

3/1/02-04015

**FINAL**

**BACKGROUND GROUNDWATER STUDY  
WORKPLAN**

**MARINE CORPS BASE  
MCB CAMP LEJEUNE, NORTH CAROLINA**

**CONTRACT TASK ORDER 0143**

**MARCH 2002**

*Prepared for:*

**DEPARTMENT OF THE NAVY  
ATLANTIC DIVISION  
NAVAL FACILITIES  
ENGINEERING COMMAND  
*Norfolk, Virginia***

*Under the:*

**LANTDIV CLEAN Program  
Contract N62470-89-D-4814**

*Prepared by:*

**BAKER ENVIRONMENTAL, INC.  
*Coraopolis, Pennsylvania***

# QC Review Page

---

Base Background Groundwater Study Work Plan

MCB Camp Lejeune

Jacksonville, North Carolina

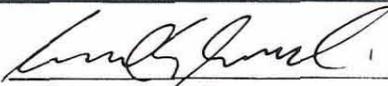
Contract Task Order Number - 0143  
Contract Number N62470-95-D-6007  
Navy CLEAN II Program

*Prepared by*

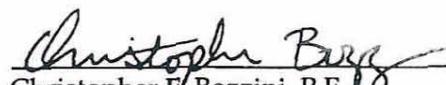
**Baker Environmental**

March 2002

---

Approved by:   
Rich Bonelli, P.G.  
Activity Manager, Baker Environmental

Date: 3/14/02

Approved by:   
Christopher F. Bozzini, P.E.  
Project Manager, CH2M HILL

Date: 3/14/02

---

## TABLE OF CONTENTS

	<u>Page</u>
<b>ACRONYMS AND ABBREVIATIONS</b> .....	<b>iv</b>
<b>1.0 INTRODUCTION</b> .....	<b>1-1</b>
1.1 Project Objective.....	1-1
<b>2.0 BACKGROUND INFORMATION</b> .....	<b>2-1</b>
2.1 Location.....	2-1
2.2 Topography.....	2-1
2.3 Geology.....	2-1
<b>3.0 DATA QUALITY AND SAMPLING OBJECTIVES</b> .....	<b>3-1</b>
3.1 Data Quality Objectives Process.....	3-1
3.1.1 Step 1 – State the Problem.....	3-2
3.1.2 Step 2 – Identify the Decision.....	3-2
3.1.3 Step 3 – Identify the Inputs to the Decision.....	3-2
3.1.4 Step 4 – Define the Boundaries of the Study.....	3-3
3.1.5 Step 5 – Develop a Decision Rule.....	3-3
3.1.6 Step 6 – Specify Tolerable Limits on Decision Errors.....	3-3
3.1.7 Step 7 – Optimize the Design for Obtaining Data.....	3-3
<b>4.0 SAMPLING LOCATIONS AND FREQUENCY</b> .....	<b>4-1</b>
4.1 Temporary Monitoring Well Locations and Construction.....	4-1
4.2 Sampling and Analytical Requirements.....	4-1
4.3 Quality Assurance/Quality Control Samples.....	4-1
<b>5.0 SAMPLE DESIGNATION</b> .....	<b>5-1</b>
<b>6.0 INVESTIGATIVE PROCEDURES</b> .....	<b>6-1</b>
6.1 Temporary Monitoring Well Construction.....	6-1
6.2 Groundwater Sample Collection.....	6-2
6.2.1 Selection of Water Quality Indicator Parameters.....	6-2
6.2.2 Purging and Sampling Procedure.....	6-2
6.3 Monitoring and Data Collection Equipment.....	6-4
6.4 Decontamination.....	6-4
6.5 Temporary Monitoring Well Abandonment.....	6-4
6.6 Investigation Derived Waste Handling.....	6-4
6.6.1 Responsibilities.....	6-5
6.6.2 Sources of Investigation Derived Wastes.....	6-5
6.6.3 Investigation Derived Waste Sampling and Analyses.....	6-6
6.6.4 Labeling.....	6-6
6.6.5 Container Log.....	6-7
6.6.6 Container Storage.....	6-7
6.6.7 Container Disposition.....	6-7
6.6.8 Disposal of Contaminated Materials.....	6-7
<b>7.0 SAMPLE HANDLING, ANALYSES, AND VALIDATION</b> .....	<b>7-1</b>
7.1 Sample Preservation and Handling.....	7-1
7.2 Chain-of-Custody.....	7-1
7.3 Field Logbook.....	7-1
7.4 Sample Analyses and Validation.....	7-1

**TABLE OF CONTENTS**  
*(Continued)*

	<u>Page</u>
<b>8.0 DATA EVALUATION AND REPORT PREPARATION .....</b>	<b>8-1</b>
<b>9.0 PROJECT MANAGEMENT AND STAFFING .....</b>	<b>9-1</b>
9.1 Field Team Responsibilities .....	9-1
9.2 Reporting Requirements.....	9-1
<b>10.0 SCHEDULE .....</b>	<b>10-1</b>
<b>11.0 REFERENCES.....</b>	<b>11-1</b>

**LIST OF FIGURES**

Figure 2-1	General Location Map
Figure 4-1	Proposed Sample Location Map
Figure 6-1	Nested Monitoring Well Construction Diagram
Figure 9-1	Project Team Organization
Figure 10-1	Project schedule

**LIST OF TABLES**

Table 4-1	Summary of Sampling, Analytical, and Data Quality Objectives
-----------	--

**LIST OF APPENDICES**

Appendix A	Borehole and Sample Logging
Appendix B	Monitoring Well Installation
Appendix C	Groundwater Sample Acquisition
Appendix D	On-Site Water Quality Testing
Appendix E	Water Level, Water-Product Level Measurements, and Well Depth Measurements
Appendix F	Photo ionization Detector (PID) HNu Models PI 101 and DL 101
Appendix G	Bacharach Oxygen/Combustible Gas Meter
Appendix H	Decontamination of Sampling and Monitoring Equipment
Appendix I	Decontamination of Drill Rigs and Monitoring Well Materials
Appendix J	Sample Preservation and Handling
Appendix K	Chain-of-Custody
Appendix L	Field Logbook
Appendix M	Statistical Evaluation Methods

## ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
Baker	Baker Environmental, Inc.
CFR	Code of Federal Register
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
COC	Chain-of-Custody
CTO	Contract Task Order
DOT	Department of Transportation
DQO	Data Quality Objective
DoN	Department of the Navy
ECBSOPQAM	Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual
EMD	Environmental Management Division
EQB	Environmental Quality Branch
ESD	Environmental Services Division
GPS	Global Positioning System
HASP	Health and Safety Plan
ID	Inside Diameter
IDW	Investigation Derived Waste
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
MCB	Marine Corps Base
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NC DENR	North Carolina Department of Environment and Natural Resources
NFESC	Naval Facilities Engineering Service Center
O <sub>2</sub> /LEL	Oxygen/Combustible Gas
PCB	Polychlorinated Biphenyl
PID	Photo Ionization Detector
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act

**ACRONYMS AND ABBREVIATIONS**  
*(Continued)*

SOPs	Standard Operating Procedures
SWMUs	Solid Waste Management Units
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSDf	Treatment, Storage, and Disposal Facility
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WQP	Water Quality Parameter

## **1.0 INTRODUCTION**

This Work Plan presents the proposed field activities to be conducted for the Background Groundwater Study at Marine Corps Base (MCB) Camp Lejeune, North Carolina (the Base). The Work Plan was prepared under Contract Task Order (CTO) 0143 of the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program and is part of the Project Plans, which also include the Quality Assurance Project Plan (QAPP) and Health and Safety Plan (HASP). Baker Environmental, Inc. (Baker) is subcontracted to CH2M Hill for implementation of this project.

The primary purpose of this Work Plan is to provide guidance for the project field activities by describing in detail the sampling and data collection methods to be used in implementing the various field tasks. This document also will help to ensure that the project activities are carried out in accordance with the United States Environmental Protection Agency (USEPA) Region IV and Naval Facilities Engineering Service Center (NFESC) standard operating procedures (SOPs), so that data obtained during the field investigation are of sufficient quantity and quality to statistically evaluate background concentrations of inorganics in groundwater at the Base.

### **1.1 Project Objective**

The objective of the Background Groundwater Study is to establish a network of temporary monitoring wells that are located in "background" areas unaffected by activities at the Base. Temporary monitoring wells will be constructed at 25 locations throughout the Base. Two wells will be installed at each location to monitor the upper and lower portions of the surficial aquifer. Data from the wells will be used to develop a statistical base for evaluating results from future investigations at Solid Waste Management Units (SWMUs) and/or newly identified areas/sites at the Base. Specifically, the purpose of this study is to produce a background database, so that a determination can be made with respect to inorganic levels in groundwater at specific sites.

## **2.0 BACKGROUND INFORMATION**

This section presents a brief summary of pertinent background information developed for the Base. Detailed descriptions of the background information including history and conditions are presented in the *Phase I SWMU Confirmatory Sampling Report* (Baker, 2001) and other documents, which are referenced herein.

### **2.1 Location**

The Base is located within the Atlantic Coastal Plain Physiographic Province in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington (Figure 2-1). The Base covers approximately 236 square miles. The Base is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The Base is bordered by the City of Jacksonville, North Carolina and State Route 24 to the north; the Atlantic shoreline to the south and east; and U.S. Route 17 to the west.

### **2.2 Topography**

The topography of the Base is generally flat and typical of the North Carolina Coastal Plain. Elevations on the Base range from sea level to approximately 72 feet above mean sea level (MSL). However, elevations on the majority of the base range from approximately 20 to 40 feet above MSL.

Drainage at the Base generally is toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, the natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of the Base is situated in broad, flat interstream areas. Drainage is poor in these areas and the soils are often wet (WAR, 1983). The U.S. Army Corps of Engineers has mapped the limits of the 100-year floodplain at the Base at 7 feet above MSL in the upper reaches of the New River increasing downstream to 11 feet above MSL near the coastal area (WAR, 1983).

### **2.3 Geology**

The Base is located within the Tidewater region of the Atlantic Coastal Plain Physiographic Province. The sediments of the Atlantic Coastal Plain consist mostly of interbedded sands, silts, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast to a combined thickness of approximately 1,500 feet. They were deposited in marine or near-shore environments and range in age from early Cretaceous to Quaternary time. Regionally, the sediments comprise ten aquifers and nine confining units, which overlie igneous and metamorphic basement rocks of the pre-Cretaceous age. Seven of these aquifers and their associated confining units are present at the Base (Cardinell, et al., 1993).

### 3.0 DATA QUALITY AND SAMPLING OBJECTIVES

The site-specific objectives presented in this section have been developed using the USEPA seven-step data quality objectives (DQO) process, as presented in *USEPA Guidance for the Data Quality Objectives Process* (USEPA, 2000a) and *USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations* (USEPA, 2000b).

#### 3.1 Data Quality Objectives Process

DQOs are qualitative and quantitative statements, developed using the USEPA DQO process, that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as a basis for establishing the quality and quantity of data needed to support decisions. DQOs define the performance criteria that limit the probabilities of making decision errors by considering the purpose of collecting data, defining the appropriate type of data needed, and specifying tolerable probabilities of making decision errors. The seven-step DQO process is as follows:

- Step 1 – State the Problem
- Step 2 – Identify the Decision
- Step 3 – Identify the Inputs to the Decision
- Step 4 – Define the Boundaries of the Study
- Step 5 – Develop a Decision Rule
- Step 6 – Specify Tolerable Limits on Decision Errors
- Step 7 – Optimize the Design for Obtaining Data

In Step 1 of the DQO Process, the planning team is established, the problem is described, a conceptual model of the environmental hazard to be investigated is developed, and available resources, constraints, and deadlines are identified.

Step 2 of the DQO Process should identify the principal study question, define alternative actions, develop a decision statement, state each decision in terms of whether to take action, and organize multiple decisions into an order of priority.

Step 3 of the DQO Process should identify the kinds of information needed, identify the sources of information, determine the basis for setting the action level, and confirm the appropriateness of proposed sampling and analyses methods.

Step 4 of the DQO Process should define the target population (i.e., what is to be sampled), determine the spatial and temporal boundaries, identify practical restraints, and define the scale of decision making.

Step 5 of the DQO Process should define the population parameter, determine what action is needed, and confirm that the action level exceeds minimum detection limits.

Step 6 of the DQO Process should specify tolerable limits on decision errors.

Step 7 of the DQO Process is the review of existing environmental data, evaluation of the operational decision rules, development of general data collection design alternatives, calculation

of the number of samples to be collected, and selection of the most resource-effective data collection system.

The following sections present the seven-step DQO process developed for the Background Groundwater Study.

### **3.1.1 Step 1 - State the Problem**

The first activity associated with this step is to establish the planning team. The planning team will include the North Carolina Department of Environment and Natural Resources (NC DENR), Atlantic Division, Naval Facilities Engineering Command (LANTDIV), the Base, CH2M Hill, and Baker. These team members are decision-makers for the DQO Process.

The planning team's objective is to statistically establish background concentrations of inorganics in groundwater at the Base through groundwater sampling and laboratory analyses. The background data will be used to evaluate results from future investigations at SWMUs and/or newly identified areas/sites at the Base. Specifically, the purpose of this study is to produce a background database, so that a determination can be made with respect to inorganic levels in groundwater at specific sites.

The problem is that the background concentrations used for several years at the Base were compiled using data collected upgradient of several Remedial Investigation (RI) sites. It was later discovered that some of the RI sites were contaminated with inorganics. This discovery led to the suspicion that background sample locations may also have been contaminated but to a lesser degree, therefore, possibly artificially inflating the average background concentration.

The project team organization and project schedule are presented in Sections 9.0 and 10.0 of this Work Plan, respectively. The schedule presents the anticipated completion and/or submittal dates for specific tasks or documents.

### **3.1.2 Step 2 – Identify the Decision**

The principal study question identified is:

- What are background concentrations of inorganics in groundwater at the Base?

Before a decision statement can be formulated, a definition of "background" must be clarified.

For this groundwater study, "background" is defined as the concentrations of inorganics that are present in groundwater at the Base, but are not related to operations/activities at the Base.

Considering the principal study question and definition of "background", the decision statement is as follows:

- Statistically establish baseline concentrations of inorganics in groundwater at the Base through groundwater sampling and laboratory analyses.

### **3.1.3 Step 3 - Identify the Inputs to the Decision**

Existing information regarding background concentrations of inorganics in groundwater at the Base is limited and may not be truly representative of naturally occurring /area wide conditions. It

is evident that additional data are required to statistically establish “background.” The kinds of data and sources used to resolve the decision statement include:

Kinds of Information

Sources of Information

Background concentrations of inorganics in groundwater

Laboratory analytical data from new, temporary monitoring wells installed at locations unaffected by activities at the Base

The groundwater samples will be analyzed for inorganics at a fixed-based laboratory as described in Section 4.2 and 7.4.

**3.1.4 Step 4 - Define the Boundaries of the Study**

Figure 4-1 shows the proposed temporary monitoring well locations within the boundaries of the study area. The wells will be installed at locations unaffected by activities at the Base. The decision regarding background locations will be based on existing conditions at the time of investigation as well as knowledge of historical activities at the Base. These locations will be reviewed by the Base as to their appropriateness.

Temporal changes in background concentrations of inorganics are expected to be negligible. Thus data collection is not time dependent.

Practical constraints to sample collection are insignificant. There are no significant physical barriers or access issues at the background areas. Weather conditions (such as heavy rain) can delay well installation and/or sampling, but is not a serious constraint.

**3.1.5 Step 5 - Develop a Decision Rule**

Development of a decision rule will not be performed at this time. The intent of the Background Groundwater Study is not to define the distribution of contaminants at the Base but rather to determine background concentrations of inorganics in groundwater at the Base through groundwater sampling and laboratory analyses.

**3.1.6 Step 6 - Specify Tolerable Limits on Decision Errors**

Specification of tolerable limits on the decision errors will not be performed at this time. The proposed well locations are flexible and were positioned to determine background concentrations of inorganics in groundwater. If it is determined that any location has been impacted by activities at the base, and does not reasonably represent background conditions, the location will not be considered representative of “background” and the boring will be abandoned/relocated.

**3.1.7 Step 7 - Optimize the Design for Obtaining Data**

Existing information/data has been reviewed to evaluate and develop the data collection strategy for the field program. Based on review of existing data, it was discovered that some of the background sample locations may have been contaminated, therefore, possibly artificially inflating the average background concentration.

The development of alternate sampling plans is not practical given the dynamic nature of this investigation. Additionally, the flexibility of the Work Plan optimizes resources, in that the location of sampling points is determined by field conditions.

The proposed sampling and analyses program is detailed in the following sections.

#### **4.0 SAMPLING LOCATIONS AND FREQUENCY**

This section of the Work Plan describes the location and frequency of environmental samples to be collected during the field program. Support activities, sampling locations, sample matrix, constituents to be analyzed for, and Quality Assurance/Quality Control (QA/QC) requirements also are discussed. Detailed investigation procedures and sample handling/analytical requirements are provided in Sections 6.0 and 7.0, respectively. The field program described below will provide data to meet the objectives presented in Section 1.1 of this Work Plan.

##### **4.1 Temporary Monitoring Well Locations and Construction**

Twenty-five temporary monitoring well clusters will be installed at background locations as shown on Figure 4-1. These locations will be reviewed by Base personnel as to their appropriateness.

Each cluster will contain one shallow well and one intermediate well constructed in a common borehole for a total of 50 temporary wells. It is anticipated that the shallow wells will be installed to a depth of approximately 15 feet below ground surface (approximately 7 feet below the groundwater table) and the intermediate wells will be installed to a depth of approximately 35 feet below ground surface. The wells will be constructed of 1-inch inside diameter (ID), polyvinyl chloride (PVC) pipe, with 10 feet of 0.010-inch slot well screen. Section 6.1 presents specific details on the well construction procedures.

##### **4.2 Sampling and Analytical Requirements**

One groundwater sample will be collected from each of the temporary monitoring wells. The samples will be collected using low-flow purge and sampling methods. Depth to groundwater and field measurements, including pH, specific conductance, temperature, dissolved oxygen, and turbidity (Level I quality) also will be collected. Section 6.2 presents specific details on procedures for groundwater sampling.

The samples will be analyzed at a fixed-base laboratory for Target Analyte List (TAL) metals using SW846 6000/7000 Series. Routine, 21-day analytical turnaround time will be requested from the laboratory. The number of samples, analytical methods, DQOs, and laboratory turnaround times are presented on Table 4-1.

##### **4.3 Quality Assurance/Quality Control Samples**

Specific QA/QC requirements are presented in the QAPP. The following QA/QC samples will be collected during the field sampling activities:

###### **Equipment Rinsate Blanks**

New polyethylene tubing will be used to collect the groundwater samples. As a result, one equipment rinsate sample is believed to be sufficiently representative of the entire lot of tubing. The equipment rinsate blank will be collected by running laboratory-supplied distilled/deionized water over/through the sampling equipment and placing it into the appropriate sample container for laboratory analyses. The results will be used to verify that the sampling equipment had not contributed to contamination of the samples.

**Field Blanks**

One field blank will be collected from each source of water used in decontamination. It is anticipated that a total of three field blanks will be collected. The field blanks will be collected by pouring the water from the original container directly into the sample bottle set. Field blanks will not be collected in dusty environments. The results will be used to verify that the water used in decontamination has not contributed to contamination of the samples.

**Field Duplicate Samples**

Field duplicate samples will consist of one unique sample, split into two aliquots, and analyzed independently. The duplicate samples will be analyzed to verify the reproducibility of the laboratory results and degree of variability of reported concentrations. Duplicate samples will be collected at a frequency of 10 percent.

**Matrix Spike/Matrix Spike Duplicate Samples**

Matrix spike/matrix spike duplicate (MS/MSD) samples will be prepared in the field to address aliquoting reproducibility and to provide information on matrix reproducibility otherwise unobtainable from samples reported below analytically reproducible and statistically valid levels. MS/MSD samples will be prepared at a frequency of 5 percent for each group of samples of a similar matrix.

## 5.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during the Background Groundwater Study, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the sample media, sampling location, the round of groundwater sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site#-Media/Station#-Round and QA/QC

An explanation of each of these identifiers is given below.

Site#	This will include the prefix "BASE GW" meaning base background.
Media	STW = Shallow Temporary Well (groundwater sample from a shallow temporary well) ITW = Intermediate Temporary Well (groundwater sample from an intermediate temporary well)
Station#	Each sample location will be identified with a unique identification number.
Round	A two digit number followed by a character (A through D) will indicate the year and quarter the sample was collected. For example:  02A = First Quarter (January through March) of 2002. 02B = Second Quarter (April through June) of 2002
QA/QC	FB = Field Blank D = Duplicate Sample (following round) ER = Equipment Rinsate Blank MS/MSD = Matrix Spike/Matrix Spike Duplicate

Under this sample designation format, the sample number BASE-GW01STW-02ADUP refers to:

<u>BASE</u> -GW01STW-02ADup	Base background
BASE- <u>GW01STW</u> -02ADup	Groundwater sample from shallow temporary well #1
BASE-GW01STW- <u>02A</u> Dup	First quarter of 2002
BASE-GW01STW-02A <u>Dup</u>	Duplicate (QA/QC) sample

The sample designation BASE-ER01-02A refers to:

<u>BASE</u> -ER01-02A	Base background
BASE- <u>ER</u> 01-02A	Equipment rinsate blank
BASE-ER <u>01</u> -02A	Sample No. 1
BASE-ER01- <u>02A</u>	First quarter of 2002

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented in the field logbook.

## 6.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for the Background Groundwater Study are discussed in the subsections that follow. These procedures include temporary monitoring well construction, groundwater sample collection, decontamination, temporary monitoring well abandonment, and handling of investigation derived wastes (IDW). These procedures will comply with the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), *Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual* (ECBSOPQAM) (USEPA, 1997). Additional guidance from other sources such as the American Society for Testing and Materials (ASTM) may be used, but if the ASTM and ESD methods conflict, the ESD procedure will be used. Additionally, in instances where the ESD has no SOP, other guidance sources will be used, such as manufacturer's SOP manuals. Field deviations will be recorded in the field logbook and discussed in the text of the report.

### 6.1 Temporary Monitoring Well Construction

The temporary, shallow and intermediate monitoring wells will be constructed as follows:

- The presence of underground utilities in and around the proposed monitoring well locations will be mapped by an independent utility locating service.
- A common borehole will be advanced to approximately 35 feet below ground surface using a drill rig and 6-1/4-inch Inside Diameter (ID) hollow-stem augers.
- Upon completion of the borehole to the desired depth, the intermediate well construction materials will be installed through the hollow-stem augers.
- 10 feet of 1-inch ID, Schedule 40, 0.010-slot, PVC screen with a bottom cap will be set at the bottom of the borehole. The screen will be connected to threaded, flush-joint, PVC riser. The casing will be installed to be approximately 2 feet above the ground surface. A PVC riser slip-cap with a vent hole will be placed at the top of the casing.
- The annular space around the well screen will be backfilled with a well-graded, fine to medium sand as the hollow-stem augers are being withdrawn from the borehole. Sand will be placed from the bottom of the boring to approximately 2 feet above the top of the screened interval.
- A sodium bentonite seal will be placed above the sand pack to a depth of 2 feet below the desired depth of the shallow well estimated to be 15 feet below ground surface (i.e., bentonite will be placed from approximately 17 to 23 feet below ground surface). An approximate 2-foot thick, well-graded, fine to medium sand layer will be placed above the bentonite seal to prevent the bentonite from swelling and plugging the screen of the shallow well.
- Upon completion of the intermediate well, a shallow well will be installed. Ten feet of 1-inch ID, Schedule 40, 0.010-slot, PVC screen with a bottom cap will be installed adjacent to the intermediate well in the same borehole. The top of the well screen will be placed such that approximately 3 feet of the screen (as subsurface conditions permit) extends above the groundwater table to allow for fluctuations in the groundwater table. The screen will be connected to threaded, flush-joint, PVC riser. The casing will be installed to be approximately 1½ feet above the ground surface. A PVC riser slip-cap with a vent hole will be placed at the top of the casing.

- The annular space around the screen will be backfilled with a well-graded, fine to medium sand as the hollow-stem augers are being withdrawn from the borehole. The sand will extend to approximately 2 feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing material.
- A sodium bentonite seal (minimum of 6 inches) will be placed above the sand pack and extended to the ground surface to prevent surface and near subsurface water from infiltrating into the screened groundwater monitoring zone. The bentonite will be hydrated with potable water, as necessary.
- The depth intervals of all backfilled materials will be measured with a weighted measuring tape to the nearest 0.1-foot and recorded in the field logbook.

Figure 6-1 depicts a typical nested monitoring well construction diagram. The wells will be surveyed for horizontal position using a Global Positioning System (GPS) and topographic elevation relative to MSL using a registered surveyor so that groundwater elevations can be determined. Appendix A presents the SOP for Borehole and Sample Logging. Monitoring well installation procedures are outlined in Appendix B.

## **6.2 Groundwater Sample Collection**

The monitoring wells will be sampled using a peristaltic pump and low-flow purge and sampling methods. The procedure for collecting groundwater samples is detailed in this section, and is based on ECBSOPQAM procedures.

### **6.2.1 Selection of Water Quality Indicator Parameters**

ECBSOPQAM SOPs call for the use of pH, specific conductance, temperature, and turbidity as water quality indicator parameters (WQPs) for stabilization. This field program will include those WQPs plus dissolved oxygen. Use of dissolved oxygen has precedence in USEPA and other studies. Dissolved oxygen and turbidity are more sensitive indicators of "fresh" groundwater than pH, specific conductance, and temperature (Puls and Powell, 1992). Barcelona et. al., 1994, suggest that dissolved oxygen and specific conductance are good indicators of stabilization.

### **6.2.2 Purging and Sampling Procedure**

The following low-flow purge and sampling procedure will be used to collect the groundwater samples:

- The well cap will be removed and escaping gasses will be measured at the well head using a photo ionization detector (PID). This will determine the need for respiratory protection.
- The static water level will be measured. The total depth of the monitoring well will not be measured, as not to stir up any sediment. The total well depth will be obtained from Test Boring and Well Construction Records. The water volume in the well will then be calculated.

- The sampling device intake (new, 1/4-inch ID, polyethylene tubing) will be slowly lowered until the bottom end is 2 to 3 feet below the top of the well screen or the top of the water level, whichever is greater. Next, the water level probe will be placed into the monitoring well just above the water.
- Purging will begin using a peristaltic pump. The pumping rate will be set to create a sustainable flow (approximately 1 liter/minute or less) without causing a significant drop in water level in the well. The static water level will be periodically measured throughout purging to verify that a significant drop in water level has not occurred.
- The WQPs, including pH, specific conductance, temperature, dissolved oxygen, and turbidity will be measured frequently.
- Purging will be complete when a minimum of three well volumes have been removed and three successive WQP readings have stabilized within 10 percent (0.1 Standard Units for pH), or there is no further discernable upward or downward trend. It is Baker's experience that at low values, certain WQPs (such as turbidity) may vary by more than 10 percent, but have reached a stable plateau.
- Upon WQP stabilization, groundwater samples will be collected from the end of the tubing and placed into the sample containers.
- The following information will be recorded in the field logbook:
  - Project location, date, and time
  - Weather
  - Sample location, number, round, and identification number
  - Static water level
  - Calculation of amount of water to be purged
  - WQPs during purging
  - Visual description of water (i.e., clear, cloudy, muddy, etc.)
  - Names of sampling personnel
  - Names of visitors on site
  - Purging and sampling technique, procedure and equipment used
  - Sampling remarks and observations
  - QA/QC samples collected
- The sample jars will be stored on ice in a cooler at approximately 4 degrees Celsius (or less) until delivered to the laboratory.
- The samples will be packed for shipping. Chain-of-Custody (COC) Forms will be properly filled out and enclosed in the shipping package. COC seals will be attached to the package prior to shipping.

Sample preservation and handling procedures are outlined in Section 7.0. Appendix C presents the SOP for groundwater sample acquisition.

### **6.3 Monitoring and Data Collection Equipment**

Field measurements including pH, specific conductance, temperature, dissolved oxygen, and turbidity will be recorded during groundwater sampling. Appendix D presents specific procedures for on-site water quality testing.

Additional monitoring well information may be obtained using water level meters and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix E.

Health and safety monitoring and environmental media screening will be conducted using a PID and an oxygen/combustible gas (O<sub>2</sub>/LEL) meter. The operation and use of the PID and O<sub>2</sub>/LEL meter are described in Appendices F and G, respectively.

### **6.4 Decontamination**

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, pH meters, etc.)
2. Machinery, equipment, and materials (e.g. drilling rigs, drilling equipment, monitoring well materials, etc.)

Appendices H and I present procedures for decontaminating the two categories of equipment and materials, respectively.

### **6.5 Temporary Monitoring Well Abandonment**

Subsequent to completion of the groundwater sampling activities, the temporary monitoring wells will be abandoned as follows:

- To the extent feasible, the well casing and screen materials will be removed.
- The borehole will be backfilled with sodium bentonite and hydrated with potable water.
- The surface will be completed with like material (e.g., grass, dirt, concrete).
- Waste materials (e.g., well casing/screen) will be disposed in on-site trash dump boxes.

### **6.6 Investigation Derived Waste Handling**

The subsections that follow discuss the responsibilities, sources, containerization, sampling and analyses, and disposal of IDW. These wastes include soil from well borings, groundwater from purging of monitoring wells, decontamination fluids, and personal protection equipment.

### **6.6.1 Responsibilities**

LANTDIV - LANTDIV or the Base must ultimately be responsible for the final disposition of the IDW. As such, a LANTDIV or a Base representative will sign waste disposal manifests as the generator of the material in the event off-site disposal is required. However, it may be the responsibility of Baker, depending on the contingency discussions during execution of the investigation, to provide assistance to LANTDIV in arranging for final disposition and preparing manifests.

Baker Project Manager - It is the responsibility of the Baker Project Manager to work with the LANTDIV-Technical Representative in determining the final disposition of the IDW. The Baker Project Manager will relay the results and implications of the chemical analyses of the IDW, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Baker Project Manager also is responsible for ensuring that field personnel involved in the IDW handling are familiar with the procedures to be implemented in the field, and that all required field documentation has been completed.

Baker Field Team Leader - The Baker Field Team Leader or Site Manager is responsible for the on-site supervision of the IDW handling procedures during implementation of the field program. The Baker Field Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

### **6.6.2 Sources of Investigation Derived Wastes**

The field investigation activities will result in the generation and handling of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These wastes may be either hazardous or non-hazardous in nature. The nature of the waste (i.e., hazardous or non-hazardous) will determine how the wastes will be handled during the field investigation. It should be noted that the monitoring wells will be located in areas representative of "background" (i.e., the locations will be "clean" and unaffected by activities at the Base). As a result, the IDW is not anticipated to exhibit hazardous characteristics.

The following sections discuss the types of IDW that will be generated as a result of the field investigation and methods used to handle the IDW.

#### **Soil Cuttings**

Soil cuttings will be generated during augering of the well borings. The soil cuttings will be field-screened using a PID. Soil containing no PID readings above background or evidence of gross contamination will be spread on the ground surface at the well head. If elevated PID readings or evidence of gross contamination are detected in soil cuttings from a well boring, the well location will not be considered representative of "background" and the boring will be abandoned/relocated. The soil cuttings will be containerized in Department of Transportation (DOT) approved 55-gallon drums for analytical testing, temporary storage on site, and subsequent treatment and/or disposal.

## **Monitoring Well Development and Purge Water and Decontamination Fluids**

Monitoring well purge water will be discharged to the ground surface at the well head. Methanol will be used in the decontamination process. Therefore, equipment and personal decontamination fluids collected from decontamination/wash pads will be containerized in DOT-approved 55-gallon drums for analytical testing, temporary storage on site, and subsequent treatment and/or disposal.

## **Personal Protective Equipment**

All personal protective equipment (i.e., Tyvek coveralls, gloves, and other health and safety disposables) will be placed in garbage bags and disposed in on-site trash dump boxes.

### **6.6.3 Investigation Derived Waste Sampling and Analyses**

One composite sample will be collected from the drums containing soil cuttings. The sample will be analyzed for Toxicity Characteristic Leaching Procedure (TCLP) organics and inorganics and Resource Conservation and Recovery Act (RCRA) hazardous waste characterization (ignitability, corrosivity, and reactive cyanide and sulfide).

One composite sample will be collected from the drums containing decontamination fluids. The sample will be analyzed for Target Compound List (TCL) organics, TAL metals (total), total suspended solids (TSS), total dissolved solids (TDS), and RCRA hazardous waste characterization (ignitability, corrosivity, and reactive cyanide and sulfide).

### **6.6.4 Labeling**

The drums, roll-off box and/or storage tank will be labeled by the field team during the field investigation. Information will be written on a plaque and affixed to the prominent side of the container. Container labels will include, at a minimum:

- LANTDIV CTO number
- Camp Lejeune point-of-contact name and phone number
- Project name
- Contractor name and Project Manager name
- Drum number
- Date
- Source
- Contents

If laboratory analyses reveals that containerized materials are hazardous, additional labeling of containers may be required. Baker will be responsible for additional labeling procedures, with assistance from the Base and/or LANTDIV as needed. These additional labeling procedures will be based on the identification of material present and USEPA regulations applicable to labeling hazardous and polychlorinated biphenyl (PCB) containing wastes, which are contained in 40 CFR Parts 261, 262, and 761.

### **6.6.5 Container Log**

A container log will be maintained in the field logbook. The container log will contain the same information as the container label plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample. The Environmental Quality Branch (EQB), Environmental Management Division (EMD), Installations and Environment Department at the Base will be informed of the status of all IDW storage containers on a regular basis.

### **6.6.6 Container Storage**

Containers of IDW will be stored on site or in a specially designated secure area that is managed by the EQB until disposition is determined.

If the laboratory analyses reveals that the IDW is hazardous, additional storage security may be implemented. Baker will coordinate, with LANTDIV and/or the Base, any additional measures that may need to be taken to insure that the containerized IDW is secure and meets applicable Federal regulations.

Baker will assist LANTDIV in devising the storage requirements as required. Weekly inspections by facility personnel of the temporary storage area also may be required. These inspections may assess the structural integrity of the containers and proper container labeling. Also, precipitation that may accumulate in the storage area may need to be removed. These weekly inspections and whatever precipitation removal is necessary will be recorded in the field logbook.

### **6.6.7 Container Disposition**

The disposition of the containers of IDW will be determined by LANTDIV, with the assistance of Baker, as necessary. Container disposition will be based on quantity of materials, types of materials, and analytical results. If necessary, specific samples of contained materials may be collected to identify further characteristics that may affect disposition. Typically, container disposition will not be addressed until after receipt of applicable analytical results, which are usually not available until long after completion of the field investigation.

### **6.6.8 Disposal of Contaminated Materials**

Actual disposal methods for IDW will be determined following receipt of the analytical results. The usual course will be a contractor specialist retained to conduct the disposal. However, regardless of the mechanism used, all applicable Federal, state, and local regulations will be observed. USEPA regulations applicable to generating, storing, and transporting hazardous wastes are contained in 40 CFR Parts 262, 263.

Another consideration in selecting the method of disposal of contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable on-site disposal or treatment structure is expected, contaminated materials generated during the site investigation may be stored at the site for treatment/disposal with other site materials. In this case, the initial containment will be evaluated for use as long-term storage. Also, other site conditions, such as drainage control, security, and soil types must be considered in order to provide proper storage.

For the Background Groundwater Study, any soil determined to be non-hazardous will be returned to the site. Soil determined to be hazardous will be taken to a Treatment, Storage, and Disposal Facility (TSDF). Monitoring well purge water will be discharged to the ground surface at the well head. Decontamination fluids may be taken to one of the on-base groundwater treatment plants designed handle solvent and petroleum contamination.

## **7.0 SAMPLE HANDLING, ANALYSES, AND VALIDATION**

Field activities will be conducted in accordance with the USEPA Region IV ESD's ECBSOPQAM (USEPA, 1997). Procedures for sample preservation, labeling, handling, and maintaining a field logbook are detailed in SOPs. Because these procedures are not specific to this project, they are provided as appendices, rather than detailed herein. Major components of sample handling and analyses are discussed in the following subsections.

The number of samples, analytical methods, DQOs, and laboratory turnaround times are presented in Table 4-1.

### **7.1 Sample Preservation and Handling**

Sample preservation, sample bottle packing, and shipping are important components to maintaining the integrity of the samples. Preservation and handling procedures to be used during the Background Groundwater Study are detailed in Appendix J and Section 6.1 of the QAPP.

### **7.2 Chain-of-Custody**

COC is another important component to maintaining sample integrity. COC procedures to be followed during the Background Groundwater Study are detailed in Appendix K. This SOP also details sample bottle labeling procedures.

COC procedures ensure a documented, traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping, and analyses.

### **7.3 Field Logbook**

Field logbooks will be used to record sampling activities and information. Entries will include general and specific sampling information so that the field activities may be reconstructed. Appendix L describes a general format for the field logbook.

Each field person will have and maintain a logbook. Logbooks will be copied daily and stored in the project files as backup in case the original is lost or destroyed.

### **7.4 Sample Analyses and Validation**

This section discusses efforts relating to the following activities:

- Sample Management
- Laboratory Analyses
- Data Validation

Sample management activities involve coordination with the laboratory, tracking of samples submitted for analyses, tracking of analyses received, and tracking of information related to samples submitted and received from a third party validator. Sample management also involves resolving technical or administrative problems (e.g., reanalysis, resubmission of information) as necessary.

Laboratory analyses begins when the samples are shipped from the field and received by the laboratory. For the Background Groundwater Study, the samples will be analyzed for TAL metals using SW846 6000/7000 Series.

Validation begins when the validator receives the "raw" laboratory data. Baker will also receive the data from the laboratory, and enter it into a database for tracking purposes. A validation report will be expected within three weeks following receipt of laboratory data packages by the validator. The data will be validated in accordance with the Contract Laboratory Program (CLP) criteria as outlined in the following document:

- USEPA, Hazardous Site Evaluation Division, *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* (February, 1994)

## 8.0 DATA EVALUATION AND REPORT PREPARATION

This task involves efforts related to the data once it is received from the laboratory and is validated. It also involves the evaluation of any field-generated data, including water level measurements, Test Boring and Well Construction Records, and other field notes. Efforts under this task will include the tabulation of validated data and field data, generation of Test Boring and Well Construction Records, and generation of other diagrams associated with field notes or data received from the laboratory (e.g., sampling location maps).

The laboratory analytical results will be statistically evaluated in accordance with the Ohio EPA *Closure Plan Review Guidance for RCRA Facilities* (Section 3.12 – Guidance for Statistical Evaluation of Hazardous Waste Constituent Levels in Soil) (March, 1999). A copy of Section 3.12 is included as Appendix M. Although this document is specific to soil, the same statistical evaluation methods apply to groundwater.

A report will be prepared to include, but not be limited to, the following:

- A summary of the investigation/sampling activities
- A discussion of investigation procedures that deviated from the Work Plan
- A discussion of the analytical results and statistical evaluation
- A complete analytical results package

## **9.0 PROJECT MANAGEMENT AND STAFFING**

Mr. Christopher Bozzini, CH2M Hill Project Manager, will provide overall coordination, project administration, and senior QA/QC functions. In addition, Mr. Bozzini will keep abreast of all project activities and will maintain close communication with the Navy Technical Representative and the Base.

Mr. Jim Culp and Mr. Scott Moffett will co-manage the Baker Project Team. Their primary responsibilities will include guiding, monitoring, and coordination of the technical aspects of the project. Mr. Culp and Mr. Moffett also will be responsible for Baker project administration and the overall QA/QC of project deliverables.

Mr. Richard Bonelli, the Baker Activity Coordinator, will serve as an essential member of the management team, maintaining communication with CH2M Hill, LANTDIV, and the Base.

The Baker Project Team will include a Site Manager, an Assistant Project Geologist, and technical support staff as shown in Figure 9-1 and discussed below.

### **9.1 Field Team Responsibilities**

The field investigation portion of this project will be conducted in conjunction with the Phase II Confirmatory Sampling Program and consist of one field team. A Site Manager will coordinate all field activities and serve as the Site Health and Safety officer. The Site Manager will ensure that all field activities are conducted in accordance with the project plans which include the Work Plan, the QAPP, and the HASP.

The Field Team will employ one drilling rig for monitoring well installation. An Assistant Project Geologist will supervise the drilling rig work.

### **9.2 Reporting Requirements**

The Site Manager will report a summary of each day's field activities to the Project Manager or his/her designee. This may be done by telephone or fax. The Site Manager will include, at a minimum, the following in his/her daily report:

- Baker personnel on site
- Other personnel on site
- Major activities of the day
- Subcontractor quantities (e.g., drilling footages)
- Samples collected
- Problems encountered
- Planned activities

The Site Manager will receive direction from the Project Manager regarding changes in the scope of the investigation. All changes in the scope will be discussed and agreed upon by CH2M Hill, LANTDIV, the Base, and the NC DENR.

## 10.0 SCHEDULE

A proposed schedule for the deliverables and milestones associated with the background study is presented on Figure 10-1 and detailed below. The assumed start date is February 11, 2002. The day in the “( )” represents the proposed deliverable or end date for each task/activity.

- Receive NC DENR’s concurrence on the proposed Background Groundwater Study Work Plan (Day 1)
- Submit the Final Background Groundwater Study Work Plan (Day 14)
- Procurement of Subcontractors (Day 14)
- Mobilize to the field/conduct field investigation (Day 21)
- Demobilize from the field (Day 62)
- Receive analytical results (Day 83)
- Receive validated analytical results (97)
- Statistical evaluation of data (Day 111)
- Submit the Draft Background Groundwater Study Report/Results (Day 151)
- Receive NCDENR comments on the Draft Background Groundwater Study Report/Results (Day 181)
- Respond to NCDENR comments on the Draft Background Groundwater Study Report and submit Final Report (Day 211)

## 11.0 REFERENCES

Baker Environmental, Inc. (Baker). Revised Final Phase I SWMU Confirmatory Sampling Report. Baker. November, 2001.

Barcelona, M.J., Wehrmann, H.A., Varljen, M.D. "Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Groundwater Sampling." Ground Water, Vol. 32, No. 1. January-February, 1994.

Cardinell, Alex P. et al. Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina. U.S. Geological Survey, Water-Resources Investigations Report 93-4049. 1993.

Ohio Environmental Protection Agency (Ohio EPA). Closure Plan Review Guidance for RCRA Facilities. Ohio EPA. March, 1999.

Puls, R.W. and Powel, R.M. "Acquisition of Representative Ground Water Quality Samples for Metals." Groundwater Monitoring and Remediation. Summer, 1992.

United States Environmental Protection Agency (USEPA), Region IV. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. USEPA, Region IV. 1997.

Water and Air Research, Inc. (WAR). Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. WAR. 1983.

United States Environmental Protection Agency (USEPA). Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses. USEPA. February, 1994.

United States Environmental Protection Agency (USEPA). USEPA Guidance for the Data quality Objectives Process. USEPA. 2000a.

United States Environmental Protection Agency (USEPA). USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations. USEPA. 2000b.

**TABLES**

---

**Table 4-1**  
**Summary of Sampling, Analytical, and Data Quality Objectives**  
**Background Groundwater Study, CTO-0143**  
**MCB Camp Lejeune, North Carolina**

Study Area	Media	Estimated Number of Samples	TCL VOCs SW846 8260B	TCL SVOCs SW846 8270C	TCL Pesticides SW846 8081A	TAL Metals SW846 6000/7000 Series	Ignitability SW846 1010	Corrosivity SW846 1110	Reactive Cyanide 7.3.3.2/9010	Reactive Sulfide 7.3.4.2/9030	Total Suspended Solids EPA 160.2	Total Dissolved Solids EPA 160.1	TCLP VOCs SW846 1311/8260B	TCLP SVOCs SW846 1311/8270C	TCLP Pesticides SW846 8081A	TCLP Metals SW846 6000/7000 Series	Data Quality Objective	Laboratory Turnaround
Background	Water	50				50											Level IV	21 Days
Field Duplicates	Water	5				5											Level IV	21 Days
Matrix Spikes	Water	3				3											Level IV	21 Days
Matrix Spike Duplicates	Water	3				3											Level IV	21 Days
Equipment Rinsate Blanks	Water	1				1											Level IV	21 Days
Field Blanks	Water	3				3											Level IV	21 Days
Investigation Derived Wastes	Soil Cuttings	1					1	1	1	1			1	1	1	1	Level III	21 Days
	Decontamination Fluids	1	1	1	1	1	1	1	1	1	1	1					Level III	21 Days
Total Number of Samples/Analyses		67	1	1	1	66	2	2	2	2	1	1	1	1	1	1	NA	NA

Notes:  
 NA = Not Applicable  
 SVOCs = Semivolatile Organic Compounds  
 TAL = Target Analyte List  
 TCL = Target Compound List  
 TCLP = Toxicity Characteristic Leaching Procedure  
 VOCs = Volatile Organic Compounds

**FIGURES**

---

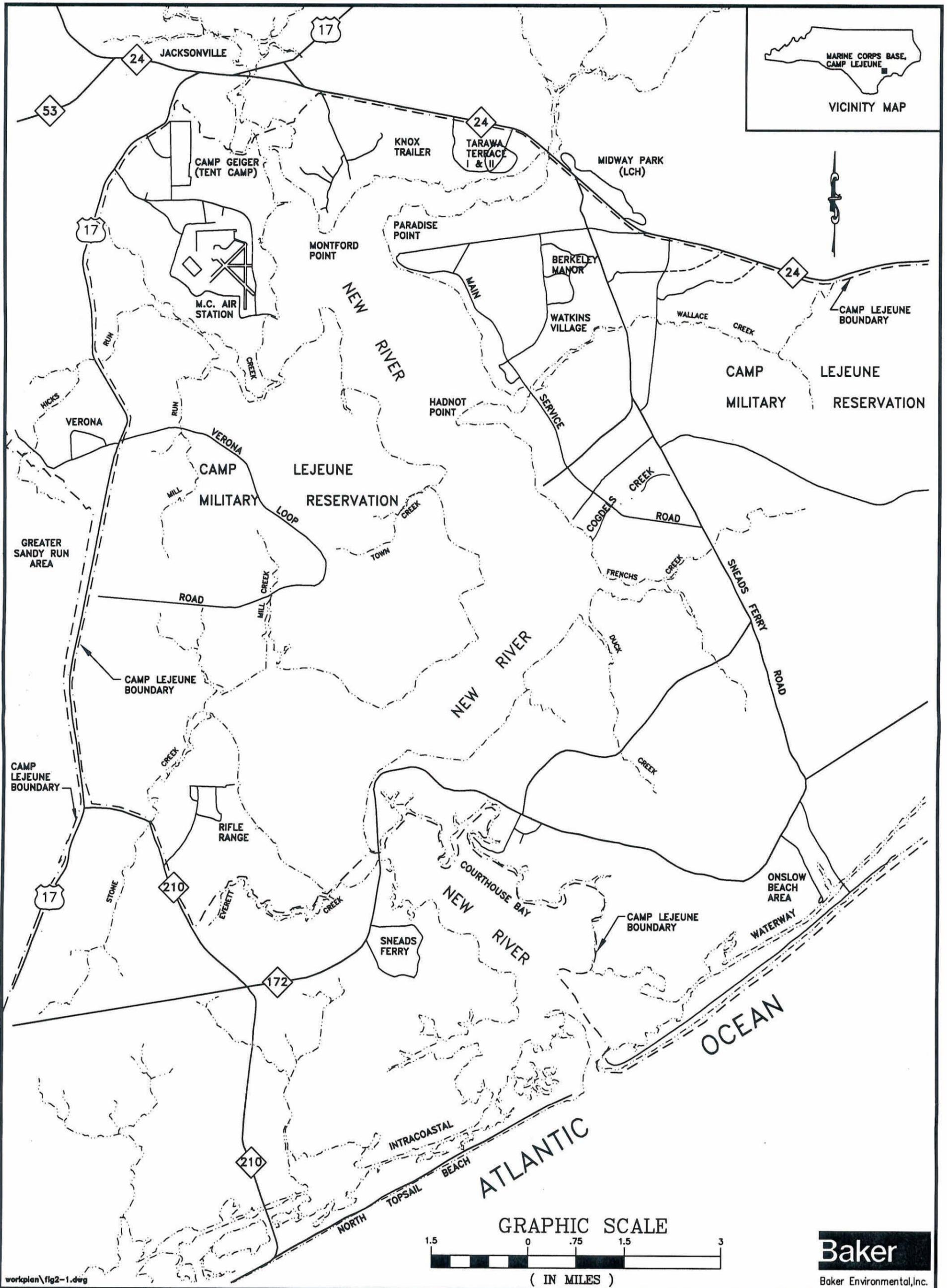


FIGURE 2-1  
 GENERAL LOCATION MAP  
 BACKGROUND GROUNDWATER STUDY WORKPLAN

MARINE CORPS BASE, CAMP LEJEUNE  
 NORTH CAROLINA

**Baker**  
 Baker Environmental, Inc.



**LEGEND**

◆ GROUNDWATER MONITORING WELL LOCATION

REVISIONS

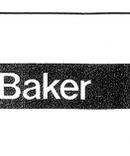
DRAWN	WJH
REVIEWED	JSC
S.O.#	26007-143
CADD#	2143500A



--

MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA

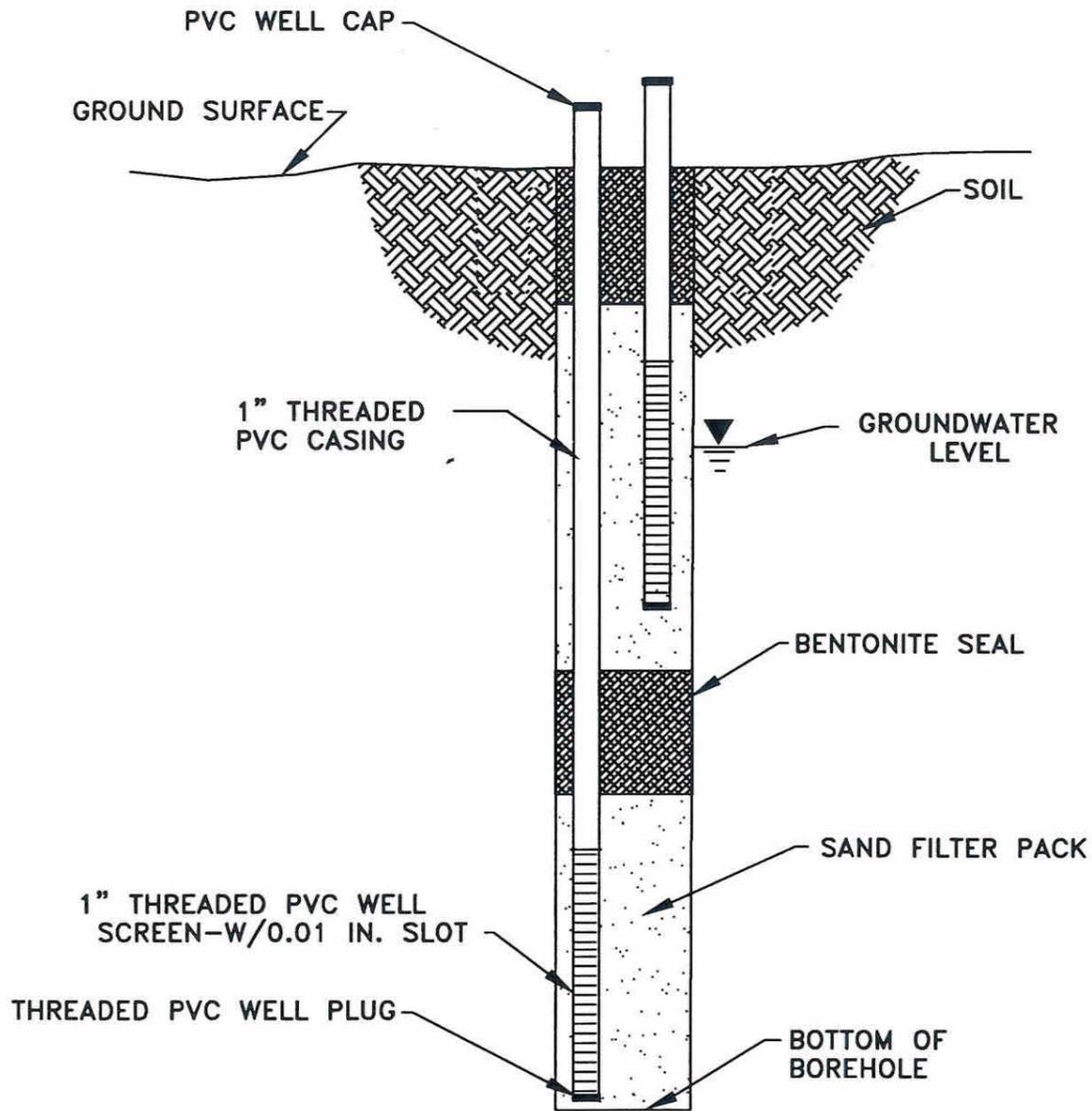
BAKER ENVIRONMENTAL, Inc.  
Coraopolis, Pennsylvania



BASE BACKGROUND GROUNDWATER MONITORING  
WELL LOCATION MAP  
CTO - 0143

SCALE 1" = 4000'  
DATE DECEMBER 2001

FIGURE NO.  
**4-1**



N.T.S.

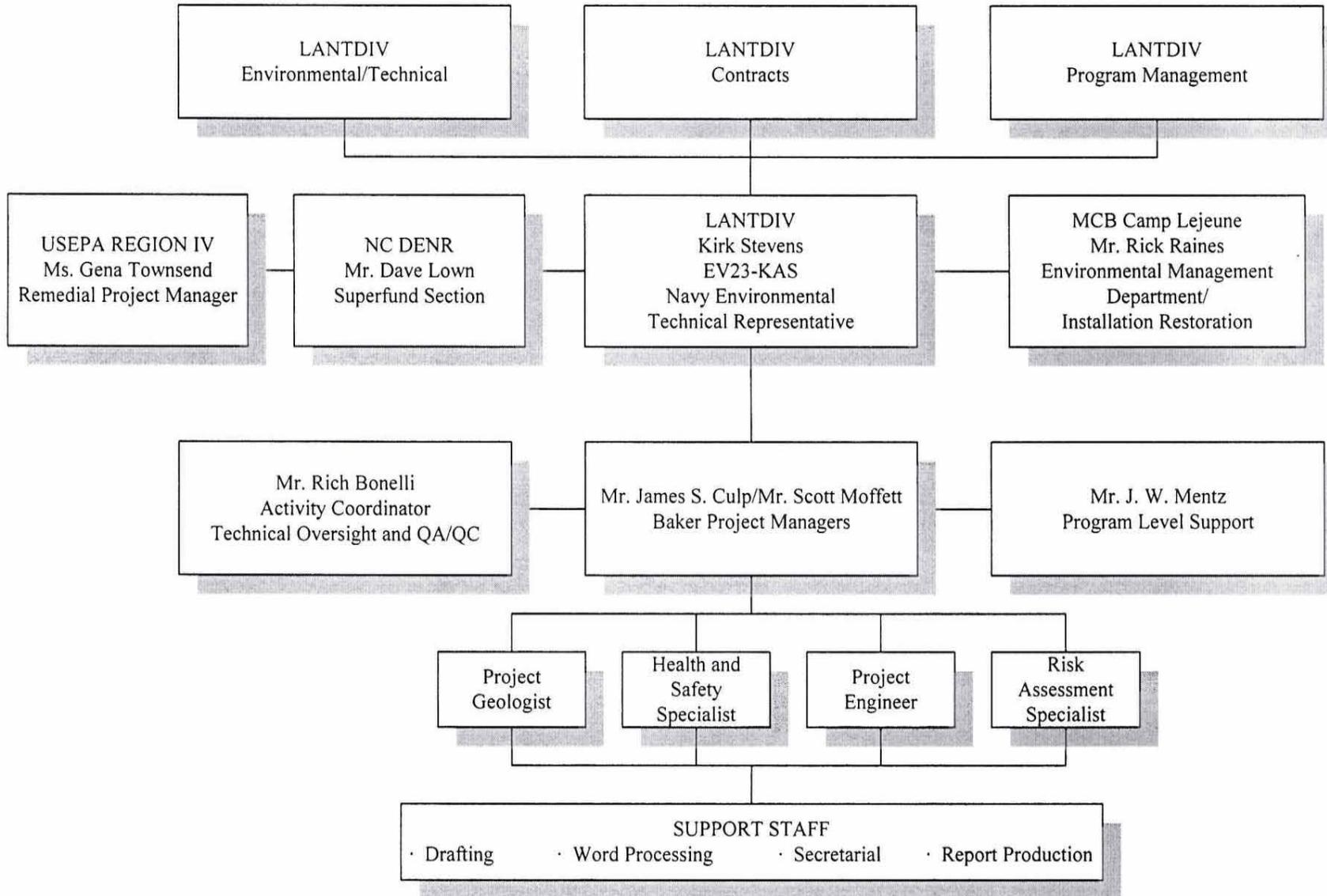
**Baker**  
Baker Environmental, Inc.

FIGURE 6-1  
NESTED MONITORING WELL CONSTRUCTION DIAGRAM  
BACKGROUND GROUNDWATER STUDY WORK PLAN

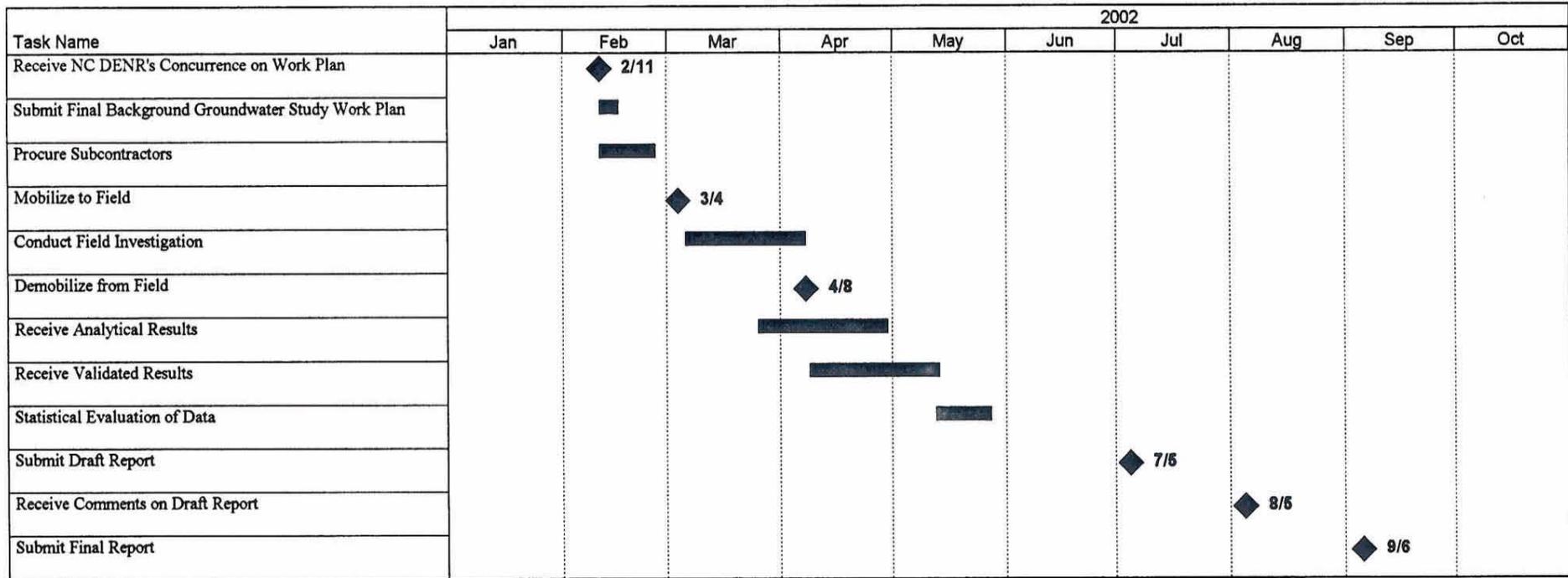
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA

FIGURE 9-1

PROJECT TEAM ORGANIZATION  
BACKGROUND GROUNDWATER STUDY (CTO-0143)  
MCB, CAMP LEJEUNE, NORTH CAROLINA



**Schedule Background Groundwater Study  
CTO-0143  
MCB Camp Lejeune**



**APPENDIX A**  
**BOREHOLE AND SAMPLE LOGGING**

---

---

**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
BOREHOLE AND SAMPLE LOGGING**

---

**Page 1 of 12  
SOP Number: F101  
Effective Date: 02/15/98**

---

**TABLE OF CONTENTS**

**1.0 PURPOSE**  
**2.0 SCOPE**  
**3.0 DEFINITIONS**  
**4.0 RESPONSIBILITIES**  
**5.0 PROCEDURES**  
    5.1 Test Boring Record  
    5.2 Soil Classification  
    5.3 Soil Descriptions  
        5.3.1 Grain Size Identification  
        5.3.2 Color  
        5.3.3 Relative Density and Consistency  
        5.3.4 Moisture Content  
        5.3.5 Stratification  
        5.3.6 Texture/Fabric/Bedding  
        5.3.7 Summary of Soil Descriptions  
    5.4 Sedimentary Rock Classifications  
        5.4.1 Rock Type  
        5.4.2 Color  
        5.4.3 Bedding Thickness  
        5.4.4 Hardness  
        5.4.5 Fracturing  
        5.4.6 Rock Quality Designation  
        5.4.7 Weathering  
        5.4.8 Other Characteristics  
        5.4.9 Additional Forms  
**6.0 QUALITY ASSURANCE RECORDS**  
**7.0 REFERENCES**

## BOREHOLE AND SAMPLE LOGGING

### 1.0 PURPOSE

This SOP provides general reference information and technical guidance on borehole and sample logging. Borehole logs provide information that is used in the determination of geological conditions, assessment of contaminant distribution, and the evaluation of remedial actions.

### 2.0 SCOPE

This SOP provides descriptions of the standard techniques for borehole and sample logging. These techniques shall be used to provide consistent descriptions of subsurface lithology for each boring that is logged. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer may develop adequate classifications through careful, thorough observation and consistent application of the classification procedure.

### 3.0 DEFINITIONS

Soil classifications and terms are given in Sections 5.2 and 5.3. Rock classification and terms are presented in Section 5.4.

### 4.0 RESPONSIBILITIES

Project Manager – It is the responsibility of the Project Manager to ensure that field personnel responsible for borehole logging are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that the appropriate documents (e.g., test boring logs, field logbooks, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader – The Field Team Leader is responsible for the overall supervision of the drilling and boring activities, and for ensuring that each borehole is completely logged by the responsible drilling inspector. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The field team leader is responsible for providing copies of the test boring logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.

Drilling Inspector – The drilling inspector (site geologist) is responsible for the direct supervision of boring and sampling activities. It is the Drilling Inspector's responsibility to log each boring, document subsurface conditions, complete the appropriate forms, and direct the drilling crew (or drilling supervisor).

## 5.0 PROCEDURES

The classification of soil and rock is one of the most important jobs of a drilling inspector or site geologist. It is imperative that the drilling inspector understand and accurately use the field classification system described in this SOP to maintain a consistent flow of information. This identification is based on both visual examination and manual tests. The results of the boring activities, including soil and rock classifications, shall be recorded on a Field Test Boring Record or the field notebook.

### 5.1 Test Boring Record

Each boring shall be fully described in a Field Test Boring Record. The drilling inspector shall log the boring, as it is being drilled, by recording relevant data on the Boring Record. It may be more appropriate to record the boring information in a bound field log book so that all boring logs recorded (by each drilling inspector) are located in one source. The use of a field log book precludes the possibility of losing individual test boring log sheets. Furthermore, use of the field log book allows for the recording of additional information (i.e. notes) for which space is not allocated on the Field Test Boring Record. Field Test Boring Records may then be transcribed from the field log book, but must be completed at a minimum, on a weekly basis. The Field Test Boring Records must be completely filled out and signed prior to demobilization from the site. Field Test Boring Records must also be legible. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record.

The data which is to be included on the Test Boring Records, when applicable is listed below.

1. Project name, location, and Project and Task Number.
2. Date(s).
3. Identifying number and location of each boring.
4. Soil classifications in accordance with the Unified Soil Classification System (see Section 5.2 and Attachment B). These classifications will be noted in the field by the drilling inspector and revised, if necessary, based on laboratory analysis and review. Both field determined USCS soil classification and a soil description shall be included on the Test Boring Record.
5. Depth limits, and the type and number of samples taken.
6. The number of blows required for each 6-inch penetration of a split-spoon sampler and for each 12-inch penetration of casing. The percentage of sample recovered, hammer weight, fall length, and hydraulic pressures to push thin-walled tubes.
7. Depth to water as first encountered during drilling operations, along with the method of determination. Any distinct water bearing zones shall also be delineated.
8. Loss of drilling fluid (indicative of subsurface voids) and the interval over which it was observed.
9. Identification of equipment used, including model and type of drilling rig, size of split spoon samplers, auger types and sizes, etc.
10. Start date and completion dates for the boring.
11. Name of the drilling company and the driller.
12. Size and length of the casing used in each hole.
13. Observations of visual contamination.
14. Field instrument readings (i.e., photoionization detector, organic vapor analyzer).

As the boring is advanced, the inspector shall evaluate the samples and the cuttings to determine the location of each stratigraphic unit. The descriptions should contain color, grain-size distribution, consistency moisture, etc., in addition to the USCS classification category (Section 5.3.7).

## **5.2 Soil Classification**

The data shall be recorded on a Field Test Boring Record, or in a field logbook. The method of deriving the classification should be described, or reference made to this SOP or other applicable manuals. Both the soil classification and the soil descriptions must be entered on the Field Test Boring Record. If required, the soil classification shall consist of the two-letter USCS classification; the soil description shall be much more detailed.

Where required, soils will be classified according to the USCS. The USCS method of classification is detailed in Attachment B and identifies soil types on the basis of grain-size and liquid limits, and categorizes them through the use of two letters. Although some laboratory testing is required for full USCS classification, preliminary classifications may be made in the field.

Fine-grained soils are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition; peat is designated by "Pt." Coarse-grained soils are divided into sand (S) or gravel (G). The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

The second letter of the two-letter USCS symbol provides information about the grain size distribution of granular soil, or the plasticity characteristics of fine-grained soils. These second letter modifiers are (P) poorly graded/well sorted, (W) well graded/poorly sorted, (C) clayey, (M) silty, (L) low plasticity, or (H) high plasticity.

## **5.3 Soil Descriptions**

The Test Boring Records shall contain complete soil descriptions in addition to the two-letter USCS classification, if required. Soil descriptions include the following components: grain size identification with descriptive terms indicating the relative percentage of each grain size, color, consistency or relative density, moisture content, organic content, plasticity, and other pertinent observations such as visual contamination, HNu measurements, etc.

### 5.3.1 Grain Size Identification

In nature, soils are comprised of varying size, shape, and combinations of the various grain types. The following terms are used to indicate soil grain size:

<u>Size</u>	<u>Size Limits</u>
Cobbles	3-inches to 12-inches
Coarse gravel	3/4-inches to 3-inches
Fine gravel	4.76 mm (# 4 sieve size) to 3/4-inches
Coarse sand	2 mm (# 10 sieve size) to 4.76 mm
Medium sand	0.42 mm (# 40 sieve size) to 2 mm
Fine sand	0.074 mm (# 200 sieve size) to 0.42 mm
Silt	0.002 mm to 0.074 mm
Clay	less than 0.002 mm

The proportion of each grain size (by weight percent) is indicated using the descriptive terms:

Trace	0 to 10 percent
Little	10 to 20 percent
Some	20 to 35 percent
And (or an adjective form of the grain size, i.e., sandy, silty, clayey)	35 to 50 percent

Some examples of soil grain size descriptions are:

- Silty fine sand: 50 to 65 percent fine sand and 35 to 50 percent silt.
- Medium to coarse sand, some silt: 65 to 90 percent medium to coarse sand, 20 to 35 percent silt.
- Fine sandy silt, trace clay: 50 to 65 percent silt, 35 to 50 percent fine sand, and 0 to 10 percent clay.

The soil type may be classified as noncohesive, granular soils or as cohesive, fine-grained soils as discussed in Section 5.3.3. The grain shape of a soil usually does not need to be determined unless unusual or unique features are readily apparent.

### 5.3.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light-gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent between borings.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors because sampling devices tend to smear the sample surface creating color variations between interior and exterior.

The term "mottled" shall be used to indicate soil irregularly marked with spots of different colors. Soil color charts shall not be used unless specified by the Project Manager.

### 5.3.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the drilling inspector first shall identify the soil type. Granular soils contain predominantly sands and gravels. These types of soil are noncohesive (particles do not adhere well when compressed). Conversely, fine-grained soils which contain predominantly silts and clays are cohesive (particles will adhere when compressed).

The density of noncohesive, granular soils or the consistency of cohesive soils is classified according to standard penetration resistances obtained from split-spoon (split-barrel) sampling performed according to ASTM D-1586. Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12-inches into the material using a 140-pound hammer falling freely through 30-inches. In cases where geotechnical information is required, the standard penetration test is performed by driving the sampler through an 18-inch sample interval, the number of blows will then be recorded for each six-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of the sample interval. It is important to note that if gravel and rock fragments are broken by the sampler, or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This must be noted on the Field Test Boring Record and referenced to the sample number. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels can be used in order to obtain a sufficient quantity of sample for required analysis. Accordingly, the second and third 6-inch increments will be used to calculate the relative density.

The relative density designations for noncohesive soils are:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very loose	Less than 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	Greater than 50

The consistency of cohesive soils is also determined by blow counts as shown:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very Soft	Less than 2
Soft	2 to 4
Medium Stiff	4 to 8
Stiff	8 to 15
Very Stiff	15 to 30
Hard	Over 30

#### 5.3.4 Moisture Content

Moisture content is estimated in the field according to four categories: dry, damp, moist, and wet:

<u>Designation</u>	<u>Moisture Content</u>
Dry	0 to 10 percent
Damp	10 to 20 percent
Moist	20 to 35 percent
Wet	35 to 50 percent

Little or no water should appear in dry soil. Wet soils appear to contain all the water they can possibly hold (i.e., saturated). Damp and moist are subjective. Laboratory analysis should be performed if it is necessary to accurately determine the natural water content.

#### 5.3.5 Stratification

Stratification can only be determined after the split-barrel sampler is opened. Typically, bedding thicknesses are described as follows:

<u>Designation</u>	<u>Bedding Spacing</u>
Indistinct	No bedding apparent
Laminated	Less than 1/2-inch
Very thin	1/2-inch to 1-inch
Thin	1-inch to 4-inches
Medium	4-inches to 1-foot
Thick	1-foot to 3-feet
Massive	Greater than three feet

### 5.3.6 Texture/Fabric/Bedding

The texture/fabric/bedding of a soil shall be described, where appropriate. Texture is described as the relative angularity of the soil particles: rounded, subrounded, subangular, angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation or orientation. The bedding structure also shall be noted (e.g., stratified, lensatic, nonstratified, heterogeneous varved, etc.).

### 5.3.7 Summary of Soil Descriptions

In summary, soils shall be classified in a similar manner by each drilling inspector. The soil description shall include:

- Soil grain size with appropriate descriptors
- Color
- Relative density and/or consistency
- Moisture content
- Stratification
- Texture/fabric/bedding
- Other distinguishing features

These descriptors are evaluated and the soil classified according to the USCS. All information, measurements and observations shall be legibly recorded on a Field Test Boring Record.

## 5.4 Sedimentary Rock Classifications

Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. Sedimentary rocks are the most predominant type exposed at the earth's surface. As such, this section will consider only classification of sedimentary rocks. Standard geologic references should be used for the complete classification of sedimentary, igneous and metamorphic rocks.

For the purpose of completing the Field Test Boring Record in the field, sedimentary rocks should be classified using the following hierarchy:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Rock Quality Designation
- Weathering
- Other characteristics

#### 5.4.1 Rock Type

There are numerous types of sedimentary rocks such as sandstone, shale, siltstone, claystone, conglomerate, limestone, dolomite, coal, etc. The drilling inspector should select the most appropriate rock type based on experience. Some of the references listed in Section 7.0 provide a more complete discussion of sedimentary rock types.

In addition to selecting a rock type, the drilling inspector should record the grain size (and composition of grains and cement, if apparent) on the Field Test Boring Record. The following designation should be used to describe grain size in sedimentary rocks:

<u>Designation</u>	<u>Grain Size Diameter</u>
Cobbles	Greater than 64 mm (2.5-inches)
Pebbles	4 mm (0.16-inches) to 64 mm
Granules	2 mm (0.08-inches) to 4 mm
Very Coarse Sand	1 mm to 2 mm
Coarse Sand	0.5 mm to 1 mm
Medium Sand	0.25 mm to 0.5 mm
Fine Sand	0.125 mm to 0.25 mm
Very Fine Sand	0.0625 mm to 0.125 mm
Silt	0.0039 mm to 0.0625 mm
Clay	Smaller than 0.0039 mm

For individual boundaries of grain size, a scale can be used for coarse-grained rocks. However, the division between silt and clay likely will not be measurable in the field. This boundary shall be determined by use of a hand lens. If the grains cannot be seen with the unaided eye, but are distinguishable with a hand lens (5x magnification) the sample is silt. If the grains are not distinguishable with a hand lens, the sample is clay.

#### 5.4.2 Color

The color of rock can be determined in a manner similar to that for soil samples. Rock cores or fragments shall be classified while wet, when possible. Rock color charts shall not be used unless specified by the Project Manager.

#### 5.4.3 Bedding Thickness

The bedding thickness designation for soils (Section 5.3.5) shall also be used for rock descriptions.

#### 5.4.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness follows:

- Very Soft – Very soft indicates that the rock is easily gouged by a knife, easily scratched by a fingernail, and/or easily broken by hand
- Soft – Soft indicates that the rock may be gouged by a knife, scratched by a fingernail, difficult to break by hand, and/or powders when hit by a hammer.
- Medium Hard – Medium hard indicates that the rock is easily scratched by a knife and/or is easily broken when hit by a hammer.
- Hard – Hard indicates that the rock is difficult to scratch with a knife but may be broken with a hammer.
- Very Hard – Very hard indicates that the rock is difficult to break with a hammer.

Note the difference in usage between the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock while a gouge is much deeper.

#### 5.4.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is measured and is described by the following terms:

- Very Broken – Less than a 2-inch spacing between fractures
- Broken – A 2-inch to 1-foot spacing between fractures
- Blocky – A 1-foot to 3-foot spacing between fractures
- Massive – A 3-foot to 10-foot spacing between fractures

#### 5.4.6 Rock Quality Designation

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding four inches and dividing by the total length of core run:

$$RQD (\%) = r/l \times 100$$

Where:

- r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches, and have resulted from natural breaks. Natural breaks include slickenslides, joints, compaction slicks, bedding plane partings (not caused by drilling) friable zones, etc.
- l = Total length of core run.

The results of the RQD calculations shall be recorded on the Field Test Boring Record.

#### 5.4.7 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and also is useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Decomposed – Soft to very soft, bedding and fractures indistinct, no cementation.
- Highly weathered – very soft to soft, with medium hard relic rock fragments, little to moderate cementation. Vugs and openings in bedding and fracture planes, some of which may be filled.
- Weathered – Soft to medium hard. Good cementation, bedding and fractures are pronounced. Uniformly stained.
- Slightly weathered – Medium hard. Fractures pronounced, nonuniform staining, bedding distinct.
- Fresh – Medium hard to hard. No staining. Fractures may be present, bedding may or may not be distinct.

#### 5.4.8 Other Characteristics

The following items should be included in rock description, where applicable:

- Description of contacts between rock units (sharp or gradational)
- Stratification
- Description of any filled cavities
- Cementation (calcareous, siliceous, hematitic, etc.)
- Description of joints and open fractures (with strike and dip, if possible)
- Observation of the presence of fossils

#### 5.4.9 Additional Terms

The following terms also are used to further identify rocks:

- Seam – thin (1/2-inch or less), probably continuous layer.
- Some – Indicates significant (15 to 40 percent) amounts of an accessory material.
- Few – Indicates insignificant (0 to 15 percent) amounts of an accessory material.
- Interbedded – Indicates thin or very thin alternating seams of material occurring in approximately equal amounts.
- Interlayered – Indicates thick alternating seams of material occurring in approximately equal amounts.

### 6.0 QUALITY ASSURANCE RECORDS

Quality Assurance Records shall consist of completed Field Test Boring Records and Test Boring Records.

## 7.0 REFERENCES

1. American Society for Testing and Materials, 1990. Standard Methods for Classification of Soils for Engineering Purposes. ASTM Method D2487-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1990. Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). ASTM Method D2488-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

**APPENDIX B**  
**MONITORING WELL INSTALLATION**

---

---

**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
MONITORING WELL INSTALLATION**

---

**Page 1 of 8  
SOP Number: F103  
Effective Date: 04/94**

---

**TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Well Installation
  - 5.2 Drive Points
  - 5.3 Surface Completion
  - 5.4 Well Development
  - 5.5 Contaminated Materials Handling
  - 5.6 Well Construction Logs
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

**ATTACHMENT A -- ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

## MONITORING WELL INSTALLATION

### 1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at various sites.

### 2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities.

These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

### 3.0 DEFINITIONS

Monitoring Well - A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer - A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

Drive Point - A monitoring well which includes a screen casing and hardened point fabricated from stainless steel that is driven into the soil to complete the well. The drive point can also be installed by hand augering to try to formulate a sand pack around the screen.

### 4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel installing monitoring wells are familiar with these procedures. The Project Manager also is responsible for ensuring that all appropriate documents (e.g., test boring logs, monitoring well construction logs, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The Field Team Leader is responsible to provide copies of the well construction logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.

Drilling Inspector (Site Geologist) - The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to record details of the well installation, document subsurface conditions, complete the appropriate forms, supervise the drilling crew (or drilling supervisor), and record quantities of the drillers billable labor and materials.

## 5.0 PROCEDURES

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used.

The objectives for installing monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Facilitating site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic determination, monitoring wells or cluster wells should be used. In areas that are inaccessible to drill rigs (i.e., unstable surface soils), driven wells (drive points) may be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account for site conditions (e.g., underground utilities). The elevation and horizontal location of all monitoring wells shall be determined through a site survey upon completion of well installation.

### 5.1 Well Installation

The methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon also are available. Generally PVC is less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials, or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment A provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually be constructed using either 2-inch or 4-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. A larger or smaller diameter screen may be used to accommodate site-specific geologic conditions. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from 1 to 20 feet depending on site-specific conditions. For light nonaqueous phase liquid (LNAPL) applications, the screen should be installed such that at least 2 feet of screen is above the water table and the remainder of the screen extends below the water surface so that free product can enter the well. Should very shallow water table conditions be encountered, the screened interval in both the saturated and unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A 6-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids (DNAPLs) may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either 6 inches below the ground surface (for flush-mounted wells) to between approximately one and 2 feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successively backfilled with a well graded quartz-sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. The sand size used in well construction will be appropriate for the formation monitored by the well. Sand shall carefully be placed from the bottom of the boring to a minimum of 2 feet (or 20 percent of the total screen length) above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least two-foot thick shall be placed above the sand pack. For deep wells, a bentonite slurry may be more appropriate than pellets due to problems with bridging in the annular space.

The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of 3 to 4 percent bentonite powder (by dry weight) or equivalent grout. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space greater than 20 feet high. If the annular space is less than 20 feet high, the grout may be poured directly into the annular space.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Well Construction Record (Attachment C) or in a field logbook.

## **5.2 Drive Points**

Drive points may be constructed in one of two ways. If the drive point is hammered into place, no other well construction will take place. (Note that the well assembly is fabricated from 2-inch diameter stainless steel

and includes a screen casing, and hardened point). The drive points will be sampled according to SOP F104, "Groundwater Sample Acquisition."

### **5.3 Surface Completion**

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a 4- or 6- inch diameter, 5-foot long steel casing into the cement grout with locking cap and lock. The bottom of the surface casing will be placed at a minimum of 2- 1/2, but not more than 3- 1/2 feet below the ground surface. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal. A concrete apron shall be constructed around the steel casing.

The second method considers flush-mounted wells, typically installed where a stick-up installation would present a traffic hazard. The monitoring well shall be completed at the surface using a "flush" mount type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete apron. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

Project specific tasks may require that all monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing or locking cap. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron, if appropriate.

### **5.4 Well Development**

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501, entitled "Decontamination of Drilling Rigs and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

In general, all wells shall be developed until well water runs relatively clear of fine-grained materials. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A minimum pumping time period (typically one hour for shallow wells 10 to 30 feet deep).
- A minimum borehole volume (typically three borehole volumes) or until well goes dry.
- Stability of specific conductance, turbidity, and temperature measurements (typically less than 10 percent change between three successive measurements).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Well development limits shall be specified in project-specific plans. A record of the well development (Figure A-3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. However, this stabilization period may be adjusted based upon project-specific requirements.

### **5.5 Contaminated Materials Handling**

SOP F504, entitled "Handling of Site Investigation Derived Waste," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the Sampling and Analysis Plan. In general, all site investigation generated wastes shall be containerized unless otherwise specified by the Sampling and Analysis Plan. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

### **5.6 Well Construction Records**

Field Well Construction Records shall be completed by the Drilling Inspector for each monitoring well installed. These records preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook

and later transfer it to the Field Well Construction Record. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within 5 days, and prior to demobilization from the field.

Field Well Construction Records shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Record, or in the field logbook, as appropriate:

- Project name and location.
- Project and Task number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Record will be used to generate a final Well Construction Record which combines the Field Boring and Well Construction Logs into one package.

## **6.0 QUALITY ASSURANCE RECORDS**

The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

## 7.0 REFERENCES

1. Driscoll, Fletcher, G., 1986, Groundwater and Wells , Johnson division. St. Paul, Minnesota. 2nd ed..
2. Roscoe Moss Company, 1990, Handbook of Ground Water Development. John Wiley & Sons. New York.
3. USEPA, September, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.
4. Aller, L. et al. , June 1989, Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. Dublin, Ohio.

**ATTACHMENT A**  
**ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

## ATTACHMENT A

### ALTERNATE WELL CASING MATERIAL JUSTIFICATION

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."
2. The anticipated compounds and their concentration ranges.
3. The anticipated residence time of the sample in the well and the aquifer's productivity.
4. The reasons for not using other casing materials.
5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.
6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.
7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

**APPENDIX C**  
**GROUNDWATER SAMPLE ACQUISITION**

---

**GROUNDWATER SAMPLE ACQUISITION  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sampling, Monitoring, and Evaluation Equipment
  - 5.2 Calculations of Well Volume
  - 5.3 Evacuation of Static Water (Purging)
    - 5.3.1 Evacuation Devices
  - 5.4 Sampling
    - 5.4.1 Sampling Methods
    - 5.4.2 Sample Containers
    - 5.4.3 Preservation of Samples and Sample Volume Requirements
    - 5.4.4 Field Filtration
    - 5.4.5 Handling and Transportation Samples
    - 5.4.6 Sample Holding Times
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## **GROUNDWATER SAMPLE ACQUISITION**

### **1.0 PURPOSE**

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

### **2.0 SCOPE**

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

### **5.0 PROCEDURES**

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained

from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from separation of flow streams by physical division (for example, around clay lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site-specific and must be addressed in the Sampling and Analysis Plan.

#### **5.1 Sampling, Monitoring, and Evacuation Equipment**

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment: Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.
2. Field tools and instrumentation: PID; Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.
3. Pumps
  - a. Shallow-well pumps: Centrifugal, Packer Pumps, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
  - b. Deep-well pumps: Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing: Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment: Bailers, Packer Pumps, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.
6. Pails: Plastic, graduated.
7. Decontamination equipment and materials: discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

## **5.2 Calculations of Well Volume for Purging**

The volume of the cylinder of water in a well is given by:

Where:  $V$  = volume of standing water in well (in cubic feet)

r=well radius (in feet)  
h=standing water in well (in feet)

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).
2. Determine well or casing diameter (D).
3. Measure and record static water level (DW-depth to water below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.
5. Calculate number of linear feet of static water (total well depth minus the depth to static water level).
6. Calculate the volume of water in the casing:

$$V_{gal} = V_W \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = V_{gal} (\# \text{ Well Vol})$$

Where:

$V_W$  = Volume of water standing in well in cubic feet (i.e., one well volume)  
 $\pi$  = pi, 3.14  
 $r$  = Well radius in feet  
 $TD$  = Total depth of well in feet (below ground surface or top of casing)  
 $DW$  = Depth to water in feet (below ground surface or top of casing)  
 $V_{gal}$  = Volume of water in well in gallons  
 $V_{purge}$  = Volume of water to be purged from well in gallons  
 $\# \text{ Well Vol.}$  = Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note:  $V_{\text{purge}}$  should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameters.

**TABLE 5-1  
WELL VOLUMES**

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

### **5.3 Evacuation of Static Water (Purging)**

The amount of purging a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

### 5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will

cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

#### 5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last

to reduce the risk of cross-contamination between wells as a result of the sampling procedures.

6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

#### 5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, measure the total depth and water level (with decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a distance just below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).
4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters. Record the method of discharge measurement.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.

7. Record measurements of specific conductance, temperature, and pH during purging to ensure that the groundwater level has stabilized. Generally, these measurements are made after the removal of three, four, and five well volumes.
8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.
11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).
12. Volatile organics septum vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

Fill the remaining sample containers in order of decreasing volatility (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.

14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

#### **5.4.2 Sample Containers**

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2 047B.

#### **5.4.3 Preservation of Samples and Sample Volume Requirements**

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

#### **5.4.4 Field Filtration**

In general, preparation and preservation of water samples for dissolved inorganics involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be analyzed as "total metals" and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of groundwater is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

#### **5.4.5 Handling and Transporting Samples**

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the

ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

#### **5.4.6 Sample Holding Times**

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

### **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

### **7.0 REFERENCES**

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D4448-85A**

**STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS**



## Standard Guide for Sampling Groundwater Monitoring Wells<sup>1</sup>

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).<sup>2</sup> The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for  $\mu\text{g/L}$  (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

### 3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

Current edition approved Aug. 23 and Oct. 25, 1985. Published May 1986.

<sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P— Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fc Pb/Se/ Ag/Mn/Na	1000-2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200-300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500-1000	G	cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Miscellaneous	1000-2000	P	cool, 4°C	28 days
Fluoride	300-500	P		28 days
Chloride	50-200	P/G		28 days
Sulfate	100-500	P/G		48 hours
Nitrate	100-250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25-100	P/G	cool, 4°C or cool, 4°C HCl or H <sub>2</sub> SO <sub>4</sub> to pH <2	24 h
Pesticides, herbicides and total organic halogen (TOX)	1000-4000	G/TFE-fluoro-carbon lined cap solvent rinsed	cool, 4°C	28 days
Extractable organics	1000-2000	G/TFE-fluoro-carbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25-120	G/vial TFE-fluoro-carbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

#### 4. Well Flushing (Purging)

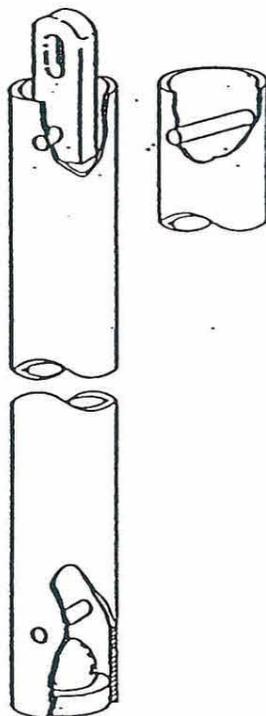
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of sample with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Baller

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

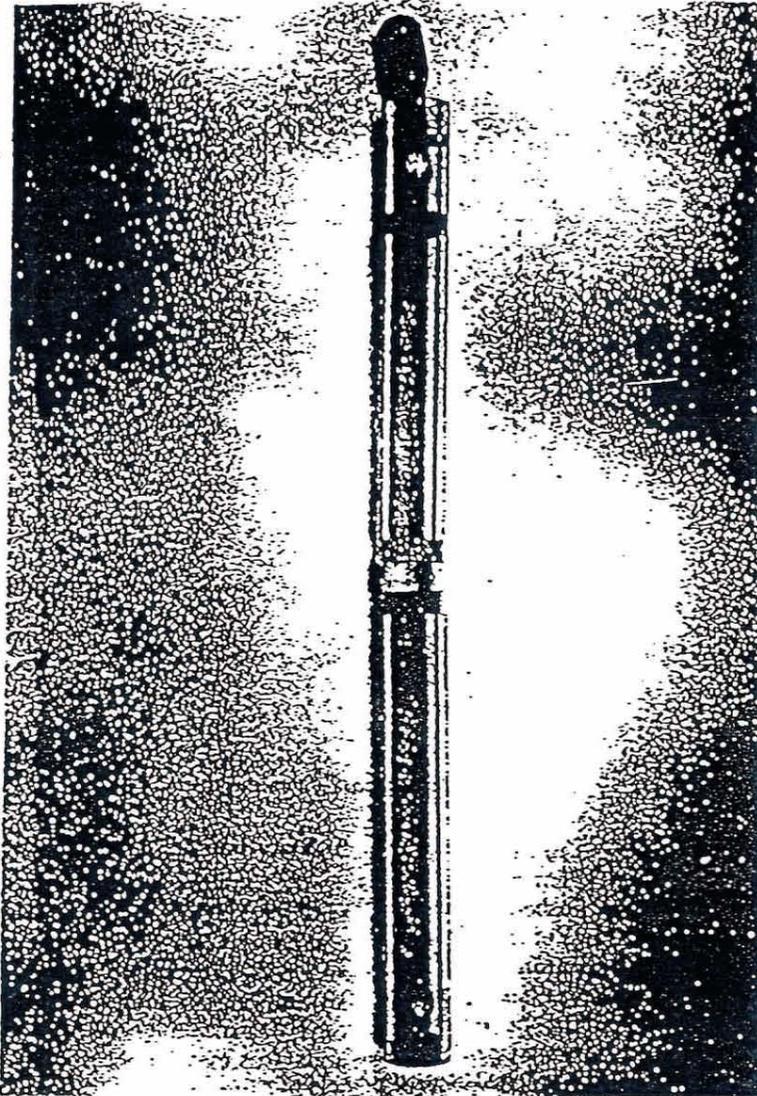
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

## 5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ( $\mu\text{g/L}$  levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Baller

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

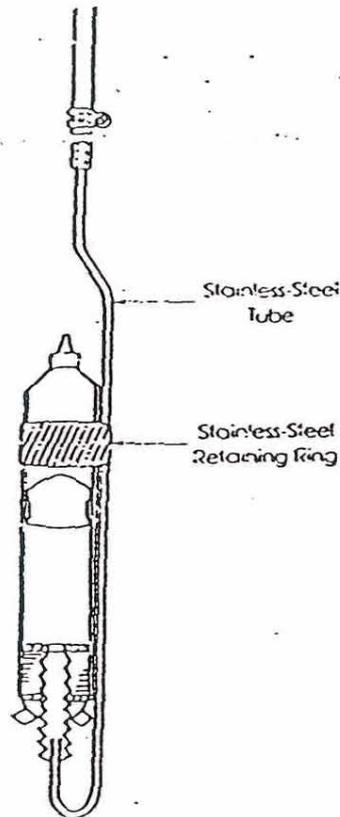
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course glass sampling equipment must be handled carefully in the field. Stainless steel is strong and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

## 6. Sampling Equipment

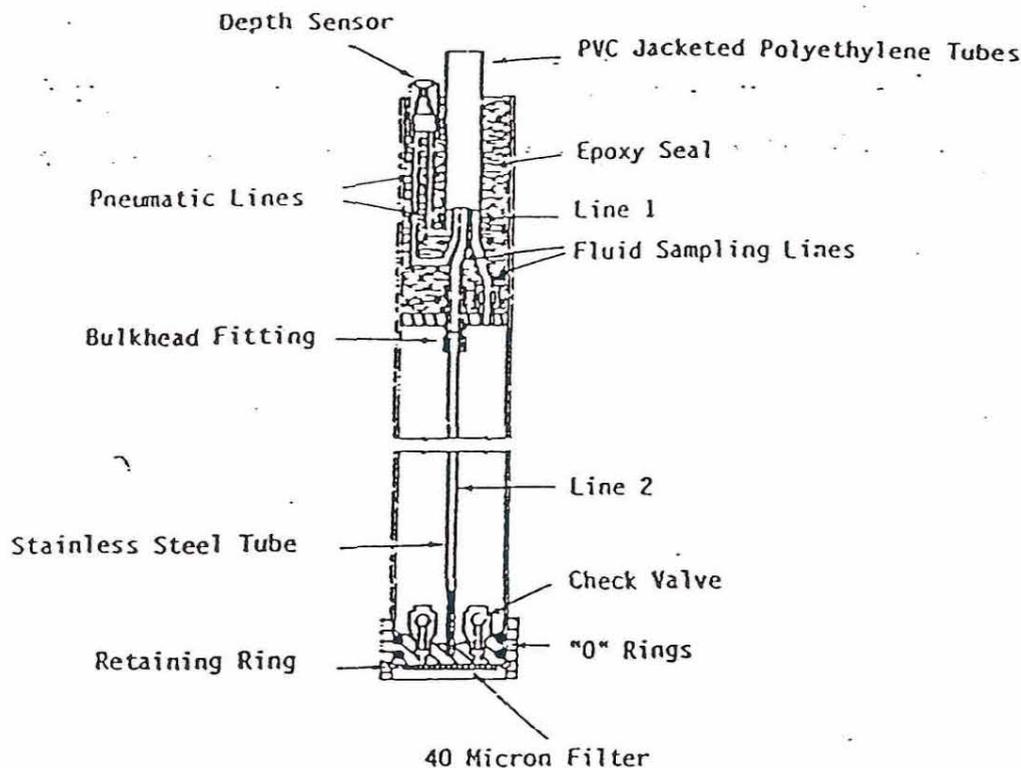
6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categorized into the following eight basic types.

### 6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are practical for removal of large volumes of water. These devices can be constructed in various shapes and sizes for a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling volatile organic compounds should have a sample collection draft valve in or near the bottom of the sampler. At withdrawal of a sample from the well below the exposure surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and samplers should be kept off the ground and free of contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in





NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

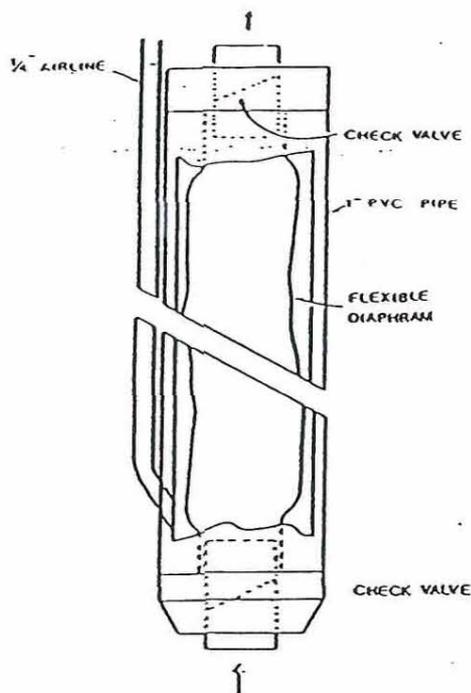
of thief or messenger devices are available in various materials and shapes.

#### 6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clear between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connecte



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton<sup>3</sup> for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

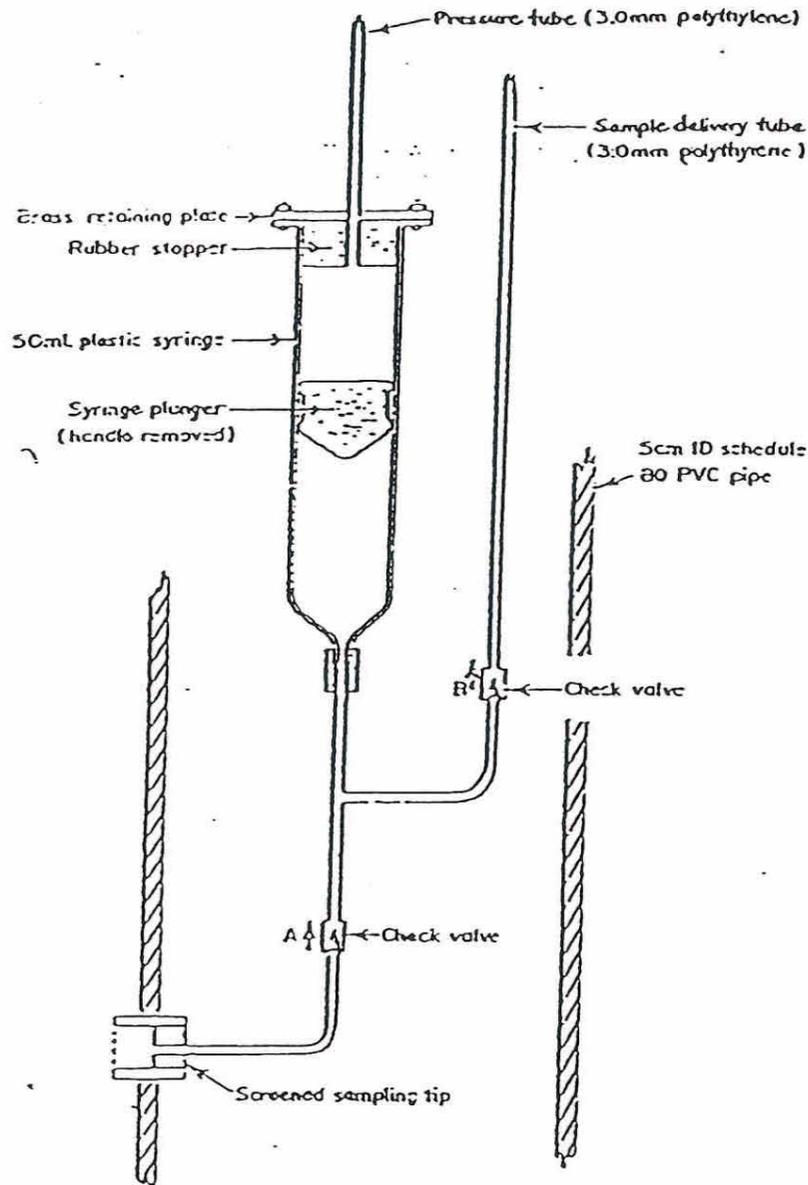
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

### 6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

<sup>3</sup> Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

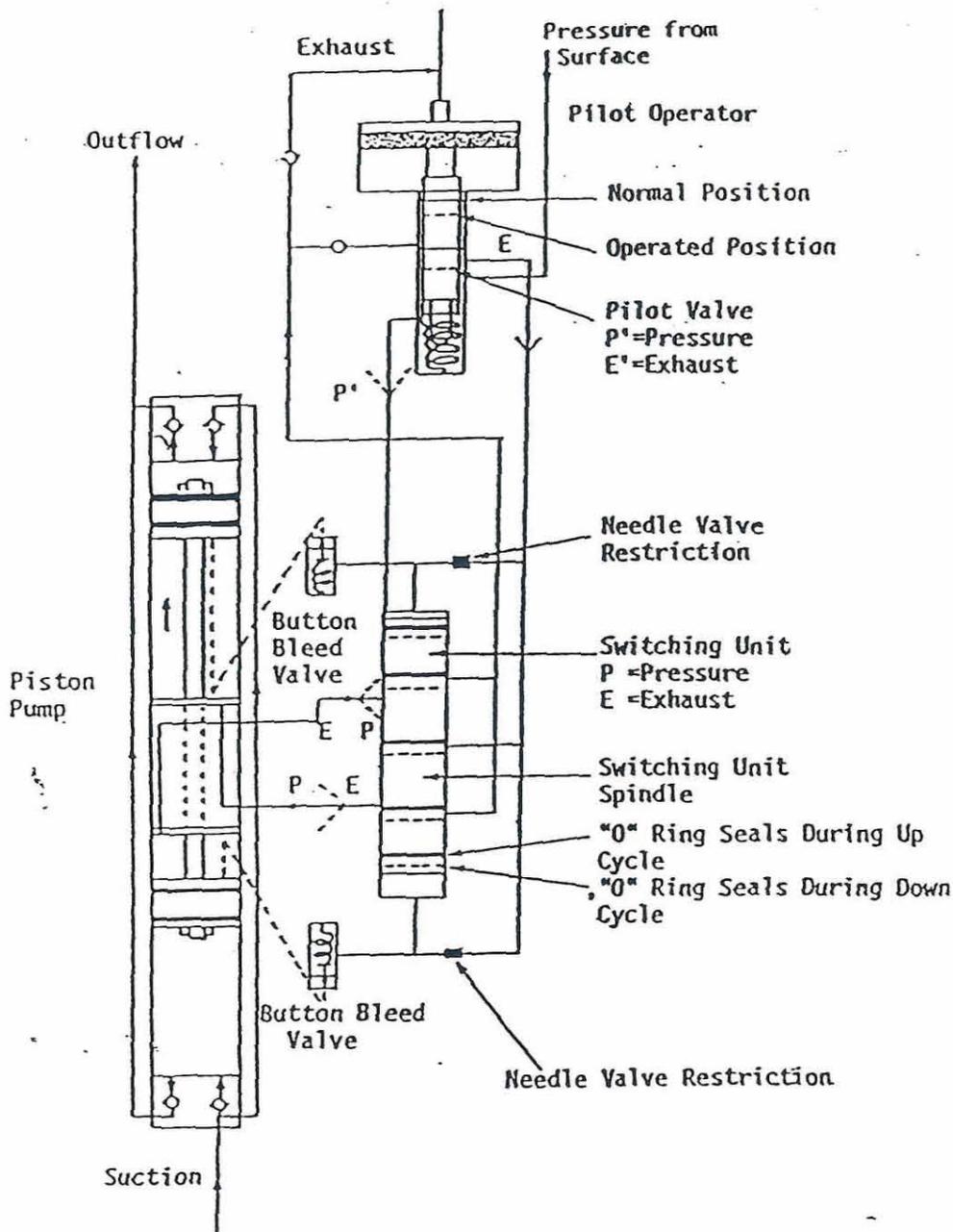
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

#### 6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

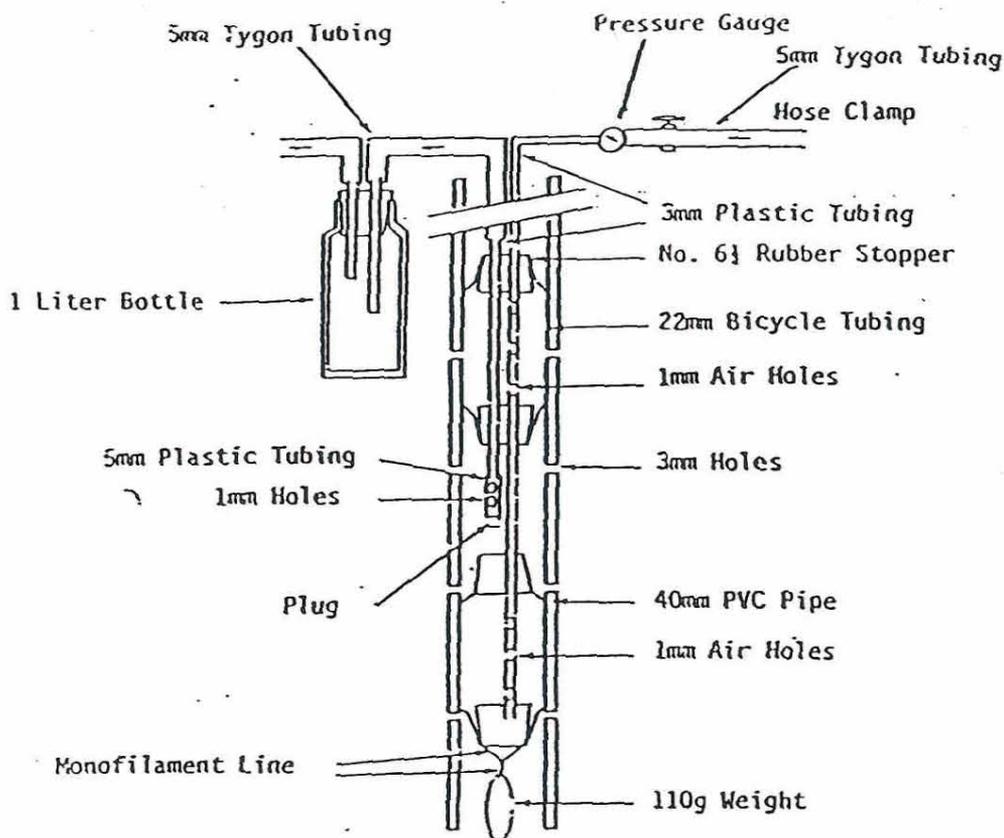
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

#### 6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 10. Water fills the chamber. A positive pressure is applied to



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sampler in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sampler with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

#### 6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.<sup>3</sup> A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volume required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

#### 6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

#### 6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

## 7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a record thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been pre-cleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

## REFERENCES

- (1) Gibb, J. P., Schuller, R. M., Griffin, R. A., *Monitoring Well Sampling and Preservation Techniques*, EPA-600/9-80-101, 1980.
- (2) Pettyjohn, W. A., Dunlap, W. J., Cosby, R. L., Keeley, J. W., "Sampling Ground Water for Organic Contaminants," *Ground Water*, Vol 19, (2), March/April 1981, pp. 180-189.
- (3) Dunlap, W. J., McNabb, J. F., Scalf, M. R., Cosby, R. L., *Sampling for Organic Chemicals and Microorganisms in the Subsurface*, EPA-600/2-77-176, NTIS PB 276 679, August 1977, 35 pp.
- (4) Scalf, M. R., McNabb, J. F., Dunlap, W. J., and Cosby, R. L., *Manual of Ground Water Quality Sampling Procedures*, National Water Well Association, NTIS PB-82 103 045, 1981.
- (5) "A Guide to Groundwater Sampling," *NCASI Technical Bulletin*, No. 362, January 1982.
- (6) Humenick, M. J., Turk, L. J., Coldrin, M., "Methodology for Monitoring Ground Water at Uranium Solution Mines," *Ground Water*, Vol 18 (3), May-June 1980, p. 262.
- (7) Marsh, J. M., and Lloyd, J. W., "Details of Hydrochemical Variations in Flowing Wells," *Ground Water*, Volume 18 (4), July-August 1980, p. 366.
- (8) Gibb, J. P., Schuller, R. M., Griffin, R. A., "Collection of Representative Water Quality Data from Monitoring Wells," *Proceeding of the Municipal Solid Waste Resource Recovery Symposium*, EPA-600/9-81-002A, March 1981.
- (9) Boettner, E. A., Gwendolyn, L. B., Zand, H., Aquino, R., *Organic and Organotin Compounds Leached from PVC and CPVC Pipe*, NTIS P8 82-108 333, 1982.
- (10) Junk, G. A., Svcc, H. J., Vick, R. D., Avery, M. J., "Contamination of Water by Synthetic Polymer Tubes," *Environmental Science and Technology*, Vol 8 (13) 1100, December 1974.
- (11) Louneman, W. A., Bufalini, J. J., Kuntz, R. L., and Meeks, S. A., "Contamination from Fluorocarbon Films," *Environmental Science and Technology*, Vol 15 (1), January 1981.
- (12) ASC Committee on Environmental Improvement, "Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry," *Analytical Chemistry*, Vol 52, 1980, pp. 2242-2249.
- (13) *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977.
- (14) *Handbook for Sampling and Sample Preservation of Water and Wastewater*, U.S. Dept. of Commerce NTIS PB-259 946, September 1976.
- (15) Timco Manufacturing Co., Inc., "Variable Capacity Bailer," *Tin Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
- (16) deVera, E., Simmons, B., Stephens, R., Storm, D., *Samplers and Sampling Procedures for Hazardous Waste Streams*, Environmental Protection Agency, EPA-600/2-80-018, 1980, p. 51.
- (17) Morrison, R., *Ground Water Monitoring Technology*, Tin Manufacturing Co., 1982, p. 276.
- (18) Eijlkamp, "Equipment for Soil Research," *General Catalogue*, Geisboeck, The Netherlands, 1979, pp. 82-83.
- (19) Wood, W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, 1976, p. 24.
- (20) Gilham, R. W., "Syringe Devices for Groundwater Monitoring," *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982, p. 1.
- (21) Masterflex, *Masterflex Pump Catalogue*, Barnant Co. Barrington, IL, 1981.
- (22) "Guidelines for Contracting Sampling and Analyses for Priority Pollutants in Pulp and Paper Industry Effluents," *NCASI Solid Waste Improvement Technical Bulletin*, No. 335, August 1980.
- (23) Allison, L., "A Simple Device for Sampling Ground Water Auger Holes," *Soil Science Society of America Proceeding* 844-45, 1971.
- (24) Willardson, L., Meek, B., Huber, M., "A Flow Path Ground Water

- Sampler," *Soil Science Society of America Proceedings* 36: 965-66, 1972.
- (25) Wilson, L., *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, U.S. Environmental Protection Agency, EPA-600/17-80-134, 1980, p. 180.
  - (26) *Ground Water and Wells*, Johnson, E. E., Inc., St. Paul, MN, 1980, p. 440.
  - (27) Keck, W. G. and Associates, *New "Keck" Submersible Water Sampling Pump for Groundwater Monitoring*, Keck, W. G. and Associates, East Lansing, MI, 1981.
  - (28) McMillion, L., and Keeley, J. W., "Sampling Equipment for Ground-Water Investigation," *Ground Water*, Vol 6, 1968, pp. 9-11.
  - (29) Industrial and Environmental Analysts, Inc., *Procedures and Equipment for Groundwater Monitoring*, Industrial and Environmental Analysts, Inc., Essex Junction, VT, 1981.
  - (30) Trescott, P., and Pinder, G., "Air Pump for Small-Diameter Piezometers," *Ground Water*, Vol 8, 1970, pp. 10-15.
  - (31) Sommerfeldt, T., and Campbell, D., "A Pneumatic System to Pump Water From Piezometers," *Ground Water*, Vol 13, p. 293.
  - (32) Smith, A., "Water Sampling Made Easier with New Device," *The Johnson Drillers Journal*, July-August 1976, pp. 1-2.
  - (33) Morrison, R., and Ross, D., "Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites," *Proceedings of 1978 National Conference on Control of Hazardous Material Spills*, April 13, Miami Beach, FL, 1968, pp. 281-286.
  - (34) Morrison, R., and Brewer, P., "Air-Lift Samplers for Zone-of-Saturation Monitoring," *Ground Water Monitoring Review*, Spring 1981, pp. 52-54.
  - (35) Morrison, R., and Timmons, R., "Groundwater Monitoring II," *Groundwater Digest*, Vol 4, 1981, pp. 21-24.
  - (36) Bianchi, W. C., Johnson, C., Haskell, E., "A Positive Action Pump for Sampling Small Bore Holes," *Soil Science Society of America Proceedings*, Vol 26, 1961, pp. 86-87.
  - (37) Timmons, R., Discussion of "An All-Teflon Bailer and An Air-Driven Pump for Evacuating Small-Diameter Ground-Water Wells" by D. Buss and K. Bandt, *Ground Water*, Vol 19, 1981, pp. 666-667.
  - (38) Timco Manufacturing Co., Inc., "Gas Lift Teflon Pump," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
  - (39) Tomson, M., King, K., Ward, C., "A Nitrogen Powered Continuous Delivery, All Glass Teflon Pumping System for Groundwater Sampling from Below 10 Meters," *Ground Water*, Vol 18, 1980, pp. 444-446.
  - (40) *Pneumatic Water Sampler*, Slope Indicator Co., Seattle, WA, 1982.
  - (41) Petur Instrument Co., Inc., *Petur Liquid Sampler*, Petur Instrument Co., Inc., Seattle, WA, 1982.
  - (42) Idler, G., "Modification of an Electronic Downhole Water Sampler," *Ground Water*, Vol 18, 1980, pp. 532-535.
  - (43) *Remote Sampler Model 200*, Markland Specialty Engineering Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.
  - (44) Middleburg, R., "Methods for Sampling Small Diameter Wells for Chemical Quality Analysis," *Presented at the National Conference on Quality Assurance of Environmental Measurements*, Nov. 27-29, Denver, CO, 1978.
  - (45) *Air Squeeze Pump*, Leonard Mold and Die Works, Denver, CO, 1982.
  - (46) *Automatic Sampler Controller: Markland Model 105 and 2105*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 105/78, 1981.
  - (47) Gillham, R. W., and Johnson, P. E., "A Positive Displacement Ground-Water Sampling Device," *Ground Water Monitoring Review*, Vol 1 (2), Summer 1981, p. 33.
  - (48) Signor, D., "Gas-Driven Pump for Ground-Water Samples," *U.S. Geological Survey, Water Resources Investigation 78-72*, Open File Report, 1978.
  - (49) *Tigre Tierra HX Pneumatic Packer*, Tigre Tierra, Inc., Puyallup, WA, 1981.
  - (50) Cherry, R., "A Portable Sampler for Collecting Water Samples from Specific Zones in Uncased or Screened Wells," *U.S. Geological Survey, Prof. Paper 25-C*, 1965, pp. 214-216.
  - (51) Grisak, G., Merritt, W., Williams, D., "Fluoride Borehole Dilution Apparatus for Groundwater Velocity Measurements," *Canadian Geotechnical Journal*, Vol 14, 1977, pp. 554-561.
  - (52) Galgowski, C., Wright, W., "A Variable-Depth Ground-Water Sampler," *Soil Science Society of America Proceedings*, Vol 44, 1980, pp. 1120-1121.
  - (53) *Samplers and Sampling Procedures for Hazardous Waste Streams*, USEPA MERL Laboratory, Cincinnati, OH; EPA-600/2-80-018, January 1980.
  - (54) *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
  - (55) *Federal Register*, Vol 44, No. 244, Dec. 18, 1979, pp. 75050-75052.
  - (56) *Standard Methods for the Examination of Water and Wastewater*, APAA, 14th ed., Washington, DC, 1976, pp. 38-45.
  - (57) *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*, EPA-600/4-79-019, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
  - (58) U.S. Department of Interior, "Groundwater," Chapter II, *National Handbook of Recommended Methods for Water Data Acquisition*, 1980.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

**APPENDIX D**  
**ON-SITE WATER QUALITY TESTING**

---

**ON-SITE WATER QUALITY TESTING  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Measurement of pH
  - 5.2 Measurement of Specific Conductance/Salinity
  - 5.3 Measurement of Temperature
  - 5.4 Measurement of Dissolved Oxygen Concentration
  - 5.5 Turbidity (Secchi Disc)
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

### 1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance (Sc)/Salinity
- Temperature (T)
- Dissolved Oxygen Concentration (DO)
- Turbidity (Secchi Disc)

The first three are the usual field parameters; dissolved oxygen may be used in particular applications according to project requirements.

### 2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

### 3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance (mhos) are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration. The range of pH is 0 to 14 standard units.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law,  $E = IR$ , where E is the potential difference (in units of volts), I is the current (in units of Amperes), and R is the resistance (in units of ohms).

Secchi disc - A metal disc having four quadrants, two opposing ones painted black and the other two either white or unpainted. The Secchi disc is used to measure turbidity based on the depth of light penetration.

Turbidity - An optical property of water that causes light to be scattered or absorbed in the water, resulting in decrease in water transparency. It is a function of at least three variables: 1) dissolved chemicals, such as tannins, acids, or salts; 2) suspended particles, such as silt, clay, and organic matter; and, 3) density of microbial and planktonic life.

Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants.

#### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP, or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

## 5.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance/salinity, temperature, dissolved oxygen concentration and turbidity measurements.

### 5.1 Measurement of pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques for solids are not described here.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required; the pH meter is used when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In most cases, use of a pH meter will be required.

#### 5.1.1 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

#### 5.1.2 Equipment

The following equipment and reagents are needed for taking pH measurements:

- Portable pH meter, or pH indicator paper, such as Mydrion or Alkacid, to cover the pH range 2 through 12.
- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

### 5.1.3 Measurement Techniques for Field Determination of pH

#### A. pH Meter

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions. The following procedure is used for measuring pH with a pH meter:

1. The batteries and instrument shall be checked and calibrated prior to initiation of the field effort.
2. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
3. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
4. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
5. Immerse the electrode(s) in a pH-7 buffer solution.
6. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.
7. Adjust the pH meter to read 7.0.
8. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.

9. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
10. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.
11. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
12. The electrode(s) shall remain immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution within the electrode, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the Field Logbook.

#### B. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

### 5.2 Measurement of Specific Conductance/Salinity

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water. Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants. One basic measure of salinity is the ability of water to conduct electric current, and, therefore, a measurement of specific conductance provides a measurement of salinity and the same instrument can be used. Salinity measurements are important in ecological field investigations because flora and fauna can be limited in their distribution based on the salinity of the sampled waters.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance and salinity measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

### **5.2.1 Principles of Equipment Operation**

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions (cations) migrate toward the negative electrode (cathode), while the negatively charged ions (anions) migrate toward the positive electrode (anode). Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

### **5.2.2 Equipment**

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements. A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

### **5.2.3 Measurement Techniques for Specific Conductance/Salinity**

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions. The steps involved in taking specific conductance and salinity measurements are listed below.

1. Check batteries and calibrate instrument before going into the field.
2. Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used. Calibration information shall be recorded in the field logbook.

3. Rinse the cell with one or more portions of the sample to be tested or with deionized water.
4. Immerse the electrode in the sample and measure the conductivity and salinity. If specified, adjust the temperature setting to the sample temperature.
5. Read and record the results on the Calibration Form (in the absence of the Calibration Form, the Field Logbook will be used).
6. If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
7. On some meters, specific conductivity and salinity measurements may need to be reported with the associated temperature measurement. If the conductivity and salinity has been corrected, the measurements shall be reported as "corrected to 25°C." (See Attachment A)
  - a. Do not take readings if the sample temperature is less than 10° C, because the calibration curve no longer follows a straight line below this temperature. If necessary, heat the sample in your vehicle to at least 10° C.
  - b. Measure the sample temperature to the nearest 0.1° C to comply with SW-846.
  - c. Only report results to the nearest two significant digits for the most circumstances, because of the inherent inaccuracy in the test and conversion procedure.

examples:

- a calculated reading of 2353 umhos/cm @ 25° C should be reported as 2400 umhos/cm @ 25° C
- a calculated reading of 2325 should be reported as 2300
- a calculated reading of 337 should be reported as 340
- etc.

### **5.3 Measurement of Temperature**

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field prior to sample collection. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

### **5.3.1 Equipment**

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or bimetal thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

### **5.3.2 Measurement Techniques for Water Temperature**

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a Field Logbook to the nearest 0.5 or 0.1°C, depending on the measurement device used.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to the manufacturer's recommendations with an approved thermometer.

## **5.4 Measurement of Dissolved Oxygen Concentration**

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms, as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time, if the sample is not adequately preserved.

The method discussed here is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible. DO meters also are free from interference caused by color, turbidity, colloidal material or suspended matter.

### **5.4.1 Principles of Equipment Operation**

Dissolved oxygen probes normally are electrochemical cells that have two solid metal electrodes of different potential immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of higher nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If gaseous interference is suspected, it shall be noted in the Field Logbook and checked if possible. Temperature variations also can cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation normally is provided by the manufacturer. Attachment B presents variations of DO in water as a function of temperature and salinity.

#### **5.4.2 Equipment**

The following, similar or equivalent, equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor (or equivalent).
- Dissolved oxygen/temperature probe.
- Sufficient cable to allow the probe to contact the sample.

#### **5.4.3 Measurement Techniques for Dissolved Oxygen Determination**

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration.

1. Calibrate equipment and check batteries in the laboratory before going to the field.
2. The probe shall be conditioned in a water sample for as long as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
3. The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).

4. Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers which are placed in wells should be moved up and down.
5. Record the dissolved oxygen content and temperature of the sample in a Field Logbook.
6. Recalibrate the probe when the membrane is replaced, or following similar maintenance, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This, however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or whether a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen dissolution and positive test interferences.

### **5.5 Measurement of Turbidity Using a Secchi Disc**

In combination with other parameters, turbidity can be a useful indicator of the likelihood of biological action in a water body. It can be used to determine the depth of light penetration of surface water and the distribution and intensity of photosynthesis in the body of water. Turbidity measurements shall be taken in-situ with a Secchi disc.

#### **5.5.1 Equipment**

Turbidity measurements may be taken with a Secchi disc. In addition, turbidity may be measured using a colimeter or a spectrophotometer. These are ex-situ measurements conducted in a laboratory environment.

#### **5.5.2 Measurement Techniques for Turbidity**

Observations must be made through a shaded area of water surface.

- Standard conditions for the use of the Secchi disc are: 1) clear sky; (2) sun directly overhead; 3) shaded, protected side of boat or under a sun shade; 4) minimal waves or ripples; and, 5) any departure from these conditions should be specifically stated on field sheets.
- Rope accurately graduated in meters with 0.1 meter graduations for the first meter and 0.5 meters thereafter.
- Observer's eye should be 1 meter above the surface of the water.

- Observations should be made during the middle of the day.
- Lower the disc into the water, noting the depth at which it disappears, then lift the disc and note the depth at which it reappears. The average of the two readings is considered to be the limit of visibility and is recorded in a Field Logbook to the nearest 0.1 meter (first meter) or 0.5 meter, depending on the depth of visibility.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records for on-site water quality management consists principally of observations and measurements recorded in the Field Logbook. Records of instrument calibration, malfunction, repair, etc., shall be maintained in an Equipment Logbook as described in the Navy CLEAN Contractor Quality Control Plan.

## 7.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

**ATTACHMENT A**

**SPECIFIC CONDUCTANCE CONVERSION TABLE**

**ATTACHMENT A  
SPECIFIC CONDUCTANCE CONVERSION TABLE**

Temperature Degrees C	Calculated Multiplier								
10	1.402	12	1.330	14	1.266	16	1.208	20	1.106
10.1	1.398	12.1	1.327	14.1	1.263	16.1	1.205	20.1	1.103
10.2	1.394	12.2	1.324	14.2	1.260	16.2	1.202	20.2	1.101
10.3	1.390	12.3	1.320	14.3	1.257	16.3	1.199	20.3	1.099
10.4	1.387	12.4	1.317	14.4	1.254	16.4	1.197	20.4	1.096
10.5	1.383	12.5	1.314	14.5	1.251	16.5	1.194	20.5	1.094
10.6	1.379	12.6	1.310	14.6	1.248	16.6	1.191	20.6	1.092
10.7	1.376	12.7	1.307	14.7	1.245	16.7	1.188	20.7	1.089
10.8	1.372	12.8	1.304	14.8	1.242	16.8	1.186	20.8	1.087
10.9	1.369	12.9	1.301	14.9	1.239	16.9	1.183	20.9	1.085
11	1.365	13	1.297	15	1.236	17	1.180	21	1.083
11.1	1.361	13.1	1.294	15.1	1.233	17.1	1.178	21.1	1.080
11.2	1.358	13.2	1.291	15.2	1.230	17.2	1.175	21.2	1.078
11.3	1.354	13.3	1.288	15.3	1.227	17.3	1.172	21.3	1.076
11.4	1.351	13.4	1.285	15.4	1.225	17.4	1.170	21.4	1.074
11.5	1.347	13.5	1.281	15.5	1.222	17.5	1.167	21.5	1.072
11.6	1.344	13.6	1.278	15.6	1.219	17.6	1.165	21.6	1.069
11.7	1.341	13.7	1.275	15.7	1.216	17.7	1.162	21.7	1.067
11.8	1.337	13.8	1.272	15.8	1.213	17.8	1.159	21.8	1.065
11.9	1.334	13.9	1.269	15.9	1.210	17.9	1.157	21.9	1.063
22	1.061	24	1.019	26	0.981	28	0.946	30	0.913
22.1	1.059	24.1	1.017	26.1	0.979	28.1	0.944	30.1	0.911
22.2	1.057	24.2	1.016	26.2	0.978	28.2	0.942	30.2	0.910
22.3	1.054	24.3	1.014	26.3	0.976	28.3	0.941	30.3	0.908
22.4	1.052	24.4	1.012	26.4	0.974	28.4	0.939	30.4	0.907
22.5	1.050	24.5	1.010	26.5	0.972	28.5	0.937	30.5	0.905
22.6	1.048	24.6	1.008	26.6	0.970	28.6	0.936	30.6	0.903

Temperature Degrees C	Calculated Multiplier								
22.7	1.046	24.7	1.006	26.7	0.969	28.7	0.934	30.7	0.902
22.8	1.044	24.8	1.004	26.8	0.967	28.8	0.932	30.8	0.900
22.9	1.042	24.9	1.002	26.9	0.965	28.9	0.931	30.9	0.899
23	1.040	25	1.000	27	0.963	29	0.929	31	0.897
23.1	1.038	25.1	0.998	27.1	0.961	29.1	0.927	31.1	0.896
23.2	1.036	25.2	0.996	27.2	0.960	29.2	0.926	31.2	0.894
23.3	1.034	25.3	0.994	27.3	0.958	29.3	0.924	31.3	0.893
23.4	1.032	25.4	0.992	27.4	0.956	29.4	0.922	31.4	0.891
23.5	1.029	25.5	0.991	27.5	0.954	29.5	0.921	31.5	0.890
23.6	1.027	25.6	0.989	27.6	0.953	29.6	0.919	31.6	0.888
23.7	1.025	25.7	0.987	27.7	0.951	29.7	0.918	31.7	0.887
23.8	1.023	25.8	0.985	27.8	0.949	29.8	0.916	31.8	0.885
23.9	1.021	25.9	0.983	27.9	0.948	29.9	0.914	31.9	0.884

Notes:

- Do not make specific conductance measurements at temperatures below 10° C.
- Measure temperature to the nearest 0.1° C.
- Report all conductivities at 25° C, to two significant digits.
- This conversion table is based on a temperature coefficient of 0.0191 (as per SW-846) and a cell constant of 1, where the ratio of conductivity at 25 C to the conductivity at temperature t° C equals  $1/(1+0.0191[t-25])$ .
- The temperature coefficient and cell constants are only approximate, actual values may differ.
- The more the temperature deviates from 25° C, the greater the uncertainty in applying the temperature correction.

**ATTACHMENT B**

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION  
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride					
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.106
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride					
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008

**APPENDIX E**  
**WATER LEVEL, WATER-PRODUCT LEVEL**  
**MEASUREMENTS, AND**  
**WELL DEPTH MEASUREMENTS**

---

**WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND  
WELL DEPTH MEASUREMENTS  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Water Level Measurement
  - 5.2 Groundwater-Product Interface Level Measurement
  - 5.3 Well Depth Measurements
  - 5.4 Decontamination of Measuring Devices
- 6.0 QUALITY ASSURANCE RECORDS**

## **WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS**

### **1.0 PURPOSE**

The purpose of this procedure is to describe the method of determining various down-hole measurements: groundwater levels and product (or non-aqueous phase liquid, NAPL) levels, if present, and total depth of groundwater monitoring wells and piezometers.

### **2.0 SCOPE**

The methods described in this SOP generally are applicable to the measurement of groundwater levels, product or NAPL levels, and well depths in monitoring wells and piezometers.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

**Field Team Leader** - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of down-hole measurements.

### **5.0 PROCEDURES**

Calculations of groundwater elevations and product or NAPL interface level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient and the direction of groundwater flow.
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow in the vertical plane).

- Floating or sinking product thicknesses which are also known as Light Non-Aqueous Phase Liquids (LNAPLS) and Dense Non-Aqueous Phase Liquids (DNAPLS), respectively.

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate the rate of contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring groundwater levels, product or NAPL levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing (though other measuring points can be used), and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum. A permanent notch, placed on the inner PVC or stainless steel casing by the surveyor will facilitate consistent water level measurements.

The manufacturer's instructions for all equipment referenced herein should be read by the equipment operator(s) and accompany the equipment to the field.

### **5.1 Water Level Measurement**

Water levels in groundwater monitoring wells shall be measured from the permanent point indicated at the top of the inner casing (the surveyed elevation point, as marked by the surveyor), unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). The point of measurement will be documented in the field logbook if different from the top of the inner casing. The reason for deviating from the measurement point should also be noted.

Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The water level is recorded to the nearest foot (0.01) using the graduated markings on the water level indicator cord. This measurement, when subtracted from the measuring point elevation, yields the groundwater elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

## 5.2 Product or NAPL Level Measurements

The procedure for product or NAPL level measurement is nearly identical to that for groundwater elevation measurements. The only differences are the use of an interface probe that detects both NAPLs and water, and the indication signal given by the measurement device. Typically, encountering NAPLs in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the NAPL layer in a well and the water/NAPL interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

WTE <sub>c</sub>	=	Corrected water table elevation
WTE <sub>a</sub>	=	Apparent water table elevation
0.80	=	Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

## 5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. A water level meter may also be used. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook. If a water level indicator is used, add the distance from the bottom of the probe to the point where water levels are measured.

## 5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with Methanol or Isopropanol

- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

## **6.0 QUALITY ASSURANCE RECORDS**

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.

**APPENDIX F**  
**PHOTO IONIZATION DETECTOR (PID)**  
**HNU MODELS PI 101 AND DL 101**

---

**PHOTOIONIZATION DETECTOR (PID)  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Calibration
  - 5.2 Operation
  - 5.3 Interferences and Potential Problems
  - 5.4 Maintenance
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## PHOTOIONIZATION DETECTOR (PID) HNu MODELS PI 101 and DL 101

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the HNu Model PI 101 or DL 101 photoionization detector (PID), or an equivalent or similar instrument, in the field. Calibration and operation, along with field maintenance will be included in this SOP.

### 2.0 SCOPE

This procedure provides information on the field operation and general maintenance of the HNu (PID). Application of the information contained herein will ensure that this type of field monitoring equipment will be used properly. Review of the manufacturer's instruction manual is necessary for more complete information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

### 3.0 DEFINITIONS

Ionization Potential - In this case, a numeric equivalent that expresses the amount of energy needed to replace an electron with a photon. This energy is further defined in terms of electron volts (eV).

PID - Photoionization Detector

ppm - parts per million: parts of vapor or gas per million parts of air (directly proportional to calibration gas).

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASp) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the Field Logbook and the daily Realtime Air Monitoring Log during each field investigation.

## **5.0 PROCEDURES**

The HNu utilizes the principle of photoionization whereby contaminant molecules enter the ion chamber and electrons are displaced by ultraviolet photons producing positive ions. These displaced positive ions are in turn collected on a special electrode. As the positive ions collect on the electrode, they create an electrical current which is amplified and displayed on the meter as a concentration in parts per million (ppm).

The HNu is only effective for contaminants that have ionization potentials (IP) of less than or equal to the electron volt (eV) capacity of the lamp (i.e., methane, having an IP of 12.98 eV, will not be detected at a lamp potential of 11.7 eV). The standard lamp is 10.2 eV with optional lamps of 9.5 eV and 11.7 eV, respectively. For the PI 101 the span settings should be as follows: 1.0 for 9.5 eV lamps; 9.8 for 10.2 eV lamps; and 5.0 for 11.7 eV lamps. During calibration, these span settings will be adjusted as necessary, using the span control knob.

The following subsections will discuss HNu calibration, operation, and maintenance. These sections, however, should not be used as a substitute for the manufacturer's instruction manual.

### **5.1 Calibration**

For calibration purposes, the following items will be needed:

- \*Gas cylinder containing 95 to 100 parts per million (ppm) of isobutylene, balance in air.
- A 0.30 liters per minute regulator.
- Connector tubing.
- Screwdriver set.
- Calibration Gas Humidifier (for high humidity environments).
- Photoionization Detector (PID) Calibration Form.

\*Note: Do not rely on accuracy of rated cylinder concentration when content drops to <200 psi.

Prior to each use, make sure that the battery is fully charged, the ultraviolet lamp is working, and that the fan is operating and drawing air into the probe (fan operates at approximately 100-200

cc/minute for the PI 101 and 225 cc/minute for the DL 101). Procedures for completing these preliminary activities are given in the manufacturer's instruction manual.

### **PI 101**

To calibrate the HNu PI 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 3-5 in the manufacturer's instruction manual. The HNu PI 101 should be calibrated on a daily basis.

- Turn the function control switch to the standby position and zero the instrument by turning the zero adjustment knob to align the indicator needle with zero on the readout meter.
- Set the range on the HNu and allow the instrument to warm up a few minutes before calibrating. Choices for range are 0-20, 0-200, and 0-2,000 ppm, respectively. Range choice must take into account the concentration of the calibration gas. For example, if you are using a concentration of 100 ppm isobutylene as the calibration gas, your range should be set on the 0-200 scale. If you have to zero the instrument in the desired range, record background if present.
- Attach tubing to the regulator (use the Calibration Gas Humidifier in high humidity environments).
- Attach the free end of the tubing to the probe and turn on the calibration gas.
- Calibrate the PID to benzene equivalents. Using the 10.2 eV (lamp) probe and 100 ppm isobutylene, the meter should read 56 units. Using the 11.7 eV (lamp) probe and 100 ppm isobutylene, the meter should read 65 units. If the reading on the meter is not  $\pm 5$  percent of the concentration of the calibration gas, adjust the span setting knob until the meter reads accordingly. If after adjusting the span setting knob the readout meter is still not responding, refer to the manufacturer's instruction manual. Also, when the HNu is calibrated it should respond to a minimum of 90 percent of the concentration of the calibration gas within three seconds after introduction of that gas. If proper calibration cannot be obtained, internal calibration may be required. Note, only qualified personnel should perform internal calibrations.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form".

### **DL 101**

To calibrate the HNu DL 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 4.4 in the manufacturer's instruction manual.

- Press and release the POWER button on the keypad and wait for the screen to stabilize then press the CALIBRATE key until "Calibrate?" appears. At this point press the ENTER key until "Elec\_Zero? Yes" appears on the screen in which case you will press the ENTER key, again, to confirm the electronic zero.
- The display will now read "CE/ENT/EXIT Conc = \_\_\_\_ ppm" which requires the concentration of the calibration gas (noted on the side of the calibration gas bottle) to be entered on the keypad. The display will prompt you to "Attach gas to probe and /ENTER/" so attach tubing to probe (use the calibration gas humidifier in high humidity environments), open valve, and press ENTER key. Press ENTER again when "Press ENTER when Ready: xxx ppm" appears on screen. This will cause "Calibrating...Please Wait" to appear on screen.

Note: This calibration is effective when the instrument is in the Survey Mode, which is the default mode. For calibrations other the one described, or if proper calibration cannot be obtained, refer to the manufacturer's instruction manual.

- For calibrations using an alternate gas or span values, refer to Section 4.5 of the manufacturer's instruction manual.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form" which accompanies each HNu.

## **5.2 Operation**

### **PI 101**

Note: IMPORTANT - The HNu should be "zeroed" in a fresh air environment if at all possible. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the HNu, check that the battery is fully charged by turning the dial to BATT and making sure that it is within range. Also make sure that the ultraviolet lamp and the fan are working properly.
- Select your desired range. HNu ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range, however, in most instances the range will be set initially at 0-20.
- When HNu is used intermittently, turn knob to STANDBY to help in extending the life of the UV lamp when operating in a low humidity environment. Otherwise, leave the knob set to the range desired so that the UV lamp will "burn off" any accumulated moisture.

Note: When using the PI 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

### **DL 101**

The DL 101 is designed to default to the survey mode when initially powered up, therefore once the calibration has been completed, the instrument is ready to go. Within the survey mode several options are available, briefly these options include:

1. The Site Function

The Site function assigns a number to a site that is being analyzed. Press the Site Key on the keypad to enter a specific site number, or press the gray button on the rear of the probe to increment a site number.

2. Logging Data

The Log function stores data in memory. To log data, press the Log key on the keypad or the Log button on the back of the probe. "Log" will appear in the upper right corner of the display when activated and disappears when not activated. To turn logging off, press either the Log key on the keypad or the red Log button on the rear of the probe.

- The DL 101 allows for the interchanging of different voltage lamps, however, refer to the manufacturer's instructions before attempting to change the lamp.
- The DL 101 also offers three other modes of operation, the Hazardous Waste Mode, the Industrial Hygiene Mode, and the Leak Detection Mode. Each of these modes increases the range of capabilities for this instrument which is covered in detail in the manufacturer's instruction manual.

Note: When using the DL 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

### **5.3 Interferences and Potential Problems**

A number of factors can affect the response of the PI 101 HNu and DL 101 HNu.

- High humidity can cause lamp fogging and decreased sensitivity. This can be significant when soil moisture levels are high, or when monitoring a soil gas well that is accessible to groundwater.
- High concentrations of methane can cause a downscale deflection of the meter.

- High and low temperature, electrical fields, FM radio transmission, and naturally occurring compounds, such as terpenes in wooded areas, will also affect instrument response.

#### **5.4 Maintenance**

The best way to keep an HNu operating properly is to keep it as clean as possible. HNu's should be decontaminated or wiped down daily or after each use, as appropriate.

##### **Corrective Maintenance**

- The ultraviolet lamp should be periodically cleaned using a special compound supplied by HNu Systems, Inc. for the 10.2 eV lamp, and a chlorinated solvent such as 1,1,1-trichloroethane for the 11.7eV lamp. Consult the manufacturer's instruction manual for specific cleaning instructions.
- The ionization chamber can be periodically cleaned with methyl alcohol and a swab.

Note: UV lamp and ion chamber cleaning is accomplished by following the procedures outlined in Section 5.2, however, this should only be performed by trained personnel.

- Documenting the HNu's observed symptoms and then referring to the manufacturer's instruction manual section on troubleshooting (Section 6.0) also can be employed. If this does not work, the Field Team Leader should be consulted for an appropriate course of action.

Repair and Warranty Repair - HNu's have different warranties for different parts, so documenting the problem and sending it into the manufacturer assists in expediting repair time and obtaining appropriate warranty service.

#### **5.5 Shipping and Handling**

Following is information regarding the transport of the HNu meter and calibration gas.

- If HNu is to be carried on in aircraft, the calibration gas must be removed from the carrying case as cylinders of compressed gas are not permitted on passenger aircraft. The calibration gas should either be shipped to the site of its intended use, or purchased locally.
- Shipping of the calibration gas requires the completion of a form (specified by the shipping company) that identifies the package as a compressed gas. Compressed gas stickers must be affixed to the package.

## **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc.) serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the HNu meter had wide range fluctuations during air monitoring activities).

## **7.0 REFERENCES**

HNu Systems, Inc. Instruction Manual. Model PI 101, 1986.  
HNu Systems, Inc. Operator's Manual. Model DL 101, 1991.

**APPENDIX G**  
**BACHARACH OXYGEN/COMBUSTIBLE GAS METER**

**BACHARACH COMBUSTIBLE GAS/  
OXYGEN METER PERSONAL GAS MONITOR  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Calibration
  - 5.2 Operation
  - 5.3 Site Maintenance
  - 5.4 Scheduled Maintenance
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## BACHARACH COMBUSTIBLE GAS/ OXYGEN METER AND PERSONAL GAS MONITOR

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the Bacharach Sentinel 4 and Bacharach Sniffer® 503-A meters in the field. Calibration and operation, along with field maintenance, will be included in this SOP.

### 2.0 SCOPE

This procedure provides information into the field operation and general maintenance of the Sentinel 4 Sniffer and 503-A. Review of the information contained herein will ensure that this type of field monitoring equipment will be properly utilized. Review of the owner's instruction manuals is a necessity for more detailed descriptions.

### 3.0 DEFINITIONS

Carbon Monoxide Sensor - Expresses the Carbon Monoxide concentration in parts per million (ppm).

Combustible Gas - Combustible gas is expressed as a percent of the lower explosive limit (LEL).

Hydrogen Sulfide Sensor - Expresses the Hydrogen Sulfide concentration in parts per million (ppm).

Oxygen Sensor - Expresses the Oxygen concentration as a percentage.

ppm - parts per million: parts of vapor or gas per million parts of air by volume.

Sentinel 4 - Combustible Gas/Oxygen/Hydrogen Sulfide/Carbon Monoxide meter.

Sniffer 503-A - portable Combustible Gas and Oxygen Alarm instrument.

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project -specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in the Field Logbook during each field investigation.

## 5.0 PROCEDURES

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A utilize the principle of detecting sensors. The following four paragraphs discuss theory of operation as it applies to each functional sensor.

The combustible gas sensor uses two elements that are wound with a platinum wire. One of the elements is impregnated with a catalyst to oxidize combustible gases. The other element is impregnated with material that will also oxidize combustible gases, but will respond to temperature and humidity conditions. When the meter is turned on, an electrical current is passed through the elements and wires. As a combustible gas enters the chamber the elements will oxidize the combustible gas, thus increasing the heat and resistance of the element. This change in resistance causes a system imbalance, which produces a measurable signal proportional to the combustible gas concentration.

The percent oxygen is measured utilizing an electrochemical sensor. As atmospheric oxygen enters the meter it diffuses into the sensor which converts the amount of oxygen in the sensor to a voltage signal. This voltage is directly proportional to percent oxygen in the atmosphere.

The concentration of hydrogen sulfide is measured utilizing an electrochemical sensor. As atmospheric hydrogen sulfide enters the meter it diffuses into the sensor which converts the amount of hydrogen sulfide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric hydrogen sulfide concentration.

The concentration of carbon monoxide as measured utilizing an electrochemical sensor. As atmospheric carbon monoxide enters the meter it diffuses into the sensor which converts the amount of carbon monoxide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric carbon monoxide concentration.

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A are intrinsically safe for use in Class I, Division 1, Groups A, B, C and D hazard areas. One fact that needs to be expressed is that this type of monitoring equipment utilizes internal oxidation of combustibles, if the meter is placed in an

oxygen deficient atmosphere, the combustible reading may be affected. Review of each of the instruction manuals will aid in determining the percentage of oxygen that affects the combustible gas readings.

The following subsections will discuss Sentinel 4 and Sniffer 503-A calibration, operation, and maintenance. These sections, however, do not take the place of the instruction manual.

## **5.1 Calibration**

### **Sentinel 4**

Due to the numerous steps involved in calibration, it is recommended that you follow the calibration procedures (on a daily basis) as outlined in the instruction manual from pages 5-12 to 5-20.

NOTE: A calibration kit will be provided for each Sentinel 4. This kit contains a cylinder for the combustible gas sensor, one cylinder for the hydrogen sulfide sensor, and one cylinder for the carbon monoxide sensor. The oxygen sensor can be calibrated with (uncontaminated/fresh air environment) atmospheric air and does not need cylinder gas.

Note: When a single sensor doesn't zero, none of the sensors are zeroed.

### **Sniffer® 503-A**

#### **Oxygen Detector**

1. Check battery charge by turning function switch to "BATTERY TEST," if battery is in recharge zone instrument will need to be charged.
2. To zero the oxygen detector, turn function switch to "BATTERY TEST" position and press "TEST" switch and observe the O<sub>2</sub> meter indication. If indicator is zero, no further adjustment is necessary. If not, follow procedures in Section 5.4.1 of the Operations Manual.
3. To calibrate the oxygen detector, turn function switch to "BATTERY TEST" position. Unlock the "OXYGEN CALIB" knob and adjust it for an O<sub>2</sub> meter indication of 21 or at the CAL mark. Relock "OXYGEN CALIB" knob. If using zero calibration gas, follow procedures in Section 5.4.2 of the Operator's Manual.
4. Record on Calibration Sheet.

### % LEL Detector

1. Check battery charge by turning function switch to "BATTERY TEST," if battery is in recharge zone, instrument will need to be charged. Allow 5 minutes for the instrument to warm up.
2. Turn function switch to the % LEL position.

Note: To eliminate the annoyance of the audible alarm, cover the alarm with a hand or duct tape during calibration. The tape must be removed, prior to operation!!

3. Connect calibration gas (typically 30% of the LEL) and allow gas to flow for 1 minute.

Note: If calibration gas has a concentration value, not a % LEL value, the % LEL can be calculated as follows:

$$\% \text{ calibration gas (i.e., methane)} \times 20\% \text{ LEL (meter alarm setting)} = \% \text{ LEL calibration setting}$$

If meter indication is within  $\pm 5\%$  of LEL calibration gas, no further adjustment is required. If not, follow procedures in Section 5.5.4 of Operator's Manual.

### Sniffer® 503-A

1. Connect sample probe and tubing to the instrument's sample inlet (refer to Sections 8.4 and 8.5 for the Operator's Manual for available hoses and probes).
2. Check that battery is in Operational Range.
3. Turn instrument to % LEL range and allow to warm up for 1 minute.
4. Check in a fresh air environment that % LEL reads 0% and that O<sub>2</sub> indicator reads 21% (calibration mark).
5. Sample air/gas from area to be tested, allow 30 seconds for readings to stabilize. When finished, allow at least 10 seconds (longer if extension line is used) to purge sample line.
6. If instrument is operating erratically, refer to "TROUBLESHOOTING" Section (Table 5-2) in Operator's Manual.

## 5.2 Operation

### Sentinel 4

Due to the Sentinel 4 having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 6-1 to 6-34.

NOTE: Since the Sentinel 4 is capable of measuring four different parameters, an understanding of the alarm, error, and fault messages must be obtained. This can be done by reviewing the troubleshooting table found on pages 9-2 to 9-9.

## 5.3 Site Maintenance

After each use, the meters should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

## 5.4 Scheduled Maintenance

<u>Function</u>	<u>Frequency</u>
Check alarm and settings	Monthly/before each use
Clean screens and gaskets around sensors	Monthly
Replace sensors	Biannually or when calibration is unsuccessful

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, date, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Sentinel 4 or Sniffer 503-A had wide range fluctuations during air monitoring activities.)

NOTE: The "Toxic Gas Meter Calibration Form" will be completed daily, prior to performing any air monitoring.

## 7.0 REFERENCES

Bacharach Installation, Operation, Maintenance Manual, Sentinel 4 Personal Gas Monitor, 1990.  
Bacharach Installation, Operation, Maintenance Manual, Sniffer® 503-A, Rev. 3 - October, 1990.

**APPENDIX H**  
**DECONTAMINATION OF SAMPLING AND**  
**MONITORING EQUIPMENT**

---

**DECONTAMINATION OF SAMPLING AND  
MONITORING EQUIPMENT**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Sampling Equipment Decontamination Procedures
5.2	Field Analytical Equipment Decontamination
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

### 1.0 PURPOSE

The purpose of this SOP is to provide a general methodology and protocol, and to reference information for the proper decontamination of field chemical sampling and analytical equipment.

### 2.0 SCOPE

This procedure applies to all field sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), bailers, beakers, trowels, filtering apparatus, and pumps. This procedure should be consulted when decontamination procedures are being developed as part of project-specific plans. Additionally, current USEPA regional procedures and decontamination guidance as well as state guidance should be reviewed.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring field personnel performing decontamination activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader.

## 5.0 PROCEDURES

In order to ensure that chemical analysis results reflect actual concentrations present at sampling locations, sampling equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling locations) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Preferably, sampling equipment should be dedicated to a given sampling location. If this is not possible, equipment must be decontaminated between sampling locations. Sampling personnel also must use disposable gloves and change them between sampling locations.

### 5.1 Sampling Equipment Decontamination Procedures

Soil and sediment sampling equipment including, but not limited to trowels, beakers, dredges, etc., shall be decontaminated using the following USEPA Region procedures.

The following sections summarize decontamination procedures for USEPA Regions I through IV for overall comparison. Each region should be contacted prior to initiation of sampling activities to assure that the most recent, accepted decontamination procedures are used.

#### USEPA Region I

Prior to use, all sampling equipment should be carefully cleaned using the following procedure:

1. A dilute hydrochloric acid rinse
2. Deionized water rinse
3. Methanol or acetone rinse; and,
4. Distilled, organic-free water rinse.

For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure. Additionally, a hexane rinse also may be needed, prior to the final distilled water rinse, when sampling for low-level organic pollutants.

### USEPA Region II

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Low-phosphate detergent wash (i.e., Alconox or Liquinox)
2. Tap water rinse
3. 10 percent nitric acid solution rinse
4. Tap water rinse
5. Methanol followed by a hexane or an acetone rinse
6. Analyte-free deionized water rinse
7. Air dry
8. Wrap in aluminum foil, shiny side out, for storage or transport

If the samples will not be analyzed for metals, then steps 3 and 4 may be omitted; if samples will not be analyzed for organics, then step 5 may be omitted. All solvents must be pesticide-grade.

### USEPA Region III

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Potable water rinse
2. Alconox or Liquinox detergent wash
3. Scrubbing, as necessary
4. Potable water rinse
5. 10 percent nitric acid rinse
6. Distilled-deionized water rinse
7. Methanol or hexane rinse
8. Distilled-deionized water rinse
9. Air dry

### USEPA Region IV

Prior to use, all sampling equipment will be decontaminated using the following procedures:

1. Clean with tap water and laboratory detergent using a brush if necessary to remove particulate matter and surface films.
  2. Rinse thoroughly with tap water.
  3. Rinse thoroughly with deionized water.
  4. Rinse twice with pesticide grade isopropanol.
  5. Rinse thoroughly with organic-free water and allow to air dry as long as possible.
  6. If organic-free water is not available, allow equipment to air dry as long as possible. Do not rinse with deionized or distilled water.
  7. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.
- \* Portable power augers (such as the Little Beaver®) or large soil boring/drill rigs should be cleaned before boring or drilling operations.

## **5.2 Field Analytical Equipment Decontamination**

Field analytical equipment which may come in direct contact with the sample or sample media, including, but not limited to water level meters, water/product level meters, pH or specific ion probes, specific conductivity probes, thermometers, and/or borehole geophysical probes must be decontaminated before and after use, according to the procedures outlined in Section 5.1, unless manufacturers instructions indicate otherwise. Probes that contact water samples not used for laboratory analyses may be rinsed with distilled water. Probes which make no direct contact (e.g. HNu or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth.

## **6.0 QUALITY ASSURANCE RECORDS**

Decontamination procedures are monitored through the collection of equipment rinsate samples and field blanks. Collection of these samples shall be specified in the project-specific Sampling and Analysis and Quality Assurance Plans following the requirements of NEESA 20.2-047B. Documentation recorded in the field logbook also shall serve as a quality assurance record.

## 7.0 REFERENCES

NEESA 20.2-047B. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. Naval Energy and Environmental Support Activity. Port Hueneme, CA. June 1988.

U. S. EPA Office of Waste Program Enforcement. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1. 1986.

U. S. EPA. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA Environmental Services Division, Athens, Georgia. 1991.

Micham, J. T., R. Bellandi, E. C. Tift, Jr. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review. Spring 1989.

**APPENDIX I**  
**DECONTAMINATION OF DRILL RIGS AND**  
**MONITORING WELL MATERIALS**

---

**DECONTAMINATION OF DRILLING RIGS  
AND MONITORING WELL MATERIALS**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Equipment
5.2	Decontamination Procedures
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

### 1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

### 2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

**Project Manager** - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

**Drilling Inspector (Site Geologist, Rig Geologist etc.)** - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

### 5.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site.

## **5.1 Equipment**

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502.

## **5.2 Decontamination Procedures**

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush andalconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding tank. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

For a given project, the location of the steam cleaning area will be identified in the Sampling and Analysis Plan.

Decontamination wastes will be collected and contained unless otherwise directed by LANTDIV. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

## **6.0 QUALITY ASSURANCE RECORDS**

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate.

Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

**7.0 REFERENCES**

None.

**APPENDIX J**  
**SAMPLE PRESERVATION AND HANDLING**

---

**SAMPLE PRESERVATION AND HANDLING  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sample Containers
  - 5.2 Preservation Techniques
  - 5.3 Sample Holding Times
- 6.0 SAMPLE HANDLING AND TRANSPORTATION**
- 7.0 REFERENCES**

## **SAMPLE PRESERVATION AND HANDLING**

### **1.0 PURPOSE**

This SOP describes the appropriate containers for samples of particular matrices, and the steps necessary to preserve those samples when shipped off site for chemical analysis. It also identifies the qualifications for individuals responsible for the transportation of hazardous materials and samples and the regulations set forth by the Department of Transportation regarding the same.

### **2.0 SCOPE**

Some chemicals react with sample containers made of certain materials; for example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the integrity of the sample prior to analysis.

Many water and soil samples are unstable and may change in chemical character during shipment. Therefore, preservation of the sample may be necessary when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s). While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that may occur after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/freezing. Their purposes are to (1) retard biological activity, (2) retard hydrolysis of chemical compounds/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

Typical sample container and preservation requirements for the CLEAN Program are referenced in NEESA 20.2-047B and are provided in Attachment A of this SOP. Note that sample container requirements (i.e., volumes) may vary by laboratory.

The Department of Transportation, Code of Federal Regulations (CFR) Title 49 establishes regulations for all materials offered for transportation. The transportation of environmental samples for analysis is regulated by Code of Federal Regulations Title 40 (Protection of the Environment), along with 49 CFR Part 172 Subpart H. The transportation of chemicals used as preservatives and samples identified as hazardous (as defined by 49 CFR Part 171.8) are regulated by 49 CFR Part 172.

### **3.0 DEFINITIONS**

HCl - Hydrochloric Acid  
H<sub>2</sub>SO<sub>4</sub> - Sulfuric Acid  
HNO<sub>3</sub> - Nitric Acid  
NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalents per liter, where an equivalent is the amount of a substance containing one mole of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one mole of H, is "one-normal," while a one molar solution of H<sub>2</sub>SO<sub>4</sub> containing two moles of H, is "two-normal."

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is also responsible for proper certification of individuals responsible for transportation of samples of hazardous substances.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures. The Field Team Leader is responsible to ensure all samples and/or hazardous substances are properly identified, labeled, and packaged prior to transportation.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate sample preservation and handling. It is also the responsibility of the field sampling personnel to understand and adhere to the requirements for proper transportation of samples and/or hazardous substances.

## **5.0 PROCEDURES**

The following procedures discuss sample containerization and preservation techniques that are to be followed when collecting environmental samples for laboratory analysis.

### **5.1 Sample Containers**

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be measured is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then glass or plastic containers may be used. Containers shall be kept out of direct sunlight (to minimize biological or photo-oxidation/photolysis of constituents) until they reach the analytical laboratory. The sample container shall have approximately five to ten percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (one liter of water at 4°C expands by 15 milliliters if heated to 130°F/55°C); however, head space for volatile organic analyses shall be omitted.

The analytical laboratory shall provide sample containers that have been certified clean according to USEPA procedures. Shipping containers for samples, consisting of sturdy ice chests, are to be provided by the laboratory.

Once opened, the sample container must be used at once for storage of a particular sample. Unused, but opened, containers are to be considered contaminated and must be discarded. Because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing liners (if required for the container) shall be discarded.

General sample container, preservative, and holding time requirements are listed in Attachment A.

## 5.2 Preservation Techniques

The preservation techniques to be used for various analytes are listed in Attachment A. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or added in the field using laboratory supplied preservatives. Some of the more commonly used sample preservation techniques include storage of sample at a temperature of 4°C, acidification of water samples, and storage of samples in dark (i.e. amber) containers to prevent the samples from being exposed to light.

All samples shall be stored at a temperature of 4°C. Additional preservation techniques shall be applied to water samples as follows:

- Water samples to be analyzed for volatile organics shall be acidified.
- Water samples to be analyzed for semivolatile organics shall be stored in dark containers.
- Water samples to be analyzed for pesticides/PCBs shall be stored in dark containers.
- Water samples to be analyzed for inorganic compounds shall be acidified.

These preservation techniques generally apply to samples of low-level contamination. The preservation techniques utilized for samples may vary. However, unless documented otherwise in the project plans, all samples shall be considered low concentration. All samples preserved with chemicals shall be clearly identified by indicating on the sample label that the sample is preserved.

## 5.3 Sample Holding Times

The elapsed time between sample collection and initiation of laboratory analyses is considered the holding time and must be within a prescribed time frame for each individual analysis to be performed. Sample holding times for routine sample collection are provided in Attachment A.

## 6.0 SAMPLE HANDLING AND TRANSPORTATION

After collection, the outside of all sample containers will be wiped clean with a damp paper towel; however sample handling should be minimized. Personnel should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, personnel should ensure that melted ice cannot cause sample containers to become submerged, as this may result in sample cross-contamination and loss of sample labels. Sealable plastic bags, (zipper-type bags), should be used when glass sample containers are placed in ice chests to prevent cross-contamination, if breakage should occur.

Samples may be hand delivered to the laboratory or they may be shipped by common carrier. Relevant regulations for the storage and shipping of samples are contained in 40 CFR 261.4(d). Parallel state regulations may also be relevant. Shipment of dangerous goods by air cargo is also regulated by the United Nations/International Civil Aviation Organization (UN/ICAO). The Dangerous Goods Regulations promulgated by the International Air Transport Association (IATA) meet or exceed DOT and UN/ICAO requirements and should be used for shipment of dangerous goods via air cargo. Standard procedure for shipping environmental samples are given in Attachment B.

## 7.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA, Washington, D.C.

USEPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

USEPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. USEPA EMSL, Cincinnati, Ohio.

USEPA, Region IV, 1991. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. Athens, Georgia.

Protection of the Environment, Code of Federal Regulation, Title 40, Parts 260 to 299.

Transportation, Code of Federal Regulation, Title 49, Parts 100 to 177.

**ATTACHMENT A**

**REQUIRED CONTAINER, PRESERVATION TECHNIQUES  
AND HOLDING TIMES**

**ATTACHMENT A**

**SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR AQUEOUS SAMPLES**

Parameter	Bottle Requirements	Preservation Requirements	Holding Time <sup>(1)</sup>	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
Cyanide	plastic/glass	NaOH to pH>12 Cool to 4°C	14 days	CLP EPA 335.2	1 x 1 liter
Metals (TAL)	plastic/glass	HNO <sub>3</sub> to pH <2	180 days except Mercury is 26 days	CLP	1 x 1 liter
Total Organic Carbon	glass, teflon lined cap	Cool to 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days	EPA 415.1	2 x 40 ml
Total Organic Halogen	plastic/glass	Cool to 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days	EPA 450.1	250 ml
Chloride	plastic/glass	none required	28 days	EPA 325.2/325.3	250 ml
Sulfate	plastic/glass	Cool to 4°C	28 days	EPA 375.4	250 ml
Alkalinity	plastic/glass	Cool to 4°C	14 days	EPA 310.1/310.2	250 ml
Gross alpha/gross beta	plastic/glass	HNO <sub>3</sub> to pH <2	6 months	9310	1 gallon
Chlorinated herbicides	glass, teflon lined cap	Cool to 4°C	14/28 days	EPA 515.1	1000 ml
Hardness	plastic/glass	HNO <sub>3</sub> to pH <2	6 months	EPA 130.2	150 ml

<sup>(1)</sup> Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991. Holding times for Non-CLP methods are based on time of sample collection.

**ATTACHMENT A (Continued)**

**SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR SOIL SAMPLES**

Parameter	Bottle Requirements	Preservation Requirements	Holding Time <sup>(1)</sup>	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C	10 days	CLP	1 x 50 gm
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 250 gm
PCB/Pesticides	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm
Metals (TAL)	plastic/glass	Cool to 4°C	Mercury is 26 days 180 days	CLP	1 x 50 gm
Cyanide	plastic/glass	Cool to 4°C	14 days	CLP EPA 335.2M	1 x 50 gm

<sup>(1)</sup> Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991.  
Holding times for Non-CLP methods are based on time of sample collection.

Note: Verify this information with the laboratory that will perform the analyses.

**ATTACHMENT B**

**SAMPLE SHIPPING PROCEDURES**

**ATTACHMENT B**  
**SAMPLE SHIPPING PROCEDURES**

**Introduction**

Samples collected during field investigations or in response to a hazardous materials incident must be classified by the project leader, prior to shipping by air, as either environmental or hazardous substances. The guidance for complying with U.S. DOT regulations in shipping environmental laboratory samples is given in the "National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Pertinent regulations for the shipping of environmental samples is given in 40 CFR 261.4(d). Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods/hazardous substance. Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by the United Nations International Civil Aviation Organization (UN/ICAO), which is equivalent to IATA.

Individuals responsible for transportation of environmental samples or dangerous goods/hazardous substances must be tested and certified by their employer. This is required by 49 CFR Part 172 Subpart H Docket HM-126 to assure the required qualifications for individuals offering materials for transportation.

Environmental samples shall be packed prior to shipment by commercial air carrier using the following procedures:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug (inside and outside) with fiber or duct tape. Line the cooler with a large heavy duty plastic bag. This practice keeps the inside of the cooler clean and minimizes cleanup at the laboratory after samples are removed.
2. Allow sufficient headspace (ullage) in all bottles (except VOAs) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).

3. Be sure the lids on all bottles are tight (will not leak). In many regions custody seals are also applied to sample container lids. The reason for this practice is two-fold: to maintain integrity of samples and keep lid on the container should the lid loosen during shipment. Check with the appropriate regional procedures prior to field work. In many cases, the laboratory manager of the analytical lot to be used on a particular project can also provide this information.
4. It is good practice to wrap all glass containers in bubblewrap or other suitable packing material prior to placing in plastic bags.
5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.
6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.
7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large heavy duty plastic bag with tape (preferably electrical or duct).
9. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Wrap the tape three to four times around each side of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
10. Each cooler (if multiple coolers) should have its own Chain-of-Custody Record reflecting the samples shipped in that cooler.
11. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill, which is secured to the top of the shipping container. Please note several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler

2 of 3, etc.”, prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).

**APPENDIX K**  
**CHAIN-OF-CUSTODY**

---

**CHAIN-OF-CUSTODY  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sample Identification
  - 5.2 Chain-of-Custody Procedures
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## CHAIN-OF-CUSTODY

### 1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used to document sample handling.

### 2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters, SOP F101).

Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis.

This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

### 3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures

which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

**Field Team Leader** - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

## **5.0 PROCEDURES**

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

### **5.1 Sample Identification**

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s)
- CTO Number
- Project Sample Number
- Sample location or sampling station number
- Date and time of sample collection and/or measurement
- Field observations
- Equipment used to collect samples and measurements
- Calibration data for equipment used

Measurements and observations shall be recorded using waterproof ink.

### 5.1.1 Sample Label

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling and Analysis Plan. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project or Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.
- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

### 5.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

### 5.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

### 5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form example is shown in Attachment B. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).
- Enter sample specific information (sample number, media, sample analysis required and analytical method, grab or composite, number and type of sample containers, and date/time sample was collected).
- Sign, date, and enter the time under "Relinquished by" entry.
- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).

- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner;
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.
- Complete other carrier-required shipping papers.

The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

## **6.0 QUALITY ASSURANCE RECORDS**

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

## **7.0 REFERENCES**

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

## **ATTACHMENT A**

### **EXAMPLE SAMPLE LABEL**

**Note:** Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

ATTACHMENT A

EXAMPLE SAMPLE LABEL

	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108
Project: <u>19026-SRN</u>	CTO No.: <u>0026</u>
Sample Description: <u>Groundwater</u>	
Date: <u>09/17/92</u>	Sampler: <u>ABC</u>
Time: <u>0944</u>	
Analysis: <u>TAL Metals (CAP)</u> Preservation: <u>HNO<sub>3</sub></u>	
Project Sample No.: <u>CAX-GW-04</u>	

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

**ATTACHMENT B**  
**EXAMPLE CHAIN-OF-CUSTODY RECORD**



**ATTACHMENT C**  
**EXAMPLE CUSTODY SEAL**

ATTACHMENT C

EXAMPLE CUSTODY SEAL

<b>Baker</b> _____/_____/_____ Date _____ Signature CUSTODY SEAL	<b>Baker</b> _____/_____/_____ Date _____ Signature CUSTODY SEAL
---	---

**APPENDIX L**  
**FIELD LOGBOOK**

---

**FIELD LOGBOOK  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Cover
  - 5.2 Daily Entries
  - 5.3 Photographs
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## FIELD LOGBOOK

### 1.0 PURPOSE

This SOP describes the process for maintaining a field logbook.

### 2.0 SCOPE

The field logbook is a document which records all major on-site activities conducted during a field investigation. At a minimum, the following activities/events shall be recorded in the field logbook by each member of the field crew.

- Arrival/departure of site workers and visitors
- Arrival/departure of equipment
- Sample pickup (sample numbers, carrier, time)
- Sampling activities
- Start or completion of boreholes, monitoring wells, or sampling activities
- Health and safety issues

The field logbook is initiated upon arrival at the site for the start of the first on-site activity. Entries are made every day that on-site activities take place. At least one field logbook shall be maintained per site.

The field logbook becomes part of the permanent site file. Because information contained in the field logbook may be admitted as evidence in legal proceedings, it is critical that this document is properly maintained.

### 3.0 DEFINITIONS

Field logbook - The field logbook is a bound notebook with consecutively numbered pages. Upon entry of data, the logbook requires the signature of the responsible data/information recorder.

### 4.0 RESPONSIBILITIES

The Field Team Leader is responsible for maintaining a master field logbook for the duration of on-site activities. Each member of the sampling crew is responsible for maintaining a complete and accurate record of site activities for the duration of the project.

### 5.0 PROCEDURES

The following sections discuss some of the information which must be recorded in the field logbook. In general, a record of all events and activities, as well as other potentially important information shall be recorded by each member of the field team.

## 5.1 Cover

The inside cover or title page of each field logbook shall contain the following information:

- Contract Task Order Number
- Project name and location
- Name of Field Team Leader
- Baker's address and telephone number
- Start date
- If several logbooks are required, a sequential field logbook number

It is good practice to list important phone numbers and points of contact here.

## 5.2 Daily Entries

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded by each team member.

- Date
- Start time
- Weather
- All field personnel present
- All visitors present
- Other pertinent information (i.e., planned activities, schedule changes, expected visitors, and equipment changes)

During the day, an ongoing record of all site activities should be written in the logbook. The master logbook kept by the field team leader need not duplicate that recorded in other field logbooks, but should summarize the information in other books and, where appropriate, reference the page numbers of other logbooks where detailed information pertaining to a subject may be found.

Some specific information which must be recorded in the logbook includes:

- Equipment used, equipment numbers, calibration, field servicing
- Field measurements
- Sample numbers, media, bottle size, preservatives, collection methods, and time
- Test boring and monitoring well construction information, including boring/well number and location
- Sketches for each sample location including appropriate measurements if required.
- Photograph log
- Drum log
- Other pertinent information

All entries should be made in indelible ink; all pages numbered consecutively; and all pages must be signed or initialed and dated by the responsible field personnel completing the log. No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single line, initialed, and dated.

### **5.3 Photographs**

If photographs are permitted at a site, the record shall be maintained in the field logbook. When movies, slides or photographs are taken of any site location, they are numbered or cross-referenced to correspond to logbook entries. The name of the photographer, date, time, site location, site description, direction of view and weather conditions are entered in the logbook as the photographs are taken. Special lenses, film, or other image-enhancement techniques also must be noted in the field logbook. Once processed, photographs shall be serially numbered and labeled corresponding to the field logbook entries. Note that it may not be permitted to take photographs at all Activities; permission must be obtained from the LANTDIV EIC and the Activity responsible individual.

### **6.0 QUALITY ASSURANCE RECORDS**

Once on-site activities have been completed, the field logbook shall be considered a quality assurance record.

### **7.0 REFERENCES**

None.

**APPENDIX M**  
**STATISTICAL EVALUATION METHODS**

---

## 3.12. Guidance for Statistical Evaluation of Hazardous Waste Constituent Levels in Soils

### 3.12.1 Introduction

When a clean closure of a hazardous waste management unit (unit) includes remediation of affected soil to the site specific background concentrations, the determination whether the soil has been successfully remediated always relies on some kind of statistical inference. In order to assist closure plan reviewers to decide whether the background-based remediation standards (BRS) were established properly and if the statistical analyses were applied correctly, some commonly used statistical procedures are discussed in the following text. In general, these procedures allow for comparison between selected observations in such a way that the result of comparison can be obtained with a specified (required) level of confidence (or significance).

In order to conduct a background-based clean closure process (closure), it is necessary to establish a BRS for each constituent of concern. For that purpose, an adequate number of background soil samples must be collected. While this number depends on many factors, the Ohio EPA believes that it should not be less than twelve (12). The concentrations of a constituent in the soil samples (determined through the laboratory analysis) form one "statistical sample" of all background concentrations - a "background data set". In addition, to complete (and certify) a closure, soil samples should be collected from under and/or around the unit (the affected area now assumed to be remediated) to prove that the constituent concentrations have been "sufficiently" lowered. These concentrations are data points which form a "confirmation data set". Unless all confirmation concentrations are below the BRS, a statistical test is necessary to demonstrate (in an objective manner) if a "sufficient" level of soil remediation has been attained. Depending on whether data is, or is not, normally distributed (or can/cannot be normalized with a transformation common to both data sets), two types of statistical methods are used. They are respectively called "parametric" and "nonparametric" methods. For the purpose of this guidance document, the more common parametric approach will be discussed in some detail, while a reference will be made to nonparametric methods whenever appropriate.

### 3.12.2 DETERMINATION OF THE NUMBER OF SAMPLES

Due to practical reasons and constraints, statistical analyses are frequently conducted on a limited number of observations. This limited number of observations represents a (statistical) sample (not to be confused with a "soil sample") extracted from a much larger group of values (called "population") in an attempt to estimate some statistical parameter(s) (such as a mean value of metal concentrations, for instance), or to conduct a statistical test, while staying within economical and technical limits. If the entire population could be taken into account, a statistical estimate would reflect a "true" value. Any lesser number of observations will probably introduce an error. In other words, how close and how reliably will a statistical parameter represent the truth, or how correct a conclusion drawn from a particular statistical test will be, depends largely on the number of observations that were chosen to represent the population. Determination of a smallest number of

---

observations (smallest sample size) that will still allow a certain satisfactory level of confidence in a statistical evaluation, is a common problem. Unfortunately, it does not have a straightforward answer. The following are some of the reasons:

- Different statistical methods for testing hypotheses, or for determination of estimators (mean, variance, quantiles, etc.), require a different number of observations (data points) in order to achieve desired accuracy and level of confidence (i.e., the kind of methods involved must be known up-front);
- Desired accuracy and confidence level have to be predetermined;
- An assumption about normality of data distribution has to be made before the data is actually collected;
- A guess has to be made about dispersion (variability) of data.

It is obvious that the above requirements lead to a somewhat arbitrary determination of a smallest acceptable number of observations. To facilitate the initial choice of a (statistical) sample size for the purpose of establishing background based remediation standards for soils, Ohio EPA recommends a minimum of 12 (twelve) soil samples to be collected from an appropriate soil type (as described under "Requirements for Background Soil Sampling and Data Management" Section 3.11.1.1). In statistical terms, these 12 data points allow for determination of a mean value with 95% probability that it will not exceed a true (population) mean by 50%. In other words, if soil sampling, analysis and the mean value calculations were done repeatedly, many times in the same manner, a chance of making an estimate of a mean value 50% greater than the true mean is only 5%. If, for example, a true mean of a metal concentration in soil is 145 mg/kg, then the estimated mean would be less than 217.5 mg/kg (true mean + 50% of the true mean) 95% of the time. This is correct only under the assumption that the soil samples (not correlated over time and space) were collected through a simple random sampling process, that the results of laboratory analysis (data) are normally distributed, and that the coefficient of variation (the ratio between the standard deviation and the mean of the collected data) is within 95%. (For more detailed explanation, see Gilbert, Chapter 4.)

The above discussion shows that the recommended minimum of 12 (twelve) soil samples offers somewhat limited accuracy in estimating the mean value (and may be inadequate for some other type of statistical inference). If a more accurate estimate of the mean concentration of a constituent in a given soil is required, or if any other requirement (statistical method) so dictates, the necessary number of background soil samples has to be increased.

It is also important to mention that all 12 (twelve) soil samples have to be valid (i.e., usable). To avoid additional sampling in case something goes wrong (lab error, outlier, etc.), it is considered a good practice to collect more than 12 soil samples initially.

Various methods on how to determine an appropriate (necessary) number of observations are presented in many statistical textbooks, papers and guidance documents (some of which are referenced at the end of this section).

### 3.12.3 Data Comparison

Under the assumption that the background and confirmation data are normally distributed (which needs to be demonstrated through appropriate tests for normality, i.e. probability plots, box and whiskers plots, Shapiro-Wilk test, and/or Kolmogorov-Smirnov test with Lilliefors critical values) a BRS is defined as a mean value plus two standard deviations of the background data (i.e., concentrations).

So defined, BRS represents the 97.72th percentile (or the 0.9772 quantile - quantiles are percentiles expressed as a fraction rather than percents) of the background distribution. In that case, the soil can be declared successfully remediated (for the metal of concern) when the 95% upper confidence limit for the mean of the confirmation data (which also has to be normally distributed for this purpose) is significantly smaller than the BRS. This can be demonstrated through a one sided 95% confidence (i.e., 0.05 significance) level t test. (If all confirmation data points are below BRS, there is no need for any formal statistical test.)

$$\frac{\bar{Y} - BRS}{S_y / \sqrt{m}} < -t_{m-1, 0.95}$$

or

$$\bar{Y} + t_{m-1, 0.95} \times (S_y / \sqrt{m}) < BRS$$

where:

$\bar{Y}$  - mean of confirmation data

$S_y$  - standard deviation of confirmation data,

$m$  - number of confirmation samples, and

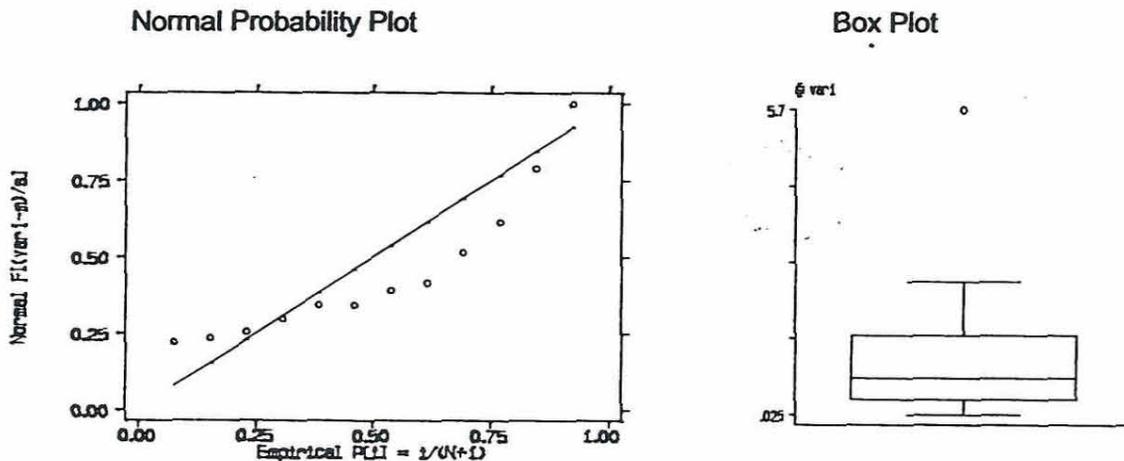
$t_{m-1, 0.95}$  - 0.95th quantile of the t distribution with m-1 degrees of freedom

NOTE: When the background and confirmation data sets (both or either one) are not normal, and cannot be normalized, an appropriate nonparametric test (such as: Wilcoxon Rank-Sum Test, test of proportions, etc.) should be utilized to prove that the soil has been satisfactorily remediated.

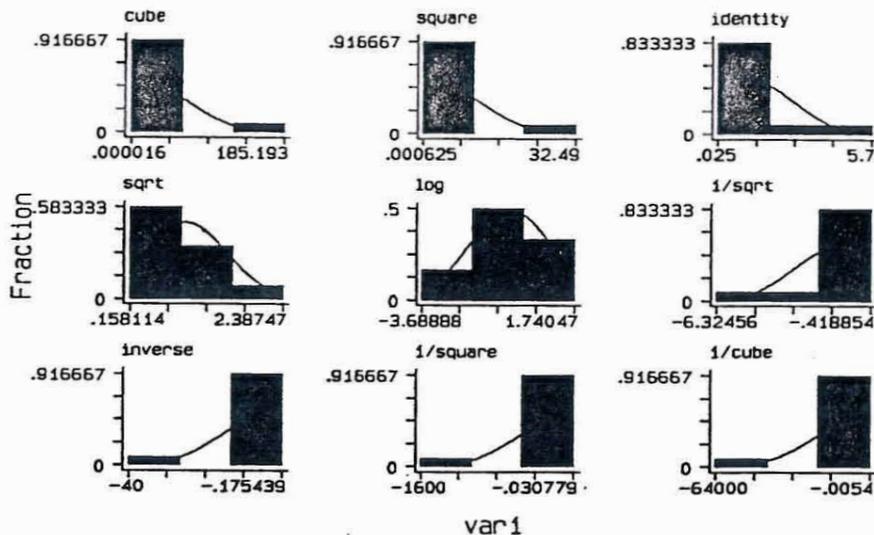
### 3.12.4 Test for Normality

In order to correctly use a t test to demonstrate that the remaining contaminant concentrations do not significantly exceed the BRS, the background and confirmation data must be normally distributed, or transformed to normality using the same transformation. The demonstration of normality should be made graphically (through probability plots and box plots) and through either the Shapiro-Wilk test (also known as the *W*-test), or the Kolmogorov-Smirnov test with Lilliefors critical values. An explanation on how to perform the Shapiro-Wilk and Kolmogorov-Smirnov tests can be found in *Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, 1980 (John Wiley & Sons); and Statistical Methods for Environmental Pollution Monitoring, R.O. Gilbert, 1987 (Van Nostrand Reinhold).*

As an example for graphical determination of normality, the data can be plotted as shown below;



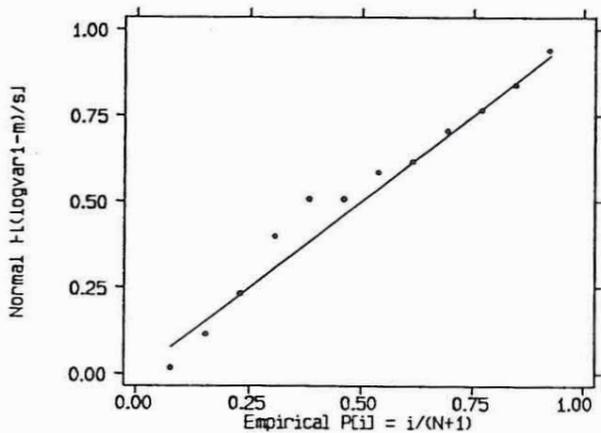
The graphs in this example tend to indicate that the data distribution is not normal. In the case of the probability plot graph, the closer the data points are to the line defining normality, the more likely the data are normally distributed. With the box plot graph, the more symmetrical the plot, the closer to normality the data distribution is. In order to proceed with the statistical analysis, the data set needs to be transformed to normality. Log or power transformations will often make a data set normally distributed. Some computer programs, as shown below, allow for a graphical comparison of several different transformations:



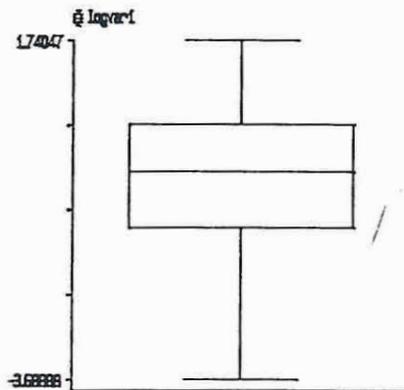
Histograms by Transformation

The graphs indicate that (in this case) a log transformation may be the best way to normalize the data. After transforming the data, a check with a probability plot and a box plot can be made to verify this indication.

Normal Probability Plot



Box Plot



A final check for normality should be made through the Shapiro-Wilk test, and/or Kolmogorov-Smirnov test with Lilliefors critical values.

It is important to note that, in order to conduct a t-test, the same kind of transformation must be applied to both, the background data set and the confirmation data set. In other words, to compare the 95% upper confidence limit for the mean of the confirmation data in the transformed scale, the remediation standard must be calculated from the background data set being transformed in the same manner.

If the data sets cannot be transformed to normality, an alternative method (one that does not rely on normality) must be used to prove that the soil has been successfully remediated. The two generally recommended (nonparametric) methods are the Wilcoxon Rank-Sum Test, and the Test of Proportions.

### 3.12.5 Test for Outliers

Prior to proceeding with statistical analysis, i.e., establishing a BRS from a normally distributed raw, or normalized (transformed) background data, a test for outliers should be conducted. This test is not required for the confirmation data set, but may be used for the screening purposes. Since, in this case, a discovery of an elevated concentration (above the BRS) usually indicates an incomplete remediation, additional soil removal (or treatment) consequently eliminates the outstanding concentration. One, or few slightly elevated concentrations in a confirmation data set may not necessarily require additional soil remediation - if an appropriate statistical test (such as t test) shows that the BRS has not been significantly exceeded. The following equations (Hoaglin et al, 1983) are used to determine whether there is statistical evidence that a background observation (constituent concentration) appears extreme and therefore does not fit the distribution of the rest of the data:

$$\text{Upper cutoff} = \text{upper quartile} + 1.5 (\text{interquartile range}) \quad \text{Equation 1}$$

$$\text{Lower cutoff} = \text{lower quartile} - 1.5 (\text{interquartile range}) \quad \text{Equation 2}$$

where:

Upper quartile ( $Q_{.75}$  or  $Q_3$ ) equals an observation in the background data set which divides the data so that 25% of the data are greater than  $Q_3$  and 75% of the data are less than or equal to  $Q_3$ ;

Lower quartile ( $Q_{.25}$  or  $Q_1$ ) equals an observation in the background data set which divides the data so that 75% of the data are greater than  $Q_1$  and 25% of the data are less than or equal to  $Q_1$ ; and

Interquartile range (IQR) equals the difference between the upper quartile and the lower quartile (i.e.,  $IQR = Q_3 - Q_1$ ).

***Example for even number of background data:***

Given the following data set consisting of twelve data points,

1.3      0.8      0.6      0.2      0.1      0.025

0.9 2.5 0.6 0.4 1.7 5.7

the first step is to order the data from least to greatest:

(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12)  
0.025 0.1 0.2 0.4 0.6 0.6 0.8 0.9 1.3 1.7 2.5 5.7

For an even number of data points, the quartiles are determined by splitting the ordered data set twice equally (i.e., into fourths). The quartiles are found at the splits and can be adequately estimated by averaging the data points on either side of the split. Using the above data set, Q1 falls between the 3rd and 4th observation and is therefore calculated as:

$$(0.2 + 0.4) / 2 = 0.3$$

Similarly, Q3 falls between the 9th and 10th observation and can be calculated as:

$$(1.3 + 1.7) / 2 = 1.5$$

This can be demonstrated visually as follows:

			Q1			(Q2 or median)			Q3					
(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		(10)	(11)	(12)
0.025	0.1	0.2		0.4	0.6	0.6		0.8	0.9	1.3		1.7	2.5	5.7
			0.3				(0.7)				1.5			

After calculating the quartiles, the next step is to calculate the interquartile range (IQR), or the difference between Q3 and Q1:

$$\text{IQR} = \text{Q3} - \text{Q1}, \text{ i.e.}$$

$$\text{IQR} = 1.5 - 0.3 = 1.2$$

The final step is to calculate the Upper and Lower cutoffs as defined by the Equations 1 and 2 above:

$$\text{Upper cutoff} = 1.5 + 1.5(1.2) = 3.3$$

$$\text{Lower cutoff} = 0.3 - 1.5(1.2) = -1.5$$

(or 0, since a negative Lower cutoff does not make sense when data represent constituent concentrations).

In this case, only one observation is not in the range between 0 and 3.3 (i.e., 5.7, or the twelfth observation). Data points not falling between the upper and lower cutoffs should be reviewed to determine whether evidence exists to suggest that these observations are not representative of the background population. The reviewer should direct the facility (entity responsible for conducting closure) to check such data for sampling and laboratory errors, field evidence of waste materials at the sampling locations, and other plausible causes. Where sufficient evidence indicates that an observation does not truly represent concentrations found in background soil, a substitute observation must be provided. If no specific error can be documented, the observation should be retained in the data set.

**Example for odd number of background data:**

For odd numbered data sets, the lower quartile (Q1) can be found by multiplying the number of observations (n) by 0.25, and then rounding the result to the next largest integer. The resulting number indicates the observation which corresponds to Q1. Similarly, Q3 can be found by multiplying n by 0.75, and rounding to the next larger integer. This number refers to the observation which corresponds to Q3. For example, with the following data set (where n = 13):

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.1	0.2	0.4	0.6	0.6	0.8	0.9
(8)	(9)	(10)	(11)	(12)	(13)	
1.3	1.7	1.8	2.1	2.5	5.7	

For Q1:

$$0.25 \times 13 = 3.25; \text{ rounded up} = 4$$

So, Q1 is the 4th observation or 0.6.

Likewise for Q3:

$$0.75 \times 13 = 9.75; \text{ rounded up} = 10$$

So, Q3 is the 10th observation or 1.8.

Q2 (median) is simply the value in the middle - 7th observation or 0.9.

The rest remains the same as in the previous example for even number of data.

If there are no outliers, statistical analysis may proceed.

If outlier are found, their origin must be investigated (as previously explained) before proceeding with statistical analysis.

### 3.12.5.1 Outlier Screening Considerations

Availability of some pertinent information on the subject of interest is a prerequisite for conducting statistical analysis. This information is usually contained in a form of a data set generated from a series of observations. Only when these observations are made in accordance with some predetermined rule and followed by a careful data screening process, will the conclusions from statistical analysis be valid. If data do not represent the truth, the results will be more or less irrelevant, no matter how much sophistication was incorporated into the analysis.

One of the reasons why statistical analysis may not render a correct result is the presence of "outliers" in a data set. By some definitions, an outlier is "an observation which appears to be inconsistent with the remainder of the data set" (Barnett and Lewis, 1984), or "an observation which deviates so much from other observations as to arouse suspicions that it was generated by a different mechanism" (Hawkins, 1980). While these definitions provide a good qualitative description of outliers, some formal test is still required to detect their existence within a data set. Due to a relatively long history of this problem, many methods have been developed and are described in statistical literature ("How to Detect and Handle Outliers" by B. Iglewicz and D.C. Hoaglin, 1993, is a good starting reference). One of such methods is the boxplot rule which, in general form, defines the upper and lower fences as:

$$U = Q_3 + k(Q_3 - Q_1) \quad \text{and} \quad L = Q_1 - k(Q_3 - Q_1), \quad \text{respectively.}$$

Values falling outside the fences (also called the upper and lower cutoff points) are considered to be the potential outliers. In the above equations,  $Q_1$  is the lower quartile,  $Q_3$  is the upper quartile,  $(Q_3 - Q_1)$  is the interquartile range, and the multiplicative constant  $k$  is one of the two factors determining the probability of labeling an observation as an outlier (the other factor is the number of observations). The common range for  $k$  is between 1.5 and 3.0. For the "standard" boxplot (the method recommended by the Ohio EPA)  $k$  equals 1.5. It is important to notice the distinction between results of the boxplot method when  $k$  takes a value on either side of this range. When  $k$  is set to 1.5, the boxplot may show a relatively high number of observations as outstanding, some of which may not be true outliers. On the other hand, when  $k$  equals 3.0, all observations that fall outside the cutoff points can be "safely" considered as outliers. A shortcoming, in this case, is that some lesser (but true) outliers may fall inside the fences and remain unflagged. In other words, the "standard" boxplot ( $k = 1.5$ ) is more likely (approximately nine times - when a normally distributed data set consists of twelve observations) to label an observation as an outlier (albeit possible errors), than a boxplot where  $k$  equals 3.0. Hoaglin and Iglewicz (1987) have provided  $k$  values with specified probability of identifying at least one outlier in a normally distributed data set, depending on the number of observations. For example, if a data set consists of twelve observations, and  $k$  equals 2.2, the probability of labeling at least one observation as an outlier is 5%. The low probability of labeling an observation as an outlier also indicates that the test is "conservative" and that the labeled observation is indeed (very likely) an outlier. In cases where no detailed information exists about the origin of data, the above method can be advantageous by providing certain (predetermined) comfort level in screening out anomalous observations.

When screening observations for the purpose of creating a representative data set for determining background based remediation standards, a considerable amount of information on the data

generating process is usually available. As required, the collection and analysis of soil samples is assumed to be a process controlled by some predetermined sampling methods, analytical procedures and sample handling protocols, where the good understanding of soils, contaminants and relevant site features provides the basis for the choice of sampling locations. Although the intent of all these requirements is to provide reliable information, it is quite possible that some anomalous observations could be made throughout the process. If these observations are judged exclusively by their numerical properties (through the use of a statistical test), there is danger that some of them could be removed from the data set, or retained within, without investigating into the causes for inconsistency. Since an outstanding observation may point to some important issue (like possible site wide contamination, inherent variability of soil, sampling problem, lab error, etc.), it is necessary to utilize all available information when deciding whether the observation will be (justifiably) discarded, or retained in the data set. For that reason, the Ohio EPA recommends a procedure in which the "standard" boxplot method (where  $k = 1.5$ ) is used for labeling potential outliers in a background data set, followed by a thorough investigation to reveal the reasons for any discovered inconsistency.

The "standard" boxplot method is considered to be accurate when data are normally distributed. In other cases, it should be used with caution. For the heavily skewed distributions, other methods are available and described in statistical literature.

#### 3.12.6 Remarks:

- (1) It is frequently found that a BRS has been calculated in the log scale and then exponentiated back to the original scale. This procedure is generally not acceptable because the results of operations conducted on means and standard deviations of transformed data may be biased when directly transformed back into the original scale.
- (2) In some cases, a BRS exclusively calculated in the log scale and then exponentiated back to the original scale can be used for the screening purpose - and only if it does not exceed 97.72nd percentile of the untransformed data set. To finally prove that the soil has been successfully remediated, a t-test should be conducted on the log transformed site and background data.
- (3) Duplicate observations (resulting from duplicate soil samples) should not be averaged prior to a statistical evaluation. Such averaging could lead to spurious conclusions (for example, an outlier could be masked by a smaller value).
- (4) When non-detects are present, the following statistical methods are recommended for data comparison:

Percent non-detects (ND)	Recommended Method
ND <= 15 %	<p>Replace NDs with MDL/2 (half Method Detection Limit) and proceed with the following analysis:</p> <ul style="list-style-type: none"> <li>- <u>For normally distributed data</u>, use parametric statistics, i.e., <i>t</i> test or 95% Upper Confidence Limit test as outlined above.</li> </ul> <p>Remark: As an alternative to MDL/2, Cohen's method may be used (when data are normally distributed) to determine sample mean and variance (i.e., standard deviation) in order to proceed with a <i>t</i> test, or 95% Upper Confidence Limit test.</p> <ul style="list-style-type: none"> <li>- <u>If data can not be normalized</u>, use nonparametric statistics such as Wilcoxon Rank-Sum test.</li> </ul>
15% < ND <= 50%	<ul style="list-style-type: none"> <li>- <u>For normally distributed data</u>, use Cohen's method to determine sample mean and variance (i.e., standard deviation) in order to proceed with a <i>t</i> test, or 95% Upper Confidence Limit test.</li> <li>- <u>If data can not be normalized</u>, use nonparametric statistics such as Wilcoxon Rank-Sum test, or Test of Proportions.</li> </ul>
50% < ND <= 90%	<p>Use nonparametric methods only:</p> <ul style="list-style-type: none"> <li>- Wilcoxon Rank-Sum Test, or</li> <li>- Test of Proportions</li> </ul>
ND > 90%	Use Poison Tolerance Limits, or establish BRS = MDL

- (5) Beside the specially designed statistical computer programs, general spreadsheet software (Excel, LOTUS, etc...) can also be very useful in assisting the closure plan reviewers with statistical reviews. Most spreadsheet applications contain many "built-in" functions for calculating statistics like mean, quartiles (or percentiles), variance, standard deviation, etc. However, quartiles (as well as other statistics) calculated by spreadsheet software sometimes may not be the same as if they were determined through the procedures described in this guidance document. The discrepancy is usually caused by the difference in methods.

---

### 3.12.7 Statistical Analysis Step-by-Step Guidance

#### Analyzing the Background Data Set (for the Constituent of Interest)

**Step 1:** Number of observations

Does the background data set consist of a minimum of 12 (or more) observations derived from 12 (or more) background soil samples (not counting split samples and duplicates)?

NO - Find out the reasons for this deficiency and request additional soil samples in order to obtain a data set with at least 12 observations.

YES - Proceed with Step 2.

**Step 2:** Number of non-detects (values reported as below the Method Detection Limit - MDL)

Are there any non-detects in the background data set?

NO - Proceed with Step 3.

YES - Check if MDL has been clearly stated and remains the same for all soil samples.

If MDL is not clearly stated (or some other value - like PQL, i.e. Practical Quantification Limit, has been used), contact the facility and request the MDL (and any previously unreported values above the MDL) before proceeding with statistical analysis.

If several different values are reported as MDL, request that additional soil samples be analyzed as necessary to obtain a data set (12 observations minimum) based on the same MDL.

If MDL is clearly stated and remains the same for all soil samples, determine the percentage of non-detects.

If the number of non-detects is less than (or about) 15% of the number of observations in the data set, substitute the non-detects with MDL/2 (one half of the Method Detection Limit) and proceed with Step 3.

If the number of non-detects is more than 15% of the number of observations in the data set, proceed in accordance with recommendations given in Section 3.12.6, remark #4.

**Step 3:** Normality of the background data set distribution

In order to be used in a meaningful calculation of a background-based Remediation Standard (BRS), the values in a data set have to be normally distributed. To test the normality of a data set, several methods are recommended:

- 
- Shapiro-Wilk (W) test
  - Kolmogorov-Smirnov (KS) test with Lilliefors critical values
  - Normal Probability plot
  - Box and Whiskers plot.

The normality check should at least include the Normal Probability and Box and Whiskers plots, and either W or KS test.

If the values in the data set are normally distributed, proceed with Step 4.

If the values in the data set are not normally distributed, it may not be possible to calculate a meaningful "single number" as a BRS. In that case, determination on whether the soil has been successfully remediated will have to be based on a statistical comparison of the normalized (transformed) background and confirmation data sets.

**Step 4: Test for outliers**

Use the following equations (see examples in the previous Section "Test for Outliers") to determine whether there is statistical evidence that a background observation appears extreme and therefore does not fit the distribution of the rest of the data:

Upper cutoff = upper quartile + 1.5 (interquartile range)      **Equation 1**

Lower cutoff = lower quartile - 1.5 (interquartile range)      **Equation 2**

If there are no outliers, proceed with Step 5.

If outlier(s) is (are) found, resolve the outlier issues (as explained in Section 3.12.5.1) and proceed with Step 5.

**Remark:** If a data set has to be transformed to normality, test for outliers can be conducted prior to transformation (i.e., on the "raw" data), bearing in mind that the heavily skewed distributions require extra caution. Sometimes elimination of outliers (and substitution with other valid observations, as necessary) can, by itself, bring a data set to normality.

**Step 5: Calculation BRS from a Normally Distributed Data Set**

- a) Calculate the mean ( $\mu_b$ ) and standard deviation ( $S_b$ ) for the background data set.
- b) Calculate BRS as:

$$BRS = \mu_b + 2 S_b$$

If BRS was calculated from a raw (untransformed) background data set, it can be either used for direct comparison with the confirmation concentrations, or in a t test (where the raw confirmation data also has to be normally distributed).

If direct comparison between the BRS and the raw confirmation data shows that no confirmation concentration exceeds the BRS, **STOP HERE** - the soil has been successfully remediated for this constituent.

If direct comparison shows that one or more confirmation concentrations exceed the BRS, a thorough evaluation be conducted to determine if this presents a threat to humans and the environment, whether the elevated concentration(s) should be considered and addressed as "hot spot(s)", whether and how many additional soil samples need to be collected, is it appropriate to perform ("switch" to) a statistical comparison, should these values be included in the data set when conducting a statistical test, etc.

If BRS was calculated from a transformed (normalized) background data set, it can only be used for a statistical comparison (where the confirmation data also has to be normalized with the same transformation).

Proceed with analysis of the confirmation data set.

#### Analyzing the Confirmation Data Set (for the Constituent of Interest)

##### **Step 1:** Number of observations

Does the confirmation data set consist of at least 12 observations derived from an equal number of confirmation soil samples (not counting split samples and duplicates)?

NO - Find out the reasons for this deficiency and request additional soil samples in order to obtain a data set with a minimum of 12 observations. (In some cases, where only direct comparison with BRS is employed, a smaller number of confirmation samples may be sufficient.)

YES - Proceed with Step 2.

##### **Step 2:** Number of non-detects (values reported as below the Method Detection Limit - MDL)

Are there any non-detects in the confirmation data set?

NO - Proceed with Step 3.

YES - Check if MDL has been clearly stated and remains the same for all soil samples.

If MDL is not clearly stated (or some other value - like PQL, i.e. Practical Quantification Limit, has been used), contact the facility and request the MDL (and any previously unreported values above the MDL) before proceeding with statistical analysis.

If several different values are reported as MDL, request that additional soil samples be analyzed as necessary to obtain a data set (12 observations minimum) based on the same MDL.

If MDL is clearly stated and remains the same for all soil samples, determine the percentage of non-detects.

If the number of non-detects is less than (or about) 15% of the number of observations in the data set, substitute the non-detects with MDL/2 (one half of the Method Detection Limit) and proceed with Step 3.

If the number of non-detects is more than 15% of the number of observations in the data set, proceed in accordance with recommendations given in the previous Section 3.12.6, Remark #4.

**Step 3: Normality of the confirmation data set distribution**

In order to be compared with BRS (through a t test), the values in the confirmation data set have to be normally distributed. To test for normality of the confirmation data set, the same methods (previously recommended for the background data set) can be used.

If the values in the confirmation data set are normally distributed, and the values in the background data set are normally distributed, proceed with the t test.

If the values in the confirmation data set are not normally distributed, a logarithmic or some other transformation should be performed on both data sets (confirmation and background) in attempt to normalize them.

If both data sets can be normalized with the same transformation, proceed with the t test.

If the attempt to normalize data fails, nonparametric statistical methods (such as Wilcoxon Rank-Sum test, or Test of Proportions) must be used in order to determine if the soil has been successfully remediated.

t Test

For convenience, t test will be explained through the following example:

Given the background and confirmation data (in mg/kg) for barium,

## Ba - Background

3.43
43.37
44.51
45.04
48.29
50.81
57.74
62.36
64.76
78.27
79.4
110.8

## Ba - Confirmation

15.7
37.5
43.7
44.63
45.88
49.5
55.84
60.71
70.26
80.62
110.3
115.24

the mean and standard deviation for the background data set are:

$$\mu_b = 57.398 \text{ and } S_b = 25.946$$

and the BRS can be calculated as:

$$BRS = \mu_b + 2 S_b$$

$$\text{or } BRS = 57.398 + (2 \times 25.946) = 109.29 \text{ mg/kg.}$$

In order for the soil to be declared remediated for barium, a t test must show that the 95% upper confidence limit for the mean of confirmation data is smaller than the BRS, i.e.:

$$\bar{Y} + t_{m-1, 0.95} \times (S_y/\sqrt{m}) < BRS$$

where:

- $\bar{Y}$  - mean of the confirmation data,
- $t_{m-1, 0.95}$  - t-distribution critical value for m-1 degrees of freedom (df) and confidence level of 95%,
- $S_y$  - standard deviation of the confirmation data, and
- m - number of confirmation data points (observations).

From the confirmation data set:

$$\begin{aligned} m &= 12 \\ df &= m-1 = 11 \\ \bar{Y} &= 60.823 \\ S_Y &= 29.236 \end{aligned}$$

From the table below:

$$t_{m-1, 0.95} = 1.796$$

t distribution critical values for 95% confidence level

df	4	5	6	7	8	9	10		12
t crt. val.	2.131846	2.015049	1.943181	1.894578	1.859548	1.833114	1.812462		1.782287

df	13	14	15	16	17	18	19	20	21
t crt. val.	1.770932	1.761309	1.753051	1.745884	1.739606	1.734063	1.729131	1.724718	1.720744

df	22	23	24	25	26	27	28	29	30
t crt. val.	1.717144	1.71387	1.710882	1.70814	1.705616	1.703288	1.70113	1.699127	1.69726

Remark: t distribution tables with critical values for other confidence levels and degrees of freedom can be found in various books on statistics.

By entering the values in the t test expression (where the left side represents the upper 95% confidence level for the mean of the confirmation data, and the right side is the BRS),

$$60.823 + 1.796 \times (29.236 / \sqrt{12}) < 109.29, \text{ i.e.:}$$

$$75.98 < 109.29$$

it can be shown that the 95% confidence level for the mean of the confirmation data does not exceed the BRS, and the soil can be declared remediated for barium.

Another way to conduct this test is to calculate a t value using confirmation and background data, and then compare it to an appropriate critical value, i.e.:

---

$$\frac{\bar{Y} - BRS}{S_y / \sqrt{m}} < -t_{m-1, 0.95}$$

$$\frac{60.823 - 109.29}{29.236 / \sqrt{12}} < -1.796$$

$$-5.743 < -1.796$$

It is interesting to note that (in this example) the soil can be declared remediated for barium, in spite of the fact that the two confirmation soil samples exhibit concentrations above the BRS.

### 3.12.8 References

American Society for Testing and Materials, 1997. *Standard Practice for Dealing with Outlying Observations*, ASTM E178-94. American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Bickel, P. J., and K. A. Doksum, 1977. *Mathematical Statistics: Basic Ideas and Selected Topics*, John Wiley & Sons Inc., New York, New York.

Conover, W. J., 1980. *Practical Nonparametric Statistics*, 2nd ed., John Wiley & Sons Inc., New York, New York.

Devore, J., and R. Peck, 1986. *Statistics: The Exploration and Analysis of Data*, West Publishing Company, St. Paul, Minnesota.

Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, New York.

Hoaglin, D. C., F. Mosteller, and J. W. Tukey, 1983. *Understanding Robust and Exploratory Data Analysis*, John Wiley & Sons Inc., New York, New York.

Iglewicz B., and D. C. Hoaglin, 1993. *How to Detect and Handle Outliers*, American Society for Quality Control, Statistics Division, Milwaukee, Wisconsin.

---

Shapiro S. S., 1990. *How to Test Normality and Other Distributional Assumptions*, American Society for Quality Control, Statistics Division, Milwaukee, Wisconsin.

Snedecor G. W., and W. G. Cochran, 1980. *Statistical Methods*, 7th ed. Iowa State University Press, Ames, Iowa.

U.S. Environmental Protection Agency, 1992. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*, Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency, 1992. *Statistical Training Course for Ground-Water Monitoring Data Analysis*, EPA/530-R-93-003. Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency, 1997. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*, 3rd ed., Final Update 3. Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.