will be conducted over each core using an organic vapor analyzer (OVA)/ flame ionization detector (FID) until the last core is removed from the boring. No samples will be collected for laboratory analysis.

4.3 Groundwater Sampling

This information will be critical for evaluating the presence of CVOCs in the intermediate aquifer as well as providing essential confirmation data for the ongoing groundwater modeling effort. The samples will be analyzed for VOCs by Kemron Environmental of Marietta, Ohio. All samples will be shipped from the site for laboratory analysis via overnight courier. All data will be validated by an internal CH2M HILL chemist. A data quality evaluation report will be attached to the TM describing the sample results.

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

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

Before sampling, each well will be purged using a low-flow bladder pump to minimize both agitation of the groundwater and sample turbidity. The following methods are consistent with the Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures (EPA, 1996). The intent of these procedures is to remove stagnant water from the well and introduce fresh groundwater into the well at a rate that does not produce significant drawdown of the water level in the well being sampled. This procedure reduces both the time required to purge the wells and the quantity of water removed (IDW). The field team will keep the pumping rate as low as possible, taking care not to lower the water level in the well. The anticipated pumping rate is 0.15 to 0.25 gallon per minute (gpm) so that water levels do not decline more than 1.2 inches (0.1 foot).

Water level measurements will be made concurrently with the water quality parameter measurements. Field measurements of dissolved oxygen (DO), oxidation-reduction potential (ORP), turbidity, pH, temperature, and specific conductance will be made at the beginning of the procedure and at 5-minute intervals during purging. The water quality parameters will be measured using an airtight flow-through cell. Measurement data will be recorded in the field logbook. Purging will continue until field measurements are stable to within ±10 percent over three successive measurements. The above parameters will be documented and the wells will then be sampled using the same low-flow pump rate.

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

Containers will be quickly and adequately sealed; container rims and threads will be clean before tightening lids. Unless otherwise specified, Teflon®-lined screw lids will be used to seal the jar. Sample containers will be properly labeled and will be immediately cooled to 4 degrees Celsius (°C) ±2°C, and this temperature will be maintained through delivery to the laboratory until the samples are analyzed. New tubing will be used and the pump decontaminated for each well.

4.4 IDW Sampling

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

4.4.1 Sediment

Sediment will be removed from the decontamination area and placed in drums. Sediment samples will be collected from the drums and analyzed for the list of parameters in Table 4-3.

4.4.2 Water

Water derived from decontamination activities will be collected and drummed. Water samples will be collected from the drums and analyzed for CVOC content, reactivity, corrosivity, flammability, and explosivity. Results will be used to determine final disposition of the water. Water samples from the pump-testing activities will be collected and tested as described in Section 3.

4.4.3 Personnel IDW

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

5.0 Data Management, Analysis, and Interpretation

5.1 Data Description

Information generated from the IAI will include land survey, geologic, biological, hydrogeologic, and geochemical data:

- Land survey data will be derived from the locating of new groundwater wells.
- Geologic data will be derived from the installation of new wells and will include:
  1) lithologic and stratigraphic characteristics of the loess and fluvial deposits that overlie the fluvial aquifer,
  2) lithologic and stratigraphic characteristics of the fluvial and intermediate aquifers, and
  3) characteristics of the CSM, especially near areas reported to be geologic "windows."
- Biological data will be derived from the analysis for microbe deoxyribonucleic acid (DNA) and time-based water quality characteristics during the microcosm study (e.g., substrate use, estimation of degradation kinetics).
- Hydrogeologic data will be derived from collection and analysis of manual water-level measurements, groundwater samples, and data loggers used during the aquifer tests.
- Geochemical information from this study will be derived from laboratory analysis of groundwater samples and field measurements during groundwater sampling.

5.2 Data Management

Data management for this investigation will meet the requirements of the DQOs presented in Section 4.1. Most of the data will be obtained through field screening with direct-reading instruments, and fixed laboratory analysis of samples. The information presented in this section is considered supplemental to the *Remedial Action Sampling and Analysis Plan* (MACTEC, 2004) for the Memphis Depot activities.

5.2.1 Sample Numbering System

During this investigation, specific sample numbers will be used to distinguish between categories of sampling events, sampling locations, and, where appropriate, depth of sample collection. The sample numbering system is provided below.

Sampling Event	Type of Sample(s) and Location	Sample Number Description	Example Sample Number
Groundwater (GW) sampling for volatile organic compounds (VOCs) and geochemical parameters	Off-Depot GW	Sampling location and depth to pump, and project.	MW-199_100_ODI
Soil sampling for microcosm study and DNA analysis	Off-Depot, within fluvial aquifer	Acronym for investigation name, soil boring number, and depth of collection	ODI-SB-1-88-89

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

5.2.2 Soil and Water Sample Labels

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

- Project identification
- Sample identification
- Sampler's name or initials
- Preservatives added, if any
- Date of collection
- Time of collection
- Analysis method number(s)

5.2.3 Management of Field Data

Field screening will include ambient air screening around wells and soil borings with an OVA/FID and tests of groundwater quality during purging and sampling. These field tests will be conducted using portable direct-reading instruments. Instruments will be calibrated in accordance with the *Remedial Action Sampling and Analysis Plan* (MACTEC, 2004). Data to be recorded in the logbook or sampling record form include the following:

- Operator name (printed and signature)
- Date and time
- Elapsed time since test began, as necessary
- Location of measurement/location where the sample was collected, as necessary
- Instrument reading

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

Other notes that will be recorded in the field logbook/sampling forms include: weather information, personnel present during onsite activities, subcontractor names and activities, notes on the proximity of the activities to established site features, and all other pertinent information that may impact data analysis. Copies of the field notebook pages and sampling forms will be included in the IAI TM, as necessary.

5.2.4 Management of Laboratory Data

Samples will be submitted to a laboratory for VOC analyses and reporting. During collection of groundwater and soil samples, the date, time, location of sample collection, and the sample number will be recorded in the field logbook. This information will be transferred, as required, to the chain-of-custody documents that accompany the samples in transit to the laboratory. Copies of the chain-of-custody documents will be kept at the site until the study is complete and will then be transferred to the site files for archiving.

After the analytical data have been received from the laboratory, the data will be reviewed by a project chemist for quality assurance (QA). If differences are evident between the chemist's review and the laboratory's review of the data, a letter report will be issued describing the differences and any potential to affect the results from the study. Data will be delivered according to Environmental Data Management System (EDMS) Version 4.11 or higher. Information on EDMS is available at the following Web site:

- http://www.aee.faa.gov/emissions/edms/edms_Updates/Updates.htm.

Laboratory data reports will be stored electronically and supplied on compact disc (CD) with the IAI TM.

5.3 Data Analysis and Interpretation

The data collected during this investigation will be tabulated and graphed to assess CVOC spatial and temporal trends. Aquifer test data will be analyzed by standard methods using commercial software (Aquifer^{WIN32} TM or equivalent). All data and the resulting interpretations will be presented and described within the IAI TM and relevant RD documents. Microcosm data will be assessed as part of the Off-Depot groundwater remedial design.

6.0 Community Relations

The Memphis Depot has an active community involvement program that monitors events at the Memphis Depot site, with special focus on events at Dunn Field. This study will be conducted with the knowledge of members of the community.

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

7.0 Reports

An Off-Depot Investigation TM will document the completed study. The TM will include the following:

- Description of the investigation and data evaluation procedures
- Any variances to written field procedures in the work performed
- Field measurement methods
- Summary of field and laboratory analytical data presented in graphs, tables, and/or figures
- Boring logs from all new injection and monitoring wells
- Complete data from the aquifer tests in an appendix
- Complete laboratory results in an appendix
- Evaluation of the pump test results, aquifer data derived from MGLW/USGS models, and revisions to the CSM
- Impact of the findings on the Off-Depot RD

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

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

The TM will be submitted to the BCT for review and comment. The final TM will be presented within the Final Off-Depot Groundwater RD report.

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Parks, W.S., Mirecki, J.E., and Kingsbury, J.A. 1995. *Hydrogeology, Ground-water Quality, and Source of Ground Water Causing Water-Quality Changes in the Davis Well Field at Memphis, Tennessee.* US Geological Survey Water-Resources Investigation Report. 94-4212.

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Figures

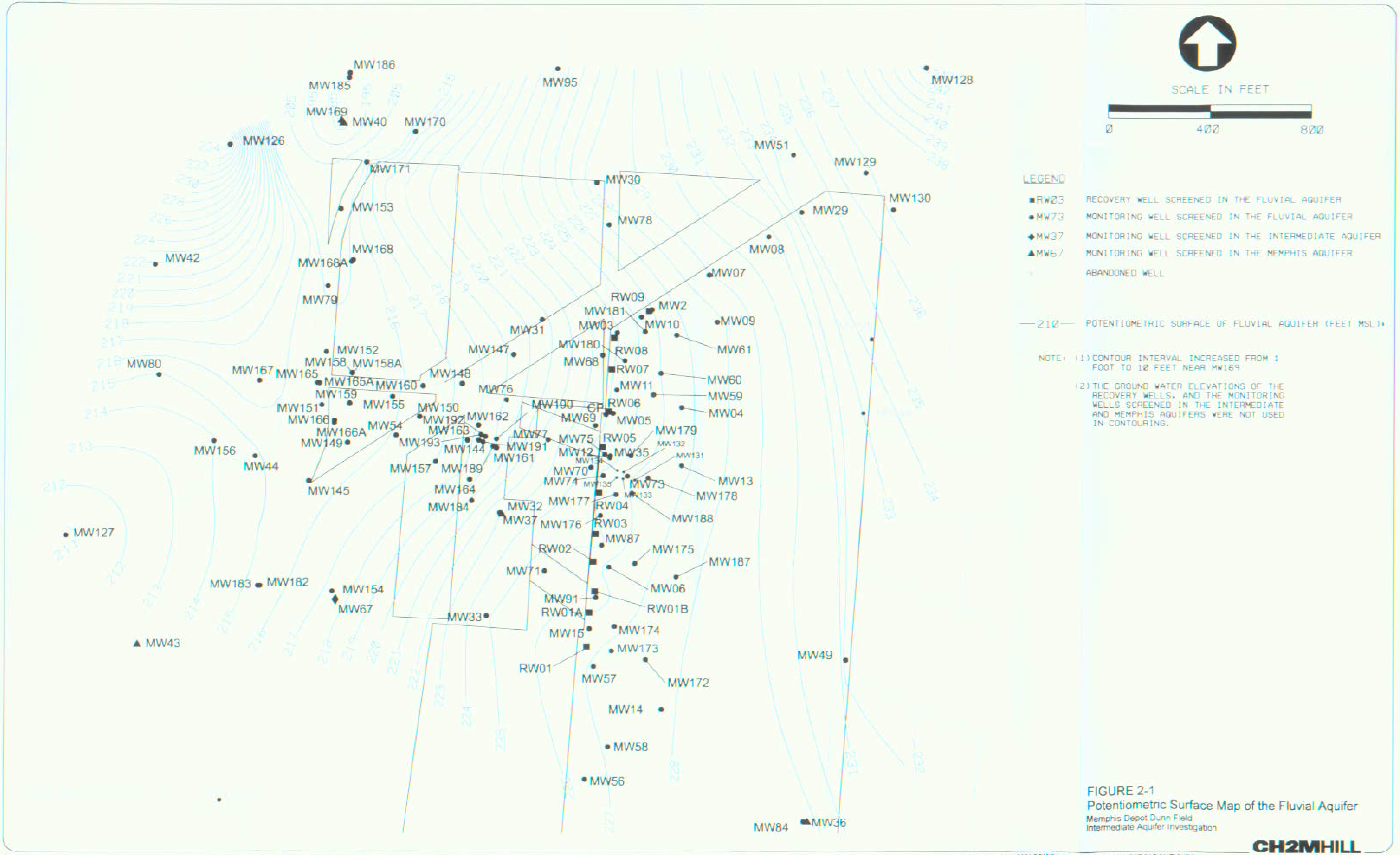
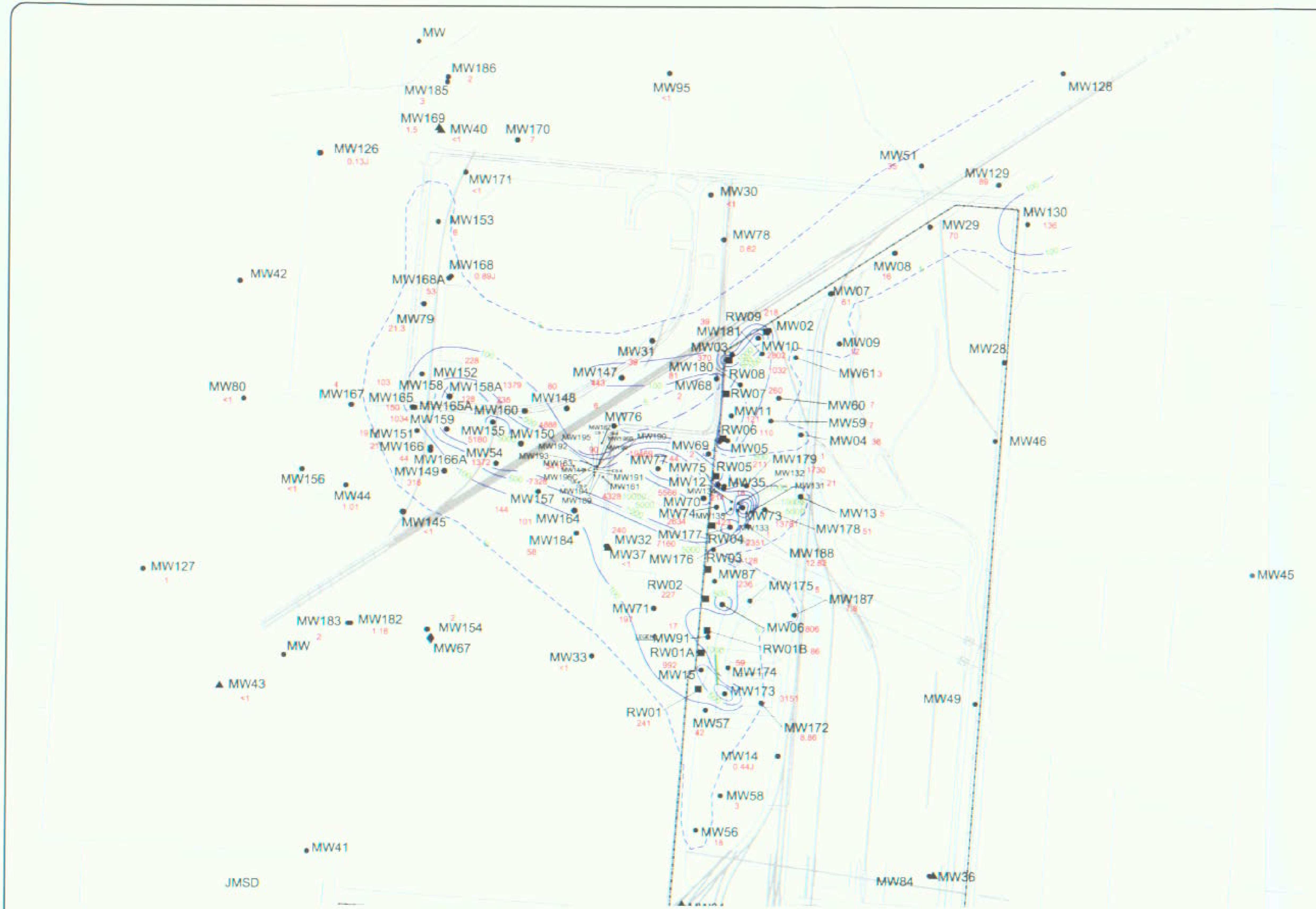


FIGURE 2-1
Potentiometric Surface Map of the Fluvial Aquifer
Memphis Depot Dunn Field
Intermediate Aquifer Investigation



LEGEND:

- - - - - -	DEPOT BOUNDARY
100 ———	ISOCONCENTRATION LINE (IN ug/L)
100 - - -	INFERRED ISOCONCENTRATION LINE FROM LIMITED DATA (IN ug/L)
● MW	MONITORING WELL SCREENED IN FLUVIAL AQUIFER
▲ MW	MONITORING WELL SCREENED IN INTERMEDIATE AQUIFER
■ RW	GROUNDWATER EXTRACTION WELL
◆ MW	MONITORING WELL SCREENED IN MEMPHIS AQUIFER
139.3	CONCENTRATIONS IN ug/L
ND	NOT DETECTED (ALL CONCENTRATIONS LESS THAN REPORTING LIMITS)
ug/L	MICROGRAMS PER LITER

NOTES:

1. ALL SAMPLES WERE COLLECTED IN NOVEMBER 2005 EXCEPT FOR SAMPLES FROM MW-172, 187, AND 188 THAT WERE COLLECTED IN APRIL 2006.
2. MW-3, -4, -6, -9, -10, -11, -13, -14, -15, -29, -30, -35, -56, -58, -59, -60, -61, -73, -74, -75, -87, -91, -129, -131, -132, -133, -134, -135, -173, -174, -175, -176, -177, -178, -179, -180, -181, -182, -183, -184, -185, AND -186 WERE COLLECTED USING LOW FLOW TECHNIQUES.
3. ALL OTHER MONITORING WELLS WERE SAMPLED USING DIFFUSION SAMPLERS.

FIGURE 2-2

TOTAL GROUNDWATER CHLORINATED VOLATILE ORGANIC COMPOUND (CVOC) CONCENTRATIONS
NOVEMBER 2005
Intermediate Aquifer Investigation

CH2MHILL

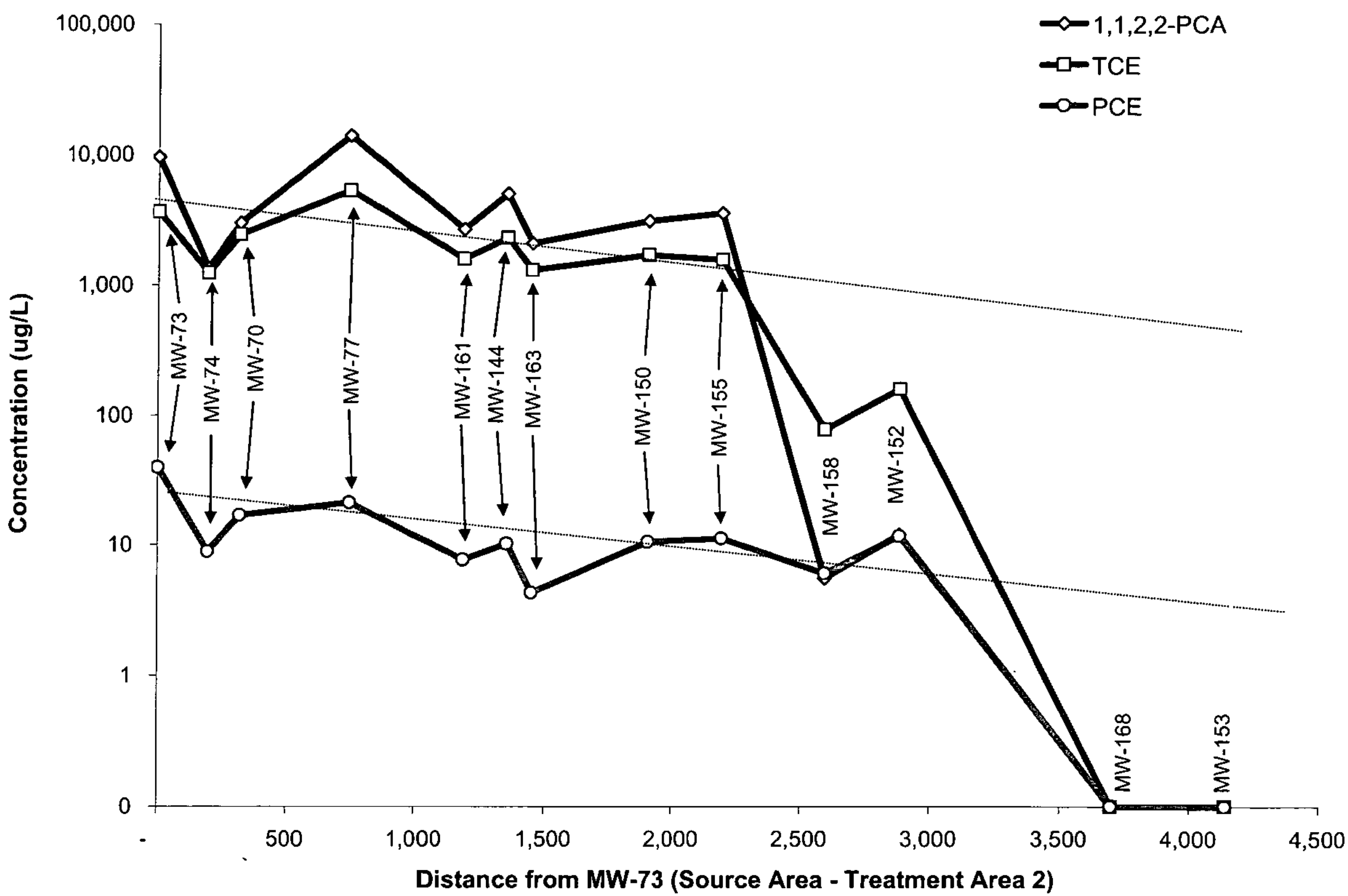
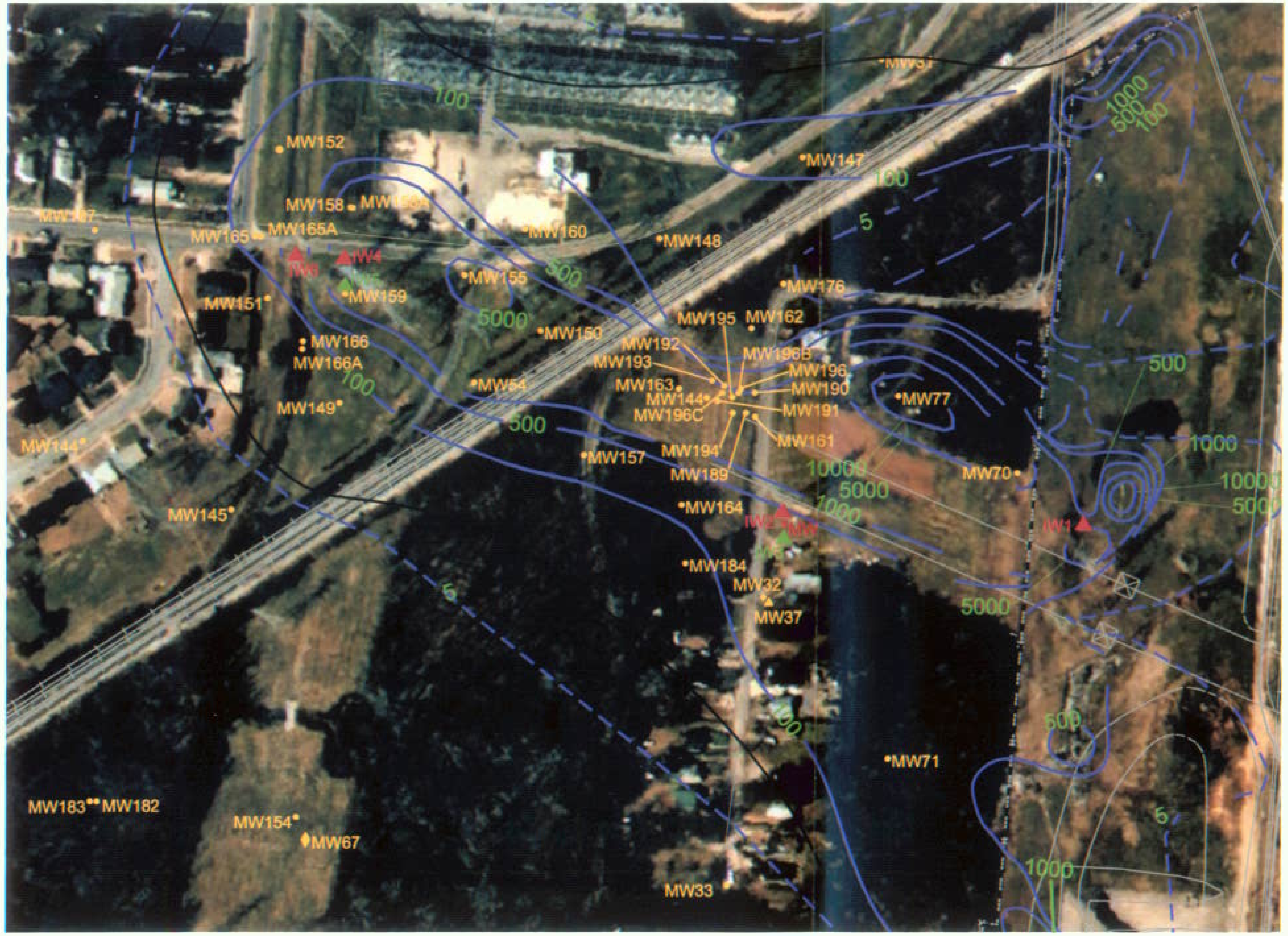


Figure 2-3
CVOC Concentrations Along Off-Depot Plume Centerline
Memphis Depot Dunn Field

905 34



LEGEND:

DEPOT BOUNDARY

ISOCONCENTRATION LINE (IN ug/L)

INFERRED ISOCONCENTRATION LINE FROM LIMITED DATA (IN ug/L)

50 INFERRED ISOCONCENTRATION LINE (IN ug/L)

MW MONITORING WELL SCREENED IN FLUVIAL AQUIFER

MW MONITORING WELL SCREENED IN INTERMEDIATE AQUIFER

IW NEW MONITORING WELL SCREENED IN INTERMEDIATE AQUIFER (4)

IW NEW PUMPING WELL SCREENED IN INTERMEDIATE AQUIFER (2)

RW GROUNDWATER EXTRACTION WELL

MW MONITORING WELL SCREENED IN MEMPHIS AQUIFER

MW NEW MONITORING WELL SCREENED IN FLUVIAL AQUIFER

NOTES:

1. ALL SAMPLES WERE COLLECTED IN NOVEMBER 2005 EXCEPT FOR SAMPLES FROM MW-172, 187, AND 188 THAT WERE COLLECTED IN APRIL 2006.
2. MW-3,-4,-6,-9,-10,-11,-13,-14,-15,-29,-30,-35,-56,-58, -59,-60, -61,-73,-74,-75,-87,-91,-129,-131,-132,-133, -134,-135,-173,-174,-175,-176,-177,-178,-179,-180, -181,-182,-183,-184,-185, AND -186 WERE COLLECTED USING LOW FLOW TECHNIQUES.
3. ALL OTHER MONITORING WELLS WERE SAMPLED USING DIFFUSION SAMPLERS.

FIGURE 3-1
PROPOSED NEW INTERMEDIATE AQUIFER MONITORING & PUMP WELLS
Memphis Depot Dunn Field
Intermediate Aquifer Investigation

CH2MHILL

LEGEND:

- DEPOT BOUNDARY
- BASE BOUNDARY
- 100 — ISOCONCENTRATION LINE (IN ug/L)
- 100 - - - INFERRED ISOCONCENTRATION LINE FROM LIMITED DATA (IN ug/L)
- • MW — MONITORING WELL SCREENED IN FLUVIAL AQUIFER
- ▲ MW — MONITORING WELL SCREENED IN INTERMEDIATE AQUIFER
- ■ RW — GROUNDWATER EXTRACTION WELL
- ♦ MW — MONITORING WELL SCREENED IN MEMPHIS AQUIFER
- 139.3 — CONCENTRATIONS IN ug/L
- ND — NOT DETECTED (ALL CONCENTRATIONS LESS THAN REPORTING LIMITS)
- ug/L — MICROGRAMS PER LITER
- MW — NEW MONITORING WELL SCREENED IN THE FLUVIAL AQIFER

NOTES:

1. ALL SAMPLES WERE COLLECTED IN NOVEMBER 2005 EXCEPT FOR SAMPLES FROM MW-172, 187, AND 188 THAT WERE COLLECTED IN APRIL 2006.
2. MW-3,-4,-6,-9,-10,-11,-13,-14,-15,-29,-30,-35,-56,-58, -59,-60, -61,-73,-74,-75,-87,-91,-129,-131,-132,-133, -134,-135,-173,-174,-175,-176,-177,-178,-179,-180, -181,-182,-183,-184,-185, AND -186 WERE COLLECTED USING LOW FLOW TECHNIQUES.
3. ALL OTHER MONITORING WELLS WERE SAMPLED USING DIFFUSION SAMPLERS.

FIGURE 3-2

PROPOSED NEW FLUVIAL AQUIFER MONITORING WELLS

Intermediate Aquifer Investigation

CH2MHILL

ATL/PROJ/148071 DDMT/ODRD 2007/AQUIFER INVESTIGATION 07-AUGUST-2007

Tables

TABLE 3-1
Microcosm Study Set-Up Summary
Intermediate Aquifer Investigation

Test	Bio-stimulation	Bio-augmentation	Description	Comment	Number of Replicates
1	No	No	Autoclaved and amended with mercuric chloride and sodium azide (sterile control).	Anaerobic intrinsic control microcosms were included in the study to measure intrinsic biodegradation activity. These controls did not receive electron donor amendments.	3
2	No	No	Unamended control.		3
3	Yes	No	Amended with lactate (soluble electron donor).	Amended at about 10 times the stoichiometric demand of the CVOCs and selected inorganic compounds (i.e., nitrate, sulfate and oxygen) (about 300 milligrams per liter [mg/L])	3
4	Yes	No	Amended with commercially available emulsified vegetable oil (EVO) (slow release electron donor).	Amended with EOS™ at a 1% concentration	3
5	Yes	Yes	Amended with lactate and WBC-2™.	Same amendment quantity as test 3.	3
6	Yes	Yes	Amended with EVO and WBC-2™.	Same amendment quantity as test 4.	3
7	Yes	Yes	Amended with commercially available chitin (slow release electron donor) and WBC-2™.	Amended with 0.5 gram of ChitoRem™.	3
				Total Number of Microcosms:	21

TABLE 4-1
Data Quality Objectives
Intermediate Aquifer Investigation

Objective	Data Quality Level	Qualitative DQO	Quantitative DQO
Land surveying of sample and well locations	Screening (initial) and definitive (post investigation)	Conduct initial land survey to layout MW locations. Post investigation survey will be conducted to establish coordinates of additional or revised sampling locations.	Use a professional land surveyor to conduct a survey and provide specific geographical coordinates in a northing and easting format.
Evaluate presence of CVOCs in intermediate and fluvial aquifer groundwater	Definitive (Level III) (groundwater samples)	Collect groundwater samples to develop CVOC plume maps for intermediate aquifer.	Install new fluvial and intermediate MWs and collect groundwater samples during supplemental groundwater investigation. MWs may also be sampled as part of RA and long-term groundwater monitoring. Analyze groundwater samples by SW-846 Method 8260B.
Enhance groundwater model data set	Screening (hydrogeologic and lithologic) and definitive (Level III) (groundwater samples)	Collect additional lithologic, hydrogeologic, and contaminant data from new MWs installed in the intermediate aquifer to support the groundwater model.	Install new intermediate MWs and collect groundwater samples during supplemental groundwater investigation. Analyze groundwater samples by SW-846 Method 8260B. Conduct constant rate pumping test to assess hydraulic connectivity of fluvial and intermediate aquifers. The test will also provide storage and transmissive properties of the intermediate aquifer, including directional transmissivity.
Obtain bench-scale biodegradation data for Off-Depot RD	Screening and definitive (Level III) (samples)	Conduct microcosm study to assess CVOC degradation rates, multiple substrates, and the need for bioaugmentation.	Employ SiREM in Guelph Ontario to run a bench-scale microcosm study. Multiple water samples will be collected and analyzed using SW-846 Method 8260B during the test to calculate degradation rates.

TABLE 4-2
Groundwater Monitoring Parameter Summary
Intermediate Aquifer Investigation

Parameter	Laboratory Method
CVOC – Laboratory	
Volatile Organics	Fixed Based Laboratory – SW846 Method 8260B
Geochemical Parameters – Field	
Color	Field/Visual
Visible particulate	Field/Visual
Turbidity	Field Direct Reading Instrument – YSI 6820 Multimeter
Dissolved oxygen (DO)	Field Direct Reading Instrument – YSI 6820 Multimeter
Oxygen Reduction Potential (ORP)	Field Direct Reading Instrument – YSI 6820 Multimeter
pH	Field Direct Reading Instrument – YSI 6820 Multimeter
Temperature	Field Direct Reading Instrument – YSI 6820 Multimeter

TABLE 4-3
Sampling and Analysis Summary
Intermediate Aquifer Investigation

Sample Task	Sample Point	Matrix	Sampling Frequency	Approx. Sample No	Sampling Method	Sampling Equipment	TAT	DQO Level/Data Package Requirement	Required Analysis	Analytical Methods	Holding Time	Sample Preservation	Containers
Groundwater Sampling													
Groundwater Sampling Event	3 existing and 8 new monitoring wells	Water	Once	11 plus 2 dup (10%) and 1 MS/MSD (5%)	Grab, Low flow technique	Flow-thru cell, bladder pump, Teflon-lined tubing	14 days	DQO Level III	TCL Volatiles	8260B	14 days	HCl pH<2, Cool to 4°C	(2) 40 mL vial
	Equipment rinsate blank		1 per 10 samples (10%)	1	Prepared in Field	Analyte-free water, SS funnel							
	Trip blank		1 per cooler containing volatile samples	1	Prepared by Lab	N/A							
IDW Disposal Characterization Sampling													
Disposal to POTW	Well development, purge water, and decon fluids	Water	Representative sample to comply with the Memphis Depot Industrial Discharge Agreement with the City of Memphis	3	Grab	Drum thief or dip jar	14 days	DQO Level III	TCL Volatiles	8260B	14 days	HCl pH<2; Cool to 4°C	(3) 40 ml vial
									TAL Metals	6010B/7470A	6 months, Hg = 28 days	HNO_3 pH<2, Cool to 4°C	(1) 500 mL HDPE
									TCL Semivolatiles	8270C	7 day extr; 40 day analysis	Cool to 4°C	(1) Amber Liter Glass Jar
	Extracted groundwater			Up to 16	Grab	Sample port or dip jar	14 days	DQO Level III	TCL Volatiles	8260B	14 days	HCl pH<2, Cool to 4°C	(3) 40 ml vial
Soil	Soil cuttings; decon residuals	Soil	Once	1	Composite comprising 5 aliquots (except for VOCs, which is a grab)	SS Auger, SS Spoons, SS Bowl	14 days	DQO Level III	TCLP Volatiles	1311/8260B	14 day TCLP extr; 14 day analysis	Cool to 4°C	(1) 4 oz glass
									TCLP Semivolatiles	1311/8270C	14 day TCLP extr; 7 day extr; 40 day analysis	Cool to 4°C	(2) 8 oz glass
									TCLP Pesticides	1311/8081A	14 day TCLP extr; 7 day extr; 40 day analysis		
									TCLP Herbicides	1311/8151A	14 day TCLP extr; 7 day extr; 40 day analysis		
									TCLP Metals	1311/6010B, 7470A	6 month TCLP extr; 6 month analysis, Hg 28 day TCLP extr; 28 day analysis	Cool to 4°C	(2) 8 oz glass
									Ignitability	1030	ASAP		
									Corrosivity	9045A	ASAP		
									Reactivity	Chapter 7 3	ASAP		

Notes.
1 - Wells will be purged with QED or equivalent low-flow device Samples will be collected using teflon tubing and pump
TAT = Turnaround time
VOCs = Volatile organic compounds
SVOCs = Semi-volatile organic compounds
C = degrees celcius
ml = milliliter
NA- Not Applicable

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE