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THE MEMPHIS DEPOT TENNESSEE



ADMINISTRATIVE RECORD COVER SHEET

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CH2MHILL

Data Collection Plan for Long-Term Operational Areas (LTOAs), Main Installation, Memphis Depot

TO: COPIES:

FROM:

DATE:

U.S. Army Engineering and Support Center, HuntsvilleMemphis Depot Caretaker (MDC)U.S. Environmental Protection Agency (USEPA), Region 4

Tennessee Department of Environment and Conservation (TDEC)

CH2M HILL

June 5, 2001



Introduction

This Data Collection Plan (DCP) was prepared to describe pre-Remedial Design (RD) sampling and testing to be conducted at the Main Installation (MI) within the Memphis Depot (see Figure 1). The objectives for the activities described herein are to evaluate groundwater downgradient of known or suspected historical long-term operational areas (LTOAs) on the MI where hazardous materials were used/stored, as identified by the Tennessee Department of Environment and Conservation (TDEC). These LTOAs have been selected by TDEC for further testing because proximal down-gradient groundwater monitoring was not conducted to TDEC's satisfaction as part of the MI Remedial Investigation (RI). Each location for LTOA monitoring points was selected based upon best professional judgement and all currently available hydrogeologic and groundwater flow data for the MI. The primary purpose of this pre-RD testing is to collect information to be used in optimizing the injection points for the selected alternative in the MI Record of Decision (ROD), enhanced bioremediation. In addition, this additional testing will supplement existing hydrogeologic and environmental data regarding the MI hydrogeological conceptual site model (CSM) for the MI.

These objectives have been outlined in several documents and other communications, beginning primarily with the issuance of the *Draft Pre-Design Data Collection Plan for Main Installation (Functional Unit 7)* (CH2M HILL, 2000). This document was developed as a result of the Base Realignment and Closure (BRAC) Cleanup Team (BCT) Meeting on July 19, 2000.

The objectives and scope of work for the activities described herein are based in part on the following (as presented in Appendix A):

- Minutes from the August 23, 2000, BCT meeting regarding BCT review of the Draft Pre-Design Data Collection Plan for Main Installation (Functional Unit 7)
- Letter from TDEC, dated September 12, 2000, regarding conditional concurrence on Memphis Depot, MI Proposed Plan

- Letter from TDEC, dated September 13, 2000, regarding Memphis Depot, MI Groundwater Feasibility Study (FS) and MI Soils FS
- Agreement between BCT Members for the MI pre-design resolution, dated September 21, 2000
- Letter from TDEC, dated October 30, 2000, regarding additional MI Pre-RD wells
- Minutes from the January 18, 2001, BCT meeting regarding LTOA wells

Originally, information gained from this study was to be submitted as part of the MI ROD. Since then, however, the ROD has been signed by the Defense Logistics Agency (DLA) and TDEC, and signature by the U.S. Environmental Protection Agency (EPA) is pending. The following information has been included in the ROD to address this pre-design 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 RI and groundwater 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 remedual 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 above referenced ESD or ROD amendment would be developed only if the data obtained from this study indicate that the groundwater remedy selected in the MI ROD requires a significant and fundamental change. All information from this study will be part of the MI RD submittal package.

The following sections of the document present background information, justification for pre-RD sampling and testing at the MI LTOAs, objectives of the data collection plan, and field activity procedures

Background Information

In January 2000, the final MI RI Report was submitted and in July 2000, the final MI Groundwater FS was submitted. Differences between CSMs and implications regarding potential plume migration led the BCT to re-evaluate groundwater results from the RI and to request additional testing prior to beginning RD.

TDEC provided proposed well locations in August 2000 in areas identified as being LTOAs of hazardous materials at the MI, and revised these in October 2000, after discussions with all stakeholders in September 2000. The approach taken by TDEC was to review the many "sites" on the MI and determine if they were LTOAs of hazardous materials, and if there was an existing groundwater monitoring well located near or downgradient from them.

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After the BCT discussed the importance and purpose of each of these well locations on August 23, 2000, a memorandum of understanding was developed on September 21, 2000, by the members of the BCT regarding locations where LTOA wells are to be installed. The following excerpt from the agreement summarizes the scope of work:

"At LTOA proposal well locations for the following sites: SS66, RI58, RI59, SS37, SS36, SS35, SS83, RI27, SS80, RI34

BCT consensus is -

We will use temporary wells at these locations. Groundwater sample [sic] will be collected with the diffusion samplers at a frequency of one per 5 feet of screened intervals. The entire saturated thickness will be screened. [This portion of the plan has changed since consensus was reached, as discussed in the "Groundwater Sampling" section below.

150-[micrograms per liter] $\mu g/L$ total VOCs will be the trigger for completing a well [All wells will now be installed as finished wells]. Phase 2 design (Post ROD) will be to delineate the plume boundary for purposes of implementing enhanced bioremediation.

If a potential source of ground water contamination is identified in the vadose zone during drilling, a well will be completed. [Each well is to be a finished well.]

If new wells change the vertical or horizontal groundwater flow picture materially, but no contamination is found exiting the base boundary or downward towards a lower aquifer, the information would focus the placement of sentinel wells, but the current proposed remedy will still be valid."

In addition to investigation areas described in the previous paragraph, another five LTOAs on the MI were proposed for potential investigation in a letter from TDEC to the Memphis Depot Caretaker on October 30, 2000. Per an e-mail issued to the BCT on November 1, 2000 from the Memphis Depot Caretaker, the investigation into five additional LTOAs will be implemented as requested. As described in the October 30, 2000 letter, the five areas are as follows:

- Building T702(NE6)
- Garage and Paint Shop, Building 260
- Automotive Maintenance and Repair Shop, Building 251 (SB1)
- Automotive Maintenance and Repair Shop, Building 265 (SC1)
- Former Drum Storage Area on the south boundary of facility

Pre-RD Sampling and Testing Justification

The RI identified several groundwater plumes of chlorinated volatile organic compounds (CVOCs) beneath the MI, but did not identify specific contaminant sources in either soil or groundwater. Numerous soil borings were completed in potential CVOC source areas, and 24 monitoring wells (along with 7 piezometers and 7 hydropunch locations) were installed to test groundwater across and off site of the MI. Many of the potential sources were not specifically targeted for groundwater monitoring, because chemical analyses of surface and subsurface soil from test borings indicated little or no residual volatile organic compound

(VOC) contamination. The principal contaminants identified in monitoring wells were TCE and PCE, and associated degradation products. Re-evaluation of the RI testing by TDEC has suggested that some sites may remain as a source-term (e.g., dense non-aqueous phase liquids [DNAPL]) for groundwater contamination. The presence of an undocumented source-term would have serious implications for design and implementation of the selected groundwater remedy (enhanced bioremediation) for the MI, as documented in the MI ROD. Therefore, soil and groundwater at selected locations will be tested to confirm that a sourceterm is or is not present at the referenced LTOAs.

As part of the soil and groundwater testing at the LTOAs, additional hydrogeological data will be collected at each of the locations to better confirm the CSM for the MI. More specifically, the investigation will provide additional data to: (1) confirm groundwater flow directions in the fluvial aquifer across the MI; (2) define the boundary of the *'limited to no flow boundary'* of the fluvial aquifer on the north-northwest/central portion of the MI; and (3) define the areal extent of the fluvial aquifer and underlying clay unit on the north-northwest/central portion of the MI. Figure 1A presents the current estimated groundwater flow patterns in the fluvial aquifer underlying the MI.

Long-Term Operational Areas

The following are the LTOAs identified for further investigation on the MI. All of the LTOAs are shown on Figure 2, and each specific LTOA and/or group of LTOAs are presented in Figures 3 though 12.

LTOA Group No. (and Figure No.)	LTOA Site or Area	Functional Unit	LTOA Description		
1 (Figure 3)	SS35	FU4	Former DRMO Bldg. T-308, Hazardous Waste Storage		
	SS36	FU4	Former DRMO Hazardous Waste Concrete Storage Pad		
	SS37	FU4	Former DRMO Hazardous Waste Gravel Storage Pad		
2 (Figure 4)	RI59	FU2	Former pesticide mixing area (Bldg. 273), located near the northeast corner of the inactive Golf Course.		
	RI58	FU6	Old pesticide shop (Pad 267), located directly north of the J- Street Café. Monitoring Well MW-26 is located directly down- gradient of this LTOA		
	SS66	FU6	Former vehicle maintenance shop (Bldg. 253). Located directly north of site RI58		
	B260*	FU6	Former garage and paint shop (Bldg. 260) Located directly northeast of site RI58		
	SB1*	FU6	Former auto maintenance and repair shop SB1 (Bldg. 251). Located directly northeast of B260		
	SC1*	FU6	Former auto maintenance and repair shop SC1 (Bldg. 265) Located directly southeast of B260.		
3 (Figure 5)	S\$78	FU5	Former Alcohol, Acetone, Toluene, Naptha, Hydrofluoric Acid Spill (Błdg 678)		
4 (Figure 6)	RI34	FU3	Former Underground Oil Storage Tanks (Bldg 770)		
5 (Figure 7)	RI27	FU3	Former Recoupment Area (Bldg. 873)		

LTOA Group No. (and Figure No.)	LTOA Site or Area	Functional Unit	LTOA Description	
6 (Figure 8)	RI32	FU3	Former Painting, Sandblasting, and Waste Accumulation (Bldg 1087 & 1088)	
	SS89	FU3	Former storage of acids, paints, and cleaning solvents (Bldg 1089)	
7 (Figure 9)	SS83	FU4	Dried Paint Disposal Area (Bldg. 949)	
8 (Figure 10)	SS42	FU4	Former PCP Dip Vat Area	
	SS43	FU4	Former Underground PCP Tank Area	
	SS80	FU4	Former Fuel and Cleaners Dispensing (Bldg 720)	
9 (Figure 11)	Bldg 690*	FU5	Former Drum Storage Area on the south boundary of the MI	
10 (Figure 12)	Bldg T702 (NE6)*	FU4	Building T702 (identified as a former paint shop in the U S Army Topographic Engineering Center [TEC] Historical Environmental Aerial Photographic Analysis, dated September 1998)	

* These 5 LTOAs were added per the 30-Oct-00 letter from TDEC referenced above, upon their review of the U.S Army Topographic Engineering Center [TEC] Historical Environmental Aenal Photographic Analysis of the Main Depot Area South of Dunn Avenue, dated September 1998.

Objectives of Data Collection Plan

The objectives of the DCP are to complete the following steps and collect the resulting information and data:

- Install monitoring wells within the fluvial aquifer or underlying sand units (within the Jackson Formation/Upper Claiborne Group) within 100 to 200 feet down-gradient of the identified LTOAs to determine if an LTOA is acting as a source-term for chlorinated hydrocarbons in the groundwater.
- Collect samples of soil and groundwater at each of the monitoring well locations to define contaminant levels in both matrices.
- Incorporate the findings into a Technical Memorandum (TM) that will be part of the MI RD submittal package; the data will be used to optimize the enhanced bioremediation injection points for both the field pilot test and final design.

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The data quality objectives (DQOs) detailed below are established to achieve the objectives outlined above.

DQO No. 01—Confirm Contamination Sources

Qualitative DQO

Confirm that concentrations of chlorinated hydrocarbons reported from the RI and FS are maximum levels expected in the fluvial and underlying Jackson Formation/Upper Claiborne Group aquifers, and are not indicative of the presence of a source-term. Pentachlorophenol (PCP) is the chemical of concern (COC) at LTOAs SS-42 and SS-43. The Federal Maximum Contaminant Level (MCL) for PCP is $1 \mu g/L$.

No VOC results to date have indicated the potential presence of DNAPL (using the rule-ofthumb of 1 percent of CVOC saturation). Selected LTOAs within the MI will be tested by installation of a new groundwater monitoring well that is screened on top of the uppermost clay unit within the Jackson Formation/Upper Claiborne Group deposits. Table 1 shows the concentrations at the 1 percent aqueous solubility for relevant COCs and target analytes at the MI.

Quantitative DQO

Analyze groundwater from approximately 19 new wells using SW-846 Method 8260B to evaluate chlorinated hydrocarbon concentrations relative to previous results. Table 2 presents the proposed locations of each of the new monitoring wells. In addition, a groundwater sample from the area of the former PCP dip vat (sites SS-42/43) will be analyzed for SVOCs (including PCP) using SW-846 Method 8270C.

Methods to Obtain DQO

Drill boreholes with continuous sampling from land surface to the top of the uppermost clay unit within the Jackson Formation/Upper Claiborne Group deposits. Collect soil samples from the borings to characterize soil conditions and lithology, perform field screening with an organic vapor analyzer (OVA) equipped with a flame ionization detector (FID), and conduct laboratory analyses (see below). Complete each boring as a monitoring well, as described in the "Field Activities Methodology" section below.

Collect groundwater samples and analyze for VOCs and SVOCs (only in the area of the PCP dip vat), as described in the Methodology section below.

DQO No. 02—Supplement Conceptual Model of Fluvial Aquifer

Qualitative DQO

As stated in the Pre-RD Sampling and Testing Justification section, various reports on the MI have proposed different CSMs of the fluvial aquifer underlying the north-northwest section of the MI. New monitoring wells in the fluvial deposits and in the top of the Jackson Formation/Upper Claiborne Group deposits will be used to confirm the depth to the water

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table and will supplement currently available information and help define whether a perched water table occurs locally.

Quantitative DQO

All monitoring wells installed for LTOAs will be surveyed and water levels measured. Water-level elevations will be tabulated and compared to elevations in nearby fluvial and Jackson Formation/Upper Claiborne Group wells. Depth to water measurements will be recorded in additional wells.

Methods to Obtain DQO

As described in DQO Number 1, a hollow-stem auger boring or rotasonic drilled borehole 5 feet into the uppermost clay layer of the Jackson Formation/Upper Claiborne Group will be made with continuous soil sampling. This boring will be completed as a monitoring well as described in the "Field Activities Methodology" section below.

The ground-surface elevation and top of casing elevation of the wells will be surveyed to determine groundwater elevations within the wells. Water level measurements will be made to the nearest ± 0.01 ft. Depth to water level measurements will also be collected from existing wells prior to sampling.

Field Activities Methodology

Drilling, monitoring well installation, well development, and groundwater sampling procedures will follow methods described below and, where appropriate, within Appendices B and C.

The methods and procedures presented herein 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). In addition, 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)

Soil Borings and Soil Sampling

Up to 19 soil borings will be drilled to define local soil conditions, stratigraphy, and groundwater quality. The proposed locations of the borings are shown on Figures 2 through 12 and described in Table 2, though exact locations may vary slightly based on site access for drilling. Northing and easting locations for the proposed well locations are provided on

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Figure 2. Estimated depths, total estimated footage for drilling, estimated saturated thickness of the groundwater, and recommended drilling techniques for each of the locations are presented in Table 3. Prior to disturbance of the surface, each boring location must be thoroughly reviewed for utility locations by contacting Tennessee Utilities Hotline (TN One Call) at (800)351-1111. This must be accomplished at least two weeks prior to commencement of drilling. Since groundwater flow direction measurements have not been completed recently within monitoring points located close to LTOAs SS35, SS36, and SS37, depth to water measurements must be made prior to drilling at the proposed locations (Figure 3). The depth to water measurements will be used to triangulate the local groundwater flow direction (see Figure 1A). The replacement of the protective casing for PZ06 may be necessary to gain entrance for depth to water measurements.

Prior to installation of borings or new LTOA monitoring wells at SS42, SS43, SS-80, and Bldg. T702, vertical flow measurements will be collected within monitoring well locations MW-89 and MW-90. The aquifer at MW-89 and MW-90 is approximately 60-feet thick, and each of these wells were constructed with 30 feet of well screen. Vertical flow measurements will be conducted using a thermal (or heat-pulse) flowmeter to define if there is a vertical flow gradient in these long screen wells (see page 12 of the 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 in Appendix C). The LTOA wells at SS42, SS43, SS-80, and Bldg. T702 may be installed in the deeper sand aquifer of the Jackson Formation/Upper Claiborne Group and may require long screen wells (>10-feet of screen). The BCT members agreed at the May 2001 BCT meeting that vertical flow measurements were not required in the fluvial aquifer, even though well screens of >10-feet may be used in the LTOA wells installed in the fluvial aquifer. This activity will take place concurrently with the installation of the LTOA boring and monitoring wells and will be completed prior to the installation of borings at SS42, SS43, SS-80, and Bldg. T702.

Also, due to uncertainties related to the presence or absence of groundwater in the fluvial aquifer under LTOAs SS42, SS43, and SS80 (Figure 10), three borings will be drilled to ascertain the direction of horizontal groundwater flow and the concentration of contaminants, if present, within groundwater.

Considerations in determining the drilling technique to be used to perform soil borings and install wells include availability of contractors, cost, and technical justification. Drilling experience at Memphis Depot suggests that rotasonic drilling allows for greater precision, which will be important for identifying the interbedded clay strata, and generates less investigation-derived waste (IDW). However, heat is generated during the drilling process, which could affect VOC concentrations in the soil. In addition, the cost is greater than conventional drilling techniques and there are no local contractors who provide the service. Hollow-stem auger drilling problems associated with heaving fluvial sands have been reported with deeper (>100-ft.) wells. To complete this drilling effort with as few geologically related problems as possible, a combination of hollow-stem and rotasonic drilling is recommended.

Most of the borings for this effort will be advanced using hollow-stem auger drilling techniques with a 5-ft continuous core sampler that is advanced along with the augers

(EISOPQAM, Section 12.3.2). The core samples will be collected in plastic sleeves placed within the core barrel prior to drilling. The core samplers will be capped immediately upon return to ground surface. Continuous sampling will be conducted at each boring location from land surface to the bottom of each boring. Headspace field screening (see field screening SOP in Appendix B) will be conducted over each core using an OVA-FID until the water table is encountered. Soil corresponding to OVA-FID concentrations greater than or equal to 20 parts per million (ppm) will be collected using EnCore[®] Samplers and sent to a laboratory for analysis; only one soil sample will be collected every 20 feet from soil associated with the highest OVA-FID concentration greater than or equal to 20 ppm (see EnCore[®] sampling SOP in Appendix B). If no OVA-FID concentrations between the ground surface and the water table are greater than or equal to 20 ppm, only one soil sample will be collected just above the water table and sent to a laboratory for chemical analysis.

Soil sampling methods will be similar for those locations where rotasonic drilling techniques are utilized except that soil cores may typically be longer. Before subcontracting with a drilling company for this effort, the possibility of using plastic core barrels similar to that used for hollow-stem auger drilling should be investigated. The heat of drilling may also affect the levels of VOCs remaining in the soil and this should be noted in the boring logs.

An estimated 19 to 38 soil samples may be collected for laboratory VOC analysis. Previously, CH2M HILL has used analytical services from Columbia Analytical Services in Redding, California for testing at the MI.

Monitoring Well Installation

As stated by EPA in the May 2001 BCT meeting "all completed monitoring wells not identified for long term monitoring in the remedial design will be properly abandoned and will no longer require management by [U.S.] Army." All LTOA monitoring wells to be installed during this field effort will be installed as finished monitoring wells. When the remedial design is completed and the selection of wells for long-term monitoring has been made, all other monitoring wells will be plugged and abandoned according to guidance presented in Section 6.9 of the EISOPQAM.

Each LTOA soil boring will be completed as a monitoring well. Figure 13 presents an example well completion diagram for this investigation. Each monitoring well will be installed using 2-inch ID polyvinyl chloride (PVC), 0.01-inch continuously slotted screen in 10- and 5 ft sections, as necessary, with the appropriate amount of riser. No more than 20 ft of saturated thickness will be screened in a well installed in the fluvial aquifer. The length of the screened interval in wells installed in the deeper sand aquifer of the Jackson Formation/Upper Claiborne Group will be defined in the field with BCT member approval pending results of the vertical flow measurements in existing wells MW-89 and MW-90. Stainless steel well screens will be used in lieu of PVC in areas where DNAPL is confirmed by field screening or laboratory results. Surface completion of each well will be a flush mount with a six-inch ID manhole set within a 3-foot by 3-foot by 0.5-foot thick concrete pad. In addition, each flush mount will have four bollards placed at each corner of the concrete pad. Each bollard will be painted with high-visibility yellow paint. In addition, orange snow-fencing will be temporarily secured around the bollards while construction activities are underway on the MI. In the period of time between completion of the well and

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construction of the manhole/concrete pad with bollards, the well will be protected temporarily with four fence-posts and snow-fencing.

Total length of the screens will depend upon the saturated thickness of the aquifer. Aquifer thickness will be based on field review of soil samples and, where possible, through the use of an electronic water-level tape by field personnel. Estimated aquifer thickness' are presented in Table 3 for each LTOA area. Screens will be placed at the top of the first "clay layer" noted at or below the bottom of the fluvial deposits. The field geologist will define a "clay layer" as a unit that is more than 5 feet thick and is composed of clay, silty clay, or sandy clay. When a boring is completed into a clay layer, the bottom of the boring should be filled with bentonite pellets up to the corresponding depth of the bottom of the fluvial aquifer.

Following installation, all newly installed monitoring wells will be developed in accordance with procedures presented in Section 6.8 of the EISOPQAM. Development water will be containerized and tested prior to off-site disposal (see "Investigation Derived Waste" section below).

Potentiometric Surface Mapping

The ground-surface elevation and top of casing elevation of the newly installed LTOA monitoring wells will be surveyed to determine groundwater elevations within the wells. Water level measurements will be made to the nearest ± 0.01 ft. Groundwater levels will be measured in all MI and Dunn Field monitoring wells during the sampling event for the new LTOA monitoring wells (EISOPQAM, Section 15.8). A revised potentiometric surface map for the fluvial aquifer will be prepared identifying groundwater elevations and the inferred groundwater flow directions.

Groundwater Sampling

Collection of groundwater samples from the new monitoring wells at the MI will occur as soon as all new LTOA wells are installed and developed. Each of the wells will be sampled using 2foot long diffusion bag samplers. 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 used continuously throughout the screened zone of each well; this should allow for a more accurate representation of the contaminated horizon(s) compared to the use of a single diffusion bag sampler. 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*, as found in Appendix C.

All LTOA and existing wells will be sampled for VOCs using diffusion bag samplers except the LTOA well(s) at sites SS42-43. Historically, PCP was used at sites SS42-43 and, therefore, groundwater samples will only be collected for SVOC analysis using low flow sampling procedures developed in EISOPQAM, Section 7.2.2. Before sampling, each well or wells in the site SS 42-43 area will be purged using a bladder pump (using low-flow, minimal drawdown techniques) in order to minimize agitation of the groundwater and sample turbidity. Field measurements of dissolved oxygen (DO), oxidation-reduction potential (ORP), turbidity, pH, temperature, and specific conductance 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. Wells will also be sampled using the bladder pump system. The bladder pump will be equipped with a high-density polyethylene (HDPE) tubing that is lined on the inside with Teflon®. *Low-Flow (Minumal Drawdown) Groundwater Sampling Procedures* from the EISOPQAM, Sections 7.2.2 and 7.3.3, will be followed along with low-flow procedures from the USEPA, 1996 (Appendix C).

All samples will be preserved as required in Table 4 and will be delivered to a laboratory within the appropriate holding period. Groundwater samples will be analyzed using SW-846 Method 8260B or 8270C, as applicable.

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.

The laboratory will apply the EPA CLP analytical methods for the preparation/isolation, detection, and quantitative measurement of organic target compounds and inorganic target analytes in water environmental samples. The laboratory will report the results in both hard copy and electronic format consistent with the CLP. Laboratory analytical data will be validated by a project chemist.

Investigation-Derived Waste

All soil cuttings will be drummed or placed in roll-off boxes, whichever appears to be more efficient If drums are used, all drums will be labeled and staged within the MI. For development and purge water, and decontamination water, drums will be necessary. No drums will be staged off-site, and all decontamination activities will be performed at the staging area. Representative samples of the IDW will be collected for chemical characterization needed for off-site disposal. All IDW will be removed for off-site disposal within 60 days following completion of the field sampling activities.

Logistics

Equipment, supplies, and personnel required to complete the pre-RD testing at the MI will be mobilized after approval of this DCP. A Site Health and Safety Plan will be prepared prior to field activities.

A site coordination meeting will be held after the final DCP has been submitted and before mobilization of the field effort. Participation will include Depot, CH2M HILL, U.S. Army Corps of Engineers (USACE), Jacobs Engineering, Inc., Depot Redeveloment Corporation, and subcontractor personnel. The meeting will include discussions of Depot regulations, DQOs, field procedures, field schedules, and review of the Site Health and Safety Plan.

Schedule

The following preliminary schedule is presented for the proposed fieldwork and preparation of the final TM.

Task	Date Completed		
Submit Draft DCP	May 10, 2001		
Present the Draft DCP to the BCT	May 17-18, 2001		
Receive Comments on Draft DCP from Agencies	May 17-18, 2001		
Submit Final DCP	June 6, 2001		
Contact Utility Locators (Tenn Utilities Hotline at 800-351-1111)	June 13, 2001		
Mobilize for Field	June 29, 2001		
Install Soil Borings, Conduct Field and Laboratory Screening Analyses, Complete Well Installations and Development	August 4, 2001		
Perform Groundwater Sampling	August 20, 2001		
Conduct Laboratory Analyses of GW Samples	September 7, 2001		
Conduct Laboratory Data Evaluation	September 14, 2001		
Prepare Draft TM	September 28, 2001		
Agency Review	October 12, 2001		
Submit Response to Agency Comments on TM	October 19, 2001		
Submit Final TM	October 26, 2001		
Submit Weekly Field Status Report to USACE & BCT and Conduct Monthly Teleconferences to Discuss Field/Lab Results	July, August, September, October 2001		

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 TABLE 1

 Summary of Concentrations at the 1 Percent Aqueous Solubility for Relevant Chemicals of Concern (COC)/Target Analytes

coc	Aqueous Solubility at 20°C (μg/L) ¹	1Percent Solubility Concentration (µg/L)	
Tetrachloroethene (PCE)	150,000	1,500	
Trichloroethene (TCE)	1,100,000	11,000	
PCP	Average: 15,333	Average 153	

1. SOURCE: (MONTGOMERY, 1996)

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TABLE 2

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Summary of Proposed New I	TOA Sample Locations	/ Wells, Memphis Depot MI

LTOA Site	Site Description	Functional Unit	Proposed Sampling Strategy	Well Purpose	
R159	Pesticide mixing area, B-273	FU2	1 boring/ well downgradient of Achieve LTOA DQO RI59 to bottom of fluvial deposits and top of confining clay layer		
RI27	Old recoupment area	FU3	1 boring/ well downgradient of RI27 to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
RI32	Paint/sand blasting/SS31- SS33	FU3	3 borings/ wells downgradient to RI31 & SS89 to bottom of fluvial	Achieve LTOA DQO (also provides stratigraphy information needed for the CSM DQO and	
SS89	Paint, solvent, acid spills area	FU3	clay layer	supplement models of off site to on site contaminant plume flow regime)	
RI34	Maintenance shop and UST	FU3	1 boring/ well downgradient of RI34 to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
SS35; SS36, SS37	DRMO Storage	FU4	2 borings/ wells downgradient of the former DRMO storage area to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
SS42-43	PCP dip vat/PCP UST	FU4	2 borings/ wells downgradient of SS42 & SS43 to bottom of fluvial deposits or top of confining clay layer or possibly deeper	Achieve LTOA DQO	
SS80	Fuel and cleaner dispenser, B-720	FU4	1 boring/ well downgradient of SS80 to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
SS83	Dried paint/POL disposal area	FU4	1 boring/ well downgradient to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
SS78	Bldg 678	FU5	1 boring/ well downgradient to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA DQO	
RI58	Pad 267, Old Pesticide shop	FU6	1 boring/ well downgradient of	Achieve LTOA DQO	
SS66	Vehicle Maintenance Shop	FU6	HI58 & SS66 to bottom of fluvial deposits and top of confining clay layer		
(10)*	Paint Shop NE6 (Building T702)	FU4	1 boring/ well downgradient of the former paint shop to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA/DNAPL DQO	

LTOA Site	Site Description	Functional Unit	Proposed Sampling Strategy	Well Purpose
(9)*	Drum Storage Area	FU5	1 boring/ well downgradient of the former drum storage area to bottom of fluvial deposits or top of confining clay layer	Achieve LTOA/DNAPL DQO
(2)*	Buildings #260, SB1 (Bldg. 251), and SC1 (Bldg. 265)	FU6	3 borings/ wells downgradient to bottom of fluvial deposits and top of confining clay layer	Achieve LTOA/DNAPL DQO

* LTOA group number

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TABLE 3

Estimated Depth of Proposed New LTOA Sample Locations/Wells, Memphis Depot MI

LTOA Site	Site Description	Functional Unit	Estimated Depth (ft bgs) / Estimated Total Footage to be Drilled	Estimated Saturated Thickness (ft)	Recommended Drilling Techniques
RI59	Pesticide mixing area, B-273	FU2	110/110	25	Hollow-stem
RI27	Old recoupment area	FU3	115 / 115	18	Hollow-stem
RI32	Paint/sand blasting/SS31- SS33	FU3	115 / 345	18	Hollow-stem
SS89	Paint, solvent, acid spills area	FU3			
RI34	Maintenance shop and UST	FU3	125 / 125	21	Rotasonic
SS35; SS36, SS37	DRMO Storage	FU4	105/210	12	Hollow-stem
SS42-43	PCP dip vat/PCP UST	FU4	115 / 230 (assumes that bottom of fluvial aquifer is present at 115 ft bgs)	12	Hollow-stem
SS80	Fuel and cleaner dispenser, B-720	FU4	150 / 150	32	Rotasonic
SS83	Dried paint/POL disposal area	FU4	100 / 100	15	Hollow-stem
SS78	Building 678	FU5	120 / 120	10	Hollow-stem
RI58	Pad 267, Old Pesticide shop	FU6	120 / 120	10	Hollow-stern
SS66	Vehicle Maintenance Shop	FU6			
(10)*	Building T702 (NE6)	FU4	150 / 150	17	Rotasonic
(9)*	Drum Storage Area	FU5	110 / 110	10	Hollow-stem
(2)*	Buildings #260, SB1 (Błdg 251), and SC1 (Bldg 265)	FU6	110 / 330	20	Hollow-stem

*LTOA group number









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Grass 972 Π 970 **SS89** \boxtimes MW82 MW21 1084 [] 1086 HY89A 1088 1087 'n **RI32** Г ****** Grass • MW22 LANG ING LEVEN DE VERIE VE -----HY07 • LEGEND Groundwater Flow Direction (January 2001) Existing Monitoring Well / Piezometer / Hydropunch FIGURE 8 LTOA RI32 & SS89 Proposed Sampling LTOA Sampling Location / Temporary Monitoring Well Long Term Operational Areas (LTOA) \mathbb{Z} Locations \sim Functional Unit Boundary 200 Feet n 100 Data Collection Plan **Base Features** Memphis Depot Main Installation SCALE IS APPROXIMATE · CH2MHILL

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Figure 13 Example Well Completion Diagram LTOA Well Installation Main Installation, Memphis Depot



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Appendix A

LTOA Background Information

- 1. Minutes from the August 23, 2000, BCT meeting regarding BCT review of the Draft Pre-Design Data Collection Plan for Main Installation (Functional Unit 7)
- 2. Letter from TDEC, dated September 12, 2000, regarding conditional concurrence on Memphis Depot, MI Proposed Plan
- 3. Letter from TDEC, dated September 13, 2000, regarding Memphis Depot, MI Groundwater Feasibility Study (FS) and MI Soils FS
- 4. Agreement between BCT Members for the MI pre-design resolution, dated September 21, 2000
- 5. Letter from TDEC, dated October 30, 2000, regarding additional MI Pre-RD wells
- 6. Minutes from the January 18, 2001, BCT meeting regarding LTOA wells

Minutes from the August 23, 2000, BCT meeting regarding BCT review of the Draft Pre-Design Data Collection Plan for Main Installation (Functional Unit 7)
MEMORANDUM FOR THE RECORD

23 AUGUST 2000

SUBJECT. Meeting Minutes, BCT Review of the Draft Pre-Design Data Collection Plan for the Main Installation (MI).

 The on-board review of the subject work plan was held on 23 August 2000, at the TDEC Office, Mt. Moriah Road, Memphis, TN. The following is the list of attendees: Shawn Phillips, DLA Turpin Ballard, EPA James Morrison, TDEC Brian Deeken, TDEC Brian Deeken, TDEC Jack Carmichael, USGS David Ladd, USGS Stephen Offner, CH2M HILL Dorothy Richards, Corps of Engineers Scott Bradley, Corps of Engineers Jordan English w/ TDEC participated in parts of the meeting.

2. Steve Offner presented an overview of the Draft MI Pre-Design Data Collection Plan. The Dunn Field Work Plan is a separate work plan, the Dunn Field wells are not shown in this work plan.

3. Turpin Ballard said that if there are no impacts from the study, the results will be folded into the Remedial Design Package report. If there is a significant change, as defined by a change in the treatment technology, then an Explanation of Significant Differences (ESD) would be required. Shawn Phillips asked what type of change would be considered a fundamental change, thereby requiring an additional public comment period. An example of a fundamental change is going from treatment to no treatment.

4. Offner said the findings would be documented in a Technical Memorandum to be included as part of the ROD. The Tech Memo would be finalized in March 2001. Turpin said that ROD development should continue and review the data, as it is available.

5. Jim Morrison said that he is flexible in the number of wells he has requested. He believes that wells can have multiple uses in addressing groundwater issues. He needs to be convinced that there is enough data. He said that soil samples can give you a false negative, based on his experience at Millington; therefore, the lack of CVOCs in the soil does not mean there is not DNAPL in the groundwater. Later in the day, the history of the observational approach used during the RI at the MI was discussed when Jordan English attended a portion of the meeting. The observational approach used by the BCT was implemented in some areas where operations could have caused impacts to the groundwater. In these areas soil borings were initially done. If there were exceedences of the U.S. EPA Region III "Soil to Groundwater Transfer Criteria" from the Region III Risk Based Concentration table, then groundwater from these areas was further sampled

in a second phase. Morrison's reference back to soil samples giving a "false negative" was in response to areas that did not go through a phase two round of sampling.

6. Offner discussed Figure 32-9, which shows total distribution of VOCs in subsurface soil, including the DRMO yard, Former Screening Sites 35, 36, and 37. VOC concentrations in the soil are in exceedance of the EPA's groundwater protection criteria This was addressed during phase two RI sampling through PZ 6. Offner recommends a sampling location down gradient to satisfy one of the DQOs, as requested by TDEC. The general groundwater flow direction here is SW on both Conceptual Site Models (CSMs), although Morrison noted that there was a slight difference in flow direction between the two CSMs. PZ06 is still there. Offner will need to get an answer on the screen interval of this PZ.

7. Phillips said that for purposes of getting multiple uses out of one boring, to sample when we hit the top of the confining unit clay. Use hollow stem auger with a continuous sample. A Sudan Dye test will be used to test for DNAPL. If the Sudan Dye test indicates DNAPL, finish the boring as a shallow well at the clay (*Please note that this approach was revised and discussed per paragraph 20 of these minutes*). Move adjacent to the shallow well and install a deeper well, developing it into confined sand for the purpose of satisfying the USGS promoted conceptual site model DQO. Is PZ06 finished at the bottom of the fluvial? How thick is the saturated thickness? Again, this is the question Offner was to answer.

8. Ballard said that if a well is not a critical point needed for remedial design, and if there is no contamination found, then there is no reason to install the deeper well. It was discussed that a decision tree should be developed to consider the possibilities. The tree should ask if there is evidence of a DNAPL source, and do we need that location for potentiometric control. Should the well be completed? The question was asked "how much additional cost is needed to install a well, once clay has been tagged." The answer was significant when future sampling, maintenance, and ultimate well closure is considered. Ballard said that if the BCT could agree to the logic tree it would save time.

9. Brian Deeken asked if PZ06 was usable. Offner said it was, but it had been dormant, and the roadbox could not be opened in the most recent water level gauging event in April 2000. It was initially sampled after it was installed in 1998. Phillips said that PZ06 could be opened and looked at again.

10. Offner said that an OVA-FID will be used for field screening, and so will the Sudan Dye Test. A sample can be sent for a 24 hour turnaround at a local fixed based lab to tell if there are indicators of a DNAPL to install a well. The sample collected for off site analysis would be a saturated sample and would be analyzed for SW-846 Method 8260B. With a saturated sampled analyzed using this EPA method, the presence of a DNAPL, or even much lower levels of VOCs, would be certain. This would satisfy the DNAPL DQO.

11. Ballard asked if any detect should be considered as evidence of a DNAPL. Offner said, for threshold criteria purposes, that a reading of 100 ppm or greater on the OVA-FID could trigger collection of a sample for lab analysis for VOCs.

12. Jack Carmichael said that we should target the worst potential sites (as they relate to the confined sand aquifer) first, because they may have influence on other well locations. Discussion by the group and USGS included the topic of double casing any deeper well below the fluvial aquifer. USGS agreed that double casing these wells was the prudent method. Steve Offner also agreed. Jack Carmichael and David Ladd stated that the deeper wells near MW24 and well MW27, and the well cluster SE of wells MW18/MW38 should be installed first to better define the conceptual site model. Based on the findings from these wells and the sampling locations downgradient of the potential DNAPL sites, then additional deeper wells may be needed. Carmichael and Ladd agreed that deeper confined wells on the NE, SE and SW portions of the MI were not needed at this time (see attached matrix for the location of the deeper wells agreed to).

13. The group discussed the southwest corner of the Depot, and the area near sites SS89, RI32 in great detail. The group agreed that 3 new fluvial wells would be installed in this area: One along the southern boundary of the Depot between MW22 and MW47; one well approximately 100' east of bldg 1084; and one well between the southern ends of bldgs 972 and 970. The wells would be keyed into the top of the confining unit clay (or rather into the base of the fluvial deposits). The elevation of the clay will be used to help confirm the CSM. BREAK.

14. Phillips asked about proceeding with the ROD. He said that we can look at the data as soon as it is available, and if it looks like a probable ESD, the ROD is still on schedule. Deeken said that if the ESD comes after the ROD is signed, that's bad as far as TDEC is concerned. The point being, if we as a group would have known that the ROD was going to need a significant change, yet we went ahead and signed the ROD without delay with knowledge that we would be changing it within a short period of time. He wants to make sure that the signed ROD has the correct remedy. Turpin Ballard said that data is still collected after the ROD for remedial design. This data can be included in an ESD.

15. CH2M HILL should be able to mobilize in late September. Turpin Ballard said that if HILL has all comments today, the next version of the work plan should be a Draft Final, and would only require checking comment responses to finalize.

16. An observational (or phased) approach was used in studying the Main Installation during the RI. Ballard asked why we are going back and opening up screening sites that were formally eliminated. Morrison's point is that soil analytical data can give a false negative to indicate if DNAPL exists and that the groundwater in the area down gradient of these sites was never investigated.

17. The meeting moved to a review of the "Map Legend" sheet of the "TDEC Proposed Well Locations with DQOs to address Objective 2 of the Main Installation Pre-remedial

Design Work Plan" to determine if each site listed should be considered a Long Term Operational Area (LTOA). Morrison said that for a site to be considered a LTOA it must have operated for a long time, and had significant potential for a release. The results of the list are as follows:

- SS46 is to be captured with SS42-43, therefore SS46 drops out; however, Morrison stated that the new fluvial well had better be located down-gradient of SS42/43, or another well would be required.
- SS69 and TEC90 dropped out and will not be further investigated.
- RI58 and SS66 are to be combined; one fluvial well will serve for both and it will be installed SW of RI58.
- RI59: Phillips will talk to Jewel Edwards and Jack Kallal regarding past practices for pesticide usage and the use of solvents as a carrier for the pesticides.
- SS83: Phillips will talk to Mr. Truitt about past practices and the type of hazardous materials used at this site. Morrison asked why SS83 was sampled. Scott Bradley said it was because it was a site on the Dunn Field Buried Materials Map, Drawing 16-4 D.
- SS78 was added based on the concentrations of TCE found in the soil.
- All the other sites (RI27, RI32, SS34, SS35, SS42-43, SS80, and SS89) remained in the list.

18. Offner and the COE will review MW25 and MW26 to see if they were terminated into clay, and where the depths of the screened intervals are. This will help to address RI58/SS66, RI59 and the SE portion of the Depot.

19. Morrison stated that he wanted to see each specific site shown on a separate map, and he wanted the whole site to be identified (boundary of site indicated), not just a dot on a map. In addition, Morrison stated that he wanted the proposed monitoring well locations shown on these specific maps, not on a Depot-wide map that does not show the specific sites, buildings, roads, etc.

20. The wells to be installed near SS42/43 (former PCP dip vat) will be analyzed for SVOCs. PCP will be used as the indicator compound to determine if the groundwater has been impacted (presence of a DNAPL) from the former operations at the PCP dip vat.

21. At the end of the meeting Phillips and Ballard asked Morrison if each LTO area discussed during the meeting (and defined above) required the installation of a monitoring well Phillips and Ballard suggested the soil boring be initially screened in the field and a saturated soil sample collected at the top of the confining clay and analyzed at a fix-based laboratory to determine the presence or absence of DNAPL. If there were no indication that a DNAPL existed, then no well would be installed, per Phillip's and Ballard's suggestion. The boring would be grouted and abandoned. Morrison stated that he wanted to see a groundwater sample collected and analyzed from a well at each of the referenced LTOA locations. Phillips asked Morrison to reconsider the soil boring/fixed-

based lab analysis approach suggested to satisfy the DNAPL DQO. Phillips requested Morrison respond to him either Friday or early the following week.

A matrix indicating the sites and the number of new wells/sampling locations (and their purpose), as a result of the meeting, is attached.

Please, direct any questions or comments to Phillips, 901-544-0617.

			Section in RI	Proposed Action from the 23 Aug 00	Proposed Sampling	
#	Site Description	#2	Desc. Site	Meeting	Strategy	Well Purpose
SS69	Flame thrower/fire practice area	FU2	1236	Eliminated from further investigation	NA	NA
				Shawn to interview Jewel Edwards and		
RI59	Pesticide mixing area, B-273	FU2	1233	vach haual reyarung pesuduersolvent usage	TBD	TBD
RI27	Old recoupment area	FU3	1631	Staved in list for investigation	1 boring with fluvial soil sample lab analysis*	Addresses LTOA/DNAPL
				Both sites stayed in list for investigation	3 additional wells will be	Addresses LTOA/DNAPL
H I32	Paint/sand blasting/SS31-33	FU3	1632	I hey are grouped as the SW corner of	installed to the bottom of	DQO (also provides
SSB9	Paint, solvent, acid spills area	FU3	1636	the MI	the fluvial deposits	stratigraphy information needed for the CSM DQO)
RI34	Maintenance shop and UST	FU3	1633	Stayed in list for investigation	1 borng with fluvial soil sample lab analysis*	Addresses LTOA/DNAPL
TEC90	Old Pond Area	FU3	1637	Eliminated from further investigation	NA	NA
SS35	DRMO Storage	FU4	20 2 1 1	Stayed in list for investigation.	1 boring with fluvial soil sample tab analysis*	Addresses LTOA/DNAPL DOO
					•	Addresses LTOA/DNAPL
						DOO (also provides
SS42-43	PCP dip val/PCP UST	FU4	20212	Stayed in list for investigation	1 additional fluvial well	Information needed for the CSM DGO)
				Eliminated from further investigation Data will be captured from well installed		
0240	Patiet Urying	FU4	20215	for SS42/43	NA	NA
SSBO	Fuel and cleaner dispenser, B-720	FU4	20213	Stayed in list for investigation	1 borng with fluvial soil sample lab analysis*	Addresses LTOA/DNAPL DQO
SS83	Dned paint/POL disposal area	FU4	20214	Shawn to interview Mr Truitt regarding site operations	1B0	TBD
SS78	Bldg 678	FUS	24 3 4	Added to list for investigation	1 additional fluvial well	Addresses LTOA/DNAPL DQO
3158	Pad 267, Old Pesticide shop	FUG	28.3.2	SS66 to be combined with RI58 for	1 boring SE of RI58 with	Addresses LTOA/DNAPL
S66	Vehicle Maintenance Shop	FUG	2833		nuviaisolisample lab analysis⁴	
See	rad 26/, Uld Pesticide shop Vehicle Maintenance Shop	FU6	2832 2833	investigation		fluvial soil sample lab analysis*

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CSM Well Location	Well Type	Pumose
	Intermediate	
	depth (Confined	
Near SS42-43 (PCP Dip Vat)	Sand Aquifer)	Confirm CSM
	Intermediate	
South Central Boundary of MI at location of existing well	depth (Confined	
MW24	Sand Aquiter)	Confirm CSM (also to check for vertical migration of TCE or PCE
	Shallow depth	
Southeast of MW18 and MW38	(Fluvial)	Confirm water table conditions
	Intermediate	
	depth (Confined	
Southeast of MW18 and MW38	Sand Aquifer)	Checked for perched water table
Former location of HY03 atong the southern boundary of th MI	Shallow depth (Fluvial)	Potentiometric control between the SE corner of the Mi, offsite to
		UIE SE, and convergence area near MW2/

• Note At these locations, a monitoring well may or may not be completed based upon the results of the saturated soil sample taken at the base of the fluvial deposits

Letter from TDEC, dated September 12, 2000, regarding conditional concurrence on Memphis Depot, MI Proposed Plan

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STATE OF TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION MEMPHIS ENVIRONMENTAL FIELD OFFICE SUITE E-645, PERIMETER PARK 2510 MT. MORIAH ROAD MEMPHIS, TENNESSEE 38115-1520

September 12, 2000

Memphis Depot Caretaker ATTN. DDSP-FE (Mr. Shawn Phillips, BEC) 2163 Airways Blvd. Memphis, Tennessee 38114-5210

RE: TDEC/DSF #79-736, cc 452 Conditional concurrence on Memphis Depot, Main Installation Proposed Plan, as a response to Depot's commitment letter, dated August 8, 2000.

Dear Mr. Phillips:

The Tennessee Department of Environment and Conservation (TDEC), Division Superfund (DSF), Environmental Assistance Center Memphis (EAC-M), has received the above referenced communique received in this office on August 14, 2000.

For clarification purposes, TDEC conditionally concurs with the preferred remedial alternative selection based on the following caveats:

- 1. A Pre-Remedial Design Work Plan must be completed and implemented before the Record of Decision is signed This work plan is to adequately address data gaps noted in the Main Installation Groundwater RI/FS. The two primary objectives of this work plan are:
 - A.) Acquire sufficient hydrogeologic and environmental data necessary to refine the Groundwater Conceptual Model with high degree of certainty.
 - B.) Acquire sufficient hydrogeologic and environmental data downgradient and proximal to Long Term Operational Areas, and areas with known VOC soil contamination on the Main Installation.

These two objectives should provide the data necessary to confirm and optimize the preferred remedial alternative.

2. If the data acquired, as a result of the Pre-Remedial Design effort, is consistent with groundwater contaminant levels previously identified on the Main Installation, then the preferred remedial alternative should be sufficient, with only minor modifications

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3. If, on the other hand, the data indicates there is a potential for DNAPL to be present, or if there is a potential for contaminants to be migrating off site or into the Memphis Sand aquifer, then the preferred remedial alternative may need to be modified significantly.

If you have any questions or require clarification please me call at (901) 368-7958.

Very truly yours James W. Morrison

State BCT Representative to DDMT Assistant Manager DSF EAC-M Tennessee Department of Environment and Conservation

TDEC/DSF, NCO - file TDEC/DSF, EAC-M - file Turpin Ballard United States Environmental Protection Agency Region IV, Waste Management Division 61 Forsyth St. Atlanta, GA 30303

Letter from TDEC, dated September 13, 2000, regarding Memphis Depot, MI Groundwater Feasibility Study (FS) and MI Soils FS

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STATE OF TENNEBSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION MEMPHIS ENVIRONMENTAL FIELD OFFICE SUITE E-645, PERIMETER PARK 2510 MT. MORIAH ROAD MEMPHIS, TENNESSEE 38115-1520

September 13, 2000

Memphis Depot Caretaker ATTN.: DDSP-FE (Mr. Shawn Phillips, BEC) 2163 Airways Blvd. Memphis, Tennessee 38114-5210

RE: TDEC/DSF #79-736, cc 452 Memphis Depot, Main Installation Groundwater Feasibility Study, July 2000. Memphis Depot, Main Installation Soils Feasibility Study, July 2000.

Dcar Mr Phillips:

, The Tennessee Department of Environment and Conservation (TDEC), Division of Superfund (DSF), Environmental Assistance Center Memphis (EAC-M), has reviewed the above-referenced documents, received July 3, 2000.

As verbally communicated in our July BCT Meeting, TDEC accepted the July 2000 Main Installation Soils Feasibility Study as final.

Also, as verbally communicated in our July BCT Meeting, TDEC conditionally accepted the July 2000 Main Installation Ground Water Feasibility Study as final so long as:

- 1. Additional transition language and graphics were incorporated explaining the conceptual model variance from that noted in the original RI.
- 2. A commitment letter from DDMT was sent to TDEC that assured us that additional Main Installation monitoring wells would be installed to resolve remaining groundwater issues as noted in the July Meeting.

TDEC has received slip-pages to resolve the first condition, and the commitment letter to address the second condition Currently the Pre-Remedial Design Work Plan for the Main Installation is being generated and revised to assist in the effort to resolve these remaining groundwater issues

This shall serve as TDECs official acceptance of these documents as final

If you have any questions or require clarification please me call at (901) 368-7958

Very truly yours, 10mina

James W. Morrison State BCT Representative to DDMT Assistant Manager DSF EAC-M Tennessee Department of Environment and Conservation

c: TDEC/DSF, NCO - file TDEC/DSF, EAC-M - file Turpin Ballard United States Environmental Protection Agency Region IV, Waste Management Division 61 Forsyth St. Atlanta, GA 30303

Agreement between BCT Members for the MI pre-design resolution, dated September 21, 2000

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Main Installation redesign resolution of dispute at staff level - September 21, 2000

At LTOA proposal well locations for the following sites SS66, RI 58, RI 59, SS37, SS36, SS35, SS83, RI 27, SS80, RI34

BCT consensus is -

We will use temporary wells at these locations. Groundwater sample will be collected with the diffusion samplers at a frequency of one per 5 feet of screened intervals. The entire saturated thickness will be screened.

150-ug/L total VOC's will be the trigger for completing a well. Phase 2 design (Post ROD) will be to delineate the plume boundary for purposes of implementing enhanced bioremediation.

If a potential source of ground water contamination is identified in the vadose zone during drilling, a well will be completed.

If new wells change the vertical or horizontal groundwater flow picture materially, but no contamination is found exiting the base boundary or downward towards a lower aquifer, the information would focus the placement of sentinel wells, but the current proposed remedy will still be valid.

TBella

Turpin Ballard Remedial Program Manager US Environmental Protection Agency (404) 562-8553

Jun Morrison

Remedial Project Manager Tennessee Department of Environment and Conservation (TDEC) (901) 368-7958

Shawn Phillips BRAC Environmental Cordinator Memphis Depot Carctaker Division (901)544-0617

Letter from TDEC, dated October 30, 2000, regarding additional MI Pre-RD wells

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October 30, 2000

Memphis Depot Caretaker ATTN.: DDSP-FE (Mr. Shawn Phillips, BEC) 2163 Airways Blvd. Memphis, Tennessee 38114-5210

RE: Additional Main Installation Pre-Remedial Design Wells TDEC/DSF #79-736, cc 452

Dear Mr. Phillips:

As you are aware, the Tennessee Department of Environment and Conservation (TDEC), Division Superfund (DSF) identified Long Term Operational Areas (LTOA) on the Main Installation that needed proximal down-gradient monitoring wells installed. The primary purpose of these wells is to assist in the optimization of injection points for the preferred alternative noted in the Proposed Plan. In addition, these LTOA wells will help to resolve numerous other ground water issues at this facility.

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At the August 2000 BCT Meeting, TDEC identified 15 LTOA needing proximal downgradient monitoring wells. In our August 2000 BCT working meeting, 5 of these well locations were agreed upon. In our September 21, 2000 meeting the other 10 LTOAs were discussed and are to be addressed via temporary wells. I will not reiterate the specifics of this agreement, as we have already signed off on it.

In researching the <u>Historical Environmental Aerial Photographic Analysis of the Main</u> <u>Depot Area South of Dunn Avenue, September 1998 Report</u>, TDEC noted that there are additional LTOAs needing proximal down-gradient wells installed. These LTOAs are:

- 1.) Paint Shop, Building NE6 (Ref. Figures 1,2,4,5,6,&7),
- 2.) Garage & Paint Shop Building 260 (Ref. Figure 3),
- 3.) Automotive Maintenance and Repair Shop, Building SB1 (Ref. Figure 3),
- 4.) Automotive Maintenance and Repair Shop, Building SC1 (Ref. Figure 3),
- 5.) Drum Storage Area on the south boundary of facility (Ref. Figure 3)

(All references are from the above noted document.)

For clarification purposes, a proximal down-gradient monitoring well is one that is within 100 to 200 feet of a site, and that is reasonably within the flow path of the contaminant of concern. Because different chemicals have different coefficients of dispersion, and

because preferential flow is also a controlling factor in contaminant transport, there are no set numbers for a degree arc. However, at a distance of 100 to 200 feet from a point of release, the variation from true down-gradient can be projected based on a chemical's historical plume configurations within the Memphis area. This variance is to be discussed by the BCT and USGS as data comes in.

In order to insure that wells are placed as close to true down-gradient as possible, monitoring wells that are reasonably close to the LTOAs should have their heads read prior to installation. If there are no reasonably close wells to a LTOA, then the temporary well's head should be used to verify that the location is adequate before it is sampled or installed as permanent.

Lastly, in order to obtain the environmental data necessary for decisions purposes, and because these may only be temporary wells, TDEC will be collecting samples on tighter intervals than what is proposed by DLA.

If you have any questions or require clarification, please me call at (901) 368-7958.

Very truly yours,

James W. Morrison State BCT Representative to DDMT Assistant Manager DSF EAC-M Tennessee Department of Environment and Conservation

c: TDEC/DSF, NCO - file TDEC/DSF, EAC-M - file Turpin Ballard United States Environmental Protection Agency Region IV, Waste Management Division 61 Forsyth St. Atlanta, GA 30303 Minutes from the January 18, 2001, BCT meeting regarding LTOA wells

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BRAC Cleanup Team

Meeting Minutes

January 18, 2001

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Attendees

55

BRAC Cleanup Team	Organization	Phone
John De Back (interim)	Defense Logistics Agency (DLA)/ Memphis Depot Caretaker Division (Depot)	(901) 544-0622
Turpin Ballard	Environmental Protection Agency, Region IV (EPA)	(404) 562-8553
James Morrison	Tennessee Department of Environment and Conservation, Memphis Field Office, Division of Superfund (TDEC)	(901) 368-7958
Project Team		
Mike Dobbs	Defense Distribution Center	(717) 770-6950
Paul Galiotto	Defense Distribution Center	(717) 770-4476
David Ladd	U.S. Geologic Survey	(615) 837-4773
Denise K. Cooper	Depot	(901) 544-0610
Jack Kallal	Depot	(901) 544-0614
Dorothy Richards	Corps of Engineers	(256) 895-1463
John Rollyson	Corps of Engineers	(931) 455-6771
Peggy DuBray	Corps of Engineers	(931) 454-6630
Robert Torstrick	Corps of Engineers	(256) 895-1512
Rick Bowlus	U.S. Army Center for Health Promotion and Preventive Medicine	(410) 436-5208
Stephen Offner	CH2M Hill	(770) 604-9182
David Nelson	CH2M Hill	(770) 604-9182
Kraig Smith	Jacobs/Sverdrup Engineering	(615) 331-9232
Trevor Smith Diggins	Frontline Corporate Communications	(888) 848-9898
Alma Black Moore	Frontline Corporate Communications	(901) 573-1812
Frank Johnson	UXB International	(703) 625-3792

Review of Previous Meeting Minutes

The BCT discussed and signed the December 19 - 20, 2000 meeting minutes.

Review of Project Status

Land Use Control Assurance Plan (LUCAP)/Land Use Control Implementation Plan (LUCIP)

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Long Term Operational Area (LTOA) Monitoring Wells Discussion

Addendum

То

Final January 2001 BRAC Cleanup Team Meeting Minutes

BRAC Cleanup Team	Organization	Phone
John De Back (interim)	Defense Logistics Agency (DLA)/ Memphis Depot Caretaker Division	(901) 544-0622
Turpin Ballard	Environmental Protection Agency, Region IV (EPA)	(404) 562-8553
James Morrison	Tennessee Department of Environment and Conservation, Memphis Field Office, Division of Superfund (TDEC)	(901) 368-7958
Project Team		
Dorothy Richards	US Army Engineering and Support Center, Huntsville	(256) 895-1463
David Nelson	CH2M Hill	(770) 604-9182
Stephen Offner	CH2M Hill	(770) 604-9182

Attendees

57

Long Term Operational Area wells

The BCT discussed the need for additional diffusion sample data for the temporary LTOA wells. Mr. Morrison requested that more diffusion samplers be placed in the temporary LTOA wells, and that CH2MHill sample them instead of TDEC The need for additional diffusion samples would be based on the saturated thickness of the unit (e.g. a temporary well with a 10' saturated thickness would have a minimum of 4 - 2' diffusion samplers hung in them). Because these LTOA wells are proposed as temporary, sufficient data is needed to be acquired during a onetime sampling event in order to establish a representative baseline of LTOA site condition. Mr. Deback agreed to this approach because it would eliminate the need to revisit the wells with multiple rounds of sampling if contaminant levels in these temporary LTOA wells turned out to be consistent with contaminate levels (150 ppb) already detected on the Main Installation In addition, by having CH2MHill collect these samples, TDEC would not need to sample these wells as intensely as previously discussed, there by saving time and resources.

SIGNED	3/8/01
JOHN DE BACK	DATE
Memphis Depot Caretaker Division	
Interim BRAC Environmental Coordinator	
SIGNED	2/29/01
TURPIN BALLARD	DATE
Environmental Protection Agency	
Federal Facilities Branch	
Remedial Project Manager	
SIGNED	2/29/01
JAMES W MORRISON	DATE
Tennessee Department of Environment and Conservation	
Division of Superfund	
BRAC Cleanup Team member	

Mr. John De Back provided Mr Turpin Ballard and Mr. Jim Morrison latest LUCAP proposed by Army Base Transition Team Mr. Ballard and Mr Morrison provided initial comments. Since the document differed from the draft previously submitted, their respective legal departments would review and provide comments. Mr. De Back agreed to send the proposed LUCAP to their respective legal representatives and to coordinate a conference call or meeting for the first part of February to discuss their comments.

The BCT discussed the timing for submitting the LUCAP and the Main Installation Record of Decision (ROD) for signature The ROD could be sent separately from the LUCAP, but Mr Ballard indicated the need to discuss the signature process if the LUCAP was not submitted simultaneously with the ROD with his supervisor.

Mr. De Back indicated that the Defense Logistics Agency, through the Defense Distribution Depot Susquehanna, PA, would sign the ROD, but that the Army would sign the LUCAP.

Findings of Suitability to Transfer (FOST) and Environmental Condition of Property (ECP) for Parcel 1.8

Mr. De Back discussed the Finding of Suntability to Transfer for Parcel 1 currently being drafted and the need to change the ECP for Parcel 1.8 to a transferable category Ms. Denise Cooper provided sampling data and the Main Installation Remedial Investigation (MI RI) baseline risk assessment (BRA) conclusion for Functional Unit (FU) 6, which contains Parcels 1, 4 and 5. The BCT discussed the BRA for FU 6 as well as Parcels 1 and 4.

The BRA concluded that FU 6 was suitable for industrial reuse The residential surrogate site that indicated restricted use was located in Parcel 4. Parcel 1 was used in the past for administrative and employee parking purposes and does not contain any long term operational areas. The MI RI results indicated levels are not inconsistent with unrestricted use. The BCT agreed that a hazardous substance release occurred as a result of pesticide application during routine grounds maintenance, but not at concentrations that require remediation. The BCT concurred that Parcel 1.8 change from ECP Category 7 to Category 3.

The BCT then discussed methods available to transfer property situated over groundwater contamination. Mr. Morrison agreed to provide Millington's CDR to Mr. De Back. The BCT then discussed the transfer strategy and schedule for the Main Installation and Dunn Field.

Defense/State Memorandum of Agreement (DSMOA)

Mr. Morrison requested assistance from the Memphis Depot in completing the state's DSMOA funding request Mr. Mike Dobbs agreed to complete the state's required funding form and submit it to Mr. Morrison.

Restoration Advisory Board (RAB) Planning

Ms Cooper presented a draft RAB meeting presentation/topics schedule for the BCT's review and comment. The BCT agreed to provide Revision 1 documents, starting with the Dunn Field Remedial Investigation (RI), on CD-ROM to each RAB member in order to begin presenting the findings at RAB meetings before finalizing documents.

The BCT discussed the issue of bi-monthly meetings and draw down of the RAB and agreed that it should be included on the topics schedule for discussion with the RAB toward the end of 2001. The BCT agreed that meetings should be cancelled if there was not sufficient technical information for a presentation, for example in the spring of 2001 before issuing the Revision 1 Dunn Field RI. The BCT agreed that the schedule should be updated to reflect any cleanup program schedule changes and presented to the RAB for their input. Ms. Cooper would update the schedule, and Mr. De Back would submit it for DDC approval prior to distributing it to the RAB before the February RAB meeting. Mr. De Back would provide the approved schedule to the appropriate contractors tasked with preparing the presentations.

Long Term Operational Area wells

Mr. Morrison asked when the wells would be installed and sampled, as he must provide his lab a timeframe to expect samples. Mr. Offner indicated the wells should be installed by the end of February 2001. Sampling results would be presented to the BCT in the Main Installation Pre-Design tech memo and that it would be separate from the Conceptual Site Model tech memo. Mr. Offner would update the project schedule to include the document review schedule for both tech memos.

Dunn Field Interim Remedial Action for Groundwater

Mr. Kraig Smith reported that Jacobs/Sverdrup Civil had mobilized the last week of October 2000 to modify the seven existing wells and to bring the four new wells on line. They replaced the insulation and thermal wrap on the existing wellheads with heated stainless steel housings and restarted the original wells in November 2000. Mr. Smith reported that he was waiting for delivery of specially designed and manufactured flow control valves and that the manufacturer's delivery schedule had slipped due to production problems Once he received the flow controls values, it would take about one week to install and restart the four new wells and to conduct the start-up tests. Mr. Smith indicated that the project was essentially completed with exception of the flow control valves and actuators, but that he still anticipated having all wells on line by end of January 2001.

Mr. Ballard asked about the shut down and restart procedures, and the project team discussed the reasoning behind the restart procedures discussed at the September 2000 BCT meeting. Mr. Ballard recalled that the entire system would be shut down for one week with all 11 wells coming back on line at same time. Mr. Ballard asked that Mr. Smith check the September 2000 BCT meeting minutes to verify the procedures on which the BCT had agreed.

Dunn Field Remedial Investigation Work Plan Addendum II Field Work

Mr Offner presented draft analytical results of the diffusion bag samples collected from the new monitoring wells installed on and off Dunn Field to address the potential dense nonaqueous phase liquid (DNAPL) issue identified in MW70. CH2m Hill hung the bags in the monitoring wells around December 13, 2000, and removed them January 8, 2001. The BCT then discussed the findings.

Mr. Offner reported that the results showed levels of the trichloroethene and tetrachloroethene breakdown products indicating that natural attenuation was occurring. Mr. Offner also reported that fairly high 1,1,2,2 PCA concentrations on Dunn Field appear to be migrating off site in a fairly narrow area following a preferential pathway instead of spreading out in a plume. Mr. Offner presented additional data that indicated particular zones along the screen length of each sampled well tend to have higher concentrations than other zones in the same well(s) and this, as a result, may allow for future investigations to focus on the same zoned within the screened area of other wells. A point of focus for the Dunn Field Feasibility Study (FS) would be the remediation of the preferential pathway of contaminant migration.

Mr. Ballard reiterated the need for vapor flux calculations in Dunn Field baseline risk assessment and indicated that the Dunn Field Feasibility Study should include off site remediation. Mr. Offner suggested that diffusion bag sampling be incorporated into the groundwater O&M plan.

Mr Offner also recommend collecting diffusion bag samples from MW79, a recently installed downgradient well, as there was a data gap in that area, and that the data be incorporated into the Dunn Field Remedial Investigation (RI). Mr. Offner indicated this would cause a 60-day delay in the project schedule The BCT concurred that CH2M Hill would collect the additional data for use in the Dunn Field RI and would update the project schedule to include the 60-day delay.

Mr. Ballard suggested that CH2M Hill produce a cross section from MW73 to MW79 and to include the appropriate sampling data on the cross section. Mr. David Ladd suggested that CH2M Hill keep a watchful eye on MW40 due to the absence of a clay layer there Mr. Ladd continued that if sampling results indicated unacceptable levels at MW79, then a monitoring well or piezometer should be installed

between MW79 and MW40 to determine the edge of the "hole" (indicated by lack of clay at MW40) for monitoring purposes

Mr Offner continued that the sampling results indicated an area on site that the Dunn Field FS would evaluate for source remediation Sampling results also indicated an area of groundwater that had moved beyond the capture area of the extraction system that the Dunn Field FS would evaluate for off site groundwater remediation. Soil sampling results found no evidence of nonaqueous phased liquids in the soil column, but groundwater sampling results indicated potential for DNAPL to be present in MW73 that was) installed in the source area of Dunn Field According to Mr. Offner, the BCT had discussed this area and the possibility of incomplete capture between recovery wells (RW) 4 and RW5. Based on the sampling information, Mr. Offner indicated incomplete capture between these two recovery wells was quite possible.

Mr. Morrison asked if the screening approach proved to be valid for determining the need for sampling, and the BCT discussed the correlation of screening results to sampling results. Mr. Ballard requested that the Dunn Field RI include a discussion of the correlation between screening results and sampling results.

Dunn Field Feasibility Study Scope

Mr. Morrison asked if CH2M Hill had evaluated whether there was enough data to support unrestricted reuse of the eastern half of Dunn Field and, if not enough data, had identified what was necessary to support unrestricted reuse. Mr. Offner would coordinate with Dr. Mylavarapu and email a response to the BCT on January 23. Mr. Ballard indicated he should look at the eastern half of Dunn Field with the exception of the pistol range. Mr. De Back requested that Mr. Offner's response include the boundaries of areas identified for unrestricted reuse Mr. Offner indicated that the boundaries would be the boundaries of the exposure units. Mr. Ballard opined that the goal was to identify the smallest area that would require use restrictions.

Update of Conceptual Site Model for Dunn Field and Main Installation

Mr Morrison asked if CH2M Hill had coordinated with Mr. Ladd regarding the need for deeper wells off site at east end of Dunn Field. Mr. Offner indicated the request was for a shallow well to include in the O&M plan that would provide Waterways Experiment Station a boundary condition at the southeast corner of Dunn Field, nested with existing deep well MW36.

Mr. Offner and Mr. Ladd then discussed whether transducers were needed in the deeper wells to show flux/relationship between the extraction system, the confined/semi confined aquifer and Memphis Sand. USGS data for MW32 and MW34 did not indicate any relationship between the fluvial aquifer above the clay and the lower sands. The BCT discussed whether to concentrate on the effect of the extraction system within the fluvial aquifer or to collect transducer data from the lower sand to determine what effect the extraction system was having, if any. Mr. Ladd indicated there was no need for deeper well transducers to monitor impact of extraction, as there were similar transducer trends in the confined sand and Memphis Sand aquifers, but they were different from transducer trends in the fluvial aquifer.

O&M Plan for 3rd Year of System Operation

Mr. Offner distributed the draft O&M plan addendum and indicated that Jacobs/Sverdrup Civil would provide future addendums. Mr. Ballard requested, and Mr. Offner agreed to update the O&M plan and provide it to the BCT on CD-ROM. Mr. De Back asked if the Jacobs/Sverdrup contract included these latest sampling requirements. Mr. Rollyson indicated the Corps was working the issue and requested BCT approval of the draft O&M plan addendum to ensure contract modified correctly. The BCT agreed to try and provide response later in the day Mr. Ballard requested that contracts for O&M should include provision to quickly incorporate trend analysis recommendations. Mr. Rollyson indicated that future contract modification would not be a problem as Jacobs/Sverdrup was not responsible for the O&M plan.

Ms. Cooper reported that she had contacted Mr. Akil Al-Chokhachi of the city of Memphis treatment works and had forwarded the request to modify the discharge agreement data. She was awaiting a response from Mr Al-Chokhachi.

Mr. Morrison asked if the draft O&M plan addendum included "contamination mass removed" calculation. Mr. Offner responded that the monthly operations report required in the O&M plan included contamination mass removed from the total system effluent for the month as well as a total, and Mr. Ballard requested that the total include results from the beginning of extraction system operations.

CWM Update

Mr. Frank Johnson reported that UXB had completed work at Sites 1 and 24A and had started work at Site 24B. He continued that during the preliminary sampling to better define the removal area at Site 24B the first geo probe detected decontaminating agent. Excavation had removed 9 cubic yards (cy) of dirt containing low concentrations of mustard that was being shipped to Nebraska for disposal (incineration) Approximately 240 cy of soil containing the degradation products thioxane and dithiane was to be shipped to Millington for treatment (fixation/solidification).

Mr. Johnson continued that they were very confident that they had found the neutralization pit. Currently, UXB was removing the overburden, which was uncontaminated, to prevent cross contamination and to provide a slope down to the excavation area for big machinery. Edgewood Chemical Biological Center tested the soil before removing it from the vapor containment structure (VCS). UXB placed soil containing mustard in 1 cy fiber boxes lined with 6 mil plastic, and the plastic is sealed shut with tape, so the box and soil would be incinerated together, no double handling to remove dirt from container prior to incineration. Two VCSs had been constructed, one over the work area and one to stage the fiber boxes and soil awaiting disposal.

The BCT asked about sampling results, and Mr. Johnson responded that TCLP analysis was performed on overburden soil samples to determine if it must be disposed of or, if clean, could be returned to the excavation. The disposal facility would perform TCLP analysis on soil known to contain mustard or by products. The after action report would contain sampling results. Per Mr. Shawn Phillips' instructions, soil containing foreign material/debris such as broken china was not returned to the excavation. Mr. Johnson indicated that he had requested, and received, approval from the city of Memphis treatment works to dispose of investigation derived waste water containing phosphates/soaps that was used to decontaminate workers' protective clothing (not involved in a ring off).

Mr Johnson asked for permission to move the mounds of soil that were waiting for TCLP analysis results from the current location to one of the stockpile pads. He indicated the soil was placed on visquene and then covered with visquene, so there was no rain leaching through. UXB maintained the covers and daily activities included an inspection of the covers. Mr. Johnson reported that overburden dirt that could not be returned to the excavation based on the TCLP results would be removed no more than 5 days after receipt of TCLP results. The BCT agreed. Mr. De Back requested that UXB use one of the centrally located stockpile pads and reminded Mr. Johnson of the dust control requirements that must be maintained during dry months if trucks must leave the road to load out Mr. Johnson indicated that the project completion date depended on the full extent of the neutralization pit, but was tentatively set for May 7.

The BCT approved of UXB's IDW storage: fiber boxes with soil containing mustard stored in VCS #2; soil containing byproducts on visquene with a visquene cover on a stockpile pad; overburden awaiting TCLP on visquene with a visquene cover on a stockpile pad. Mr. Ballard and Mr. Morrison agreed to visually inspect current storage after the meeting.

Mr. Offner reported that CH2M Hill had collected samples for TCL/TAL analysis and that results had not indicated a source area, so no excavation had been required to remain open in order to manage hazardous waste issues.

Main Installation Record of Decision

Mr. Offner reported that CH2M Hill had distributed Revision 1 ROD to the Defense Logistics Agency and the BCT for review and comment by January 31. The BCT discussed how the ROD should address the LUCAP and would focus their ROD review on the current LUCAP language and provide comment by January 31. Mr. Offner also asked Mr. Morrison to focus his review on the required resource damage statement as well as its placement within the ROD

Mr. Ballard initiated a discussion of the fence between in the golf course and the residential areas on and off the facility that was included in the selected remedy for the Main Installation. Mr. Ballard indicated that there was no need for a fence separating the golf course from the industrial area. Mr. De Back indicated the land use control applied only to the golf course. The land use control would provide for limited access to the golf course, so the fence should be specific to the golf course and not to the entire facility perimeter fence. Mr. Offner reported that the ROD included a fence around the golf course, only.

Mr. Ballard then asked about the fishing/swimming restriction in the selected remedy since it was not necessary from a risk based perspective. The BCT agreed that the ROD contain only those restrictions that were required for risk management and discussed how to delete the fishing/swimming restriction from the ROD. Mr Ballard indicated that Revision 2 ROD contain an Explanation of Significant Differences section Mr. Ballard agreed to work with Mr. Offner on the necessary language.

Documents in Electronic Format

The BCT agreed that all contractors should provide all documents from Revision O through Revision 2 (final) on CD-ROM in Adobe pdf format and that each CD-ROM should include Adobe Reader software. The BCT also agreed that contractors should provide hard copies for Revision 1 and Revision 2 (final) documents to be placed in the information repositories. Mr. Offner reiterated Mr. Ballard's earlier request that the cover letter be included on the CD-ROM cover. The BCT agreed that the current cover template be used for all future submittals. Mr. Offner will provide the cover template to Jacobs/Sverdrup and UXB.

Mr. De Back indicated the Depot would determine the number of CD-ROM and hard copies that were required and provide the information to Ms. Richards and Ms. DuBray

SIGNED	2/23/01
JOHN DE BACK	DATE
Memphis Depot Caretaker Division	
Interim BRAC Environmental Coordinator	
SIGNED	2/15/01
TURPIN BALLARD	DATE
Environmental Protection Agency	
Federal Facilities Branch	
Remedial Project Manager	
SIGNED	2/27/01
JAMES W. MORRISON	DATE
Tennessee Department of Environment and Conservation	
Division of Superfund	
BRAC Cleanup Team member	

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TAB

Appendix R

Appendix B Field Standard Operating Procedures

1

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).

Collecting Soil Samples

- 1. Place latex gloves on hands for protection and to prevent 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, core barrel) 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 sampler 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.

TECHNICAL MEMORANDUM

CH2MHILL

Standard Operating Procedure for Soil Headspace Field Screening Using an OVA/FID at the Memphis Depot

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	September 28, 2000

This memorandum describes the use of the Organic Volatile Analyzer (OVA)/Flame Ionization Detector (FID) headspace method for performing field soil screening at the Memphis Depot in association with the use of continuous soil samplers with soil core liners.

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 soil sampler and extract the two 2.5-foot clear soil core 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 <u>remembering to only remove the end caps briefly to prevent</u> <u>volatilization</u>. Document if any changes in soil lithology exist (i.e., sand to clay, gravelly sand to sandy clay, etc).
- 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 in the soil core, then proceed to #6.

- 6. Mark the outside of the soil core liner with a permanent pen where 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 (for example, the area of concern is the higher permeability soil immediately above the lower permeability layer).
- 9. <u>Immediately</u> place a cap on the cut end of soil core liner section protecting the area of concern above the area of soil change (this section of the soil core 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. <u>Quickly</u> fill 2 quart sized sealable plastic bags at least 1/2 full with soil using a stainless steel sampling spoon.
- 12. <u>Immediately</u> seal the bags.
- 13. ***For soil core liners that contain soil lithology changes*** Label the soil core liner that contains the soil from 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 <u>unfiltered concentration</u>. If the unfiltered measurement is non-detect, do not proceed to line #19. 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 <u>filtered concentration</u>.
- 22. Subtract the filtered reading from the unfiltered reading for the <u>total corrected</u> <u>hydrocarbon measurement</u>.

TAB

Appendix C

Appendix C Field SOP Guidance Documents



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

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

Water-Resources Investigations Report 01-4060

Prepared in cooperation with the

U.S. AIR FORCE U.S. NAVAL FACILITIES ENGINEERING COMMAND U.S. ENVIRONMENTAL PROTECTION AGENCY FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE DEFENSE LOGISTICS AGENCY U.S. ARMY CORPS OF ENGINEERS and INTERSTATE TECHNOLOGY REGULATORY COOPERATION WORK GROUP

U.S. Department of the Interior U.S. Geological Survey

Acknowledgments

Technical Advisory Board



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Defense Logistics Agency (DLA) Lt. Col. Daniel L. Welch

U.S. Environmental Protection Agency (EPA) Steve Schmelling, Office of Research and Development (ORD) Dick Willey, EPA Region 1 Kathy Davies, EPA Region 3 Richard Steimle, Technology Innovation Office (TIO)





U.S. Naval Facilities Engineering Command (NAVFAC) U.S. Naval Facilities Engineering Service Center (NFESC) Cliff C. Casey (Southern Division) Dennis Howe (NFESC) Richard G. Mach, Jr. (Southwest Division) Nick Ta (NFESC)





of Engineers.

U.S. Army Corp of Engineers (USACE) Johnette Shockley

Federal Remediation Technologies Roundtable





Interstate Technology Regulatory Cooperation Work Group (ITRC) George H. Nicholas (New Jersey) Team Lead Paul M. Bergstrand (South Carolina) Chris A Guerre (California) David Randolph (Tennessee)

Funding for this Guide was provided by the U.S. AIR FORCE and NAVFAC (Southern and Southwest Divisions). Additionally, the following persons are recognized for their leadership and support to this project: Marty Faile, Joe Dunkle, Kay Wishkaemper, Vince Malott, and the Passive Diffusion Bag Sampler (PDBS) Work Group.
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

Prepared in cooperation with the U S AIR FORCE U.S. NAVAL FACILITIES ENGINEERING COMMAND U S ENVIRONMENTAL PROTECTION AGENCY FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE DEFENSE LOGISTICS AGENCY U.S. ARMY CORPS OF ENGINEERS and INTERSTATE TECHNOLOGY REGULATORY COOPERATION WORK GROUP



Columbia, South Carolina 2001

U.S. DEPARTMENT OF THE INTERIOR GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY Charles G. Groat, Director

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and

U.S Geological Survey Branch of Information Services Box 25286 Denver, CO 80225 Phone: 888-ASK-USGS For additional information, write to:

District Chief U.S. Geological Survey Stephenson Center-Suite 129 720 Gracern Road Columbia, SC 29210-7651

Additional information about water resources in South Carolina is available on the World Wide Web at http://sc.water.usgs.gov

Report can be downloaded from http://www.itrcweb.org and http://www.frtr.gov

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1.	Photo showing typical water-filled passive diffusion bag samplers used in wells, including diffusion
	bag with polyethylene mesh, diffusion bag without mesh, and bag and mesh attached to bailer bottom
2.	Photo showing example of multiple passive diffusion bag samplers prepared for deployment

Table

1.	Compounds tested under laboratory conditions for use with passive diffusion bag samplers
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Multiply	By	To obtain
	Length	
inch (in)	25 4	millimeter
foot (ft)	0 3048	meter
mile (mi)	1 609	kılometer
	Area	
square mile (mi ²)	2 590	square kilometer
	Flow	·
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft ² /d)	0 09294	meter squared per day
gallon per minute (gal/min)	0.06308	liter per second
gallon per day (gal/d)	0 003785	cubic meter per day
inch per year (in/yr)	25 4	millimeter per year
	Volume	
gallon (gal)	3 785	liter

Conversion Factors, Vertical Datum, Acronyms, and Abbreviations

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Temperature is given in degrees Celsius (°C), which can converted to degrees Fahrenheit (°F) by the following equation °F = 9/5 (°C) + 32

Sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)-a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929

Chemical concentration in water is expressed in metric units as milligrams per liter (mg/L) or micrograms per liter (µg/L)

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Additional Abbreviations ----····· CDD / 1.2-Dibromomethane

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EDB (
AFCEE	Air Force Center for Environmental Excellence		
cDCE	c1s-1,2-Dibromoethene		
ft ³ /d	cubic feet per day		
ft ³ /mg	cubic feet per milligram		
°Ċ	degrees Celsius		
g,	gram		
ITRC	Interstate Technology Regulatory Cooperation		
LDPE '	low-density polyethylene		
L	liter		
μg	microgram		
μm	micrometer		
μL	microliter		
mg	milligram		
mL	milliliter		
mL/min	milliliter per minute		
MTBE	Methyl-tert-butyl ether		
NAVFAC	Naval Facilities Engineering Command		
NAPL	non-aqueous phase liquid		
PDB	passive diffusion bag		
PCE ,	Tetrachloroethene		
TCE	Trichloroethene		
USEPA	US Environmental Protection Agency		
USGS	U S Geological Survey		
VOA	Volatile organic analysis		
VOC	Volatile organic compound		

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 wellcharacterized 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 intrabore-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.

Following the initial equilibration period, the samplers maintain equilibrium concentrations with the ambient water until recovery. Thus, there is no specified time for sampler recovery after initial equilibration. PDB samplers routinely have been left in ground waters having concentrations of greater than 500 parts per million (ppm) of trichloroethene for 3 months at a time with no loss of bag integrity, and at one site, the PDB samplers have been 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, however. Moreover, 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 comparison to a conventional sampling method before continuing to use PDB samplers for long-term deployment in that well.

Recovery consists of removing the samplers from the well and immediately transferring the enclosed water to 40-milliliter sampling vials for analysis. The resulting concentrations represent an integration of chemical changes over the most recent portion of the equilibration period (approximately 48 to 166 hours, depending on the water temperature and the type of compound).

The method has both advantages and limitations when compared to other sampling methods. Advantages include the potential for PDB samplers to eliminate or substantially reduce the amount of purge water associated with sampling. The samplers are relatively inexpensive and easy to deploy and recover. Because PDB samplers are disposable, there is no downhole equipment to be decontaminated between wells, and there is a minimum amount of field equipment required. The samplers also have the potential to delineate contaminant stratification in the formation across the open or screened intervals of monitoring wells where vertical hydraulic gradients are not present. In addition, the samplers integrate concentrations over time, which may range between about 48 to 166 hours depending on the compound of interest. 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 on the VOC sample from the PDB material.

Water-filled polyethylene PDB samplers are not appropriate for all compounds. The samplers 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. A variety of factors influence the ability of compounds to diffuse through the polyethylene These factors include the molecular size and shape and the hydrophobic nature of the compound. Unpublished laboratory test data of semivolatile 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.

VOC concentrations in PDB samplers represent concentrations in the vicinity of the sampler within the well screen or open interval This may be a limitation for PDB samplers and some other types of sampling, such as low-flow sampling, if the ground-water contamination is above or below the screen or not in the sample intervals providing water movement to the PDB samplers. If there is a vertical hydraulic gradient in the well, then the concentrations in the sampler may represent the concentrations in the water flowing vertically past the sampler rather than in the formation directly adjacent to the sampler. Vertically spaced multiple PDB samplers may be needed in chemically stratified wells or where flow patterns through the screen change as a result of ground-water pumping or seasonal water-level fluctuations.

The purposes of this document are to present methods for PDB sampler deployment, and recovery; to discuss approaches to determine 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 passive diffusion 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.

INTRODUCTION

The use of PDB samplers for collecting groundwater samples from wells offers a cost-effective approach to long-term monitoring of VOCs at wellcharacterized 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 intraborehole 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) and Eon Products (800-474-2490). 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.





Table 1. Compounds tested under laboratory conditions for use with passive diffusion bag samplers [From Vroblesky and Campbell, 2001]

Benzene	2 Chlorovinyl ether	cis-1,2-Dichloroethene	1.1.1-Trichloroethane
Bromodichloromethane	Dibromochloromethane	trans-1,2-Dichloroethene	1.1.2-Trichloroethane
Bromoform	Dibromomethane	1,2-Dichloropropane	Trichloroethene
Chlorobenzene	1,2-Dichlorobenzene	cis-Dichloropropene	Trichlorofluoromethane
Carbon tetrachloride	1,3-Dichlorobenzene	1,2-Dibromoethane	1.2.3-Trichloropropane
Chloroethane	1,4-Dichlorobenzene	trans-1,3-Dichloropropene	1,1,2,2-Tetrachloroethane
Chloroform	Dichlorodifluoromethane	Ethyl benzene	Tetrachloroethene
Chloromethane	1,2-Dichloroethane	Naphthalene	Vinvl chloride
	1,1-Dichloroethene	Toluene	Total xylenes

between diffusion-sampler water and test-vessel water) in laboratory tests

Styrene

Acetone*	Methyl-tert-butyl ethe
110010110	weutys-tert-butys eth

*T M Sivavec and S S Baghel, General Electric Company, written commun , 2000

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

4

Summary of Passive Diffusion Bag Sampler Advantages and Limitations

Advantages

I. 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 semivolatile 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 formation water because of inadequate exchange across the well screen. PDB samplers have not yet been adequately tested to determine their response under such conditions.

4. VOC concentrations in PDB samplers represent ground-water concentrations in the vicinity of the screened or open well interval that move to the sampler under ambient flow conditions. This is a limitation if the ground-water contamination lies above or below the well screen or open interval, and requires the operation of a pump to conduct contaminants into the well for sampling.

5. In cases where the well screen or open interval transects zones of differing hydraulic head and variable contaminant concentrations, VOC concentrations obtained using a PDB sampler may not reflect the concentrations in the aquifer directly adjacent to the sampler because of vertical transport in the well. However, a vertical array of PDB samplers, used in conjunction with borehole flow meter testing, can provide insight on the movement of contaminants into or out of the well. This information then can be used to help determine if the use of PDB samplers is appropriate for the well, and to select the optimal vertical location(s) for the sampler deployment.

6. In wells with screens or open intervals with stratified chemical concentrations, the use of a single PDB sampler set at an arbitrary (by convention) depth may not provide accurate concentration values for the most contaminated zone. However, multiple PDB samplers distributed vertically along the screened or open interval, in conjunction with pump sampling (as appropriate), can be used to locate zone(s) of highest concentration in the well. Multiple PDB samplers also may be needed to track the zone of maximum concentration in wells where flow patterns through the screened interval change as a result of ground-water pumping or seasonal water-table fluctuations

PASSIVE DIFFUSION BAG SAMPLER DEPLOYMENT

A variety of approaches can be used to deploy the PDB samplers in wells. A typical deployment approach, described in this section, is to attach the PDB samplers to a weighted line. It also is acceptable to attach the weights directly to the PDB sampler if the attachment point is of sufficient strength to support the weight The weights attached to the bottom of the

line are stainless steel and can be reused, but must be thoroughly decontaminated with a detergent before the first use or before using in a different well. Rope, such as 90 pound, 3/16 inch braided polyester, can be used as the line for single-use applications if it is of sufficient strength to support the weight and sampler, is nonbuoyant, and is subject to minimal stretch, however, the rope should not be reused because of the high potential for cross contamination. Stainless-steel or Teflon-coated stainless-steel wire is preferable. The weighted lines should not be reused in different wells to prevent carryover of contaminants. A possible exception is coated stainless-steel wire, which can be reused after sufficient decontamination. An alternative deployment approach, not discussed in this section, is to attach the PDB samplers to a fixed pipe in the well (Vroblesky and Peters, 2000, p. 3; also included in Part 2 of this publication). The PDB samplers should not contact non-aqueous phase liquid (NAPL) during deployment or retrieval to prevent cross contamination. An approach that can be utilized to deploy diffusion samplers through a layer of floating NAPL is described in the field test at Naval Station North Island, California (Vroblesky and Peters, 2000, p. 3-4, also included in Part 2 of this publication).

If the PDB sampler is to be compared with a conventional pumping approach to sampling, then it is suggested that both the pump and the PDB sampler be deployed at the same time, with the sampler attached near (such as directly below) the pump inlet This approach eliminates potential concentration differences between the two methods that may result from well disturbance during equipment removal and deployment at the time of sampling. An alternative method is to deploy the PDB samplers independently of the pumps and recover the samplers immediately prior to placing the pump down the well.

PDB samplers are available either prefilled with laboratory-grade deionized water or unfilled. The unfilled samplers are equipped with a plug and funnel to allow for field filling and sample recovery. To fill these samplers, remove the plug from the sampler bottom, insert the short funnel into the sampler, and pour laboratory-grade deionized water into the sampler. The sampler should be filled until water rises and stands at least half way into the funnel. Remove excess bubbles from the sampler. Remove the funnel and reattach the plug. A small air bubble from the plug is of no concern. 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.



Figure 2. Example of multiple PDB samplers prepared for deployment.

(c) PDB samplers should not be used in wells having screened or open intervals longer than 10 ft unless used in conjunction with borehole flow meters or other techniques to characterize vertical variability in hydraulic conductivity and contaminant distribution or used strictly for qualitative reconnaissance purposes. This is because of the increased potential for cross contamination of water-bearing zones and hydraulically driven mixing effects that may cause the contaminant stratification in the well to differ from the contaminant stratification in the adjacent aquifer material. If it is necessary to sample such wells, then multiple PDB samplers should be installed vertically across the screened or open interval to determine the zone of highest concentration and whether contaminant stratification is present.

4. The samplers should be attached to the weights or weighted line at the time of deployment. For samplers utilizing the hanger and weight assembly,

the line can be attached directly to the top of the sampler. PDB samplers utilizing an outer protective mesh can be attached to a weighted line by using the following procedure:

(a) Insert cable ties through the attachment points in the weighted line.

(b) At each end of the PDB sampler, weave the ends of the cable ties or clamp through the LPDE mesh surrounding the sampler and tighten the cable ties. Thus, each end of the PDB sampler will be attached to a knot/loop in the weighted line by means of a cable tie or clamp The cable ties or clamps should be positioned through the polyethylene mesh in a way that prevents the PDB sampler from sliding out of the mesh.

(c) Trim the excess from the cable tie before placing the sampler down the well. Caution should be exercised to prevent sharp edges on the trimmed cable ties that may puncture the LDPE. 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 (cDCE), 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, cDCE, 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 1,1dichloroethane 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 porewater 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 underestimate pore-water concentrations. Guidelines for equilibration times and applicability of PDB samplers in low-permeability formations have not yet been established. Therefore, in such situations, a side-byside comparison of PDB samplers and conventional sampling methodology is advisable to ensure that the PDB samplers do not underestimate concentrations obtained by the conventional method A detailed discussion of diffusion rates relevant to diffusion sampler equilibrium in slow-moving ground-water systems can be found in Harrington and others (2000).

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. 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 have been left in place in VOC-contaminated ground water for 1 year with no reported loss of sampler integrity (Paul Hare, General Electric Company, oral commun., 2000). 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. Moreover, 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 may be reduced, but not stopped, across a heavily biofouled polyethylene membrane (Ellis and others, 1995; Huckins and others, 1996; Huckins and others, in press). If a heavy organic coating is observed on a PDB sampler, it is advisable to determine the integrity of the sample by comparing contaminant concentrations from the PDB sampler to concentrations from a conventional sampling method before continuing to use PDB samplers for long-term deployment in that well.

Recovery of PDB samplers is accomplished by using the following approach:

1. Remove the PDB samplers from the well by using the attached line. The PDB samplers should not be exposed to heat or agitated.

2. Examine the surface of the PDB sampler for evidence of algae, iron or other coatings, and for tears in the membrane. Note the observations in a sampling field book If there are tears in the membrane, the sample should be rejected. If there is evidence that the PDB sampler exhibits a coating, then this should be noted the validated concentration data.

3. Detach and remove the PDB sampler from the weighted line. Remove the excess liquid from the exterior of the bag to minimize the potential for cross contamination

4. A variety of approaches may be used to transfer the water from the PDB samplers to 40-mL volatile organic analysis (VOA) vials. One type of commercially available PDB sampler provides a discharge device that can be inserted into the sampler. If discharge devices are used, the diameter of the opening should be kept to less than about 0.15 inches to reduce volatilization loss. Two options are presently available to recover water from the sample using discharge devices. One option involves removing the hanger and weight assembly from the sampler, inverting the sampler so that the fill plug is pointed upward, and removing the plug. The water can be recovered by directly pouring in a manner that minimizes agitation or by pouring through a VOC-discharge accessory inserted in place of the plug. The second approach involves piercing the sampler near the bottom with a small-diameter discharge tube and allowing water to flow through the tube into the VOA vials In each case, flow rates can be controlled by tilting or manipulating the sampler. Alternatively, the PDB sampler can be cut open at one end using scissors or other cutting devices which have been decontaminated between use for different wells. Water can then be transferred to 40-ml VOA vials by gently pouring in a manner that minimizes water agitation. Acceptable duplication has been obtained using each method. Preserve the samples according to the analytical method. The sampling vials should be stored at approximately 4 °C in accordance with standard sampling protocol. Laboratory testing suggests that there is no substantial change in the VOC concentrations in PDB samplers over the first several minutes after recovery; however, the water should be transferred from the water-filled samplers to the sample bottles immediately upon recovery.

5. A cost-effective alternative when using multiple PDB samplers in a single well is to field screen water from each sampler using gas chromatography. These results can be used to decide which of the multiple PDB samplers should be sent to an EPA-approved laboratory for standard analysis. Typically, at least the sample containing the highest concentration should be analyzed by a laboratory. 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 intraborehole 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).

The decision on whether to use PDB samplers in such situations depends on the data-quality objectives for the particular site. If the goal is to determine and monitor higher concentrations or to examine contaminant stratification within the screened interval, then the PDB samplers may meet this objective. If the goal is to determine the average concentrations for the entire screened interval, then a pumped sample or an average from multiple diffusion samplers may be appropriate

As an aid in the decision-making process, the following section examines the influences that hydraulic and chemical heterogeneity of an aquifer can have on sample quality in long-screened wells Because VOC concentrations from PDB samplers commonly are compared to VOC concentrations from other sampling methodologies, the second section examines the differences in sample quality between these methodologies in situations of hydraulic and chemical heterogeneity

Influences of Hydraulic and Chemical Heterogeneity on Sample Quality in Long-Screened Wells

Sampling biases and chemical variability in long-screened wells, which can be loosely defined as wells having significant physical and chemical heterogeneity within the screened interval and in the adjacent aquifer (Reilly and Leblanc, 1998), have been the subject of numerous investigations. Sources of chemical variability in such wells include non-uniform flow into wells (Robbins and Martin-Hayden, 1991; Reilly and Gibs, 1993; Chiang and others, 1995; Church and Granato, 1996; Reilly and LeBlanc, 1998), lithologic heterogeneity (Reilly and others, 1989; Robbins, 1989; Martin-Hayden and others, 1991; Gibs and others, 1993; Reilly and Gibs, 1993), and in-well mixing. In a well open across a chemically or hydraulically heterogeneous section of the aquifer, differences in the sampling methodology can produce significant differences in the sampling results

Long-screened wells have the potential to redistribute chemical constituents in the aquifer where there are vertical hydraulic gradients within the screened interval. Water can move into the well from one horizon and exit the well at a different horizon (Church and Granato, 1996; Reilly and LeBlanc 1998). If there is vertical flow in the screened or open interval, and the zone of low hydraulic head (outflow from

the well) is within the contaminated horizon, then the PDB samplers (or any standard sampling methodology) can underestimate or not detect the contamination. The reason is that, in this case, the contaminated horizon does not contribute water to the well under static conditions. Instead, water from other horizons with higher hydraulic head will invade the contaminated horizon by way of the well screen. Under pumped conditions, the majority of the extracted water will be from the most permeable interval, which may not be the contaminated zone. Even when pumping induces inflow from the contaminated interval, much of that inflow will be a reflection of the residual invaded water from other horizons. In this situation, a substantial amount of purging would be required before water representative of the aquifer could be obtained (Jones and Lerner, 1995). Such sampling is not likely to reflect a significant contribution from the contaminated zone, and concentrations in the contaminated zone probably will be underestimated.

Similarly, if VOC-contaminated water is flowing into the well and is exiting the well at a different horizon, then VOCs will be present along the screened interval between the two horizons. In this case, VOC concentrations in the screened interval may be representative of aquifer concentrations at the inflow horizon, but may not be representative of aquifer concentrations near the outflow horizon.

In areas where vertical stratification of VOC concentrations are anticipated, using multiple PDB samplers may more fully characterize the contaminated horizon than using a single PDB sampler. This is particularly true in wells having screens 10 ft or longer; however, significant VOC stratification has been observed over intervals of less than 5 ft (Vroblesky and Peters, 2000). Because of the increased probability of vertical concentration or hydraulic gradients within the open interval of long-screened (greater than 10 ft) wells, it is advisable to determine the zones of inflow and outflow within the screened or open interval of these wells using borehole flowmeter analysis (Hess, 1982, 1984; 1986; 1990; Young and others, 1998).

Comparison of Passive Diffusion Bag Sampling Methodology to Conventional Methodologies

Traditional sampling methodologies, such as the purge-and-sample (or conventional purging method), low-flow or low-volume sampling, and using straddle packers and multilevel samplers, produce VOC 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 vertical flow in the gravel pack outside the well screen. Such vertical flow can result from small vertical differences in head with depth. A field test conducted by Church and Granato (1996) found that vertical head differences ranging from undetectable to 0.49 ft were sufficient to cause substantial flows (as much as 0.5 liters/minute) in the well bore.

QUALITY CONTROL AND ASSURANCE

The sources of variability and bias introduced during sample collection can affect the interpretation of the results. To reduce data variability caused during sampling, a series of quality-control samples should be utilized.

Replicate samples are important for the quality control of diffusion-sampler data. Sample replicates provide information needed to estimate the precision of concentration values determined from the combined sample-processing and analytical method and to evaluate the consistency of quantifying target VOCs. A replicate sample for water-filled diffusion samplers consists of two separate sets of VOC vials filled from the same diffusion sampler. Each set of VOC vials should be analyzed for comparison. Approximately 10 percent of the samplers should be replicated.

The length of the PDB sampler can be adjusted to accommodate the data-quality objectives for the sampling event The length can be increased if additional volume is required for collection of replicate and matrix spike/matrix spike duplicate samples.

Trip blanks are used to determine whether external VOCs are contaminating the sample due to bottle handling and/or analytical processes not associated with field processing. Trip blanks are water-filled VOA vials prepared offsite, stored and transported with the other bottles used for collecting the environmental sample, and then submitted for analysis with the environmental sample. Consideration also should be given to the collection of a predeployment PDB trip blank to determine if the PDB samplers are exposed to extraneous VOCs prior to deployment. The predeployment trip blank should be a PDB sampler that is stored and transported with the field PDB samplers from the time of sampler construction to the time of deployment in the wells. An aliquot of the predeployment blank water should be collected from the PDB sampler in a VOA vial and submitted for analysis at the time of sampler deployment.

Water used to construct the diffusion samplers should be analyzed to determine the presence of background VOCs. Although many VOCs accidentally introduced into the diffusion-sampler water probably will reequilibrate with surrounding water once the diffusion samplers are deployed, some VOCs may become trapped within the diffusion-sampler water. For example, acetone, which is a common laboratory contaminant, does not easily move through the polyethylene diffusion samplers (Paul Hare, General Electric Company, oral commun., 1999). Thus, acetone inadvertently introduced into the diffusion-sample water during sampler construction may persist in the samplers, resulting in a false positive for acetone after sampler recovery and analysis.

Consideration should be given to the collection of a PDB trip blank to determine if the PDB samplers are exposed to extraneous VOCs prior to deployment. A trip blank is collected from a PDB sampler that is stored and transported with the field PDB samplers between the time of sampler construction and deployment in the well. The water for the trip blank is collected from the PDB sampler in VOA vials at the time of sampler deployment.

SUMMARY

Water-filled passive diffusion bag (PDB) samplers described in this report are suitable for obtaining a variety of VOCs in ground water at monitoring wells. The suggested application for PDB samplers is for long-term monitoring of VOCs in ground-water wells at well-characterized sites. Where the screened interval is greater than 10 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 suggested 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 intraborehole flow be determined in wells having screens longer than 10 ft. A typical PDB sampler consists of a 1- to 2-ft-long low-density polyethylene lay-flat tube closed at both ends and containing deionized water. The sampler is positioned at the target horizon by attachment to a weighted line or fixed pipe.

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 water within the PDB sampler equilibrates with ambient water depends on multiple factors, including the type of compound being sampled and the water temperature. Concentrations of benzene, cis-1,2-dichloroethene, tetrachlorethene, trichloroethene, toluene, naphthalene, 1,2dibromoethane, 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 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) PDBsampler 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 PDBsampler 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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EPA Ground Water Issue

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

by Robert W. Puls¹ and Michael J. Barcelona²

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.

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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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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 nos. 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 metalioids) 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 siteassessments 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:

- 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;
- Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques, and
- 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 charactenzation 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. Lowflow 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 oxidationreduction 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 cnteria 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). Highguality 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 groundwater 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 lowflow (minimal drawdown) purging and sampling and include penstaltic 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 illsuited 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 CO₂ 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 nondisposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 μ m). 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 quide 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 \pm 0.1 for pH, \pm 3% for conductivity, \pm 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., Fe2+, CH,, H,S/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 TeflonTM (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, sitespecific 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 lowflow 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 Tvr	 xe
Sampling Device	Tubing type _		Water Level	
Measuring Point		or		

Sampling Personnel____

Time	рН	Temp	Cond.	Dis.O ₂	Turb.	[]Conc		Notes
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Type of Samples Collected

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

627 106

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

Project	Site W	ell No	Date	
Well Depth	Screen Length	Well Diameter	Casing Type	
Sampling Device	Tubing type		Water Level	
Measuring Point	Other Infor			<u> </u>
Sampling Personnel				<u> </u>

Time	Pump Rate	Turbidity	Alkalinity	[] Conc	Notes
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Type of Samples Collected

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: Vol_{oyi} = $\pi r^2 h$, Vol_{sphere} = 4/3 π r³

