Chapter 6
Sample Collection

Table of Contents

6.1 General Information Applicable To All Sampling Events
6.1.1 Preparation
6.1.2 Type of Samples
6.1.2.1 Environmental and Waste Samples
6.1.2.2 Grab vs. Composite
6.1.3 Laboratory Procurement
6.1.4 Quality Assurance Samples
6.1.5 Quality Assurance Project Plans
6.1.6 Assuring Health and Safety
6.1.7 Post Sampling Activities
6.2 Soil Sampling
6.2.1 Selection of Sampling Equipment
6.2.2 Equipment Preparation
6.2.3 Soil Logs
6.2.3.1 Wentworth Scale
Table 6.1 Wentworth Scale as Modified from Driscoll, 1986, and Folk, 1975.
6.2.3.2 Unified Soil Classification System (USCS)
Table 6.2 Unified Soil Classification System; from American Society for Testing and Materials, 1985
Table 6.3. Unified Soil Classification System (USCS)
6.2.3.3 Burmister System
Table 6.4 Burmister Soil Classification Naming System (source: Dunn Geoscience Corporation)
Table 6.5 Burmister Soil Classification System Coarse-Grained Soils, Gradation of Components
Table 6.6 Burmister Soil Classification System Fine-Grained Soils, Plasticity of Components
Table 6.7 Burmister Soil Classification System, Components and Fractions, Modified from Burmister, 1950
6.2.3.4 U.S. Comprehensive Soil Classification System
Table 6.8 Textural Descriptions for USDA System
6.2.3.5 Comparison of the Soil Classification Systems
6.2.4 Field Log Books
Table 6.9 Comparison of the Soil Classification Systems compiled from various sources
Boring Log
6.2.5 Determination of Soil Sample Location
6.2.5.1 Surface Soil Selection
6.2.5.2 Subsurface Soil Selection
6.2.6 Field Screening Soil Samples
6.2.7 VOCs Sample Collection for Soils
6.2.7.1 VOC Soil Sample Depth Selection
6.2.7.2 VOC Soil Sample Collection Devices - Small Diameter Core Samplers
6.2.7.2.1 Disposable Syringe

6.2.7.2.2 Easy-Draw Syringe and Power-Stop Handle
6.2.7.2.3 Purge and Trap Soil Sampler®
6.2.7.2.4 En Core® Sampler
6.2.7.3 VOC Soil Sample Collection Technique
6.2.7.4 VOC Soil Sample Preservation Methods
6.2.7.4.1 Closed-System Vials, No Chemical Preservation
6.2.7.4.2 Closed-System Vials, No Chemical Preservation with Organic Free Water (OFW)
6.2.7.4.3 Small Diameter Core Sampler for Storage and Transport (e.g., En Core® Sampler)
6.2.7.4.4 Closed-System Vials, Chemical Preservation – Sodium Bisulfate

6.2.7.4.5 Closed-System Vials, Chemical Preservation – Methanol
6.2.7.4.6 Glass Containers, No Chemical Preservation, No Headspace
6.2.7.5 Sample Aliquot for Moisture Determination and Sample Screening
6.2.7.6 Commercial Equipment Suppliers
Table 6.10 Discrete Soil Sampler Suppliers
6.2.8 Non-VOC Sample Collection for Soils
6.2.9 Sampling Alternatives for Situational and Matrix Variations
6.2.9.1 Sampling Hard or Cemented Material
6.2.9.2 Sampling a Mixture of Fines and Gravel
6.2.9.3 Sampling Dry Non-Cohesive Material
6.2.9.4 Sampling Sediments
6.2.9.5 Sampling Oil Waste, Tars and Other Waste Material
6.2.9.6 Sampling from Test Pits

6.3 Rock Core Sample Collection

6.3.1 Coring Methods
6.3.1.1 Drill String Coring
6.3.1.2 Wireline Coring
6.3.2 Coring Tools
6.3.2.1 Tube-Type Coring Tools
Figure 6.1 Double tube coring tool
Figure 6.2 Impregnated diamond bit
6.3.2.2 Sidewall Coring Tools
6.3.2.3 Oriented Coring Tools
6.3.3 Coring Procedures
6.3.4 Rock Core Logging
6.3.5 Rock Core Storage
6.3.6 Special Tests and Analyses of Rock Cores
Table 6.11 Rock Coring Requirements

6.4 Direct Push Technology

6.5 Sampling Containerized Material

6.5.1 Drums, Bags, Sacks, Fiberdrums and Similar Small Containers
6.5.1.1 Containerized Solids
6.5.1.2 Containerized Liquids
6.5.2 Tanks, Vacuum Trucks, Process Vessels and Similar Large Containers
6.5.3 Transformers

6.6 Waste Pile Sampling

6.6.1 Considerations for the Sampling Plan

6.6.1.1 Shape and Size
6.6.1.2 Characteristics of the Material
6.6.1.2.1 Type of Material
6.6.1.2.2 Chemical Stability
6.6.1.2.3 Particle Size
6.6.1.2.4 Compactness/Structure of Material
6.6.1.3 Purpose of Sampling
6.6.2 Sampling Procedures
6.6.2.1 Surface
6.6.2.2 At Depth
6.6.3 Required Analytes and Frequency
6.6.3.1 Waste Classification
6.6.3.2 Quality Assurance
6.6.3.3 Characterization

6.7 Surficial Sampling

6.7.1 Wipe Samples
6.7.2 Chip Samples
6.7.3 Sweep Samples
6.7.4 Rinsate Samples

6.8 Surface Water And Sediment Sampling

6.8.1 General Considerations and Requirements for NJDEP Programs
6.8.1.1 Health and Safety Considerations
6.8.1.2 Physical Characteristics and Water Quality Measurements for Ambient Monitoring
6.8.1.3 Sample Number and Location
6.8.1.4 Sampling Sequence
6.8.1.5 Surface Water Flow Conditions
6.8.1.6 Tidal Influences
6.8.1.7 Equipment Selection
6.8.1.7.1 Aqueous
6.8.1.7.2 Non-Aqueous
6.8.1.8 Considerations for Wastewater Point Source Sampling
6.8.2 Freshwater and Biological Monitoring Program
6.8.2.1 Sampling Objectives
6.8.2.2 Aqueous Samples
6.8.2.2.1 Stream/Flowing Water
6.8.2.2.2 Composite Sampling
6.8.2.2.3 Grab Sampling
6.8.2.2.4 Point Sampling
6.8.2.2.5 Lake/Standing Water Sampling
6.8.2.2.6 Estuarine and Marine Water Sampling
6.8.2.2.7 Bacteriology
6.8.2.2.8 Trace Element Sampling
6.8.2.3 Non-Aqueous Samples
6.8.2.3.1 Sediments
6.8.2.3.1.1 Onshore
6.8.2.3.1.2 Offshore
6.8.2.3.1.3 General Procedures
6.8.2.3.2 Sludge

6.8.2.4 Flow Measurements
6.8.2.4.1 Open-Channel Flow Measurement
6.8.2.4.2 Open-Channel Flow Meters
6.8.2.4.2.1 Palmer-Bowlus Flumes
6.8.2.4.2.2 Parshall Flumes
6.8.2.4.3 Weirs
6.8.2.4.3.1 V-Notch Weirs
6.8.2.4.3.2 Rectangular Weirs
6.8.2.4.3.3 H-Type Flumes
6.8.2.4.4 Instrumentation for Open-Channel Flow
6.8.2.4.5 Closed-Pipe Flow Metering Systems
6.8.2.4.6 Types of Meters, Methods and Systems
6.8.2.4.6.1 Electromagnetic Flow Meters
6.8.2.4.6.2 Turbine Meters and Propeller Meters
6.8.2.4.6.3 Rotating Element Current Meters
Figure 6.3 Propeller Current Meter
Figure 6.4 Price Current Meter
6.8.2.4.6.4 Ultrasonic Meters
6.8.2.4.6.5 Pitot Tube Meters
6.8.2.4.6.6 Differential Pressure Systems
6.8.2.4.6.7 Velocity Modified Flow Meters
6.8.2.4.6.8 Floats
6.8.2.4.6.9 Salt Velocity Method
6.8.2.4.6.10 Color Velocity Method
6.8.2.4.6.11 Discharge
6.8.2.4.7 Miscellaneous Flow Measurement Methods
6.8.2.4.7.1 Water Meters
6.8.2.4.7.2 Measure Level Changes in Tank
Figure 6.5 Stationary Volume of Liquid in Horizontal Cylinders
6.8.3 Site Remediation and Waste Management Program
6.8.3.1 Sampling Objectives
Table 6.12 Comparison of Various Methods to Obtain Mean Velocity
6.8.3.1.1 Site-Related Sample Locations
6.8.3.1.2 Reference Sample Location
6.8.3.2 Aqueous Samples
6.8.3.2.1 Flowing Non-Tidal Water Bodies
6.8.3.2.2 Standing Water Bodies
6.8.3.2.3 Tidal Water Bodies
6.8.3.2.4 Determination of Contaminated Ground Water Discharge Points
6.8.3.3 Non-Aqueous Samples
6.8.3.3.1 General
6.8.3.3.2 Flowing Non-Tidal Water Bodies
6.8.3.3.3 Standing Water Bodies
6.8.3.3.4 Tidal Water Bodies
6.8.3.4 Use of Passive Diffusion Bag Samplers
6.9 Ground Water Sampling Procedures
6.9.1 Scope
6.9.2 Means of Sample Collection
6.9.2.1 Temporary Well Points and Direct Push Technology

6.9.2.2 Low-Flow Purging and Sampling
6.9.2.2.1 Method Summary and Application
6.9.2.2.2 Introduction
Low Flow Sampling Data Sheet
Field Instrumentation and Calibration Data Sheet
Monitor Well Information in Support of Pump Intake Depth Placement
6.9.2.2.3 Low Flow Policy
6.9.2.2.4 Laboratory Certification (N.J.A.C. 7:18)
6.9.2.2.5 Specific LFPS Considerations
6.9.2.2.5.1 Pump Intake Location
6.9.2.2.5.2 Water Quality Indicator Parameters (WQIPs)
6.9.2.2.5.3 Purge Volume vs. Stabilization Time
6.9.2.2.5.4 Tubing
6.9.2.2.5.5 Flow-Through Cell
Figure 6.6 Illustration of Flow Cell with stand
6.9.2.2.5.6 Pump Selection
6.9.2.2.5.7 Plumbing Fittings
Figure 6.7 Closeup of Needle Valve
6.9.2.2.5.8 Calibration of Probes
6.9.2.2.5.9 Water Level Measurements
6.9.2.2.5.10 Pump Installation
6.9.2.2.5.11 Purge Rates
6.9.2.2.5.12 Sampling
6.9.2.2.5.13 Pump Decontamination
Figure 6.8 Grundfos® Pump being prepared for decontamination
6.9.2.2.5.14 Field Blank Collection
6.9.2.2.6 Tips
6.9.2.2.6.1 Temperature Measurement and Submersible Pumps
6.9.2.2.6.2 Control of Pump Speed
6.9.2.2.6.3 pH
6.9.2.2.6.4 Temperature of Calibration Solutions
6.9.2.3 Low-flow Purging and Sampling for Low-Yielding Wells
6.9.2.4 Volume-Averaged Purging and Sample Collection
6.9.2.5 Point Source (No-Purge) Sampling
6.9.2.5.1 Passive Diffusion Bag Samplers (PDBS)
6.9.2.5.1.1 Introduction
6.9.2.5.1.2 Limitations And Concerns
6.9.2.5.1.3 Theory
6.9.2.5.1.4 PDBS Construction
6.9.2.5.1.5 Contaminant Detection Capabilities
Table 6-13 Passive Diffusion Bag Samplers (PDBS)
6.9.2.5.1.6 Well Construction Considerations
6.9.2.5.1.7 Contaminant Stratification/Multiple Sampler Deployment
6.9.2.5.1.8 Vertical Flow Within the Well
6.9.2.5.1.9 Comparison of PDBS Results with Conventional Sampling Methods
6.9.2.5.1.10 Use of PDBS in Sentinel Wells
6.9.2.5.1.11 Procedures for PDBS Use (Deployment/Retrieval)
6.9.2.5.1.11.1 Weights and Deployment Lines
6.9.2.5.1.11.2 Measuring and Attaching the PDBS to the Deployment Line

6.9.2.5.1.11.3 Equilibration Time
6.9.2.5.1.11.4 Sample Retrieval
6.9.2.5.1.11.5 Quality Assurance/Quality Control Samples
6.9.2.5.1.11.5.1 Blanks for Lab filled PDBS
6.9.2.5.1.11.5.2 Blanks for Field Filled PDBS
6.9.2.5.1.12 Data Reporting Requirements
NJDEP Checklist for the Submission of Sampling Data for Passive Diffusion Bag Samplers (PDBS)
6.9.3 Sampling Private Homeowner Wells (a.k.a. Public Non-Community/Non-Public/Domestic Wells)
6.9.4 Sampling Point of Entry Treatment (POET) Systems
6.9.5 Sampling Industrial Wells
6.9.6 Sampling Municipal and Industrial Wastewater
Table 6.14 Suggested Biochemical Oxygen Demand Dilutions
6.9.7 Public Community Water Systems
6.9.7.1 Source Sample (Raw Water)
6.9.7.1.1 Ground Water
6.9.7.1.2 Surface Water
6.9.7.2 Plant Delivered Sample (Finished Water)
6.9.7.3 Point of Entry Sample
6.9.7.4 System Sample
6.9.8 Ground Water-Level Measurements
6.9.8.1 Steel Tapes
6.9.8.2 Electronic Ground Water-Level Indicators
6.9.8.3 Helpful Hints
6.9.8.4 Ground Water Level and Non-Aqueous Phase Liquid (NAPL) Measurements
6.9.8.4.1 Clear Bailer
6.9.8.4.2 Interface Probes
6.9.9 New Well Construction and Stabilization
6.9.9.1 Well Development
Figure 6.9 Sand Bridges
6.9.9.2 Other Considerations
6.9.10 Filtering Ground Water Samples
6.9.10.1 Total Metals Sampling
6.9.10.2 Trace Metals Sampling
6.9.10.3 Dissolved Metals Sampling
6.9.10.4 Filtering Procedures for Dissolved Metals Analysis
6.9.11 Sampling for Light, Non-Aqueous Phase Liquids (LNAPLS)
6.9.12 Sampling for Dense, Non-Aqueous Phase Liquids (DNAPLs)
6.10 Biological Sampling Procedures
6.10.1 Phytoplankton Sampling
6.10.1.1 Sample Site Location
6.10.1.2 Sampling Depth
6.10.1.3 Sampling Procedure
6.10.2 Zooplankton Sampling
6.10.2.1 Sample Site Location
6.10.2.2 Sample Depth
6.10.2.3 Sampling Procedure

6.10.3 Macrophyte Sampling
6.10.4 Macroinvertebrates
6.10.4.1 Hester-Dendy Artificial Substrates
6.10.4.1.1 Sampler Placement
6.10.4.1.2 Sampler Retrieval
6.10.4.2 Surber or Square Foot Bottom Sampler
6.10.4.2.1 Sampler Placement
6.10.4.2.2 Sampler Retrieval
6.10.5 Grab Samplers
6.10.6 Periphyton Sampling
6.10.6.1 Artificial Substrates
6.10.6.1.1 Sampler Placement
6.10.6.1.2 Sampler Retrieval
6.10.6.2 Natural Substrates
6.10.7 Rapid Bioassessment (RBP) Techniques*
6.10.7.1 Benthic Macroinvertebrates
6.10.7.2 Single Habitat Sampling
6.10.7.3 Multi-habitat Sampling
6.10.7.4 Periphyton

6.11 Toxicological Sampling (Toxicity Test or Bioassay)

6.11.1 Dilution Water Sample Collection and Handling
6.11.2 Effluent Samples Shall be Collected and Handled in the Following Manner
6.11.3 The Following Chain of Custody Procedures

Appendix 6.1 Monitor Well Construction and Installation

A.6.1.1 Introduction

A.6.1.2 Conventional Well Drilling Methods

A.6.1.2.1 Hollow-Stem Augers (HSAs)
A.6.1.2.2 Rotary Drilling
A.6.1.2.3 Drilling Fluids

A.6.1.3 Specialized Drilling Methods

A.6.1.3.1 Sonic Drilling
A.6.1.3.2 ODEX® Method
Figure 6.10 ODEX® System
A.6.1.3.3. Direct-Push Drilling

A.6.1.4 Monitor Well Design And Construction Considerations

A.6.1.4.1 Well Diameter
A.6.1.4.2 Well Construction Materials
A.6.1.4.3. Screen Length
A.6.1.4.4 Screen Slot Size and Filter Pack Materials
A.6.1.4.5 Grouting Materials
A.6.1.4.6 Well Depth
A.6.1.4.7 Multi-Screened Wells
A.6.1.4.8 Pre-Packed Well Screens
A.6.1.4.9 Horizontal Wells
A.6.1.4.10 Wells Used to Investigate LNAPL and DNAPL
A.6.1.4.11 Lysimeters

A.6.1.5 Miscellaneous Well Construction Considerations
A.6.1.5.1 Well Development
A.6.1.5.2 Maintenance of Wells
A.6.1.5.3 Well Decommissioning Requirements
A.6.1.5.4 Flush Mount Wells
Figure 6.11 Typical Flush-Mount Completion
A.6.1.5.5 Subsurface and Overhead Utilities

Appendix 6.2 NJDEP Monitor Well Specifications for Bedrock, Unconsolidated and Confined Aquifers

A.6.2.1 Monitoring Well Requirements For Bedrock Formation
Figure 6.12 Bedrock Formation Well

A.6.2.2 Monitor Well Requirements For Unconsolidated Aquifers
Figure 6.13 Unconsolidated Aquifer Well

A.6.2.3 Monitor Well Requirements For Confined Unconsolidated Aquifers
Figure 6.14 Confined Unconsolidated Aquifer Well

References

USGS Links of Interest

USEPA Links of Interest

Other URLs of Interest
Soil Science
Soil Classification
Sediments
Manufacturers/Vendors of Environmental Sampling Equipment
General

◀ Return to TOC

Chapter 6
Sample Collection

6.1 General Information Applicable To All Sampling Events

This chapter details many of the step by step procedures to be followed during the collection of environmental samples from various matrices. The use of different kinds of sampling equipment dictates that different factors must be considered for each type of sample collected. Some factors concerning sample collection, however, remain the same regardless of the sample's matrix or device used. This non-site specific information comprises the first part of this section. For site-specific considerations, contact the appropriate regulatory authority. The general information in presented here, when used with information in any of the other sections of this chapter and as dictated by the site-specific conditions, will allow the most representative sample to be collected in a safe and efficient manner.

6.1.1 Preparation

Thorough preparation before the initiation of a sampling event is undoubtedly one of the most important steps in the sampling process. Additional costs can be incurred if sampling must be continued on another day or completely re-done due to inadequate or improper preparation. Therefore, equipment lists should be prepared and personnel needs should be projected. In cases where it is questionable which type of sampling device will work best, several should be on hand. If potential obstacles to the timely completion of the job exist, extra personnel should be scheduled.

In addition to procurement of the appropriate equipment, sampling preparation includes assuring that equipment is in good working condition and properly decontaminated. The sampling device should be cleaned per one of the approved methods described in Chapter 2 and properly prepared for transport to the site. Care must be taken in transporting and storing cleaned sampling equipment. Equipment should never be stored or transported in the same vehicle used to transport generators, gasoline or decontamination solvents. Under such conditions cross-contamination is likely to occur.

The material of construction for sampling equipment should be PTFE or stainless steel (see Chapter 5. *Sampling Equipment*, 5.1 *Introduction*). Each sampling device should be used to collect one sample. In some cases, the use of dedicated samplers may be impractical. When collecting numerous surface soil samples (using trowels) or subsurface soil from boreholes (using direct push or split spoon samplers) it may be necessary to decontaminate equipment in the field. An equipment decontamination area must be set up to accomplish this. The decontamination area should be established in a non-contaminated zone and should consist of chemical resistant buckets placed on clean plastic sheeting. Solutions required for equipment decontamination must be on-hand and should be in easy to use squirt bottles. Assorted heavy-duty scrub-brushes must be available. All rinse fluids must be collected and provisions made for their proper disposal.

When decontaminating equipment in the field, extra care must be taken to assure thorough cleaning. Because of the difficulty encountered in cleaning bailers, field decontamination is not allowed for this piece of equipment. Bailers must be laboratory cleaned, wrapped and dedicated to each well for each day's sampling.

In addition to the site specific decontaminated sampling device, other equipment is necessary during the execution of a sampling event, which may include but not be limited to:

- Lab-cleaned sample containers of the proper size and composition provided by the laboratory performing the analysis.
- Quality control samples (e.g., field and/or trip blanks, duplicates, performance evaluation samples).
- Bound field logbook, and camera.
- Appropriate paperwork (e.g., Chain of Custody, Logging and Calibration forms).
- Sample labels.
- Reagents, preservatives, coolers and a means to maintain sample temperature at 4ºC.
- Portable instrumentation (e.g., Geiger counter, explosimeter, oxygen level monitor, photoionization detector, flame ionization detector, flow through cell).
- Narrow range pH paper, that is within the "Use By" time frame indicated by the manufacturer, to check the pH of preserved samples.
- Appropriate personal safety equipment (e.g., disposable gloves, eye protection, and respirators).
- Decontamination equipment for personnel and/or equipment.
- Absorbent pads.
- Plastic bags for containerizing contaminated items.
- Packaging materials for sample shipment and custody seals for shuttles. This includes appropriate shipping containers that meet either USDOT or USDOT/IATA standards depending upon the "dangerous goods" classification for packaging and shipping samples to the laboratory.

Finally, one must plan for all other equipment needed to meet specified requirements in the sampling plan and the Technical Requirements for Site Remediation. Examples include equipment used to determine the depth of sample, pH, temperature, and dissolved oxygen content of aqueous samples, or the instrumentation necessary to determine the geographically referenced location of any sample.

6.1.2 Type of Samples

Return to TOC

6.1.2.1 Environmental and Waste Samples

Environmental: samples of naturally occurring matrices such as soil, sediment, ground water, surface water and air.

Waste: samples, which are comprised of process waste or other man-made materials.

Making the distinction between environmental and waste samples is important when it comes to choosing sampling equipment, the material of construction (see Chapter 5), personal safety precautions, and for complying with transportation requirements. For waste samples, the volumes needed by the laboratory for certain analysis can be reduced thus minimizing the volumes collected in the field and disposal issues for the laboratory. The actual volumes of waste samples needed by the laboratory should be determined and detailed in the QAPP.

Environmental and waste samples have the potential to contain significant amounts of hazardous materials. Since these samples pose a safety threat, they should be designated, handled and shipped as dangerous goods according to U.S. Department of Transportation regulations (see Chapter 11, *Sample Shipment*).

6.1.2.2 Grab vs. Composite

Grab sample: a discrete aliquot that is representative of one specific sample site at a specific point in time. Since the entire sample is collected at one particular point and all at one time, a grab sample is representative only of those static conditions. If the source or condition is fairly consistent over a period of time and/or geographical area, the grab sample can be considered to be fairly representative. However, for sources that vary greatly over time, distance or area (e.g., release of contaminants into moving water or air) the representativeness of a grab sample is not as easily discernable.

Composite sample: a non-discrete sample composed of more than one specific aliquot collected at various sampling points and/or at different points. Composite samples may give an "average" concentration or composition over time or area. When compositing is performed the concentration of contaminant in individual grab samples may be diluted proportionately to the number of samples taken. Not only is contaminant dilution possible, the detection limits for each individual sample may be raised proportionally by the number of samples added to the composite. For instance, if a sampler wishes to composite two discrete samples into one and the method detection limit for a target compound were 330 ppb, the detection limit for the target compound does not change for the composite. However, the detection limit for the compound in the individual samples, which make up the composite is two times the normal detection limit or 2 x 330 = 660 ppb. This is important to keep in mind because if a contaminant were present in only one of the two composited samples, and if it were at a level between 330 and 660 ppb, that contaminant would not be quantified or possibly even identified due to the effective dilution of the contaminant concentration in the composite. This concept should be taken into account when determining the data quality objectives of a composite-sampling event, to ensure that useful data is collected. It is advisable that if a positive identification is made in the course of analyzing a composite sample, that the discrete samples then be analyzed individually to determine the true distribution of contaminant throughout each component of the composite.

When collecting samples at hazardous waste sites for the Site Remediation and Waste Program, grab sampling should be the chosen method. While composite samples may have merit when performed for specific purposes and under known conditions, the risks involved may be great (mixing unknown/reactive waste) and the information provided not particularly useful. To improve the quality of the composite sample, follow the compositing considerations offered in ASTM D6051-96 *Standard Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities*. Two possible homogenization options to consider for soil are the cone and quarter technique or use of a riffle splitter. For aqueous samples use of a churn splitter may be a suitable option.

Compositing samples may pose a potential safety risk when samples of unknown content are combined. Changes in the chemical nature of the sample may occur as a result of this combination causing the sample to be non-representative of actual field conditions for a particular time or location. Additionally, contaminants in one aliquot of sample may be masked when this portion is composited with other, cleaner aliquots.

If compositing is allowed in site specific instances, it should occur in the laboratory for hazardous samples, and in the field for wastewater or stormwater samples. Samples should be composited on a weight/weight or volume/volume basis under controlled conditions. Be aware that there are no formal laboratory methods for compositing samples at the laboratory, so procedures will vary from laboratory to laboratory and possibly within a laboratory. Always keep in mind that consistency helps to ensure comparability of data.

Note: For discussion on duplicate, split, and other QA/QC sample collection requirements see Chapter 2.

6.1.3 Laboratory Procurement

Return to TOC

The analytical needs associated with the collection of samples should be clearly defined in the site-specific sampling plan. Important information regarding the data quality objectives, analytical methods to be employed, turnaround times, deliverables, and funds available must be specified. When choosing a lab, these factors act as a guide. Additional considerations include:

- whether the lab has maintained the required certifications and approvals for specific parameters for which samples are to be analyzed.
- whether the lab is available to perform the analysis requested.
- whether the lab has the capacity to handle all the samples that will be delivered.
- whether the lab can perform the analysis within the time frame specified (if applicable).
- the lab's proximity to the site or capability to pick up and deliver as needed.
- whether the lab provides DOT/IATA shipping containers and packaging materials.

6.1.4 Quality Assurance Samples

When advising the chosen laboratory of the required analyses, specifications regarding quality control samples should be relayed. The lab should be informed as to the rate of inclusion of trip and field blanks, how this water should be provided (e.g., identical sets of filled and empty bottles for field blank collection), the requirements for the quality and origin of the blank water (e.g., the same as the method blank) and the analysis desired (see Chapter 2) for the associated blanks.

The laboratory's procedure for bottle preparation and storage, blank preparation and mechanism for transport and maintenance of temperature should be evaluated and the associated paperwork should be reviewed for adequacy.

Quality assurance considerations must be addressed prior to sampling. If upon initiation of the sampling it is discovered that one or several quality assurance considerations have not been properly addressed, no sampling should occur. In such a situation, with personnel and equipment on standby in the field, the importance of effective communication with the lab is crucial.

6.1.5 Quality Assurance Project Plans

Since sampling situations vary widely and no universal sampling procedure can be recommended, it is important that a sampling plan or quality assurance project plan be developed per regulatory authority requirements. As stated in Chapter 2, all regulatory programs require the submittal to and approval by the Department of a QAPP prior to the sampling. Please refer to Chapter 2 for the Quality Assurance Project Plan Requirements

6.1.6 Assuring Health and Safety

The health and safety of sampling and support personnel is the most important priority during collection operations. Appropriate portable monitoring devices, which have been properly calibrated, should be used by properly trained personnel to monitor site conditions. A complete Health and Safety Plan should be developed based on information gathered during the file search and instrument readings from the pre-sampling site visit. This Plan should detail potential hazards, instruments to be used, their calibration and use, level of protection to be worn by personnel during various on-site activities, emergency services locations and phone numbers, etc. To assure

health and safety in unknown situations (e.g., sites with little available historic information or in initial entry situations) a worst case scenario should always be assumed until instruments confirm otherwise. (See Chapter 4, *Site Entry Activities*.)

For example, test pit excavation sampling or the sampling of containerized materials, may initially require level B personal protection. The results of continuous air monitoring may determine that downgrading personnel protection is acceptable.

6.1.7 Post Sampling Activities

There are several steps to be taken, even after the transfer of the sample into the sample bottle, that are necessary to properly complete collection activities. Once the sample is transferred into the appropriate container, the bottle should be capped and, if necessary, the outside of the bottle should be wiped with a clean paper towel to remove excess sampling material. The bottle should not be submerged in water in an effort to clean it. Rather, if necessary, a clean paper towel moistened with distilled and deionized water may be used.

The sample should be preserved immediately (4ºC and/or with appropriate reagent as detailed in the approved QAPP), properly labeled, properly packaged for transportation and custody sealed. Information such as sample number, location, collection time and sample description should be recorded in the field logbook. Associated paperwork (e.g., Chain of Custody forms, Sample Analysis Request forms) should then be completed and should stay with the sample. The samples should be packaged in a manner that will allow the appropriate storage temperature to be maintained during shipment to the lab. Samples should be delivered to the lab so the proper temperature level is assured and analytical holding times are not exceeded.

Return to TOC

6.2 Soil Sampling

This recommended protocol outlines procedures, equipment and other considerations specific to the collection of representative surface and subsurface soil samples. When followed, these guidelines serve to maintain sample integrity by preserving physical form and chemical composition to as great an extent as possible. In addition to this section, the reader should refer to the following chapters in order to attain a more complete understanding of the requirements associated with soil sampling: Chapter 2, *Quality Assurance*; Chapter 5, *Sample Equipment*; Chapter 7, *Field Analytical Methods*; and Chapter 13, *Personnel Protection*. Finally, effective soil sampling can not be complete without reference to The Technical Requirements for Site Remediation (N.J.A.C. 7:26E, (http://www.state.nj.us/dep/srp/regs/techrule/).

6.2.1 Selection of Sampling Equipment

New Jersey's soil types range from the principally unconsolidated sandy soils of the southern coastal plain to the more heterogeneous soils in the north. Particular attention should be paid to the soil type being investigated in order to select the most appropriate sampling device. Generally, the northern region's rocky soil increases the difficulty obtaining a representative sample. Therefore, when sampling outside the coastal plain, extra consideration for the proper selection and advancement effort of the chosen sampling device must be factored into the planning of the sampling effort.

In certain site-specific circumstances, the parameters being investigated or the reagents being used for decontamination may influence the device's type and style of construction. Specifically, the sensitive chemical/physical nature displayed by the volatile organic fraction requires special consideration in sample equipment selection. Some sampling devices (e.g., bucket auger) may churn or otherwise alter or destroy certain physical attributes (e.g., pore space, ped formation, horizon delineation, color, etc.) and aerate the soil. This can cause an unwanted loss of volatiles from the sample. These devices can not be used for volatile organic sample collection. The recommended device (e.g., soil corer or split spoon) should produce a relatively undisturbed soil core, which will minimize the loss of VOCs and the destruction of soil characteristics (i.e., silt/clay). The chosen device should also be able to present the soil in such a fashion as to lend reasonable accessibility to field screening instruments (e.g., PID/FID) which in turn will assist in a reasonable interpretation of potential contamination across a measurable segment of the soil horizon. The optimum device will yield a sample, which has been minimally disturbed, where any biased sample may be easily identified and whose depth can be determined for future reference. For further clarification, advanced discussion with the regulatory authority is recommended before proceeding. Correct selection of sampling equipment will not only save time and expense, but will allow for collection of the most representative sample possible.

Typical soil sampling devices and accessories include but are not limited to the following:

- scoop or trowel*
- bucket/hand auger*
- soil coring device
- waste pile sampler
- split spoon sampler
- Shelby tube sampler
- mixing bowl or tray*
- spatula*

*Not acceptable for use when sampling VOCs

All of the above devices must be of stainless steel construction. In certain pre-approved circumstances, scoops or trowels constructed of rigid polyvinyl or polyethylenes are acceptable, but their reuse limited to a particular site and/or excessive wear. Another exception to this rule is the split spoon sampler, which is commonly constructed of carbon steel.

6.2.2 Equipment Preparation

After selection of the proper device, consideration must be given to equipment decontamination. When the decontamination procedure is properly performed (see Chapter 2), the potential for cross contamination can be significantly reduced. Care must be taken if a parameter of concern (i.e. acetone) is part of the decontamination process, or equipment damage by the reagents used during decontamination is a possibility (i.e. nitric acid rinse is detrimental to components constructed of bronze or carbon steel). When these site-specific questions arise, discussion with the regulatory authority may be prudent before a sampling plan is finalized.

All soil sampling devices used for chemical analysis must be decontaminated prior to use and in between sample locations. Once the equipment has been cleaned, it must be protected from incidental contact by wrapping in aluminum foil or placing in sealed plastic bags.

Additionally, any heavy equipment necessary for the advancement of any sampling device must be steam cleaned or high pressure/hot water washed prior to and between sample locations. This would include, but is not limited to, auger flights, drill rods, backhoe buckets and other respective accessories.

Depending on site conditions or sampling requirements, soil may have to be collected from beneath concrete pads, floors or asphalt paved areas. In these instances, the equipment used to expose the soil beneath must also be decontaminated if the equipment will directly contact the sample. Similar to the treatment of heavy equipment, decontamination of sampling equipment must be performed prior to each sample acquisition. Particular attention should be paid to the lubricating water associated with concrete coring equipment. If a potable water source is not available and the potential integrity of the sample is in jeopardy, analysis of the lubricating water used may be necessary.

It can not be overstated that costly and lengthy cleanup or permit decisions are based on the outcome of soil samples collected in relatively short order. Therefore, initial attention to equipment selection and its preparation can offer a significant reduction in oversight expense while providing the most professional results.

6.2.3 Soil Logs

Pursuant to N.J.A.C. 7:26E-3.6(a)2, a profile of subsurface conditions is required for investigations concerning soil contamination. Soil logs must be prepared to document soil types, field instrument measurements, depth to groundwater, soil mottling, presence of odors, vapors, soil discoloration, or the presence of free and/or residual product. Information obtained by performing the Standard Penetration Test (SPT, ASTM Method 1586-84) must also be included on the soil boring logs. Similar information must also be recorded when installing monitor wells, pursuant to N.J.A.C. 7:26E-4.4(g)4.

Important! Soil logs must be completed after sample collection for laboratory analysis to minimize losses due to volatilization and biodegradation as well as cross contamination due to excessive handling of the soil.

Soil logs should include a description of texture, moisture content, color, stratification, fabric and structure. Texture descriptions include the relative angularity, roundness and sorting of the particles as well as their grain size. Description of moisture content include terms such as dry, moist, wet, or saturated. Descriptions of soil fabric should include whether the particles are flat or bulky and whether the particles are stratified, laminated, varved etc. Soil color descriptions should reference Munsell color charts. Variations in color, e.g., mottling, can provide information on the extent of water-table fluctuations and geochemical conditions (aerobic vs. anaerobic) or formational changes. Soils with bright and uniform colors generally are well drained. Soils with gray or dull colors may be poorly drained. Color changes may also indicate the presence of contaminants. For example, soils and clay may become darker in a reducing environment ("gleying") caused by the presence of petroleum hydrocarbons. The size, type and condition of rock fragments should also be included (e.g., shale, sandstone, decomposed, and friable, etc.).

Soil texture must be classified according to one of the standard systems discussed below. Since there is some variability between the different soil classification systems, all logs should specify which soil classification system is being used or provide the size ranges on the log. For consistency, it is also important to compare the soil samples in the field with a reference card for the classification system being used. These are commercially available from various sources. The following is a discussion of some of the soil classification systems commonly used to characterize the texture of soils and sediments. Although the terms used in the classification systems (e.g., sand, silt, and clay) have mineralogical connotations, the terms used here refer strictly to soil and sediment textures. An example of a boring log is provided on page 23 to assist field personnel in recording observed soil data.

6.2.3.1 Wentworth Scale

The Wentworth scale was developed in 1922 and is based on the work of Udden. It is the generally accepted standard used by geologists and sedimentologists in North America (Pettijohn, 1975). It is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit (Folk, 1974, page 25). It is used to describe the texture of sedimentary rocks (e.g., sandstone) as well as unconsolidated sediments. The US Geological Survey uses this classification but has taken the gravel size range and subdivided it into groups as shown in Table 6.1 below.

Table 6.1 Wentworth Scale as Modified from Driscoll, 1986, and Folk, 1975.

Wentworth Size Class	Millimeters	Inches	Standard Sieve #
Boulder	256 +	10.08 +	
Cobble	64 - 256	2.52 - 10.08	
Pebble	4 - 64	0.16 - 2.52	
Very coarse gravel	32 - 64	1.26 - 2.52	
Coarse gravel	16 - 32	0.63 - 1.26	
Medium gravel	8 - 16	0.31 - 0.63	
Fine gravel	4 - 8	0.16 - 0.31	No. 5 +
Granule (v.f. gravel)	2 - 4	0.08 - 0.16	No. 5 - No. 10
Very coarse sand	1 - 2	0.04 - 0.08	No. 10 - No. 18
Coarse sand	0.5 - 1	0.02 - 0.04	No. 18 - No. 35
Medium sand	0.25 - 0.5	0.01 - 0.02	No. 35 - No. 60
Fine sand	0.125 - 0.25	0.005 - 0.01	No. 60 - No. 120
Very fine sand	0.0625 - 0.125	0.002 - 0.005	No. 120 - No. 230
Silt	0.004 - 0.0625	0.0002 - 0.002	analyze by pipette or hydrometer
Coarse silt	0.031 - 0.0625		
Medium silt	0.0156 - 0.0625		
Fine silt	0.0078 - 0.0156		
Very fine silt	0.0039 - 0.0078		
Clay	below 0.0039	below 0.0002	

6.2.3.2 Unified Soil Classification System (USCS)

The USCS was developed for the US Army Corps of Engineers and Bureau of Reclamation for classifying soils for engineering purposes based on laboratory determination of particle size, liquid limit and plasticity index. It was first used to judge a soil's suitability as a subgrade for roads and airfields, but it is used today for most engineering applications of soil. It differentiates soils into three major divisions: coarse-grained, fine-grained and highly organic soils as shown in the table below. Fine-grained soils are classified as those that will pass through a No. 200 U.S. standard sieve (0.074 mm). Organic material is a common component of soil but it has no size range. Each type of soil is given a two-letter designation based primarily on its particle-size distribution (texture), Atterberg limits, and organic matter content. Tables 6.2 and 6.3 below describe the USCS.

Table 6.2 Unified Soil Classification System; from American Society for Testing and Materials, 1985

Major Divisions			Group Sym.	Group Name
Coarse Grained Soils–More Than 50% Retained On No.200 Sieve	Gravel–More Than 50% of Coarse Fraction Retained On No.4 Sieve	Clean Gravel	GW	Well-Graded Gravel, Fine to Coarse Gravel
			GP	Poorly-Graded Gravel
		Gravel With Fines	GM	Silty Gravel
			GC	Clayey Gravel
	Sand–More Than 50% of Coarse Fraction Passes No.4 Sieve	Clean Sand	SW	Well-Graded Sand, Fine to Coarse Sand
			SP	Poorly-Graded Sand
		Sand With Fines	SM	Silty Sand
			SC	Clayey Sand
Fine Grained Soils–More Than 50% Passes No. 200 Sieve	Silt And Clay Liquid Limit Less Than 50	Inorganic	ML	Silt
			CL	Clay
		Organic	OL	Organic Silt, Organic Clay
	Silt And Clay Liquid Limit 50 Or More	Inorganic	MH	Silt of High Plasticity, Elastic Silt
			CH	Clay of High Plasticity, Fat Clay
		Organic	OH	Organic Clay, Organic Silt
Highly Organic Soils			Pt	Peat

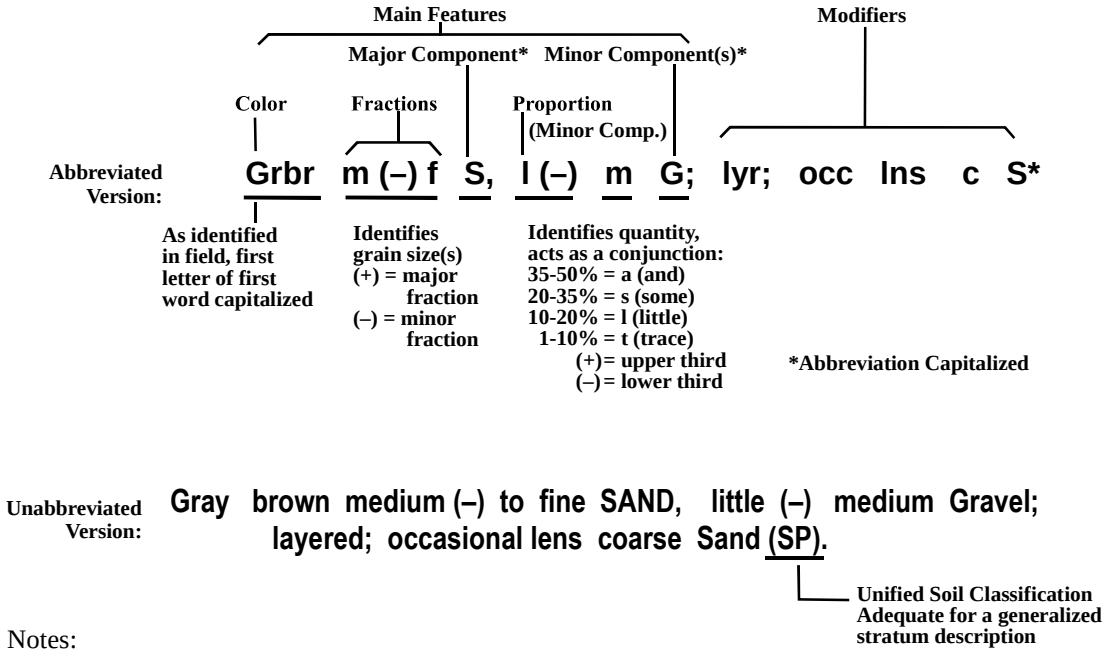
Table 6.3. Unified Soil Classification System (USCS)

	Millimeters	Inches	Sieve Size
Boulders	> 300	> 11.8	-
Cobbles	75 - 300	2.9 - 11.8	-
Gravel:			
Coarse	19 - 75	0.75 - 2.9	-
Fine	4.8 - 19	0.19 - 0.75	3/4" - No. 4
Sand:			
Coarse	2.0 - 4.8	0.08 - 0.02	No. 4 - No. 10
Medium	0.43 - 2.0	0.02 - 0.08	No. 10 - No. 40
Fine	0.08 - 0.43	0.003 - 0.02	No. 40 - No. 200
Fines:			
Silts	< 0.08	< 0.003	< No. 200
Clays	< 0.08	< 0.003	< No. 200

6.2.3.3 Burmister System

The Burmister System uses similar textural size ranges as the Wentworth scale (see Tables 6.4 through 6.7). In addition, it adds a specific nomenclature to describe the soil's texture, color, plasticity, mineralogy, and even geologic origin, etc. as shown below.

Table 6.4 Burmister Soil Classification Naming System (source: Dunn Geoscience Corporation)



Notes:
Major Component (>50%): all letters are capitalized.
Minor Component: first letter is capitalized.

Table 6.5 Burmister Soil Classification System Coarse-Grained Soils, Gradation of Components

Coarse to fine	cf	All sizes
Coarse to medium	cm	Less than 10% fine
Medium to fine	mf	Less than 10% coarse
Coarse	c	Less than 10% medium and fine
Medium	m	Less than 10% coarse and fine
Fine	f	Less than 10% coarse and medium

Table 6.6 Burmister Soil Classification System Fine-Grained Soils, Plasticity of Components

Component	Symbol	Overall Plasticity	Plasticity Index
Silt	$	Non-plastic	0 to 1
Clayey Silt	Cy$	Slight	1 to 5
Silt & Clay	$ & C	Low	5 to 10
Clay & Silt	C & $	Medium	10 to 20
Silty Clay	$yC	High	20 to 40
Clay	C	Very High	over 40

Table 6.7 Burmister Soil Classification System, Components and Fractions, Modified from Burmister, 1950

	Millimeters	Sieve Size
Gravel (G):		
Coarse		1" - 3"
Medium		3/8" - 1"
Fine		No.10 - 3/8"
Sand (S):		
Coarse	0.590 - 2	No.30 - No.10
Medium	0.250 - 0.59	No.60 - No.30
Fine	0.074 - 0.25	No.200 - No.60
Silt ($):		
Coarse	0.074	0.02mm - No.200
Fine	< 0.020	< No. 200

6.2.3.4 U.S. Comprehensive Soil Classification System

The U.S.Department of Agriculture (USDA) developed the U.S. Comprehensive Soil Classification System. It was developed primarily in order to organize soils into established groups, identify their best uses and allow for estimates of their agricultural productivity (Dragun, 1988). It established ten soil orders (e.g., alfisols and ultisols, etc.) and uses soil profiles to characterize topsoil and subsoil horizons. Textural descriptions for the USDA system are shown in comparison to the other soil classification systems in Table 6.8 below.

Table 6.8 Textural Descriptions for USDA System

Granular Soils		Cohesive Soils		Grain Size (USCS)	
Blows/ft	Density	Blows/ft	Density	silt/clay	<0.08 mm
0-4	v. loose	>2	v. soft	f. sand	0.43 - 0.08 mm
4-10	loose	2-4	soft	m. sand	2.0 - 0.43 mm
10-30	m. dense	4-8	m. stiff	c. sand	4.8 - 2.0 mm
30-50	dense	8-15	stiff	f. gravel	19 - 4.8 mm
>50	v. dense	15-30	v. stiff	c. gravel	75 - 19 mm
		>30	hard	cobble	300 - 75 mm
				boulder	>300 mm

Proportions	
trace	0-10%
little	10-20%
some	20-35%
and	35-50%

6.2.3.5 Comparison of the Soil Classification Systems

As shown in Table 6.9, comparison of the different size classification systems shows that, although there are some similarities there are some differences between them. Notably, for most of the classification systems, the upper limit of coarse sand is 2.0 mm while the upper limit of coarse sand using the USCS is 4.8 mm, which is in the gravel range of most other systems. Sands and gravels have different hydraulic conductivity, which can affect the fate and transport of contaminants in the subsurface. For this reason, it is important to accurately describe the soil samples and reference the appropriate classification system being used to describe the soil samples in the soil boring log. When more than one mobilization of field equipment occurs or when different consulting firms are employed at a site, the same soil classification system should be used at a site for consistency. In addition, a qualified geologist or soil scientist should perform logging of soils and sediments. A recommended soil-boring log is provided following Table 6.9.

6.2.4 Field Log Books

In addition to soil logs, accurate field books are essential to the evaluation and interpretation of analytical results after sampling is complete. Information compiled in the field log book or soil logs for each sampling point should include:

- date/time/weather
- sampler/geologist/soil scientist name(s)
- sample identification (as specified in sampling plan)
- sketch showing the sampling location (including reference distances)
- depth to water and/or bedrock (refusal) when encountered
- soil profile using Wentworth, USCS, Burmister, or USDA classification, etc.
- sample recovery and interval submitted for analysis
- sampling equipment used
- field measurements of any direct reading instruments, their calibration, and settings
- general comments (e.g., odor, staining, etc.)

Table 6.9 Comparison of the Soil Classification Systems compiled from various sources

Wentworth	Burmister	USCS	USDA	mm	in	US Stan. Sieve Size
boulders		boulders	cobbles	4026		No. 5+
				2048		
				1024		
				512		
				256	10.08	
		cobbles		128	2.52	
cobbles				64		
	coarse gravel	coarse gravel	medium gravel	32	1.26	
v. coarse				16	0.63	
coarse pebble gravel	medium gravel	fine gravel	fine gravel	8	0.31	
medium fine	fine gravel			4	0.16	
gran. (vf) gravel		coarse sand		2	0.08	No. 5-10
v. coarse sand	coarse sand	medium sand	v. coarse sand	1	0.04	No. 10-18
coarse sand			coarse sand	0.5	0.02	No. 18-35
medium sand	medium sand	fine sand	medium sand	0.25	0.01	No. 35-60
fine sand	fine sand		fine sand	0.125	0.005	No. 60-120
v. fine sand			v. fine sand	0.031	0.002	No. 120-No. 230
	coarse silt	silts & clays	silt			
coarse silt	fine silt			0.0625		<No. 230
medium silt				0.0156		
fine silt				0.0078		
v. fine silt				0.0039	0.0002	
clay			clay	<0.0039	<0.0002	

Boring Log

Project Name: _____
Location: _____
Drilling Contractor: _____
Geologist: _____
Sampling Method: _____
FID/PID Used: _____
Soil Class System: _____
_____
Screen Length/Type: _____
Sand Pack Amount/Type: _____
Screen Slot Size: _____

Project No: _____
State Plane Coords.: X= Y=
Water Table Depth: _____
Drilling Equip.: _____
Size/Type of Bit: _____
Development Method: _____
_____
Well Yield: _____
Riser Stickup: _____
Riser Length/Type: _____
Permit No.: _____

Boring No: _____
Well No: _____
Date Started: _____
Date Comp.: _____
Weather Cond.: _____
Hammer Weight/Fall: _____
Total Depth: _____
Ref. Elevation: _____
Notes: _____
_____
Sump Installed/Length: _____

Depth (ft.)	Sample No.	Blows per 6 in.	Penetration/ Recovery	FID/PID Reading (ppm)	Sample Description	Well Construction	Remarks

Site conditions (including equipment refusal) may warrant relocation or modification of the sampling plan during actual field activities. If this occurs, additional information should be noted in the field book noting the sampling plan modification and new sample location relative to the old as well as fixed objects such as a building or road. This will ensure accurate data interpretation for the modified sampling plan by non-field personnel.

6.2.5 Determination of Soil Sample Location

Determination of sample location is the first step in proper sample collection. In general, sampling should be conducted in potentially contaminated areas of concern, whether relating to former or current uses of the site to determine whether contaminants are present above applicable standards. Locations should be biased to suspected areas of greatest contamination based on professional judgment, site history, stressed vegetation, soil discoloration, odor, etc (N.J.A.C. 7:26E-3.4 to 3.6). Sample locations should also be chosen based on Area Specific Requirements pursuant to N.J.A.C. 7:26E-3.9 such as sampling in and around above and below ground storage tanks, impoundments, septic tanks, etc.

6.2.5.1 Surface Soil Selection

Surface soil samples should be collected using decontaminated or dedicated sampling equipment dependent on the chosen analytical parameter and sampling locations. All inconsequential surface debris (e.g., vegetation, rocks, etc.) should be removed from the surface before commencing sampling. Disposable gloves should be changed between each sample location. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis.

Initial characterization soil sampling with the exception of Area Specific Requirements and soil to be analyzed for VOCs, should be collected from the zero to 6 inches below grade. Additional sampling of soil below the 0 to 6.inch interval or those specified in the Area Specific Requirements may be necessary where the surface has been regraded or physical evidence indicates the possible presence of deeper contamination.

Soil samples shall be collected from discrete six-inch intervals. Deviations from this requirement due to poor sample recovery or logistical problems should be noted in the soil log and field logbook. Composite sampling is not allowed except in the case of waste characterization analysis for proper disposal. Surface soil collected for parameters other than VOC analysis should be homogenized in-situ or in a decontaminated stainless steel bowl or tray. Sampling should occur in progression from the least contaminated area to the most contaminated area, if this information is available.

Soil logs should be completed after sample collection to minimize losses due to volatilization and biodegradation, and cross contamination due to excessive handling of the soil.

Soil samples collected for VOC analysis must be handled in a manner that will minimize losses due to volatilization and biodegradation. See section 6.2.7., *VOC Sample Collection for Soils*, for appropriate sample collection procedures.

Soil samples collected for analytical parameters other than VOCs must be homogenized before being placed into the appropriate sample container. See section 6.2.8., *Non-VOC Sample Collection for Soils*, for appropriate sample collection procedures.

6.2.5.2 Subsurface Soil Selection

The advancement of any downhole large-diameter sampling device must follow ASTM #D1586-84 for disturbed (split spoon) samples, or, ASTM #D1586-83 for undisturbed (Shelby tube) samples. In addition, all borings must be performed in accordance with the procedures and regulatory requirements pursuant to the Subsurface and Percolating Water Act, N.J.S.A. 58:4A-4.1 et. seq. Soil boring permits are required for borings greater than 50 feet in depth. Borings greater than 25 feet deep must be sealed with approved sealing material pursuant to N.J.A.C.7:9D-3.4. Borings less than 25 feet deep may be sealed by backfilling with cuttings/ sand in pursuant to NJAC7:9D-3.4. However, NJDEP recommends that contaminated soils should not be returned to the borehole. If the contaminated soils are returned back to the borehole, the responsible party shall address the presence of this contamination in the remedial action workplan in pursuant to NJAC 7:26E-3.6.

Subsurface soil samples can be collected via a standard drill rig or direct push drilling by advancing a dedicated or decontaminated large-diameter sampling device (e.g., split spoon, Shelby tube or soil corer) in the borehole. A decontaminated split spoon retaining basket should be used to prevent loss of the soil back into the borehole while raising the split spoon sampling device to the surface. Upon retrieval to the surface, the large-diameter sampling device (e.g. split spoon, soil corer or Shelby tube) should be handled and transported in such as way to prevent lose while opening or during shipment preparation. The split spoon or soil corer sampling devices should be opened with caution to ensure that soil remains within one half of the split barrel or liner for later screening and sample collection. Soil that has fallen out of the large-diameter sampling device can not be used for laboratory analysis and should be discarded to prevent cross-contamination.

The top few inches of soil collected either via split spoon or soil core liner sampling device may contain material (often referred to as slough-pronounced sluff) that may have fallen back into the borehole. In addition “mud or water” used during rotary drilling may infiltrate into the surrounding formation. This infiltration may also be visible in the top few inches of the core or as coating on the core’s outer edges. This “slough or mud/water impacted soil” is not representative of in-situ conditions, should not be used for laboratory analysis and should be discarded to prevent cross contamination.

Upon opening, the split spoon or soil core liner should be opened and screened with a direct reading instrument (DRI) to determine the sample interval of interest. Soil samples shall be collected from discrete six-inch intervals. Deviations from this requirement due to poor sample recovery or logistical problems should be noted in the field logbook. Disposable gloves should be changed between each sample location. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis. Soil logs should be completed after sample collection to minimize losses due to volatilization and biodegradation, and cross contamination due to excessive handling of the soil.

Shelby tubes are typically used to collect undisturbed solid soil cores for laboratory analysis such as geotechnical parameters. Shelby tubes, once collected, should not be open by field personnel. Upon retrieval from the borehole, the Shelby tubes should be wiped clean and the ends sealed with melted wax to prevent leakage or drying of the soil core. Endcaps should be placed on both ends and taped prior to shipment to the laboratory.

Composite sampling is not allowed except in the case of waste characterization analysis for proper disposal.

Soil samples collected for VOC analysis must be handled in a manner that will minimize losses due to volatilization and biodegradation. See section 6.2.6., *VOC Sample Collection for Soils*, for appropriate sample collection procedures.

Soil samples collected for analytical parameters other than VOCs must be homogenized before being placed into the appropriate sample container. See section 6.2.8., *Non-VOC Sample Collection for Soils*, for appropriate sample collection procedures.

6.2.6 Field Screening Soil Samples

Each soil core should be screened with a properly calibrated direct reading instrument (DRI) equipped with a PID or FID detector or other suitable field-screening instrument capable of detecting the contaminants of concern pursuant to N.J.A.C. 7:26E-2.1(b).

To obtain the most representative monitor reading, use a decontaminated stainless steel spoon, knife or other appropriately constructed device and make a longitudinal score deep enough to expose a porous surface the length of the core. Or optionally, make very small divots at six-inch intervals to expose a porous surface. Simultaneously, place the probe of the DRI immediately above the opened area being careful not to touch the sample, and move the probe slowly above the lateral scoring and note any peaks. Record results of peaks in 6-inch intervals to determine sample location. Instrument readings will be biased low and not representative of in-situ conditions if the soil core is not scored or inner core not exposed for proper field screening. Other methods of field screening (e.g., bag headspace, jar headspace, warming, UV light, dye testing etc.) should be discussed with the appropriate regulatory authority for approval before sample collection.

The Technical Requirements for Site Remediation N.J.A.C. 7:26E-3.6(a)4.(ii), instruct one to select a six-inch increment of soil for volatile organic laboratory analysis based on field screening with a DRI. If a boring is continuously cored to 20 feet below grade where ground water is first encountered, then 4 to 5 individual 48" - 60" soil core segments will have to be opened and screened before determination as to which six-inch increment is to be selected for sampling and analysis. Special attention must be paid to labeling and storage of individual core samples when continuous soil samples are collected from a single boring. In many instances soil cores can be produced faster than they can be opened, logged, screened and sampled by a technician. In those instances when a backlog of cores are being generated, care must be made to protect the cores from direct sunlight, excessive ambient temperatures and rain. These conditions may have an adverse effect on highly sensitive volatile organics within the core or the instruments used for screening. Always keep the cores labeled so that the up/down orientation is not lost. Proceeded carefully, but quickly when field screening. If necessary, log soils for lithology information *after* sample collection. Always calibrate the DRI at the start of each day.

Another option is to select (using the DRI), and sample (using a small diameter coring device), a six-inch increment from every individual core segment, and only submit the sample required from that particular boring for analysis as directed in 7:26E-3.6(a)4(ii). This option can be more costly as several sample containers will have to be discarded at the end of the each boring. If chemical preservation is used (methanol), proper disposal could be an issue. Sampling every individual core first, prior to determining which increment to ship for laboratory analysis will also require additional labor. This particular option, to collect a representative six-inch incremental sample from every individual segment of a continuous core with its associated cost, makes the first option to carefully protect and manage the cores to control the loss of volatile organics even more critical.

6.2.7 VOCs Sample Collection for Soils

VOCs can be mobile as either gas or liquid phases in a non-aqueous environment. Because unique physical and chemical characteristics associated with each of these phases contribute to a contaminant's behavior in a non-aqueous environment, accurate identification and quantification of VOCs in this matrix becomes essential.

Precise characterization of VOCs in soil, and other non-aqueous matrices (e.g., sediment), is critical since decisions for remediation are based on analytical measurement. Unfortunately, it has been the acts of collection and storage that subject a sample to numerous variables that can alter VOC concentration. These variables may enhance volatilization and biodegradation of VOCs in the sample.

To improve sample collection procedures and storage requirements of soils and other non-aqueous matrices for VOC analysis, samples must be handled in a manner that will minimize losses due to volatilization and biodegradation. Many environmental professionals have conducted and are continuing research to determine how to best maintain the integrity of samples collected for VOC analysis. This ongoing research has resulted in analytical and sampling procedure updates. Current sample preparation and analytical methods can be found in the USEPA Office of Solid Waste and Emergency Response's (OSWER), *Test Methods for Evaluating Solid Waste Physical/Chemical (SW-846)* and, *USEPA Contract Lab Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*.

6.2.7.1 VOC Soil Sample Depth Selection

Soil sample collection for VOC analysis is a two-step process consisting of the collection of the larger soil core and sub-sampling this larger soil core for submittal to an analytical laboratory. The collection of all soil and non-aqueous samples for VOC analysis must be as follows:

The collection of samples for VOC analysis must be performed with a decontaminated or dedicated large-diameter coring device such as a split spoon or soil corer, which does **not** break up the structure of the matrix. These sampling devices typically have a diameter range of 1.5 to 4 inches. Use of a soil collection device that causes mixing, such as a hand auger, cannot be used for VOC sample collection since the tool will break up the soil structure and aerate the soil causing significant VOC loss.

When sampling for VOC analysis, the device must be retrieved from the borehole as soon as possible. Each large-diameter soil core should be screened with a properly calibrated DRI equipped with a PID or FID detector or other suitable field-screening instrument capable of detecting the contaminants of concern pursuant to N.J.A.C. 7:26E-2.1(b). Field screening data should be recorded on the soil boring log or other field documentation for eventual reporting in the investigation report.

Important! **Soil samples for VOC analysis must be collected immediately (within minutes) to reduce loss of VOCs to volatilization and biodegradation.**

Using the field-screening data, select samples for VOC analysis using the following criteria:

If field-screening measurements are detected above background:

- Extend the boring from ground surface until either background readings are achieved, ground water is encountered or bedrock is encountered; and

- Collect a soil sample from the six (6) inch interval registering the highest value on the DRI, at a minimum, using the appropriate sample collection method and device as specified in N.J.A.C. 7:26E-2.1(a)4 and
- Collect any additional samples as necessary based on DRI readings or laboratory data to delineate VOC contamination pursuant to the requirements specified in N.J.A.C. 7:26E-4.1 and 4.3.

If all intervals register the same measurement from the DRI or if all measurements do not exceed background:

- Extend the boring to ground water, bedrock, or 10 feet, whichever is encountered first, and;
- Collect an undisturbed sample from the six-inch interval at the bottom of the soil boring, at a minimum, using the appropriate sampling sample collection method and device as specified in N.J.A.C. 7:26E-2.1(a)4.
- Collect additional samples as necessary based on DRI readings or laboratory data to delineate VOC contamination pursuant to the requirements specified in N.J.A.C. 7:26E-4.1 and 4.3.

Contaminants that cannot be detected with field screening instrumentation must be sampled from locations or depths that are most likely to be contaminated based on the location and nature of the discharge or type of matrix to which the contaminant was discharged (N.J.A.C. 7:26E-3.4(a)). Include this information in the appropriate field documentation for eventual reporting in the investigation report.

6.2.7.2 VOC Soil Sample Collection Devices - Small Diameter Core Samplers

Important! **Soil samples for VOC analysis must be collected immediately (within minutes) to reduce loss of VOCs to volatilization and biodegradation.**

Soil to be collected for laboratory analysis **can not** be stored for extended periods in the large-diameter sampling device or a capped liner (brass, acetate, lexan, polycarbonate etc.) for later sample collection. In addition the soil **can not** be transferred to an intermediate container such as another empty sample bottle, zip lock bag, aluminum foil, etc, for later sample collection. Research has shown leaving samples in core tubes, splitspoons, covered liners or intermediate containers will lead to VOC losses and thus yield poor quality data. See Section 6.2.6., *Field Screening Soil Samples*, for more information.

Sub-sampling of the large-diameter sampling device for VOCs must be performed with the use of a dedicated or decontaminated small-diameter core sampler. The small-diameter core sampler must be capable of collecting the required amount of sample from the large-diameter sampling device (e.g., split spoon or soil corer) or from freshly exposed soils. The small-diameter core sampler must be capable of delivering the sample quickly and directly into the sample container without disturbing the native soil structure.

It is important that the small-diameter core sampler provide the required mass of sample material. As such, a **test sample** (of similar matrix to be sampled) should be collected and weighed to determine the amount of soil needed to obtain the required mass of sample material for each type of small-diameter core sampler and analytical method. Using a small electronic portable scale with an accuracy of 0.1grams, weigh the empty small-diameter core sampler (e.g., disposal syringe) to the nearest 0.1grams. The scale must be calibrated before use and intermittently checked during the day to ensure accurate weight measurement. Calibration information must be recorded in the field logbook. A translucent cover can be placed over the scale during the weighing process to negate variations caused by wind. Push the small-diameter core sampler

test sample into the matrix to collect the required mass of material (3cm^3 should yield approximately 5-grams of sample [wet weight]). Wipe clean any soil adhering to the outside of the small-diameter core sampler before weighing. If the weight is above the required amount, excessive soil can be removed by extruding a small portion of the core and cutting it away with a decontaminated trowel or spatula. If the weight is below the weight limit, obtain additional soil by reinserting the small-diameter core sampler into the soil core. Reweigh after each addition or removal of sample from the small-diameter core sampler until the target weight is attained. Note the sample volume and amount in the small-diameter core sampler. **Discard the test sample.** Use this volume when collecting soil of similar matrix. Additional test samples should be weighed whenever a change in the matrix is observed.

All small-diameter core samplers used in the collection of samples for VOCs must be constructed of non-reactive materials that will not sorb, leach or alter the concentration of VOCs in the sample. Examples of these materials are stainless steel, glass and brass. Other materials, such as Viton, PTFE and some ridged plastics, which have demonstrated limited absorptive or diffusive passage of VOCs, can be used as long as the contact time between the sample and the sampler is minimized, or, the materials are used for an airtight seal of the sampler.

Acceptable small-diameter core samplers include a modified 10-ml disposable plastic syringe, a Purge and Trap Soil Samplerä, En Core® sampler, Easy Draw Syringe® or other small-diameter tube/plunger sampler. The small-diameter core sampler must be able to deliver a minimum of 5-gram sample (≈3cm^3 of sample assuming a density of 1.7g/cm^3) into a 40-ml VOA vial. While most small-diameter core samplers can only be used for sampling and placement into the appropriate sample containers, only the En Core® sampler can be used for sampling, storage and transportation of the sample to the lab. Small-diameter core samplers should be selected based upon the properties of the matrix, the type of preservation method (field vs. lab) and personal preferences.

6.2.7.2.1 Disposable Syringe

A disposable syringe is an easy and inexpensive tool for sample collection and transfer to appropriate sample containers. It can be prepared by cutting off the injection tip, removing the rubber plunger tip, and removing the retaining post on the plunger. If the plunger maintains a tight seal with the barrel of the syringe, the plunger must be flush with the opening of the barrel for sampling. This position will prevent air from being forced through or around the sample plug during sample collection and extruding into the sample container. If a modified disposable syringe is used, syringes with less than 5 cm^3 total volume cannot be used. Research has demonstrated that high surface-area to total volume ratios in soil cores create significant volatilization loss within seconds of exposure to such devices.

The disposable syringe is a one-time use device and cannot be decontaminated.

The disposable syringe can not be used for storage or shipment to the laboratory. The soil sample must be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.2 Easy-Draw Syringe and Power-Stop Handle

The Easy-Draw Syringe® and Power-Stop Handle® is a 5-gram volumetric coring system for sample collection and transfer into appropriate sample containers. The

device consists of two parts, the sampling syringe and handle. The polypropylene syringe is used to collect and transfer the sample. The handle allows for easier sampling and controls the volume of soil collected. The handle has three positions to control the volume of soil collected based on the density of the matrix and can be set to collect 5, 10 or 13-gram samples.

Once the sample is collected, remove any excess material that extends beyond the end of the syringe and cap. Remove the syringe from the handle and extrude the sample into the appropriate sample container.

The Easy-Draw Syringe® and Power Stop Handle Purge and Trap Sampler® can not be used for storage or shipment to the laboratory. The soil sample must be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.3 Purge and Trap Soil Sampler®

The Purge and Trap Soil Sampler®is a 5-gram volumetric coring system for sample collection and transfer into appropriate sample containers. The device consists of two parts, the coring tube and the handle. The coring tube is removable from the handle, so numerous core tubes can be used with one handle. The sampler is also capable of sampling harder materials than other sampling systems. If sample weights other than 5 grams are required, the device can be adjusted so sample sizes of 1 to10 grams can be collected. The supplied plunger is used to extract the sample into the sample container.

The Purge and Trap Soil Sampler® is constructed of stainless steel, which allows the sampler to be decontaminated for reuse.

The Purge and Trap Soil Sampler® can not be used for storage or shipment to the laboratory. The soil sample must be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.4 En Core® Sampler

The En Core® sampler is a one-time-use volumetric sampling and storage device. The En Core® sampler is made of an inert composite polymer designed to collect, seal and store a 5-gram sample, with no headspace, prior to preservation or analysis. The En Core® sampler is designed to extrude the sample directly from the coring body into the sample container without disturbing the matrix structure. The sampler has three components: the coring body, the plunger and the cap. A specially designed “T” handle, available from the manufacturer, is used to push the En Core® sampler into the soil matrix and to lock the sampler after collection. Three Viton® O-rings, two on the plunger and one on the cap, seal the sampler preventing the loss of VOCs. Each En Core® sampler is packaged in an airtight, resealable foil package to prevent contamination during storage and shipping.

Prepare the En Core® sampler in accordance with the manufacturer’s recommendations. **The plunger bottom must be flush with the bottom of the coring body <u>before</u> sampling**. This prevents air from being trapped behind the sample during coring. Trapped air can potentially cause a loss of VOCs when air passes through the sample. If air is trapped behind the sample, it may cause the sample to be prematurely expelled from the coring device.

Use of En Core® sampler is ideal for reducing the handling of preservation chemicals in the field. The practice of immediate field preservation of samples can lead to the creation of hazardous materials if all samples are not sent for laboratory analysis. The En Core® sampler can be effectively used during soil boring operations to store samples on-site until field analytical results are available, potentially reducing the number of samples sent for laboratory analysis. Upon review of the field analytical results, the field sampler can either extrude the soil stored in the En Core® sampler into the appropriate containers or retained in the En Core® sampler for later shipment to the laboratory. If an En Core® sampler is used to ship a soil sample directly to the laboratory for VOC analysis, the soil must be extruded from the En Core® sampler and preserved by the laboratory within 48 hours of sample collection.

The En Coreâ sampler cannot be used on cemented or consolidated materials, or, coarse materials large enough to interfere with proper coring techniques.

The En Core® sampler is a single use sampling and storage device and can not be decontaminated for reuse. The T-handle and laboratory-extruding device can be decontaminated and reused.

6.2.7.3 VOC Soil Sample Collection Technique

Small-diameter core samplers should be selected based upon the properties of the matrix, the type of preservation method (field vs. lab) and personal preference. The small-diameter core sampler should fit inside the mouth of the sample container to avoid loss of sample, prevent damage to the sealing surfaces or container threads and ease the soil transfer process.

Once the sampling interval has been selected, trim off the exposed surface of the matrix to expose a fresh surface. A loss of VOCs from the surface of the matrix will occur even if the matrix has been exposed for a short period of time (during screening, etc.). Removal of the unwanted surficial material can be accomplished by scraping the matrix surface with a decontaminated spatula or trowel. Soil sampling must commence immediately once a fresh surface has been exposed.

Push the small-diameter core sampler into the matrix to collect a volume of material which will yield the required mass of sample (wet weight) as determined by the analytical method. If the small-diameter core sampler does not have a seal between the barrel and plunger, the plunger of the coring device can be pulled back, positioned flush with the opening of the barrel or completely removed allowing the open barrel of the sampler to be inserted into the matrix. If the small-diameter core sampler has a seal between the core barrel and plunger, the plunger must be flush with the end of the core barrel to avoid pushing air through the sample during collection. Depending upon the texture, depth or moisture content, the small-diameter core sampler can be inserted straight into the matrix, on an angle or multiple insertions can be made to obtain the required sample weight.

After sample collection, wipe the outside of the small-diameter core sampler to remove any excess material adhering to the barrel. Immediately open the sample container and extrude the soil core into the sample container. If present, avoid splashing any preservative out of the sample container by holding the container at an angle while slowly extruding the soil core into the sample container. Do not immerse the small-diameter core sampler into the preservative. If an En Core® sampler is to be used for storage and shipment, prepare the sampler for shipment according to manufacturers instructions (see below for additional information). Collect the required number of sample containers or En Core® samplers based on the chosen preservation

and analytical methods as discussed in section 6.2.7.4., *VOC Soil Sample Preservation Methods*. Include an additional sample volume for percent moisture determination and sample screening as discussed in the sections below.

Ensure the threads and cap of the sample container or En Core® sampler are free of soil particles. Use a clean paper towel to remove soil particles from the threads and sealing surface of the sample container or En Core® sampler. The presence of soil particles will compromise the container's seal and may result in preservative or VOC loss. This loss ultimately may invalidate the sample analysis. Always make sure the sample lid is firmly secure.

Record the laboratory and field identification numbers in the field notes and on the chain of custody. Container labels with wire or rubber band attachments should be used provided they can be removed easily for sample weighing. **Do not attach any additional adhesive backed labels or tape to the sample containers unless requested by laboratory or specified in manufacturer instructions. This will increase the weight of the sample container and the laboratory will not be able to determine the sample weight.**

After sample collection, immediately return the containers to an iced cooler. Sample containers from different locations should be placed in separate ziplock bags to help avoid cross contamination. The laboratory sample number or field sample identification number may be placed on the bag and crossed referenced on the chain of custody. The laboratory performing the analysis will determine the sample weight.

If the laboratory has determined a sample container has leaked by noting a visible reduction in preservative or unusually low weight, the sample may be rejected for analysis by the laboratory. The sampling team leader or project manager must be notified immediately of any problems with the sample condition. Only the suspect vial will be in question, not the entire sample shipment.

6.2.7.4 VOC Soil Sample Preservation Methods

The preservation of samples for VOC analysis can be initiated either at the time of sample collection or in the laboratory. This section deals with the preservation of soil samples for VOC analysis in the field using chemical and physical preservation methods. Please note the first three preservation methods (1 through 3) are preferred sample preservation method under the, *USEPA Contract Lab Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*. The last three preservation methods (4 through 6) though not preferred are acceptable under specific circumstances as outline below.

It is important that the laboratory analytical methods, field preservation methods, appropriate sample containers and sample holding times are determined and agreed upon prior to mobilizing to the field. Also, additional sample containers maybe required for various quality control/quality assurance (QA/QC) samples such as matrix-spike and matrix-spike duplicates (MS/MSD). The number of extra containers required vary by laboratory and analytical procedure. It is up to the laboratory and sampling team to determine the required number of containers for each QA/QC sample submitted.

In addition to the various chemical preservation methods, samples must be physically preserved (e.g. iced or frozen) in the field immediately upon sample collection. Physical preservation methods such as "icing" or freezing" are accomplished by placing sample containers in insulated coolers containing "wet ice", "blue ice" or "ice gel packs". It is important to match up the correct physical preservation method with the appropriate sample container and field chemical

preservation method. According to USEPA CLP Guidance for Field Samplers, the physical preservation methods are described as:

Iced – soil and sample containers are cooled to 4°C (± 2°C)
Frozen – soil and sample containers are cooled to between -7°C and -15°C

Sample containers, which will be frozen, should be placed on their side prior to freezing process to prevent breakage. Additional aliquots for screening and moisture determination need only be iced and kept cooled at 4°C (± 2°C): these sample containers should not be frozen. ***Sample containers and En Core® sampler should not be frozen below -20° C as the integrity of the container seals, o-rings and septum may be compromised by the freezing, resulting in the loss of VOCs upon sample thawing.***

In addition, the use of dry ice to freeze samples immediately upon sample collection or for use during shipment is not recommended. Dry ice, which is at a temperature of -78.5°C, will lower the temperature of the sample container below the design specifications causing damage to the glass, septum, seals o-rings and cap. In addition, dry ice has specific handling, storage and shipping requirements that far out-way its usefulness to the field sampling team.

6.2.7.4.1 Closed-System Vials, No Chemical Preservation

This preservation and sampling method employs the use of tared, un-preserved 40-ml glass vials with PTFE-lined septum screw cap and a magnetic stir bar. A minimum of three (3) sample containers with a stir bar must be used for each sample location. An additional sample aliquot is also necessary for screening and moisture determination. ***This is a preferred method of preservation by USEPA CLP SOW.***

Using a small-diameter core sampler as described above, 5-grams of soil should be placed in each of the vials. Care must be taken when placing the soil in the vial to limit loss of soil. Each vial must also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Vials (with stir bars and septum caps) must be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in bound logbook, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The vials should also have a label affixed by the laboratory or vendor with a unique numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. The holding time for non-chemically preserved, iced (cooled to 4°C [± 2°C]) and frozen (-7°C and-15°C) samples is 48 hours from sample collection to chemical preservation, freezing or analysis by the laboratory. The holding time for soil sample can be extended to 14 days if the soil is chemically preserved or kept frozen until actual analysis. This

method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

In addition, the sample containers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The analytical laboratory or a vendor can supply sample containers with a stir bar.

Disadvantages

- Increased possibility of breakage during shipment due to freezing the sample below -20 ^{o} C.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.
- A 48 hour holding time for non-chemically preserved, soil samples cooled to 4°C ($\pm$ 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.

6.2.7.4.2 Closed-System Vials, No Chemical Preservation with Organic Free Water (OFW)

This preservation and sampling method employs the use of tared, un-preserved 40-ml glass vials with PTFE-lined septum screw cap, a magnetic stir bar and reagent water (organic free water-OFW). A minimum of two (2) sample containers must be prepared with the required OFW and stir bar for each sample location. The USEPA CLP Guidance for Field Samplers also recommends collecting one additional vial without OFW for backup analysis. Additional sample aliquot is also necessary for screening and moisture determination. ***This is a preferred method of preservation by USEPA CLP SOW.***

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the vials. Care must be taken when placing the soil in the vial to limit splashing or loss of the OFW. The volume of OFW is dependent upon the analytical method, however USEPA CLP SOW recommends 5ml of water for each vial collected. Each vial must also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Vials with OFW (with stir bars and septum caps) must be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). Once the OFW and/or stir bar is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if OFW has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of OFW. The loss of greater than 0.2 grams is an indicator that OFW has been lost and the vial must not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in bound logbook, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The vials with OFW should also have a label affixed by the laboratory or vendor with a unique numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is

negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. The holding time for non-chemically preserved, iced (cooled to 4°C [± 2°C]) and frozen (-7°C and -15°C) samples is 48 hours from sample collection to chemical preservation, freezing or analysis by the laboratory. The holding time for soil sample can be extended to 14 days if the soil is chemically preserved or kept frozen until actual analysis. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

In addition, sample containers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The pre-preserved sample containers with OFW and a stir bar can be supplied by the analytical laboratory or a vendor.

Disadvantages

- Increased costs due to the addition of a preservative and magnetic stir bar into each sample container.
- Increased possibility of breakage during shipment due to freezing the sample below -20 ° C.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.
- A 48 hour holding time for non-chemically preserved, soil samples cooled to 4°C (± 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.

6.2.7.4.3 Small Diameter Core Sampler for Storage and Transport (e.g., En Core® Sampler)

This preservation and sampling method employs the use of a small-diameter core sampler known as the En Core® sampler. The En Core® sampler is a one-time-use, volumetric sampling, storage and transportation device. It is designed to collect and store soil samples for transportation to the laboratory. (See previous discussion on use of the En Core® sampler as a sample collection tool.) ***This is a preferred method of preservation by USEPA CLP SOW.***

Please note: Prior to using any other small-diameter core sampler not mentioned here for storage and transportation to the laboratory, a comparison data and an equivalency study must be provided to NJDEP in accordance with N.J.A.C. 7:26E-1.6(c) and deemed acceptable by the NJDEP.

Soil should be collected using the En Core® sampler in accordance with the manufacturer's recommendations. A specially designed "T" handle, available from the manufacturer, is used to push the En Core® sampler into the soil matrix and to lock the sampler after collection.

A minimum of three (3) individual 5-gram En Core® samplers must be collected for each soil sample. Upon sample collection, label each En Core® sampler cap with the label provided by the manufacturer and return it to the airtight, resealable foil package. Additional sample aliquot is also necessary for screening and moisture determination as discussed below. En Core® samplers should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. En Core® samplers can be shipped directly to the laboratory for VOC analysis; however, laboratory must extrude the soil from the En Core® sampler and analyze, chemically preserve or freeze the soil within 48 hours of sample collection. The soil samples must be extruded from the En Core® sampler into appropriate sample containers using a specially designed "T" handle push-rod tool available from the manufacturer. Soil **can not** be scooped out of the En Core® sampler using a trowel or spatula as this can cause a significant loss of VOCs. The holding time for soil stored in an En Core® sampler can be extended if the soil is extruded by the laboratory within 48 hours to a sealed vial and frozen or chemically preserved until actual analysis. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

En Core® samplers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The En Core® samplers can be supplied by the analytical laboratory or a vendor.

Disadvantages

- The En Core® sampler cannot be used on cemented or consolidated materials, or, coarse materials large enough to interfere with proper coring techniques.
- Any "alternative" to the En Core® sampler must have a plunger to allow for proper mechanical dispensing at the laboratory, and must be approved for use by NJDEP.
- A 48 hour holding time for non-chemically preserved, soil samples cooled to 4°C (± 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.
- Currently the En Core® sampler is the only small-diameter core sampler approved for use by NJDEP for sampling, storage and transport.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.

6.2.7.4.4 Closed-System Vials, Chemical Preservation – Sodium Bisulfate

This preservation and sampling method employs the use of tared, pre-preserved 40-ml glass vials with PTFE-lined septum screw cap, a magnetic stir bar and sodium bisulfate (ACS reagent grade or equivalent). A minimum of two (2) sample containers must be prepared with the required preservative and stir bar for each sample location. The USEPA CLP Guidance for Field Samplers also recommends collecting one additional un-preserved vial for backup analysis. Additional sample aliquot is also necessary for screening and moisture determination.

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the 40-ml vials (with or without preservative). Care must be taken when placing the soil in the vial to limit splashing or loss of the preservative. The volume of sodium

bisulfate is dependent upon the analytical method, however USEPA CLP SOW recommends 1 gram of sodium bisulfate in 5ml of water for each vial collected. Each vial must also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Pre-preserved vials (with stir bars and septum caps) must be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). Once the preservative and/or stir bar is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if preservative has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of preservative. The loss of greater than 0.2 grams is an indicator that preservative has been lost and the vial must not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in bound logbook, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The pre-preserved vials should also have a label affixed by the laboratory or vendor with a unique numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [$\pm$ 2°C]) for later shipment to the laboratory. The holding time for chemically preserved, iced (cooled to 4°C [$\pm$ 2°C]) samples is 14 days from sample collection to analysis by the laboratory. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW. Sodium bisulfate preservation of soil may result in the destruction or creation of certain target VOCs. As a result, sodium bisulfate should not be used in the following circumstances:

- If contaminants of concern include VOCs such as vinyl chloride, trichloroethene, styrene, 2-chloroethylvinyl ether, trichlorofluoromethane, or cis- and trans-1, 3-dichloropropene. Low pH conditions caused by the preservation of soil with sodium bisulfate cause the destruction or breakdown of these VOCs resulting in biased low analytical data.
- Soils with a higher proportion of decayed matter where acetone is a contaminant of concern should not be preserved with sodium bisulfate. Decomposition of the decayed matter due to sodium bisulfate preservation results in the creation of a false positive acetone artifact yielding biased high analytical results.

- If the soils contain carbonaceous material. The carbonaceous material present in the soil, either natural or amended, will react with the sodium bisulfate and cause the sample to effervesce resulting in a loss of VOCs.

Pre-preserved sample containers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure the container's contaminant free integrity. The pre-preserved sample containers with stir bar can be supplied by the analytical laboratory or a vendor.

Disadvantages

- Sodium bisulfate can not be used on carbonaceous soils as effervescence may ensue with subsequent VOC loss.
- Sodium bisulfate creates low pH conditions that may result in the destruction of certain target VOCs.
- Increased costs due to the addition of a preservative and magnetic stir bar into each sample container.

6.2.7.4.5 Closed-System Vials, Chemical Preservation – Methanol

This method employs the use of tared, pre-preserved 40-ml glass vials with PTFE-lined septum screw cap and methanol (purge and trap quality grade or equivalent). A minimum of two (2) sample containers must be prepared with the required preservative. Additional sample aliquot is also necessary for screening and moisture determination.

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the 40-ml pre-preserved vials. Care must be taken when placing the soil in the vial to limit splashing or loss of the preservative. The volume of methanol is dependent upon the analytical method. The USEPA CLP SOW recommends 5 to 10 ml of methanol in each vial collected.

Pre-preserved vials (with septum caps) must be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). Once the preservative is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if preservative has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of preservative. The loss of greater than 0.2 grams is an indicator that preservative has been lost and the vial must not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in bound logbook, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The pre-preserved vials should also have a label affixed by the laboratory or vendor with a unique numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or

string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) for later shipment to the laboratory. The holding time for chemically preserved, iced (cooled to 4°C [± 2°C]) and samples is 14 days from sample collection to analysis by the laboratory. This method is appropriate for medium-level analysis under USEPA CLP SOW and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW. Methanol preservation of soil results in higher detection limits and is therefore not applicable to low-level analysis. Additional problems associate with the use of methanol include:

- Soils with high moisture content (>10 %) that are field preserved with a water miscible solvent such as methanol are diluted by the total volume of the solvent/water mixture. The detected contaminant concentrations must be corrected to account for the solvent/water dilution factor. If this calculation is not made, the additional dilution by soil pore water will result in biased low analytical data.
- Leakage of methanol from the container during sampling or in shipment causing the loss of VOCs in the methanol and resulting in biased low analytical data.
- Possible contamination of methanol by other sampling related activities including the absorption of diesel fumes from running equipment or vehicles on to the sample containers.
- The preservation of soil by methanol results in the re-classification of the sample as a hazardous waste. This hazardous waste classification results in increased shipping and disposal costs.

Pre-preserved sample containers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The pre-preserved sample containers can be supplied by the analytical laboratory or a vendor.

Disadvantages

- Methanol preservation is applicable to medium and high level analysis only. Low-level concentrations not detectable with this preservation method.
- Biased low analytical data due to the loss of methanol after sampling or high moisture content in the soil.
- Increased costs due to the addition of a preservative and the classification as a hazardous waste resulting in higher shipping and sample disposal costs.

6.2.7.4.6 Glass Containers, No Chemical Preservation, No Headspace

This preservation method employs the use of un-preserved-glass sample containers with a PTFE-lined screw cap. A minimum of two 4-oz glass containers must be used for each soil sample. Soil should be placed in the containers using decontaminated stainless steel spoons or spatulas in such a manner as to minimize the headspace (e.g. the containers must be completely filled). Additional sample aliquot is also necessary for screening and moisture determination as discussed below. The samples are then

iced and cooled to 4°C (±2°C) for later shipment to the laboratory. The holding time for non-chemically preserved, cooled to 4°C (±2°C) soil samples is 48 hours from sample collection to preservation or analysis in the laboratory. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW as losses of VOCs from biodegradation and volatilization may occur when the sample containers are opened in the laboratory. Due to the configuration of the container as the volume of soil within, the laboratory must open the container to remove the required sample volume for analysis. Studies had shown that substantial loss of VOCs occur during this laboratory procedure. However, circumstances exist where chemical preservation or freezing is not recommended. In these instances best professional judgement must be used in the selection of this method as pursuant to N.J.A.C. 7:26E-1.6(c). The circumstances which may result in the use of this method include:

- Waste characterization sampling under Subtitle C of RCRA, the use of specific test methods for some applications are required in 40 CFR parts 260 through 270.
- Sampling unknown wastes or oily wastes (from containers, drums, etc.) when the reactivity of the waste with chemical preservative or freezing is not known. After initial laboratory analysis has characterized the waste, subsequent sampling using preservation can be performed if the waste is found to be non-reactive to the chemical preservative.
- During emergency response actions when there is no time for prepared sample containers to arrive from the laboratory. Re-sampling of potential impact areas may be required using approved preservation procedures after the emergency has been mitigated.

Sample containers must be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The sample containers can be supplied by the analytical laboratory or a vendor.

Disadvantages:

- Potential loss of VOCs when the sample containers are opened at the laboratory.
- Biased low analytical results due to the loss of VOCs.
- Holding time of 48 hours for non-chemically preserved, soil samples cooled to 4°C (± 2°C) requires the laboratory to preserve or analyze samples quickly.

6.2.7.5 Sample Aliquot for Moisture Determination and Sample Screening

This sample aliquot will be used for laboratory screening and percent moisture analysis. They will first screen the sample to determine the appropriate analytical level of analysis, which will be dictated by the concentration of VOCs in the sample. To accommodate the laboratory's preparatory steps, additional sample matrix must be provided to the laboratory from each sample location. The additional sample aliquot must be collected using a decontaminated stainless steel trowel or spatula and place into an un-preserved sample container, usually a 60-ml wide mouth PTFE-lined glass container. This sample is not chemically preserved. The sample must be obtained from the same interval and location as the sample for VOC analysis. The sample container must be completely filled with sample to minimize headspace and loss of

VOCs. The laboratory must report the analytical results for soil and sediments (non-aqueous) samples on a dry weight basis

Ensure the threads and cap of the sample container are free of soil particles by wiping with a clean or paper towel. The presence of soil particles will compromise the container's seal and may result in preservative or VOC loss. Always make sure the sample lid is firmly secure. The sample aliquot for moisture determination and sample screening must be placed and shipped on ice at 4°C (± 2°C).

6.2.7.6 Commercial Equipment Suppliers

A partial listing of equipment suppliers for sampling equipment is included in Table 6.10. This listing of equipment suppliers is not an endorsement by the New Jersey Department of Environmental Protection; it is supplied for information purposes only.

Table 6.10 Discrete Soil Sampler Suppliers

Discrete Soil Sampler	Supplier
Purge and Trap Soil Sampler®	Associated Design and Mfg. Co. 814 N. Henry St. Alexandria, VA 22314-1619 703-549-5999
En Core® Sampler Terra Core Sampler® Easy-Draw Syringe® and Power Stop Handle	En Novative Technologies 1241 Bellevue St. Green Bay, WI 54302 1-888-411-0757
10-cc Syringes	J&H Berge, Inc. 4111 South Clinton Ave. South Plainfield, NJ 07080 1-908-561-1234 VWR Scientific Products P.O. Box 369 405 Heron Drive Swedesboro NJ 08085 856-467-2600 Thomas Scientific 99 High Hill Road @I-295 P.O. Box 99 Swedesboro, NJ 08085 856-467-2000

6.2.8 Non-VOC Sample Collection for Soils

Contaminants such as semivolatile organic compounds (SVOCs), pesticides, PCBs, metals or cyanide that cannot be detected with field screening instrumentation must be sampled from locations or depths that are most likely to be contaminated. These locations should be based on the location and nature of the discharge or type of matrix to which the contaminant was discharged. The sampler should include in the logbook any information noted during sampling activities that

aided in the determination of non-VOC sample location selection. This will ensure accurate data interpretation by non-field personnel at a later time.

It is important that the laboratory analytical methods, field preservation methods, appropriate sample containers and sample holding times are determined and agreed upon by the sampling team and laboratory prior to mobilizing to the field. Also, additional sample containers maybe required for various quality control/quality assurance (QA/QC) samples such as MS/MSDs. The number of extra containers required vary by laboratory and analytical procedure. It is up to the sampling team to know the required sample volume and number of containers for each QA/QC sample submitted.

In instances where a soil is collected for VOC analysis as well as other non-VOC parameters, the soil for VOC analysis must be collected first to minimize volatilization and biodegradation. Once VOC soil sampling is complete the remaining soil to be analyzed for non-VOC parameters such as SVOCs, pesticides, PCBs, metals or cyanide must be homogenized to create a representative sample. In case of limited sample quantity, prioritization of analytical parameters should be determined beforehand by the project leader or case manager.

Homogenization or mixing of the soil with a decontaminated spoon or spatula can take place either in-situ (in the case of shallow soil sample) or in a decontaminated stainless steel bowl or tray. The bowl or tray must be large enough to hold more than the required sample volume and to allow proper mixing without spillage. It is important that mixing of soil be as thorough as possible. The mixing technique will depend on the physical characteristics of the soil including moisture content, particle size and distribution however, the goal is to achieve a consistent physical appearance over the entire soil sample. Prior to homogenization, twigs, roots, leaves, rocks and miscellaneous debris (glass, bricks, etc.) should be removed from the sample using the decontaminated stainless steel spoon or spatula. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis.

Homogenization of the soil includes a series of mixing and quartering steps. The soil should be scraped from the sides, corners and bottom, rolled into the middle of the decontaminated stainless steel bowl or tray (or in-situ hole) and mixed. The soil should then be quartered (divided into 4) and moved to the sides of the bowl/tray/hole. Each quarter should then be mixed individually, and then rolled to the center of the bowl/tray/hole and mixed with the entire sample again. These steps of quartering the soil, mixing individually and then mixing the entire sample again should be repeated at least twice. Once a consistent physical appearance over the homogenized soil has been obtained, the soil should be transferred into the appropriate sample container using the decontaminated stainless steel spoon or spatula.

Once the sample containers are full, ensure the threads, lid and outer edges of the sample container are free of soil particles. Use a clean paper towel to remove soil particles from the threads and sealing surface of the sample container. The presence of soil particles will compromise the container's seal and may result in loss of soil moisture, cross contamination or the lid opening in transit. Always make sure the container lid is firmly secure.

After sample collection, immediately return the container to an iced cooler in an upright position. Sample containers from different sample locations should be placed in separate ziplock bags to protect other containers in case of leakage during transport. The laboratory sample number or field sample identification number may be placed on the bag and crossed referenced on the chain of custody. Record the laboratory and field identification numbers in the field notes and on the chain of custody. The laboratory performing the analysis will determine percent moisture.

Return to TOC

6.2.9 Sampling Alternatives for Situational and Matrix Variations

Sample collection procedures discussed above are appropriate in a majority of cases. However, situational or matrix variations require some modification to the sampling methods. Documentation of using any alternative sampling procedures is critical to aid in data interpretation. The data generated from non-core samples must be used with caution due to the potential for significant VOC loss. Anytime a coring device is not used for VOC sample collection an explanation of the procedure and reasons for its use must be provided to the Department.

6.2.9.1 Sampling Hard or Cemented Material

Sampling of cemented materials may be too hard to allow sample collection via previously discussed methods. Therefore other techniques may be employed. Collecting a sample of this material can be performed by fragmenting the sample with a decontaminated chisel to generate aggregate of material for placement into the sample container. Caution is warranted due to potential injury when performing sampling using this method due to flying particles during the fragmentation process. The aggregate material can be transferred to the sample container with the use of a stainless steel spatula or small trowel. A small funnel can be used to channel the sample into the container. The funnel must not restrict the passage of the larger pieces of sample aggregate. Loss of VOCs may occur when sampling this matrix during the fragmentation process and the increased exposure of surface area of the material.

6.2.9.2 Sampling a Mixture of Fines and Gravel

Sampling of poorly sorted material consisting of large aggregate and fines may not allow a core sampler to be used. In these conditions, a stainless steel spatula or trowel can be used for sample collection. The sample collection process must be performed quickly to prevent a loss of VOCs. A small funnel can be used to channel the sample into the container. The funnel must not restrict the passage of the larger pieces of sample aggregate. A separation of coarse and fine-grained material will be inherent to the process, which will bias the data due to non-representation of all size material. As a result, data generated from samples of this matrix must be used with caution. Loss of VOCs may occur when sampling this matrix due to the increase exposure of surface area of the material.

6.2.9.3 Sampling Dry Non-Cohesive Material

For material such as dry sand, packing a cohesive plug will be very difficult. In these situations, obtain a core sample or push the sample into the barrel of the sampler with a spatula, packing the sample into the barrel. Then cover the opening of the core sampler with the spatula so the material does not fall out of the sampler until the material is extruded into the sample container. A small funnel can be used to channel the sample into the container. The funnel must not restrict the passage of the larger pieces of sample aggregate. Loss of VOCs may occur when sampling this matrix due to the increased exposure of surface area of the material.

6.2.9.4 Sampling Sediments

When sampling sediment, a wide variety of materials may be encountered. The matrix may include fine grained material, a mixture of coarse and fine grained material which may include dead vegetative material (leaves, sticks, etc.) or peat moss. The bulk sampling of sediments can be collected with a core sampler or clamshell dredge. The method of collecting the discrete sample will depend upon the type of material encountered. Therefore, various sampling tools must be available to ensure the collection of representative samples.

One of the problems encountered when sampling sediments is the amount of water in the sample. The high level of moisture will increase the detection limits of the analysis due to the concentration calculation on a dry weight basis.

In some cases the density of the material may not allow a sample to be collected within the required weight range of the analytical method or the required weight of material may not be fully submerged in the preservative. These cases may require the addition of preservative by the laboratory to submerge the sample which will increase the detection limits of the sample.

6.2.9.5 Sampling Oil Waste, Tars and Other Waste Material

The collection of a discrete waste sample may be successful using one of the methods mentioned previously. The type of material will dictate the best sampling method. If none of the discrete core sampling methods is applicable to the matrix, then a sample can be collected in an unpreserved glass sample container with a PTFE lined lid. Headspace in the container must be minimized. The laboratory will collect a sub-sample from the material for analysis. Documentation of using this sampling procedure is critical to aid in data interpretation. Loss of VOCs may occur when sampling this matrix due to the increased exposure of surface area of the material.

6.2.9.6 Sampling from Test Pits

Test pit excavation is useful in the identification of waste material buried on site and for direct observation of the soil horizons for any apparent band of soil contamination. However, this method does have limitations. Due to the amount of disturbance involved, test pit samples are not reproducible and are not considered to represent the undisturbed formation. Additionally, equipment, visual observation, distance and the integrity of the trench walls limit the depth of the evacuation. The health and safety hazard associated with test pits is great. Because the trench walls may be unstable, no personnel should enter any test pit that is deeper than three (3) feet. Care must be taken in working near the backhoe. All personnel must be alert to the machine's movement and be prepared for any potential contaminant release from the excavation. During test pit operations, the potential exists to leave contaminated soils at the surface where it may not have been present before excavation. Consideration must be given to potential exposures from the contaminated surface soils. Finally, in areas where surface soil contamination is a problem, this contamination may be carried deeper by excavation and backfilling. In such a situation test pits should not be used.

For these reasons, test pits should only be used as a sampling approach to locate specific hot spots of contamination or to locate specific buried waste. To most efficiently collect representative soil samples at depth, a drill rig or direct push should be used.

If it is determined that test pits will be utilized to access samples at depth, the backhoe used must be equipped with a protective shield and its operator properly trained in the use of level B respiratory and dermal protection. The backhoe bucket and arm must be thoroughly decontaminated by steam cleaning or standard cleaning procedures for non-aqueous sampling equipment prior to use and between each test pit location.

The operator should be directed to excavate until the sampler indicates that the desired depth has been reached. All excavated material should be placed on a tarp or plastic sheeting. If the pit is shallow (less than three feet) the sampler can enter the pit and collect the soil sample using a decontaminated trowel for non-VOCs or small a diameter soil coring device. As the pit gets deeper, the sampler may collect the soil directly from the bucket of the backhoe in an area where the sample material is not in contact with the bucket. The sample should be transferred

from the bucket following appropriate collection techniques for each analytical parameter to be analyzed.

6.3 Rock Core Sample Collection

The Technical Requirements for Site Remediation require, if appropriate, that rock cores be collected during the drilling of bedrock monitoring wells, piezometers and other borings [N.J.A.C., 7:26E-4.4(g)5].

Rock core drilling is a drilling method that can provide core samples of the bedrock under investigation. The core samples can be obtained from specific depth intervals. Rock coring is conducted in materials that are too hard to permit the use of direct-push or split-spoon coring techniques.

Since core samples provide an actual rock sample, the geologist can observe and evaluate the true character of the bedrock material (Wells 1991). The evaluation can include analyses and descriptions of lithologies, rock textures, stratigraphy, bedding plane structure, fracture characteristics, primary and secondary porosities, permeability, rock fluids, and contaminant content.

6.3.1 Coring Methods

There are two fundamental rock-coring methods: drill string coring and wireline coring.

6.3.1.1 Drill String Coring

Drill string coring is a procedure where the core sample is obtained from the bottom of the borehole. This sampling is accomplished by attaching tube-type coring equipment to the end of the drill string. The core sample is obtained while the coring device drills the borehole.

6.3.1.2 Wireline Coring

Wireline coring techniques utilize a cable to lower and/or raise the coring tools through an existing borehole. The coring tools used in wireline coring can be either tube-type tools or sidewall coring tools. Wireline coring is generally faster and less costly than drill string coring methods.

6.3.2 Coring Tools

6.3.2.1 Tube-Type Coring Tools

Tube-type coring tools can be either a single or double-tube design (Lapham, et. al., 1997). Most rock coring operations associated with ground-water remedial investigation work is completed using double-tube coring tools and drill string coring methods. Double-tube coring tools basically consist of a rotating outer sleeve with a circular diamond coring bit and a swivel-mounted stationary inner sleeve (i.e., core barrel) (Figure 6.1). Usually double-tube coring tools are constructed in 30-foot lengths.

Tube-type coring provides a continuous vertical section of the formation under study. During the coring procedure the outer sleeve simultaneously drills the borehole and cuts the core sample. As the coring tool descends, the core sample is pushed into the stationary inner barrel. The core sample is held in place by a core retaining device (a.k.a. core lifter). When the inner sleeve is full, the drill string and coring tool are pulled from the borehole to permit core recovery. The core barrel can also be extracted from the cutting tool and borehole by means of wireline methods.

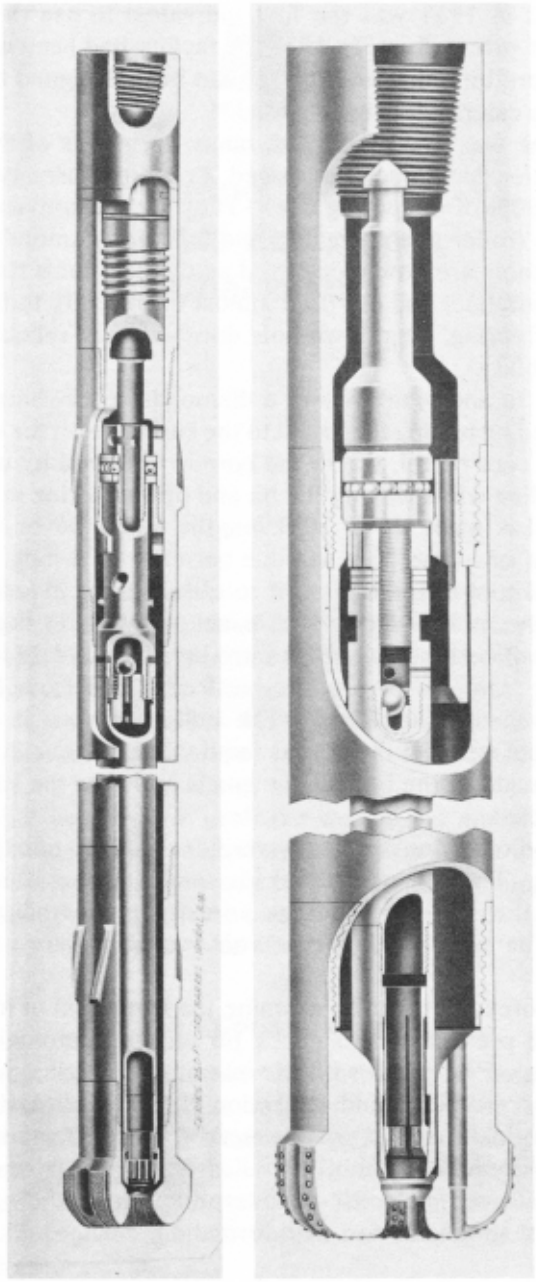


Figure 6.1 Double tube coring tool. Anderson, 1975, printed with permission.

Figure 6.2 Impregnated diamond bit. Acker, 1974, printed with permission.

Descriptions of specifications for various types of tube-type tools can be found in the ASTM standard practice reference designation D 2113-83, "Practice for Diamond Core Drilling for Site Investigation."

Most conventional coring tools are fitted with a circular diamond core bit (Figure 6.2). Diamond core bits consist of a diamond-impregnated, hardened matrix. The circular shape allows a core sample to pass into the core barrel during the drilling operation. A detailed discussion of the various types of bits and their applications can be found in Acker, 1974.

The main disadvantage of tube coring is the high cost.

6.3.2.2 Sidewall Coring Tools

Sidewall coring tools obtain core "plugs" from the side of the existing borehole by means of either explosive charges detonated at predetermined depths or by use of a rotating core bit. Since these tools are generally run into the borehole on a wireline, the core sample plugs are extracted by removing the tool from the borehole with the cable.

Sidewall coring is faster and less expensive than conventional coring methods. In addition, sidewall core samples can be taken from predetermined zones of interest and over a large borehole interval. Sidewall methods are often employed to verify and correlate the results of downhole electric and nuclear logging procedures.

The explosive method of sidewall sample collection often causes compression and distortion of the material's structural integrity. Consequently, the accuracy of structural and permeability analyses is compromised.

Sidewall coring methods were developed for the petroleum industry and are not generally employed for use in ground-water remedial investigations.

6.3.2.3 Oriented Coring Tools

Oriented core samples can be used to obtain strike and dip data for fractures, bedding, joints, formation contacts, and other planar features present in the bedrock. This type of information is important for use in the evaluation of contaminant fate and transport and the determination of additional well locations.

The orientation of the sample is established relative to magnetic north by means of a continuous scribe etched onto the core during the drilling process. A magnetic survey instrument that is located within the core barrel orients the scribe. Borehole inclination and directional orientation of the reference scribe on the core are also recorded on film by the survey tool.

The core analyst can later determine the orientation of the planar features by placing the core sample in a goniometer. The core sample can be physically oriented in the goniometer relative to its original position within the borehole. A sighting ring on the goniometer is then aligned so it appears as an extension of the planar feature to be measured. The strike and dip can then be determined by means of a graduated base ring and protractor mounted on the goniometer.

6.3.3 Coring Procedures

The following list contains general guidelines that should be addressed during the coring process (PSE&G SOP 310,1997):

- The borehole shall be cased through the entire thickness of any overburden present. The casing shall also be firmly seated into the bedrock prior to the coring operation.
- The coring pressure of the drilling rig shall be adjusted to maximize core recovery.
- Coring shall not be conducted with worn or damaged bits and core lifters.
- Potable water should be used as a drilling fluid.
- In order to prevent possible damage to a core sample, a full core run should not be drilled if it suspected that part of a core from a previous run is still in the borehole. The next run shall be shortened by a factor equal to the length of any core still remaining downhole.

6.3.4 Rock Core Logging

A field log of each core must be completed and maintained by the project geologist. Table 6.11 lists and describes the information that is required for entry into each core log. The necessary information should be recorded on an appropriate rock core log form. An example of a rock core log form is illustrated in Table 6.10.

6.3.5 Rock Core Storage

Rock cores should be placed into wooden boxes constructed with partitions designed to hold core samples. The cores should be stored in stratigraphic order and labeled in such a way that indicates the stratigraphically up direction (PSE&G SOP 311,1997).

Wooden blocks should be placed in the storage boxes between each core run sample. The blocks shall be marked with the appropriate depths and run number. Each box should be labeled with the facility name and location, boring identification number, depth range, box number, and RQD.

6.3.6 Special Tests and Analyses of Rock Cores

The following analytical procedures can be applied to further examine rock core samples:

- Thin section analysis

Table 6.11 Rock Coring Requirements	
Information Required	**Notes**
Names of contractor, driller, and project geologist	
Core identification number and location	
Date and time of core commencement and completion	
Depth and size of casing	
Description of equipment used	
Type and condition of bit	
Depth of start and finish of each core run	
Core diameter	
Time required to drill each foot of core	
Total core recovery with information as to possible location of core losses	
Details of delays and breakdowns	
Macroscopic description of core	This description should include, but not be limited to, a photographic record of each core sample.
Depth to the water table and any other distinct water-bearing zones	
Characteristics of structures and fractures present	Fracture information should include the frequency, spacing, size, continuity and relative orientation of the fractures within the core sample. Any open fractures and joints should be noted.The description should note whether or not the fractures are due to natural or mechanical breaks.Calculating the Rock Quality Designation (RQD) can approximate the structural integrity of the rock. The RQD is equal to the total length of all core pieces exceeding four inches in length as a result of natural breaks (r) divided by the total length of the coring run (l). This result is converted to a percentage. RQD = (r/l)x100 The log shall include descriptions of the contacts between different rock units.
Description of lithology	The description of the rock should include information on rock type, color, composition, degree of stratification, hardness, fracturing, and degree of weathering. Any changes in lithology shall be noted.
Description of stratigraphy	Characteristics such as clarity and thickness of bedding should be described. The angle of bedding and other planar features in a non-oriented core should be measured from the perpendicular to the core axis (e.g., horizontal fracture in core equals 0°).
Description of any evidence of contamination present in core	Any evidence of contamination must be noted including elevated air monitoring instrument readings, odors, visual observations, and the presence of NAPL, etc.

- Observing stratigraphic direction or fossil indicators
- Chemical analysis
- Plotting fracture sets, joint sets and/or faults on stereographic projection or rose diagrams
- Radiometric age determinations
- Regional structural analysis
- Correlating facies changes
- Strain analysis

6.4 Direct Push Technology

Use of direct push technology to obtain soil samples in cored segments has gained wide acceptance. The relative ease to collect minimally disturbed soil samples at depth plus, the ability to visually determine geological data has made this system attractive. While various manufactures make and distribute their own soil sampling equipment and accessories, the same general principles still apply when collecting soil samples. Chief among them is following NJDEP required decontamination procedures. When using direct push technology you must apply, at a minimum, the Cold Regions decontamination procedure discussed in Chapter 2, *Quality Assurance*, Section 2.4., *Decontamination Procedures*.

One of the special applications of direct push technology relative to soil sampling is the ability to obtain vertical profile contaminant information while working the same bore hole. This process only further stresses the need to eliminate all possible sources of extraneous or cross contamination. High pressure, hot water (100° C) cleaning is the only acceptable means to decontaminate direct push sampling equipment and maintain confidence that data is not influenced by unwanted variables. In addition, equipment must be maintained in good working order to insure its performance. This means (but is not limited to) all rods used for boring advancement must have unworn O-rings (if applicable) at each connection and undamaged threads to insure that each connection can be drawn tight. All downhole equipment must be decontaminated between each use. Operators must have boring certification in good standing from the Bureau of Water Allocation and all permit approvals must be on-site. Extreme caution must be taken to insure that communication between various water bearing zones within the same boring does not take place therefore, all grouting must be tremied under pressure starting from the bottom of the boring and completed at the surface using grout of the required density. Finally, no boring work can begin without first contacting New Jersey One Call service to secure utility mark-outs.

Specific guidance on direct push technology for both soil and ground water sampling can be referenced through the USEPA document, *Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators*, EPA 510-B-97-001. Released by the USEPA's Office of Underground Storage Tanks, this 60 page document contains "how to" discussion on soil and ground water sampling and the geotechnical tools and accessories available for direct push applications. The document can be viewed at: http://epa.gov/swerust1/pubs/esa-ch5.pdf.

Considerable general guidance on direct push technology can be referenced through the following USEPA website: http://www.epa.gov/superfund/programs/dfa/dirtech.htm. Additional information on direct push technology can be obtained through ASTM D6001-96, *Direct Push Water Sampling for Geoenvironmental Investigations*, and via the following vendor Internet links: http://geoprobe.com, and http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm.

Return to TOC

6.5 Sampling Containerized Material

Sampling containerized materials presents a unique obstacle to field personnel, whether the container involved is a fiber drum or vacuum truck. Container staging, identification and opening are all issues to be considered. Health and safety precautions associated with sampling containerized materials are generally more stringent. Quality assurance guidelines for waste samples, as opposed to environmental samples are unique and each site should be considered individually. When sampling waste materials, high levels of contaminants can be expected. Therefore trip and field blanks may be inappropriate. However, if residual or low-level waste/chemicals are expected (e.g., sampling contaminated soils in drums or containers) trip and field blanks may be appropriate. Quality assurance requirements will be determined on a site by site basis by a NJDEP representative.

6.5.1 Drums, Bags, Sacks, Fiberdrums and Similar Small Containers

Prior to the initiation of the sampling event, all containers should be inventoried. All available information concerning each container should be recorded in the field logbook including the type of container, total capacity estimate, actual capacity (if container is open), markings, labels, color, origin, condition, etc. Photographs should be taken to provide a permanent record.

Depending on the location and position of the containers, it may be necessary to upright and/or relocate them prior to sampling. ***Drums Containing Liquid Waste Can Be Under Pressure Or Vacuum. A Bulging Drum Should Not Be Moved Or Sampled Until The Pressure Can Be Safely Relieved.*** Containers that can be moved should be positioned so that the opening or bung is upright (if the integrity of the container will allow). Containers should not be stacked.

Next, the containers should be marked with an identification number for present and future reference. Enamel spray paint is often suitable for this purpose. Again, photographs of the numbered containers can prove valuable in documenting the containers' condition.

The procedure used to open a container will depend directly upon the container's condition. The sampling team leader should determine which drums will be opened using a remote opening device or penetrating apparatus. If such devices are used, an experienced operator must be employed and specific procedures for assuring health and safety must be clearly defined. All containers should be opened with utmost care. For drums, the bung opening should be loosened slowly with a non-sparking bung wrench. If the bung is badly rusted or frozen, it may be necessary to use a non-sparking hydraulic penetrating device. During container opening operations organic vapor concentrations should be monitored with portable instrumentation. Results should be recorded in the field logbook.

The integrity of the drums may dictate that overpacking is necessary prior to sampling, therefore overpack drums should be available.

6.5.1.1 Containerized Solids

The sampling of containerized solid materials (sludges, granular, powder) is generally accomplished through the use of one of the following samplers:

- scoop or trowel
- waste pile sampler
- sampling trier
- grain sampler

Once the container to be sampled is opened, insert the decontaminated sampling device into the center of the material to be sampled. Retrieve the sample and immediately transfer it into the

sample bottle. If the sampling device is disposable, it may be left in the container sampled. Otherwise, decontaminate the device thoroughly before collecting the next sample. Each container should be sampled discretely. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be made prior to analysis.

6.5.1.2 Containerized Liquids

The sampling of containerized liquids is generally accomplished through the use of one of the following samplers:

- COLIWASA
- open tube sampler
- stratified sample thief (multiple liquid layer sampling)
- liquid/sludge sampler

Once the container to be sampled is opened, insert the decontaminated sampling device into the center of the liquid contents to be sampled. Retrieve the sample and immediately transfer it into the sample bottle. If the sampling device is disposable, leave it in the container sampled. Otherwise decontaminate the device thoroughly before collecting the next sample. It should be noted that dedicated laboratory decontaminated samplers offer the least potential for cross contamination. Each container should be sampled discretely. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be determined prior to analysis.

6.5.2 Tanks, Vacuum Trucks, Process Vessels and Similar Large Containers

Prior to the initiation of the sampling event, all containers should be inventoried. All available information concerning each container should be recorded in the field logbook including type of container, total capacity estimate, actual capacity (if container is open), markings, labels, color, origin, condition, existence and condition of ladders and catwalks, etc. Each container should be marked with an identification number for present and future reference. Enamel spray paint is often suitable for this purpose. Photographs of the numbered vessels can prove useful in documenting the containers' condition and can provide a permanent record.

The procedure used to open a large containment vessel to provide access to its contents will vary with different containers. Most large tanks and vacuum trucks will have valves near the bottom of the tank and hatches near the top. It is most desirable to collect samples from the top of a tank for several reasons. The integrity of valves near the bottom of the tank cannot be assured. The valve may be immobile or may break or become jammed in the open position resulting in the uncontrolled release of the tank's contents. Secondly the contents of a large vessel may become stratified. Collecting a sample from the bottom will not permit the collection of a sample of each stratum. Instead a cross-sectional sample of the tank's contents should be obtained from the top access.

In opening and sampling larger containment vessels precautions must be considered to assure personal health and safety. Accessing storage tanks requires a great deal of manual dexterity. It usually requires climbing to the top of the tank through a narrow vertical or spiral stairway while wearing protective gear and carrying sampling equipment. At least two persons must always perform the sampling: One to open the hatch and/or collect the actual samples, and the other to stand back, usually at the head of the stairway and observe, ready to assist or call for help.

Prior to opening the hatch, the sampler should check the tank for a pressure gauge. If necessary, the release valve should be opened slowly to bring the tank to atmospheric pressure. If the tank pressure is too great or venting releases gas or vapor, discontinue venting immediately. Measure releases to the atmosphere with portable field instrumentation and record in field logbook.

If no release valve exists, slowly loosen hatch cover bolts to relieve pressure in the tank. Again, stop if pressure is too great or if a release occurs. Do not remove hatch cover bolts until tank is at atmospheric pressure.

If a discharge to ambient air occurs, sampling may need to be postponed until the proper equipment is available to control the release.

Once the tank has been stabilized, sample collection may begin using one of the previously recommended samplers for containerized liquids and solids and employing the proper safety precautions and backup personnel. If the contents of the tank have stratified, each stratum should be sampled discretely. At a minimum, a top, middle and bottom sample should be collected. If the container has separate compartments, each should be sampled separately at varying depths, as required. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be determined prior to analysis.

Upon retrieval, immediately transfer the sample into the sample bottle. If the sampling device is disposable, it may be left in the container sampled. Otherwise the device must be thoroughly decontaminated before collecting the next sample.

6.5.3 Transformers

The peculiarities that are associated with transformers warrant that these containers be considered separate from drums and tanks. Because transformers are often located in secured, out-of-the-way locations, access may present a problem. For pole mounted transformers a power operated scissors lift or cherry picker may be needed. In other cases the transformer may be in an underground cell.

The toxic nature and degree of hazard posed by PCBs which may be present in a transformer dictate that a high level of caution be used. Sampling and support personnel should wear appropriate protection. Spill prevention and control must be planned; plastic sheeting and sorbent pads should be employed. And most importantly, the transformer must be certified as “off-line” and de-energized by an electrician or other responsible person.

Once the power source to the transformer is cut and spill control measures (plastic sheeting on ground and/or floor surface of lift) are in place, the cover of the transformer can be removed with hand tools. A sample of the dielectric fluid is most efficiently obtained with a disposable glass COLIWASA.

In order to obtain a representative sample, lower this device at a rate that allows the levels of the fluid inside and outside the sampler to remain the same. When the sampler reaches the bottom of the transformer, close it and as it is retrieved, wipe the COLIWASA with a disposable absorbent pad. Transfer the sample directly into the sample bottle. If a disposable sampling device is used, and if the transformer is out of service, it may be possible to leave the used sampler in the sampled materials. However this should only be done after consultation with the responsible authorities. Otherwise the sampler should be drummed along with protective clothing, sheeting and absorbent pads, and disposed of at a pre-determined approved location.

The transformer drain valve should never be utilized for sample collection for several reasons. The integrity of these valves cannot be assured. The valve may be rusty, may break or may become

jammed in the open position resulting in the uncontrolled release of the transformer's contents. Secondly, it is likely that transformer contents may have stratified. Since PCBs are heavier than other insulating oils this stratification may prevent the collection of representative samples. Samples obtained from the valve near the bottom of the transformer might reveal higher PCB concentrations than the true concentration of the total dielectric fluid.

6.6 Waste Pile Sampling

This recommended protocol outlines general procedures for collecting samples from waste piles and other waste materials, equipment necessary for sampling, and the adequate representation of the material. Also presented will be necessary factors for consideration when formulating a sampling plan. Because of the variables involved in waste material sampling, including shape and size of piles; size, compactness and structure of the waste material; and make-up throughout the material, exact procedures cannot be outlined for every sampling situation. Considerations must be made for the above mentioned variables, the purpose of sampling, and the intended use of the data to help determine correct sampling methodology.

6.6.1 Considerations for the Sampling Plan

The physical and chemical make-up of the waste pile and the purpose of sampling should be considered in planning for the sampling event. Information about these items is presented below. Also refer to the discussion on composite sampling in Section 6.1.2.2. of this chapter.

6.6.1.1 Shape and Size

Shape and size of waste material and waste piles may vary greatly in a real extent and height. The pile may be cone shaped, long and rectangular, square, oval or irregularly shaped. State and federal regulations often require a specified number of samples per volume of waste, therefore size and shape must be used to calculate volume and to plan for the correct number of samples. Shape must also be considered when planning physical access to the sampling point and the type of equipment necessary to successfully collect the sample at that location.

6.6.1.2 Characteristics of the Material

6.6.1.2.1 Type of Material

Material to be sampled may be homogeneous or heterogeneous. Homogeneous material resulting from known situations (e.g., process wastes) may not require an extensive sampling protocol if the material remains homogeneous. Heterogeneous and unknown wastes require more extensive sampling and analysis to ensure the different components are being represented.

6.6.1.2.2 Chemical Stability

Waste materials may be affected by their inherent chemical stability. Exposure to the elements and leaching over time may cause older material to differ in chemical composition from newly deposited material in the same pile. Heterogeneous material may undergo chemical reactions resulting in pockets or layers of different compounds.

6.6.1.2.3 Particle Size

The particle size of the material affects sampling by preventing certain volumes from being analyzed. Large chunks of material, which are left behind and not sampled, may result in positive or negative bias of contaminants in samples. If it is necessary

to sample larger material, provisions must be made in the planning stage to render the larger material capable of producing a sample.

6.6.1.2.4 Compactness/Structure of Material

The compactness/structure of the material may vary across the diameter of the pile. The material may range from monolithic to free flowing, and of a consistency from muddy to compact and dry. This should be considered when planning sampling procedures.

6.6.1.3 Purpose of Sampling

During the investigation of a site, areas of waste materials or waste piles are often encountered. For complete evaluation of a site, these areas must be characterized. Often information about the waste is available, thus providing insight to its chemical composition. If sufficient information is known about the process generating the waste and it is homogeneous, sampling may not be required for classification. However, for verification of that information, or when no information is available about the nature of the material, the involved Site Remediation Program in NJDEP will direct the first round of sampling for analysis of the waste. This can be performed at or about the same time as the first round of sampling for the rest of the site. From the analytical data generated, two scenarios are commonly encountered: contaminant concentrations below specific action levels which usually allows the material to remain on site after delineation; or contaminant concentrations above action levels requiring additional evaluation of the waste.

When additional evaluation is required, the next step is to determine whether a material is a hazardous waste in accordance with New Jersey Administrative Code (N.J.A.C.) 7:26G et. seq. This is performed under the direction of NJDEP and the Division of Solid and Hazardous Waste/Bureau of Resource Recovery and Technical Programs, which promulgates the requirements necessary to render a waste classification. The main objective at this point is to quantify the contaminants of concern, to look for the presence of wastes listed in N.J.A.C. 7:26G et. seq. and look for any other characteristics that would give reason to consider the waste hazardous.

After the waste has been classified as hazardous, additional sample points and analysis for a wide range of parameters is usually required. The sampling scheme should address delineation of the extent of hazardous material exceeding clean-up criteria. It should characterize waste with contaminant concentrations above a specific, significant level but below removal criteria which may be removed to another approved facility, remain on site after risk assessment, or undergo some other form of remediation such as on-site treatment.

6.6.2 Sampling Procedures

As with soil sampling, waste pile samples can be collected at the surface or at depth, and different equipment is required in each instance. Surface samples can be collected most efficiently with a trowel or scoop. For samples at depth, a decontaminated bucket auger may be required to advance the hole, then another decontaminated auger used for sample collection. For a sample core, waste pile samplers or grain samplers may be used.

Waste pile sampling is generally accomplished through the use of one of the following samplers:

- scoop or trowel
- waste pile sampler
- sampling trier
- soil auger

- grain sampler
- split spoon sampler
- soil coring device

6.6.2.1 Surface

At the desired location, clear surface debris. Collect the adequate volume of waste from a depth of 0-6 inches using a trowel, scoop or auger. For a core sample from the surface use the waste pile sampler, trier, or other listed corer/sampler. Transfer the sample directly into the sample container, or use a decontaminated trowel or spatula for transfer if necessary. A wide mouth bottle is preferable for containing the sample, as it requires less disturbance of the sample transferred into the bottle.

6.6.2.2 At Depth

At the sampling location, advance the hole to the desired sampling depth with a decontaminated bucket auger or power auger. Use another decontaminated bucket auger or corer/sampler to collect the sample, and, if necessary, a decontaminated spatula to transfer the sample into the sample bottle. For samples greater than three feet, a hand operated hammer and extension rod may be utilized with a split spoon for sample collection. Upon retrieval the split spoon should be opened, its contents logged if necessary, and immediately transferred into a sample bottle using a decontaminated spatula or spoon.

6.6.3 Required Analytes and Frequency

6.6.3.1 Waste Classification

Requirements to render a waste classification pursuant to N.J.A.C.7:26G et. seq. are promulgated by the Division of Solid and Hazardous Waste. The applicable requirements, in terms of frequency of sample, analysis and quality assurance are specified in the, *Guidance Document for Waste Classification*. This document is available from the Bureau of Resource Recovery and Technical Programs within the above noted Division and is also available at http://www.state.nj.us/dep/dshw/rrtp/index.htm.

The requirements consist of a sampling plan and an analytical test of the material. The sampling plan specifies the number of samples to be taken per volume of waste. Required analyses include RCRA characteristics, total petroleum hydrocarbons (TPHC) content and total polychlorinated biphenyl (PCB) content. Further details on the testing requirements and for the development of a site-specific sampling plan can be obtained from the Bureau of Resource Recovery and Technical Programs.

6.6.3.2 Quality Assurance

For the purpose of analytical quality assurance, the NJ Laboratory Certification Program must certify the laboratory performing the requested analysis for that specific contaminant or parameter. The analytical results and the corresponding detection limits must be submitted on the stationary of the laboratory performing the analysis with the laboratory's certification ID number. Chain of custody and quality control procedures as specified by EPA SW-846 3rd (or most recent) Edition must be submitted along with analytical results.

6.6.3.3 Characterization

When the material that is being evaluated to determine if it can be left on site, then the considerations previously mentioned in this section should be used to plan a sampling strategy. The

characterization may require one or several phases of sampling, but the first phase should be positively biased or statistically random.

Once contaminants of concern have been identified and quantified, additional sampling and analysis may be necessary. Due to the site specific aspects of waste pile sampling and the various reasons for which it is performed, the number of required samples and analytes should be determined by the personnel accumulating the data and directing the investigation from the NJDEP Site Remediation Program.

If the materials to be characterized are excavated soils, a guidance document entitled *Guidance Document for the Remediation of Contaminated Soils* can be otained from the NJDEP Maps and Publications office at 609-777-1038. This document provides guidance on the evaluation of soils in order to determine their regulatory status and recommends appropriate sampling in support of the determinations.

If the party desires to obtain a Certificate of Authority to Operate (CAO) for a beneficial use project, contact the Bureau of Resource Recovery and Technical Programs at 609-984-6985. The CAOs are issued pursuant to N.J.A.C. 7:26-1.7(g) for the beneficial use of materials which otherwise must be disposed of as waste. For Beneficial Use Determinations (BUD), the material must normally be sampled at a rate of one sample per five hundred (500) cubic yards of the material. To obtain a representative sample, the material must be divided into grids and each grid must represent no more than twenty (20) cubic yards of material.

6.7 Surficial Sampling

Return to TOC

This recommended protocol outlines procedures and equipment for the collection of representative wipe, chip and sweep samples.

Surficial sampling is used to assess the existence and/or extent of contamination on various surfaces rather than in a soil, water or air matrix. For example, collecting wipe samples of the process vessels and interiors of ventilation ducts may assess the interior of a building. Though all three types of samples are for similar purposes, the three types of sampling are performed in very different ways because they are intended to assess different surface areas.

6.7.1 Wipe Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, and TCDF) on non-porous surfaces (e.g., metal, and glass). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, migration pathways and available surface area. Suggested sampling points include process vessels, ventilation ducts and fans, exposed beams, windowpanes, etc. The area wiped should be large enough to provide a sufficient amount of sample for analysis (smaller sample volumes cause higher detection limits).

To collect a wipe sample the following equipment is needed:

- a ruler or measuring tape to measure out the area being wiped
- disposable surgical gloves, to be changed prior to handling clean gauze, sample container or solvent
- sterile, wrapped gauze pad (3 in. x 3 in.)
- appropriate pesticide grade solvent or distilled and deionized water

To facilitate the collection of a wipe sample, 3 in. x 3-in. gauze should be utilized. The use of filter paper for wipe sampling is not recommended. Filter paper will tend to rip and crumble if the surface wiped is slightly rough. If filter paper is to be used, it should be four-inch diameter heavy gauge paper, such as Whatman #4 Filter Paper.

The solvent of choice may change based upon the analytes of interest and surface being sampled. Gauze pads for semi-volatiles, pesticide and PCB samples should be moistened in a 1:4 acetone/hexane mixture and those for metals with distilled and deionized water. The gauze pad should be soaked and excess squeezed out immediately before the collection of each sample. Use of pre-soaked pads is not acceptable. Alternate solvents may be acceptable for certain parameters, however, their approval for use will be at the discretion of NJDEP.

Occasionally samples are desired from painted or waxed surfaces. Since hexane may degrade the finish or pick up interfering substances, an alternate solvent should be used. In this case, methanol or distilled/deionized water for semi-volatiles, pesticides and PCB's and distilled and deionized water alone for metals should be used. Surface interference should be recorded in the field log-book.

Once the sample location has been determined, sample collection can begin. It is recommended that an area be premeasured (e.g. 25 cm x 25 cm) to allow for easier calculation of final results. However, this is not always feasible and may be done after area is wiped. Wearing a new pair of disposable surgical gloves, remove the gauze pad from its sterile wrapping and soak it with the appropriate solvent. Wipe entire area to be sampled once in the horizontal direction and once in the vertical direction, applying moderate pressure. Wipe the entire area so that all the sample material is picked up. Place the gauze pad into the sample container.

A blank must always be collected for each wipe-sampling episode in order to ensure the quality of the data. This blank will help to identify potential introduction of contaminants from the pad, solvent, sample container or ambient air conditions. To perform a wipe blank, start by wearing new gloves, then wet a gauze pad with the solvent or water (for each collection parameter) and place the pad directly into the sample bottle.

When samples are submitted for analysis, the laboratory should be told to rinse the sample jars with the appropriate extraction or digestion solvent, depending on the analysis to be performed, when transferring sample to the extraction glassware. This will ensure that the entire sample has been removed from the container.

6.7.2 Chip Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, and TCDF) on porous surfaces (e.g., cement, brick, wood). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination and available surface area. Suggested sampling points include floors near process vessels and storage tanks, loading dock areas, etc. The sampling area should be large enough to provide a sufficient amount of sample for analysis (smaller sample volumes cause higher detection limits). To facilitate the calculations once the analytical data is received, the area sampled should be measured. To collect a chip sample, the following equipment is needed:

- a ruler, or measuring tape to measure out area to be sampled
- disposable surgical gloves, to be changed prior to collection of each sample

- decontaminated chisel of borosilicate construction and hammer or electric hammer
- dedicated natural bristle brush and a dust pan lined with aluminum foil or one that is dedicated, decontaminated and constructed of a pre-approved material which will not interfere with the contaminants of concern
- container for sample

Once the sample location has been determined and marked off, sample collection can begin. Wearing a new pair of disposable gloves, and using a decontaminated chisel and hammer, break up the surface to be sampled. An effort should be made to avoid scattering pieces out of the sampling area boundary. Any pieces that fall outside the sampling area should not be used. The area should be chipped to less than one-quarter inch (preferably 1/8 in.). Record how deep chips were taken. Collect the chipped pieces using a dedicated, decontaminated dustpan and natural bristle brush and transfer the sample directly into the bottle.

6.7.3 Sweep Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, TCDF) in residue found in porous (e.g., asphalt) or non-porous (e.g., metal) surfaces. Sweep sampling allows collection of dust/residue samples that may help in the assessment of contaminant determination and delineation. Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, migration pathways and available surface area.

Suggested sampling points include ventilation systems where dust can collect, floor surfaces near process vessels and storage tanks, or street gutters where contaminated sediments may have migrated and accumulated. The area sampled should be large enough to provide a sufficient amount of sample for analysis. Keep in mind that on linoleum floors a solvent cannot be used or too much residue may exist for a wipe sample to be easily collected.

To collect a sweep sample the following equipment is needed:

- dedicated natural bristle brush
- decontaminated stainless steel spatula and/or a dustpan lined with aluminum foil, or one that is dedicated, decontaminated and constructed of a pre- approved material which will not interfere with the contaminants of concern
- disposable dedicated surgical gloves to be changed prior to collection of each sample.
- container for sample

Once the sample location has been determined, sample collection can begin. Wearing a new pair of disposable gloves, sweep all residue in the area to be sampled onto a decontaminated or dedicated dustpan or directly into the sample container. A decontaminated or dedicated spatula may be used to aid in transferring the sample into the sample bottle.

6.7.4 Rinsate Samples

This method of sampling is utilized to determine if surfaces contain hazardous waste residual after being cleaned. It is normally associated with drum storage pads, floors of buildings and the inside of waste tanks.

Collecting the water from the last rinse when cleaning a tank or surface area constitutes the Rinsate sample. This water, which is normally potable water, is then analyzed and compared against a blank consisting of the same type of water.

6.8 Surface Water And Sediment Sampling

Return to TOC

This section outlines the recommended protocols and equipment options for the collection of representative aqueous and non-aqueous samples from standing lakes, ponds and lagoons, and flowing streams, rivers, estuaries, marine waters, channels, tidal ditches, sewers, landfill leachate seeps and groundwater seeps.

6.8.1 General Considerations and Requirements for NJDEP Programs

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine, e.g., collecting a surface water or sediment sample from an easily accessible, very shallow, very slow moving stream. At other times more dynamic site-specific conditions may dictate that special equipment or more formalized sampling plans be in place prior to sample collection. Personnel safety associated with surface water and sediment will always be the first priority when selecting the appropriate equipment and related procedures to use. Study objectives and logistics, while important, play a secondary role.

6.8.1.1 Health and Safety Considerations

Refer to Chapter 1, *The Sampling Plan*, and the site-specific or program-specific health and safety plan: this plan must be accessible to all personnel during the sampling event. Chapter 4, *Site Entry Activities*, offers additional considerations, especially when sampling at sites associated with the Site Remediation and Waste Management Program.

If the sampling plan calls for the samples to be collected from a stream, use the USGS rule of thumb: Do not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals 10 or greater. This rule varies among individuals according to their weight and stature and to the conditions of the streambed. If the sampling plan calls for the samples to be collected from the shore of a water body or impoundment, the person collecting the sample should be fitted with a safety harness with a rope secured to an immobile object on shore. Backup personnel must be available to assist in collection and shall be prepared and able to pull the sampler to safety if unstable banks are encountered. If the banks are not sloped, the sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where the liquid to be sampled cannot be reached, a pond sampler, by virtue of its extension capabilities, may offer an option. In this case, assemble the pond sampler ensuring adequate extension to obtain the sample without placing the sampling personnel in danger of falling into the water body impoundment being sampled.

Samples may need to be collected away from the shoreline, via boat, barge or bridge, often at various depths. If the content of the channel or impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. Again, each person on the barge or in the boat must be equipped with a life preserver and/or lifeline. Sampling from a bridge may require consideration for vehicular traffic.

Wastewater sampling has it own set of safety issues. Access to sample locations within a working treatment facility or its associated outfalls requires that one follow the safety rules applicable to working within an industrial setting. Wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

6.8.1.2 Physical Characteristics and Water Quality Measurements for Ambient Monitoring

Prior to sample collection, water body characteristics (e.g., size, depth, and flow) should be recorded in the field logbook. Water quality measurements shall include temperature, pH, total

hardness (as $CaCO_3$), alkalinity (as $CaCO_3$), salinity (parts per thousand, 0/00), conductivity (as *u*mhos/cm), and dissolved oxygen (mg/l). These measurements must be properly documented as per Chapter 10, *Documentation*. Non-aqueous data must be accompanied by laboratory-analyzed total organic carbon (TOC) and particle grain size for each sample.

6.8.1.3 Sample Number and Location

Refer to Chapter 1, *The Sampling Plan*, to assist in the development of a site-specific or program specific field sampling and quality assurance plan that addresses the appropriate State regulation(s). The sampling network design must be adequate to achieve the project and data quality objectives for the sampling event.

6.8.1.4 Sampling Sequence

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect sampling quality. If surface water and sediment samples will be collected during the same sampling event, they must be co-located, and the aqueous samples must be collected first. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation to collect surface leachate. This will allow for the partial submersion of leachate sample containers. The objective of collecting a leachate sample is typically for contaminant identification purposes, not necessarily to categorize ambient surface water condition. It is important, therefore, to always be clear of the objective prior to sample collection.

6.8.1.5 Surface Water Flow Conditions

Personnel may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and streams it may be nearly impossible to collect a mid-channel sample at a specific point. For low flowing shallow streams, the sampler should attempt to find a location where flow is naturally obstructed and a pool created which affords some depth from which to better submerge sample bottles. In no way should the environmental setting be altered with the intent to construct an artificial condition which aids in capturing a naturally occurring surface water sample unlike the leachate sample above.

6.8.1.6 Tidal Influences

Salinity and tides can be strong factors in the distribution of contaminants. The delineation of the point at which these effects are most pronounced, and the distribution of the highly contaminated sediments, might be confounded by these factors. For example, as contaminated water moves downstream, an abrupt increase in salinity can cause a sudden change in contaminant solubility. When less soluble, a contaminant may precipitate and appear in the sediment at substantially higher concentrations than the previous (i.e., upstream) location. These factors should be taken into consideration and assessed when making decisions regarding the selection of sample locations and relation of contaminants to the site. Tidal influences should be considered and their potential effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to NJDEP program requirements for sampling at varied tidal stages.

6.8.1.7 Equipment Selection

The factors that will contribute to the selection of the proper sampler include the physical configuration of the location being sampled and the location of the personnel performing sampling. For selection of appropriate sampling apparatus, refer to Chapter 5, *Sampling Equipment*.

◀ Return to TOC

6.8.1.7.1 Aqueous – The collection of surface water samples is generally accomplished through the use of the following samplers:

- Laboratory Cleaned Sample Bottle
- Pond Sampler
- Weighted Bottle Sampler
- Wheaton Dip Sampler
- Kemmerer Depth sampler
- Bacon Bomb Sampler
- Water Bottle Sampler
- ISCO Manual or Automatic sampler

6.8.1.7.2 Non-Aqueous – The sampling of sediments/sludges is generally accomplished through the use of one of the following stainless steel or PTFE samplers:

- Scoop or Trowel
- Sampling Trier
- Bucket Auger
- Soil Coring Device
- Waste Pile Sampler
- Split Spoon Sampler
- Ponar Dredge
- Box Corer
- Ekman Dredge
- Shipek
- Van Veen Grab
- Russian Peat Sampler
- Hand corer
- Gravity Corer

The factors that contribute to the selection of an ambient water sampler include the width, depth, flow and bed characteristics of the impoundment or stream to be sampled, and whether the sample will be collected from the shore or a vessel. Refer to Chapter 5, *Sampling Equipment*, for further information.

6.8.1.8 Considerations for Wastewater Point Source Sampling

The first step in preparing for compliance sampling is to verify that the sample location is appropriate. Every permit requiring compliance sampling must specify the sampling location for compliance sampling. This sampling location must be representative of the actual discharge from the facility. If the sample location specified in the permit is not adequate to collect a representative sample, the permitting authority should be advised promptly, and an alternative location should be recommended. In this case, as well as in sampling to characterize a wastestream for purposes of obtaining a permit, the determination should be based on the inspector or applicant's knowledge of the facility itself, the on-site processes, and the outfalls.

For permit application and compliance monitoring, in which some of the sampling equipment may remain in place between sample events, care is needed to remove accumulated sediment or floating material, which may have accumulated after any previous sample.

Sample taps and lines should be flushed with a small volume of the wastewater to be sampled, prior to beginning actual sample collection.

When possible, sumps and monitoring manholes at which sampling is required should be suctioned to remove any accumulated silt or floating layer, then allowed to refill before sampling begins. It is essential to prevent accidental intake of such material into a sampler when intending to assess qualities of bulk liquids or wastestreams.

If the samples are being taken to determine compliance, all associated flows should be measured. Personnel should always collect samples from a sampling location or locations that reflect the total regulated effluent flow (i.e., is representative). Convenience and accessibility are important considerations, but are secondary to the representativeness of the sample. The most representative samples will be drawn from a wastewater depth where the flow is turbulent and well mixed and the chance of solids settling is minimal. Depending on the sampling location, ideally, the depth of sample collection should be 40 to 60 percent of the wastestream's depth. To avoid contamination, personnel should take care to collect samples from the center of the flow. Wide channels or paths of flow may require dye testing to determine the most representative-sampling site. If dye testing is inconclusive, multiple samples may need to be collected by cross sectional sampling. Stagnant areas should be avoided as well, particularly if the wastewater contains immiscible liquids or suspended solids. If it is absolutely necessary to sample from a sump or other standing liquid, take care that the sample is representative of the material you intend to sample. This may entail sealing the sample container while it is below any floating layer, or sampling floating and lower layers separately for later combination in representative proportions at the laboratory. It may also be possible to pump down or drain standing liquid, then allow the pool or sump to refill before sampling.

Samples can be collected either manually (grab or composite) or with automatic samplers. The following general guidelines apply when taking samples:

- Take samples at the site specified in the permit or at the site selected by the inspector to yield a representative sample if the site has not yet been specified by in permit.
- To obtain a representative sample, sampling must be conducted where wastewater is adequately mixed. Ideally, a sample should be taken in the center of the flow where the velocity is highest and there is little possibility of solids settling. The inspector should avoid skimming the surface of the wastestream or dragging the channel bottom. Mixing of the flow is particularly important for ensuring uniformity. Sampling personnel should be cautious when collecting samples near a weir because solids tend to collect upstream and floating oil and grease accumulate downstream.
- List the sampling method (grab or composite) required by the permit (or the method which the inspector deems most appropriate if the method has not yet been specified in a permit). Note that is some cases, sampling methods and locations may be specified or defined by regulation, and should change only with the explicit approval of the permitting authority.
- Samples of certain pollutant parameters may not be taken by automatic samplers, but must be taken by manual grab samples. These parameters include dissolved oxygen, residual chlorine, pH, temperature, oil and grease, fecal coliforms, purgeable organics, and sulfides.
- To maintain sample integrety, avoid disturbing stagnant liquids, or flowing liquids upstream of the sample point. When sampling in multiple locations, begin with the downstream sample point.
- The opening of the sampling device or container should face upstream.

Return to TOC

- Avoid collecting large nonhomogeneous particles and objects.
- Do not rinse the sample container with the effluent when collecting oil and grease and microbiological samples, but fill the container directly to within 2.5 to 5 cm from the top.
- Fill the container completely if the sample is to be analyzed for purgeable organics, dissolved oxygen, ammonia, hydrogen sulfide, free chlorine, pH, hardness, sulfite, ammonium, ferrous iron, acidity, or alkalinity.
- When taking a grab sample, the entire mouth of the container should be submerged below the surface of the wastestream. A wide mouth bottle with an opening of at least two inches is recommended for this type of sampling. When using a composite sampler, the sample line should be kept as short as possible and sharp bends, kinks, and twists in the line (where solids can settle) should be avoided. The sample line should be placed so that changes in flow will not affect sample collection.
- The volume of samples collected depends on the type and number of analyses needed. The parameters to be measured and the method requirements guiding the analytical laboratory will determine this. Sample volume must be sufficient for all analyses, including QA/QC and any repeat analyses used for verification. Laboratory personnel should be contacted for the sample volume required completing all analyses, since the lab is in the best position to estimate the necessary volume of sample. Individual, minimum composite portions should be 100-ml with a total composite volume of 2-4 gallons. Larger volumes may be necessary if samples are to be separated into aliquots or if bioassay tests are to be conducted.

6.8.2 Freshwater and Biological Monitoring Program

6.8.2.1 Sampling Objectives

The objectives of the surface water monitoring, which determine sampling procedures, are generally to:

- bracket a stream segment traversing a particular geomorphologic zone or land use area;
- bracket known or potential point and nonpoint sources of pollution;
- evaluate streams or stream segments sensitive to water quality changes or consistently exceeding a water quality standard;
- define the rates of nutrient deposition at lake or reservoir inlets and outlets;
- sample at the confluence of a tributary to the mainstream river; and
- sample in segments of the river determined to be representative of larger segments.

6.8.2.2 Aqueous Samples

6.8.2.2.1 Stream/Flowing Water

For a stream, channel, river, etc., collect the sample from mid-depth. Once the sample is obtained, transfer it directly into the sample bottle. Decontaminate the sampling device before taking the next sample. If the liquid has stratified, a sample at each strata should be collected. One of the depth samplers listed will allow collection of discrete representative liquid samples at various depths. Proper use of the sampling device chosen includes slow lowering and retrieval of the sample, immediate transfer of the liquid into the sampling container, and logbook notation of the depth at which the sample was collected. After collection, decontaminate the sampling device before taking the next sample.

6.8.2.2.2 Composite Sampling

When regularly scheduled sampling from a wastewater tank, pipe or very narrow channel is required, an automatic composite sampler is generally preferred and flow-weighted samples are usually preferred. The remainder of this section is applicable to manual sampling or sampling from wider streams.

The characterization of a water column generally requires the representation of a cross section of a water body. This characterization is most often achieved with a composite sample procedure.

Water samples can be collected by either wading in the stream using a hand-held sample container or by lowering a depth-integrating sampler (a mechanism designed for holding and submerging the bottle such as a weighted bottle sampler) into the stream from the bridge. If collecting samples for trace elements, be sure to use acid rinsed sample containers and churn splitters. When wading, position the sample container upstream relative to stream flow and the wader. When using a depth-integrating sampler the sample should be collected on the upstream side of the bridge, unless stream or site conditions preclude sampling from the upstream side. These methods will minimize the possibility of sample contamination.

Before the start of sampling, the churn splitter must be rinsed three times using 1L of sample water per rinse. Be sure to allow rinse water to completely drain from the spigot each time. It’s important to store the churn splitter in double-bagged clear polyethylene bags prior to use in order to reduce air deposition contamination.

The number of individual samples in a composite varies with the width of the stream being sampled. Horizontal intervals should be at least one foot wide. Determine the number of stream intervals by using a tag line, bridge markers or visual inspection. At the interval (or vertical) of apparent maximum discharge determine the equal transit rates (or constant rates of speed) at which the sampling apparatus is to be lowered and then raised at all succeeding verticals. Lower and raise the sampling apparatus at a rate which, when all the verticals through the water column are sampled, will provide an adequate sample volume. Contact with the streambed should be avoided to decrease the possibility of suspended material entering the sample container. The contents of the sample container are then emptied into the churn splitter for rinsing of the churn.

The transit rate, number of verticals and the number of passes at each vertical are influenced by the volume of water required for the parameters to be analyzed and the mixing characteristics of the stream. A narrow or shallow stream may require each vertical to be sampled more than once, but all verticals must be sampled the same number of times. The compositing of the verticals in the churn splitter creates a single cross-sectional representation of the stream. The composited sample must now be split into the necessary subsamples as explained below. Samples collected for organic analysis, organic carbon, pesticides, herbicides and bacteria should not be composited in the churn splitter nor collected in any plastic device because of the potential for contamination. These parameters require glass samplers and containers. Bacteriological samples can be collected in auto-claved plastic containers.

The *Churn Splitter* is a 1/4-inch thick, white polyethylene cylinder. Currently, there are two types in use. One has an 8 3/16-inch inside diameter, a depth of 10 3/4-

inches, holds a volume of 8.6 liters and has a white polyethylene lid. The valve and spout are white polypropylene. The stirring disc is a 3/8 in. thick, white polypropylene disc 8 inches diameter with 16 apertures; 9 as scallops in the outer edge, and 8 in a inner circle. The handle, a 3/4-inch diameter by 14-in. long white polypropylene rod, is welded perpendicular to the center of the disc and supported by four ribs. A small "notch" on the disc aligns the disc with a guide rib and maintains the correct alignment with the valve. The valve is a screw type, also made of white polyethylene. The second type of churn splitter is constructed in the same way but holds approximately 14 liters. It has a 10 1/8-inch inside diameter, and is 11 3/4-inch deep. The stirring disc is 10 inches in diameter with an attached 1-inch rod, 16 3/4-inches long. All other aspects of this churn splitter are the same as the smaller version except for the valve. The valve on the larger version is a push button type with a metal string inserted. The model should be avoided when sampling for trace metals.

The *Sample Splitting Procedure* requires a total sample volume of 3 to 8 liters of which 1 to 6 liters are suitable for composited water column subsamples. The remaining two or more liters may be used for filtered subsamples if required by the analytical schedule. If not, they may be discarded. This size churn splitter does not reliably produce representative composited water column subsamples when it contains less than 2 liters. Before collection of the representative sample of the stream flow, determine the total volume needed. Add to this volume at least 10% to cover filter losses and rinse water. Collect approximately one liter of water and thoroughly rinse the churn splitter.

When the required volume plus 10% for waste is collected in the splitter, place all subsample containers within easy reach so that once started, the stirring can be continuous. The sample should be stirred at a uniform rate of approximately 9 inches per second. If faster or slower churning rates are used, maximum errors of 45% to 65% are possible. As the volume of sample in the splitter decreases the round trip frequency should be increased so that the churning disc velocity is constant. The disc should touch bottom, and every stroke length should be as long as possible without breaking the water surface. If the stroke length, and or disc velocity, is increased beyond the recommended rate, there is a sudden change of sound and churning effort which is accompanied by the introduction of excessive air into the mixture. This is undesirable because excessive air may tend to change the dissolved gases, bicarbonate, pH and other characteristics. On the other hand, inadequate stirring may result in non-representative subsamples. The sample in the splitter shall be stirred at the uniform churning rate for about 10 strokes prior to the first withdrawal to establish the desired churning rate of 9 inches per second and to insure uniform dispersion of suspended matter. The sample containers are to be rinsed with churned sample water prior to filling them. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A5* at http://water.usgs.gov/owq/FieldManual/

When all composited water column subsamples have been obtained, the remaining portion of sample is used for filtered samples. Rinse the bottles for filtered samples with filtered water first. When all of the necessary filtered subsamples have been obtained, the mixing tank, churning disk and filtered apparatus shall be rinsed thoroughly with distilled/deionized water.

Note: The churn splitter lid should be kept on at all times except when pouring samples, in order to protect samples from dust contamination.

Note: Acid-rinsed bottles for trace metals and hexane-acetone rinsed bottles for pesticide analyses should be rinsed with sample water prior to sample collection. These containers are appropriately preserved following sample collection. Bottles that are pre-preserved by the laboratory and whose data are not directly related to ambient surface water programs should not be pre-rinsed for the obvious reasons

6.8.2.2.3 Grab Sampling

This alternative to composite sampling is used when: 1) natural stream conditions (i.e. uniform mixing, high velocity) make compositing unnecessary; 2) requested parameters require special handling or; 3) non-representative samples are desired. Pre-rinse the sample container with water from the site. Position the appropriate sample container upstream below the surface and allow the container to fill as required. The grab sample may also be taken, as a dip or surface sample when the stream velocity is too high for sampler penetration to any significant depth, when there is large floating and submerged debris, or when the stream is very shallow.

6.8.2.2.4 Point Sampling

Point sampling is used to obtain a water sample from a specific depth in the liquid column. A Kemmerer sampler or similar device is lowered to the appropriate depth and a weighted messenger is sent down the suspension line to trigger the closing mechanism. The sample may be composited with other point samples or placed directly into the sample containers pre-rinsed with water from the same point in the water column. A point sample may also be taken in shallow waters by holding a sample container with the top still on below the surface at the desired depth. Remove the top and allow the container to fill to the required volume then replace the top and remove the container from the liquid.

6.8.2.2.5 Lake/Standing Water Sampling

The sampling of lakes/other standing water is performed with methods similar to those of stream sampling. Lake surface water samples should be taken at a depth of one meter; for more shallow standing water bodies, collect the sample from just below the surface or at mid-depth. If temperature recordings at varied depths indicate a stratification of the lake, point (discrete) samples shall be taken in the observed layers using a Kemmerer sampler. These samples may be composited or analyzed individually. A PVC sampler may be used to lower a bottle through a vertical or several verticals, which may then be composited depending on the purpose of the sampling program. Care should be taken when sampling from a boat that water is not disturbed by the wake of the boat.

6.8.2.2.6 Estuarine and Marine Water Sampling

The sampling of estuaries and marine waters is performed with the methods used in the sampling of streams and lakes. Stratification in estuaries is observed with the recording of specific conductivity/salinity along a vertical to the estuary bed. Sampling schedules must consider tidal stages and currents. Sampling from a boat should be performed as far from the stern as possible and only after the turbulence from the wake has subsided. The site should be approached from downstream.

6.8.2.2.7 Bacteriology

Bacteriology samples are to be collected directly into the special bacteriological container. Sample collection devices (i.e. composite samplers, sewage samplers, etc.) are not to be used for bacteriological sampling unless otherwise stated. The following methods are to be employed:

When sampling a stream, lake, bay or wastewater discharge, a grab sample is obtained in the following manner:

Take a bacteriological sample container and remove the covering and closure (protect from contamination). Grasp the container at the base with one hand and plunge the container (opening down) into the water to avoid introducing surface scum. *Do Not Rinse The Container*. Position the mouth of the container into the current away form the hand of the collector and away from the sampling platform or boat. The sampling depth should be 15 to 30 cm (6 to 12 inches) below the water surface. If the water body is static, an artificial current can be created by moving the container horizontally in the direction it is pointed and away from the sampler. Tip the container slightly upward to allow air to exit and the container to fill. After removal of the container from the water, pour out a small portion of the sample to allow an air space of 2 to 3 cm (1 inch) above the sample for proper mixing of the sample before analysis. Tightly close and label the container.

When collecting a sample at a depth greater than an arm's reach, use a Kemmerer or weighted container sampler. The devices are lowered into the water in the open position, and a water sample is collected in the device. A drop messenger closes the Kemmerer sampler. The Kemmerer sampler should not be used to collect bacteriological samples without obtaining data that supports its use without sterilization. Sample collection frequency for bacteriological samples should be appropriate for the project objectives.

6.8.2.2.8 Trace Element Sampling

Sampling for trace elements requires a more rigorous sampling procedure recommended by USEPA (see USEPA Method 1669: *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*, EPA 821-R-96-011, July 1996).

6.8.2.3 Non-Aqueous Samples

6.8.2.3.1 Sediments

Sediment (a.k.a. "bottom material") is a heterogeneous media and therefore care must be taken when designing an adequate sampling plan to ensure collection of representative samples. There are numerous factors such as particle size, organic content, stream flow, resuspension rate, biological activity, and physical/chemical properties, which affect the concentration and distribution of contaminants in a sediment system. For some applications, organic material should be sieved using a sieve with a maximum 2mm opening mesh. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/

The goals of sediment sampling are: 1) identify areas of highest contamination/impact; 2) to delineate the full spatial extent of contamination/impact and/or; 3) determine ambient conditions. The areas of greatest contamination will occur in

depositional areas in aquatic systems and these areas must be specifically targeted by the sampling plan except in ambient monitoring where a spatial composite would be appropriate. However, sand and gravel sediments rarely reflect pollution loading. The sampling team should specify the location of samples, the collection protocol, and the type(s) of sampling apparatus in the sampling plan. The plan should be thoroughly reviewed prior to implementation.

An adequate assessment of sediment quality involves four components:

- The concentration of contaminants (Bulk chemistry)
- Potential for contamination of the environment (elutriate, Extraction Procedure [EP] and Toxicity Characteristics Leaching Procedure [TCLP]).
- A measure of bioavailability and toxicity of environment samples via tissue analysis and/or toxicity testing (ASTM 2000; USEPA 2000)
- Assessment of resident biota (USEPA 1997; USEPA 1999)

These four components provide complementary data and no single component can be used to predict the measurements of the other components. For instance, sediment chemistry provides information on the extent of contamination but not on biological effects. Sediment toxicity tests provide direct evidence of sediment toxicity but cannot discriminate among contaminants nor predict actual in-situ responses. In-situ responses of resident biota, measured by infaunal community analysis, provide direct evidence of contaminant-related effects, but only if confounding effects not related to pollution can be excluded. Sediment evaluation must be based on several techniques to provide strong evidence for the identification, delineation, and ranking of pollution induced degradation.

It is imperative that in sediment sampling, all data be collected considering the overall needs of the assessment. Each bulk sediment sample must be analyzed for total organic carbon, pH, and particle grain size, in addition to site specific analytical parameters, to fully characterize each sediment sample and to assist in subsequent modeling and assessment efforts.

If the contamination event or the greatest contamination occurred in the past, it is likely that recent actions have resulted in the deposition of a layer of relatively uncontaminated sediment on top of the sediments of concern. Commonly used dredges collect only near-surface sediments and will result in data biased low. In these situations, a sediment corer may be the most appropriate sampling device. Additionally, the analysis of the sediment can include fractionating of the various layers found in the sediment cores (i.e., oxic and anoxic zones).

Particular attention should be paid to chemicals that are very persistent in the aquatic environment, have high bioaccumulation potential, have high toxicity to aquatic organisms, and have a high frequency of detection.

Surface water data should be included in the overall hazard assessment for sediments. However, in aquatic systems that contain quiescent waters such as lakes, wetlands, ponds, and intermittent or slow moving streams, the release of contaminants from the sediment may play a significant role in surface water quality. Lake stratification and associated anoxia may affect the exchange of contaminants at the water sediment interface. Under these conditions it may be necessary to collect seasonal samples or

discrete samples at various depths. Elevated concentrations of contaminants in the water column are indicative of a higher degree of concern associated with contaminated sediments.

Note: When sampling for both surface water and sediment at the same location, always collect the surface water sample first. If the samples being collected are from a flowing stream, always start from a downstream location and proceed upstream. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation. This will allow for the partial submersion of leachate sample containers. After the excavation disturbance has had time to fill with leachate, proceed with sampling.

Once contaminants of concern for sediments have been identified, further evaluation of the ecosystem in question should be performed. It must be emphasized that the screening level criteria can only evaluate the potential for biological effects to occur. In the environment, many factors such as bioavailibility, species composition, natural physical and chemical characteristics will determine whether actual adverse effects become expressed.

In collecting sediment samples from any source, care must be taken to minimize disturbance and sample washing as it is retrieved through the liquid column above. Sediment fines may be carried out of the sample during collection if the liquid above is flowing or deep. This may result in collection of a non-representative sample due to the loss of contaminants associated with these fines. While a sediment sample is usually expected to be a solid matrix, sampling personnel should avoid placing the sample in the bottle, and decanting off the excess liquid. Decantation promotes the loss of water-soluble compounds and volatile organics present in the sediment. If the sample is collected properly, any liquid that makes it into the bottle is representative of sediment conditions.

As with aqueous sampling, a determination of tidal influences on the impoundment being sampled should be made and its effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages.

6.8.2.3.1.1 Onshore

If liquid flow and depth are minimal and sediment is easy to reach, a trowel or scoop may be used to collect the sediment. Generally, where the liquid above the sediment collection point is flowing or is greater than four (4) inches in depth, a corer or clam shell should be used to collect the sample in an attempt to minimize washing the sediment as it is retrieved through the water column. This assumes sufficient sediment accumulation to accommodate the sample device. In some cases a corer is not the appropriate device when collecting sediments associated with ambient surface water quality. Confer with the proper oversight program, approved sample plan objectives or assigned case manager prior to sample collection should the question of selecting the correct sampling device arise. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/

6.8.2.3.1.2 Offshore

In some instances, the dimensions of an impoundment or channel dictate that a barge or boat must be used. The device used for the sample collection in this case will, again, depend upon the depth and flow of the liquid above the sample location and the bed characteristics of the impoundment. Generally, trowels or scoops cannot be used in an offshore situation. Instead, cores or dredges are more efficient means for sample collection. The barge or boat should be positioned just upstream (if it is a flowing impoundment) of the desired sample location. As the corer or dredge is lowered it may be carried slightly downflow, depending on the force of the flow. Upon retrieval transfer the contents of the corer or dredge directly into the sample bottle using a decontaminated trowel of appropriate construction. Decontaminate both the corer and dredge and the trowel before collecting the next sample.

6.8.2.3.1.3 General Procedures

Sediment samples must be collected from the 0-6” interval (biotic zone) of the water body bottom and may be obtained using an Eckman dredge Ponar dredge or hand scoop. If deeper sediment samples are required, a core sampler should be used. Loss of contaminants should be avoided by utilizing plastic bottles when sampling for metals and using brown borosilicate glass containers with Teflon® lined lids for organics.

If compositing or homogenization of sediment samples is necessary, the optimal methods will depend on the study objectives. Important considerations include: loss of sediment integrity and depth profile; changes in chemical speciation via oxidation and reduction or other chemical interactions; chemical equilibrium disruption resulting in volatilization, sorption, or desorption; changes in biological activity; completeness of mixing; and sampling container contamination. Several studies of sediment toxicity suggest it is advantageous to subsample the inner core area since this area is most likely to have maintained its integrity and depth profile and not be compromised by contact with the sampling device. Subsamples from the depositional layer of concern, for example, the top 1 or 2 cm should be collected with the appropriate sampling tool. Samples are frequently of a mixed depth but a 2-cm sample is the most common depth obtained.

For some studies it is advantageous or necessary to composite or mix single sediment samples. Composites usually consist of three to five grab samples. Subsamples collected with a decontaminated appropriate sampling scoop should be placed in a decontaminated appropriate bowl or pan. The composite sample should be stirred until texture and color appears uniform. Due to the large volume of sediment, which is often needed for toxicity or bioaccumulation assays and chemical analyses, it may not be possible to use subsampled cores because of sample size limitations. In those situations, the investigator should be aware of the above considerations and their possible biased affect on assay results as they relate to in-situ conditions.

If samples are to be analyzed from a certain particle size fraction or if the laboratory has maximum particle size limitations (generally 2 mm) the samples must be sieved before transfer to the sample bottles. Properly decontaminated, sieves of the appropriate construction (i.e., metal for organics and plastics or PFTE for metals)

must be used. All sediment samples should arrive at the laboratory within the specified analytical method holding time, at 4º Celsius and in the appropriate containers.

6.8.2.3.2 Sludge

All sludge samples shall be representative for the chemical and physical characteristics of the sludge removed from the treatment unit process immediately preceding ultimate management. For example, if a treatment works discharges dewatered filter cake for land application, then sampling activity must focus on the output sludge stream from the dewatering device (that is, vacuum filter, bed press, etc.)

All domestic and industrial treatment works are required to develop and maintain a sludge-sampling plan on-site. The plan must identify sludge sampling points that are established at locations which ensure sample homogeneity and best represent the physical and chemical quality of all sludge, which is removed from the treatment works for use or disposal. The plan must identify the equipment to be utilized for sampling, and the plan must demonstrate adherence to quality assurance and quality control requirements and procedures for sampling and analysis.

When a treatment works generates several different types of sludge (for example primary, secondary or advanced wastewater treatment sludge) each of which is removed separately for ultimate management, separate composite samples shall be collected and analyzed.

For sludge sample preservation, samples generally should not by chemically preserved in the field because the sludge matrix makes it difficult to thoroughly mix the preservative into the sample. Therefore, requirements for field preservation will be limited to the chilling of samples at 4º Celsius during compositing, holding, and transporting. Samples requiring preservation shall be preserved upon receipt in the laboratory that will be conducting the analysis.

Sampling locations shall be as follows unless the Department approves alternate sampling locations

- Sampling points for liquid sludge shall be at taps on the discharge side of the sludge pumps.
- For treatment works utilizing drying beds, one-quarter cup sludge samples should be taken at five-foot intervals across the bed surface. Neither the weathered surface nor sand should be included in the sample.
- For treatment works processing a dewatered sludge cake, sampling of the sludge should be taken from the point of sludge cake discharge.
- For treatment works with a heat-treated sludge, samples shall be taken from taps on the discharge side of positive displacement pumps after decanting for the heat treatment unit.

When a treatment works generates several different types of sludge (for example primary, secondary or advanced wastewater treatment sludges) each of which is removed separately for ultimate management, separate composite samples shall be collected and analyzed.

The sample collection, handling and preservations techniques set out in Appendix 2-1, shall be followed for all sludge analyses. Samples requiring preservation shall be preserved at the time of collection. If a preservative cannot be utilized at the time of collection (that is, incompatible preservation requirements), it is acceptable to initially preserve by icing the entire sample during compositing and immediately ship it to the laboratory at the end of the sampling period. Upon receipt in the laboratory, the sample shall be properly preserved.

All samples shall be chilled at four degrees Celsius during compositing and holding. For dewatered or dried sludge samples, preservation shall consist of chilling to four degrees Celsius. Use of a chemical preservative is generally not useful due to failure of the preservative to penetrate the sludge matrix.

6.8.2.4 Flow Measurements

During the course of site investigations it is often necessary to assess the quality and quantity of liquids flowing in channels. While the quality of liquid is determined through sampling and analysis, determinations of quantity of flow are made through the use of field measurements. Flow information should be gathered when samples are collected to allow a full characterization of the channel. Flow measurements also may be made without the collection of samples when assessing the channel's potential as a migratory pathway for pollutants.

Flow is the amount of liquid going past a reference point during a period of time. It can be calculated by measuring both the average velocity and the area through which the liquid is moving. Flow is reported as volume per unit time and is expressed in units such as cubic feet per second (CFS), gallons per minute (GPM) and million gallons per day (MGD).

Flow is measured by a flow metering system. The "primary element" is the measuring structure that contains the liquid. The "secondary element" is used to make measurements from the primary element and convert them to flow.

Flow methods fall into two broad categories: open-channel flow and closed-pipe (pressure conduit) flow. In open-channel flow the liquid has a free surface; in closed-pipe flow the water completely fills the conduit.

6.8.2.4.1 Open-Channel Flow Measurement

The open-channel primary element creates a known relationship between flow and depth. Under these conditions, the channel width is known and the velocity does not need to be measured. The secondary element is used to measure depth at a specific measurement point.

All open-channel primary elements create observable flow profile characteristics by manipulating the channel slope and size. The flow is constricted and made to drop through a steep and precisely dimensioned section (the primary element) before flow through the regular channel is resumed. A known and repeatable relationship between depth and flow results.

Starting some distance upflow of the primary element, the liquid will be relatively deep and slow moving. As it passes through the primary element, it will become much shallower and faster. Downflow from the primary element the liquid will return to a deeper and slower condition.

The flow is “subcritical” in the upflow and downflow reach and “supercritical” when it is moving shallower and faster. A hydraulic lift occurs as the flow changes between subcritical and supercritical. In all cases the approach flow must be subcritical and the change from subcritical to supercritical must be clearly evident.

The depth of the liquid in the primary element is measured at a particular location in the channel. The depth-to-flow relationship is only accurate at the measuring point. The depth can be measured directly from the throat or it can be measured at a stilling well.

A stilling well is a small, circular well, connected to the throat or to an upstream measuring point of the flume or weir, generally through a small-diameter pipe. The stilling well provides a calm pooling area where the depth can be accurately measured. The water level in the stilling well is the same as in the flume or weir at the measuring point. The stilling well should only connect to the flume or weir at the measuring point for the device being used. Stilling wells are not affected by wave action, foam or floating or partially submerged debris. Frequent cleaning may be necessary to keep the well and the connection to the flume or weir clean to ensure accurate measurements.

The accuracy of both the primary and secondary elements should be checked. Observe the flow through the primary element for certain characteristic flow conditions described in the following sections. Check the secondary element by comparing the depth reading with and independent depth measurement. Convert depth measurements to flow using hydraulic equations for the measuring device and evaluate the calculated flows with those indicated by the measuring device or the attached totalizer, recording disk, or discharge meter.

6.8.2.4.2 Open-Channel Flow Meters

6.8.2.4.2.1 Palmer-Bowlus Flumes

This type of flume is designed to be installed in an existing channel providing the channel is on an acceptable slope and the flows do not exceed the flume’s capacity. The dimension of the channel sizes the flume. For example, a six-inch Plamer-Bowlus flume is used in a six-inch channel. Smaller Palmer-Bowlus flumes of the “quick-insert” type are often used due to the ease with which their inflatable collar is inserted into the exit section of a pipe.

When installed, a Palmer-Bowlus flume is preceded by a section of straight pipe (about 25 pipe diameters long) and on an acceptable (subcritical) slope. The point of measurement for a Palmer-Bowlus flume is located at a distance D/2 upstream from the top of the flume, where D is the size of the flume.

The depth-to-flow relationships for Palmer-Bowlus flumes are available in tabular form. The depth, H, *is the vertical distance between the floor of the flume and the water surface at the measuring point*. The distance from the channel bottom to the floor of the flume is approximately D/6. This dimension may vary considerably due to the way the flume is installed or to corrosion or deposition.

Subcritical flow should be observed upstream of the flume with the hydraulic drop starting to be just noticeable just downstream of the measuring point. The water should drop more noticeably with supercritical flow obvious around the down-

stream portion of the flume. The water surface will often show a “V” section formed by standing waves as the water enters the flume. The hydraulic jump also often has a “V” shape to it. At flumes installed in sewer lines, the supercritical section tends to be less evident and to be located further downstream than average. On steeper lines, it will be more pronounced. A hydraulic jump that occurs upstream of the flume may be an indication that the upstream piping was laid at too steep a slope or that accumulated debris needs to be removed.

In some cases, the change from subcritical to supercritical flow will be evident, but the hydraulic jump will not be visible. That is perfectly acceptable. The jump may occur farther downstream in the discharge pipe. A steeply sloped discharge pipe may carry supercritical flow a considerable distance.

If the hydraulic jump seems to be within the flume itself, or if the supercritical section does not seem to exist, the flume may be operating in a submerged condition. If the submergence is too great, the flume will no longer be accurate, as measured by a single measurement. A submerged condition can occur when the discharge pipe is not able to carry the flow. This can happen because of an improper slope of the pipe, debris in the pipe, or from flow conditions in the sewer line father downstream that cause a backup of water in the flume. Any of these unusual conditions should be promptly investigated.

The dimensions to which a Palmer-Bowlus flume is constructed have been standardized, but in a generic sense the term Palmer-Bowlus-type flume can apply to any flume of this general shape and size. Be aware, however, that head-to-flow tables are not identical for different manufacturers due to slight differences in style. For instance, another similar type of flume, the Leopold-Lagco flume, also is occasionally installed in an existing line. It has a rectangular cross-section rather than a trapezoidal cross-section and, consequently, produces a different head-to-flow reading than a Palmer-Bowlus flume of the same nominal size.

6.8.2.4.2.2 Parshall Flumes

A Parshall flume operates on the same principle as the Palmer-Bowlus flume. The measuring point for this flume located in the converging section at a distance of 2/3A upstream from the beginning of the throat of the flume. The distance A is the length of the converging section measured along the wall, rather than along the centerline of the flume.

The main advantage of a Parshall flume is that the flume will handle a wide range of flows. The flumes are available already installed in prefabricated manholes and vaults but installation in an existing sewer line may involve replacing some of the line because of the required drop in the floor of the flume.

Subcritical flow should occur upstream of the flume, the hydraulic drop (drop in flowing water surface) occurs in the converging section of the flume, and supercritical flow occurs in the throat of the flume. The hydraulic jump generally occurs in the throat, the diverging section, or farther downstream.

As with the Palmer-Bowlus flume, the hydraulic jump does not have to be within view. Parshall flumes are often installed to discharge to a sump or to a more steeply sloping line to prevent submergence of the flume due to water backing up in the downstream pipe.

Many flumes have a staff gauge installed on the side of the flume for depth of flow measurements. If a staff gauge is not available, measure the water depth at the appropriate location with a steel rule. The use of a wooden yardstick to measure water depth should be avoided because these devices may create a wave in the flowing water, which could lead to erroneous depth measurements. Record the depth reading from the steel rule. Using the proper table or rating curve for the size of the flume, use the depth of flow reading to determine the flow.

A Parshall flume is not always installed to carry the maximum flume capacity. For instance, a flume that can accommodate a depth of three feet at the measuring point could be cut at two feet if space limitations so necessitated, although this reduces its capacity.

Parshall flumes were initially designed to be installed in irrigation systems on relatively flat surfaces and are capable of operating partially submerged. However, such operations require additional depth measurement. Most instrumentation is not designed for that circumstance, so the flume should not be operated past a certain degree of submergence. If the hydraulic jump is located well up the throat of the flume, further investigation is advised.

A number of other types of flumes have been developed. These are the cutthroat flume, the San Dimas flume, and trapezoidal flumes. Many other flumes have been designed for specific applications. All of these flumes control the cross-sectional flow area and convert the depth of flow measurement to a rate of flow.

6.8.2.4.3 Weirs

Weirs differ from flumes in that a weir is essentially a dam across the flow, as compared to reshaping the channel. Weirs are either broad-crested (wide in the direction of flow) or sharp-crested. The sharp-crested weir is more commonly used in measuring industrial wastewater flow than the broad-crested weir. The V-notch weir is the most common of the sharp crested weirs because it is the most accurate flow measuring device for the small, fluctuating flows which are common for small industries.

Weirs can be installed in a variety of situations; often an existing sump will be large enough to serve as a weir box. Always provide adequate clearance below the notch for a free discharge to occur. This requirement may limit the installation in existing lines if the backup of water would flood or submerge the weir.

Weirs operate on the same principle as flumes; however they can look quite different. The approach section, which is sized so that the approach velocity is minimal, has subcritical flow. Supercritical flow occurs as the water pours through the weir notch. The flow returns to subcritical flow in the afterbay of the weir.

Under normal conditions, you will see that the flow through the notch, called the nape (pronounced NAP) of the flow, springs away form the weir plate. This means that the weir is operating with a free discharge and that the nape is well ventilated, or aerated; that is, air can move freely beneath the nape. Only at low flows should the water cling to the face of the weir plates.

A weir cannot be operated under submerged conditions. The nape of the water must fall freely into the weir afterbay. If the level in the afterbay rises too high, aeration of the nape may cease and the measured discharge will be greater than the actual

discharge. A weir should be constructed with several inches clearance between the crest of the weir (the bottom of the notch) and the afterbay level. In general, a weir should be constructed with the top of the downstream pipe at least six inches below the crest of the weir. If the discharge pipe is not visible and the afterbay level is approaching the crest of the weir, it is likely that the proper depth-to-flow relationship does not exist.

To develop the proper depth-to-flow relationship with a weir, it is generally necessary that an upstream pool be formed to dissipate the approach velocity of the flow. The dimensions (determined by qualified design engineers) of this pool are based on the maximum capacity, expressed as the depth (head) behind the weir. The absence of this pool may cause the weir to measure a lower than actual flow.

The measurement point for all types of weirs is located at a distance of about 3H to 4H upstream (or to the side) of the weir. H is the maximum head on the weir. The depth of flow (head) through a weir is measured from the crest (bottom or lowest point) of the weir to the water surface at the measuring point.

6.8.2.4.3.1 V-Notch Weirs

Cutting a 22 ½ °, 30°, 45°, 60° or 90° notch in a metal plate and fixing the plate in appropriate supports forms a V-notch weir. Other materials are used for weir plates, including polycarbonate (a plastic material like plexiglass). The edges of the notch must be cut and beveled to the correct dimensions. For permanent installations, the weir plates should be made of metal since the accuracy of a weir is affected by the gradual rounding of the edges of the notch. The angle of the weir and the depth of the notch fix the dimension of the upstream pool.

The actual formula that should be used by the secondary measurement device should be determined when checking the accuracy of the system. (Use the formula that is recommended by the manufacturer.) The cone formula for 90° V-notch weirs is Q=2.49H2.48.

6.8.2.4.3.2 Rectangular Weirs

Another common type of weir is the rectangular weir. The rectangular opening may span the width of the channel in which case the weir is known as a suppressed (without end contractions) weir. Aeration of the nape is achieved by installing vent pipes beneath the nape. When the opening spans only a portion of the width of the channel, the weir is known as a contracted (with end contractions) weir. As with the V-notch weirs, the weir pool dimensions depend on the type and capacity of the rectangular weir. The measuring point is located at about 3H to 4H upstream of the weir. The weir should be sized so that the minimum depth is about 0.2 foot and the maximum depth is about one-half the length of the crest, although greater depth can be adequately measured. Rectangular weirs will measure larger flows than V-notch weirs.

The depth-to-flow formula for suppressed rectangular weirs is usually given as:

$$Q = 3.33\ LH1.5$$

The formula for contracted rectangular weirs is usually given as:

$$Q = 3.33\ (L - 0.2H)H1.5$$

In these formulas, H is the depth in feet from the crest of the weir to the water surface at the measuring point, L is the crest length in feet, and Q is the flow in cubic feet per second.

A Cipolletti weir is quite similar to a contracted rectangular weir, but has a trapezoidal-shaped opening rather than a rectangular opening. The discharge formula for this weir, with the same units as above is usually given as:

$$Q = 3.367LH1.5$$

Several other types of sharp-crested weirs are occasionally used in flow measurement work, but because of their unusual shapes, and a resulting difficulty in construction, they are not usually selected for installation.

6.8.2.4.3.3 H-Type Flumes

H-type flumes were developed to measure the runoff from agricultural watersheds and have found use in other applications. The H-flume, HS-flume and HL-flume combine features of both weirs and flumes. Flow control is achieved at a sharp-edged opening and the flat floor allows passage of solids. The maximum depth of the flume designates these flow measurement devices; for instance the 1.0-foot H-flume has a maximum head of 1.0 foot. The dimension to which the flume is constructed, and also the point of measurement, depends on the maximum depth. For the H-flume, the measurement point is located at a distance of 1.05D from the discharge tip of the flume, where D is the size of the flume (maximum head). For the HS-flume the distance is D; for the HL-flume the distance is 1.25D. The discharge formulas for the H-type flumes are complicated, thus tables that are easy to read should be used to relate depth to flow. The depth of flow is measured from the floor of the flume to the water surface. The flume should discharge in a free flow condition, as with a weir, and without submergence.

H-flumes are more correctly classified as flow nozzles. Two other types of flow nozzles, the Kennision nozzle and the parabolix nozzle and also occasionally used to measure flow.

6.8.2.4.4 Instrumentation for Open-Channel Flow

Several different types of instruments are available for measuring open-channel flow. Generally, all of them can be installed on any type of flume or weir, at either the channel or the stilling well, although the characteristics of a particular wastewater may preclude the use of certain types of instrumentation. The function of the instrumentation is to secure the level of the water; convert the depth to flow; and to indicate, record and totalize the flow. The instrumentation may also be used to activate an automatic sampler, and outputs are usually available for other uses.

The totalizer, indicator, and recorder should be properly labeled to prevent problems in interpreting their readings. Also the pulse output for a contact closure used in flow proportional sampling should be clearly labeled. Totalizer readings usually require that a multiplier factor be used and this factor should be posted. Analog readout indicators often use a span of zero to 100 percent. The flow at 100 percent should be posted. The recorder often has the same span as the indicator, but when it differs is should be posted. The chart paper on the recorder should be regularly annotated with the time and date and the totalizer reading. Some meters are constructed without

indicators and instantaneous readings of the flow must be taken directly from the recorder. The timer operation generated by the flow must be taken directly from the recorder. The timer operation generated by the flow meter to activate an automatic sampler should also be posted.

The methods described above are not equally accurate. Errors related to the reading of a staff gauge are assumed to be minor and therefore this means of determining a flow rate should be considered very accurate, provided the staff gauge is properly installed and can be accurately read. Errors related to the determination of head by means of a reference point should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered to be the greatest since the insertion of any obstruction into the flow can affect flow conditions.

6.8.2.4.5 Closed-Pipe Flow Metering Systems

Closed-pipe (pressure conduit) flow meters are installed in a section of pipe that remains full under all normal discharge conditions. The pipe may flow from gravity conditions or from a pump discharge. Closed-pipe flow meters are divided into two categories, (1) those that measure the average velocity of the flow (which is applied to the cross-sectional area of the pipe to determine flow) and (2) those that produce a differential of pressure across the meter by constricting the flow. The flow can be determined from that differential pressure.

A closed pipe meter should be preceded and followed by five to ten pipe diameters of straight pipe to develop and maintain a satisfactory flow profile. A satisfactory profile means that the velocity is fairly uniform across the pipe. An unsatisfactory profile could occur near a bend or elbow. Manufacturers of such devices recommend that certain distances of straight pipe equal to so many pipe diameters be installed upstream and downstream of their meters.

As with open-channel meters, closed-pipe flow meters should also be hydraulically calibrated with known flows when first installed. Instrument calibrations and hydraulic calibrations should be performed at regular intervals thereafter.

A general disadvantage of a closed-pipe flow meter in the measurement of industrial wastewater is the difficulty in determining if the meter is clean. The material present in some wastewaters can coat, clog, or corrode a meter in an undesirably short period of time. This possibility should be considered in the selection of a meter. Flow meters must be calibrated regularly (every six months) after installation.

6.8.2.4.6 Types of Meters, Methods and Systems

6.8.2.4.6.1 Electromagnetic Flow Meters

Electromagnetic flow meters use Faraday’s Law to determine flow rates. This principle states that if a conductor, in this case the water is passed though a magnetic field, voltage will be induced across the conductor and the voltage will be proportional to the velocity of the conductor and the strength of the magnetic field. Electromagnetic flow meters produce a magnetic field and measure the voltage created by the movement of the water; the voltage reading is translated to a flow

measurement based on the pipe diameter. The mag meter does not have any intrusive parts and operates over a wide range of velocities and is not sensitive to viscosity, density, turbulence, or suspended material. A minimum conductivity of the fluid is necessary; most wastewater is adequately conductive. Deposits of grease or oil can affect results, and some electromagnetic flow meters are equipped with self-cleaning probes to remove these deposits from the measuring area.

6.8.2.4.6.2 Turbine Meters and Propeller Meters

Both of these meters operate on the principle that a fluid flowing past an impeller causes it to rotate at a speed proportional to the velocity of the flow. On some models the axis of the impeller is located in the direction of the flow; the other is perpendicular to the flow. The motion of the impeller is conveyed through a mechanical device or a magnetic coupling to the register of the meter. These meters are commonly used in water measurement. The accuracy of the meter is affected by a poor flow profile, misalignment of the impeller, and accumulation of solids, especially oil and grease, on the impeller. Turbine and propeller meters are not used to measure flows in wastewaters that carry rubber or plastic goods, and other abrasive debris or corrosive liquids.

6.8.2.4.6.3 Rotating Element Current Meters

Of the various types of meters that exist for measurements of flow velocity, rotating element current meters are perhaps the most commonly used. The principle of operation is based on the proportionality between the velocity of water and resulting angular velocity of the meter rotor. In conventional current meters there is a wheel which rotates when immersed in flowing water and a device which determines the number of revolutions of the wheel. The general relation between the velocity of the water and number of revolutions of the wheel is given by:

$$V = a + bN, \text{ where}$$

V = velocity of water meter per second
a and b are constants
N = number of revolutions per second

These current meters can be grouped into two broad classes: 1) vertical-axis rotor with cups and vanes, and 2) horizontal-axis with vanes. Figure 6.3 shows the propeller current meter, which is typical of a horizontal-axis current meter with vanes. Figure 6.4 shows the Price current meter, which is typical of a vertical-axis rotor current meter with cups.

Practical considerations limit the ratings of these meters to velocities of 0.030 m/s (0.11 fps) to about 4.57 m/s (15 fps). The comparative characteristics of these two types are summarized below:

Vertical-axis rotor with cups or vanes

- operates in lower velocities than do horizontal-axis meters.
- bearings well protected from silty water.
- rotor is repairable in the field without adversely affecting the rating.
- single rotor serves for the entire range of velocities.

- Horizontal-axis rotor with vanes
- rotor disturbs flow less than do vertical-axis rotors because of axial symmetry with flow direction.
- rotor is less likely to be entangled by debris than are vertical-axis rotors.
- bearing friction is less than for vertical axis rotors because bending moments on the rotor are eliminated.
- vertical currents will not be indicated as positive velocities as they are with vertical-axis meters.
- they have a higher frequency of mechanical problems.

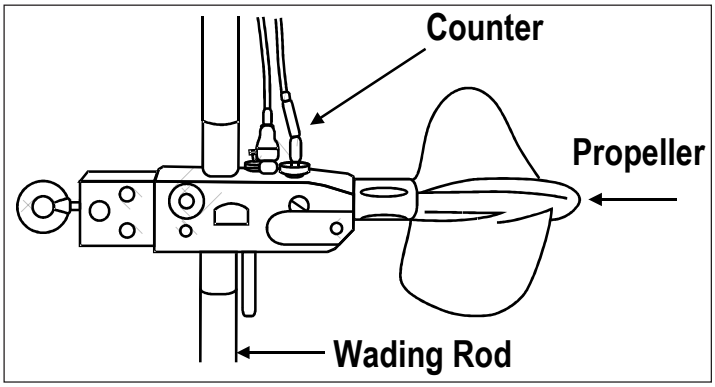


Figure 6.3 Propeller Current Meter

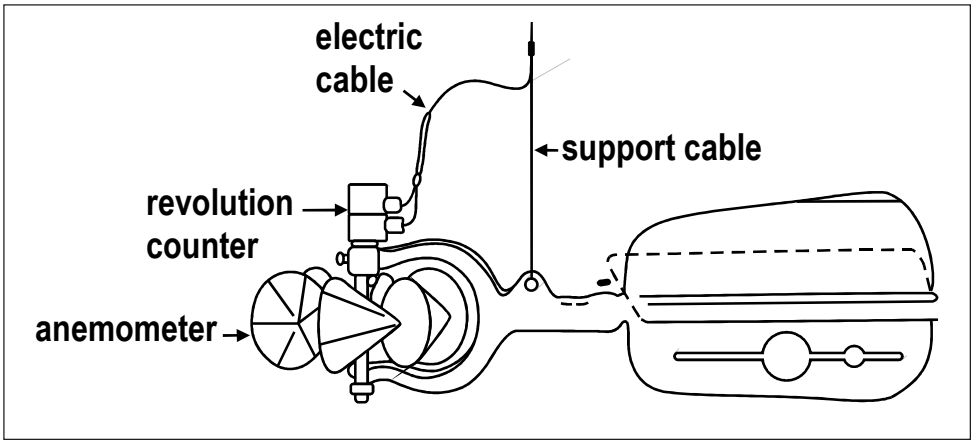


Figure 6.4 Price Current Meter

6.8.2.4.6.4 Ultrasonic Meters

Ultrasonic flow meters for closed-pipe flow use sonic waves to measure the velocity of the water. In comparison, ultrasonic meters for open-channel flow measure distance. The velocity of the water is measured either by the travel time of the sound waves, or by the Doppler Effect. With the former type of meter, two transducers, each of which includes a transmitter and a receiver, are located along the pipe. One transducer sends a signal in the direction of flow and the other

transducer sends a signal opposite to the flow. The signal sent with the flow is received sooner than the signal sent against the flow. The difference in transit time is used to determine the velocity of the flow.

The Doppler type of ultrasonic flow meters makes use of the principle that a frequency shift of an ultrasonic signal occurs when the signal is reflected from a moving object; in this application, suspended solids or entrained air bubbles in the wastewater reflect the signal. The frequency shift results in a higher returned frequency if the water is moving toward the transducer, and a lower frequency if the water is moving away from the transducer. The velocity of the water can be determined from the frequency shift.

Ultrasonic flow meters are sensitive to flow profile effects. The manufacturer's recommendations for distances of upstream and downstream pipe diameters should be followed. The type of meter's accuracy is affected by pipe wall buildup and particle solid absorption. The in-line type of transducer is affected by a buildup of solids in the transducer. The clamp-on type of transducer is affected if the pipe and liner have sonic discontinuities in them or between them.

6.8.2.4.6.5 Pitot Tube Meters

The pitot tube, and similar devices, measure the velocity at a single point within the pipe. With a proper length of straight pipe upstream, a pitot tube installed approximately 30 percent of the pipe radius from the inside pipe wall will give an average velocity reading. However, it may be necessary to profile the flow to find the location at which this average velocity occurs. Pitot tubes are appropriate for measuring clean water or gasses rather than wastewater since they are sensitive to fouling.

6.8.2.4.6.6 Differential Pressure Systems

These systems use pressure differentials and their relationship to discharge to determine flow in closed systems. Differential pressure systems are used for measuring clean matrices rather than wastewater. Problems with fouling and deposition in the devices affect the configuration and hence the relationship between the pressure in the device and the flow. For these reasons the measurement ports and the device itself must be kept clean for accurate measurements.

An orifice plate meter consists of a thin plate with a hole drilled through it, with the pressure differential measured through access ports on both sides of the plate. A venturi meter creates this differential by gradually decreasing the cross sectional area of the pipe. Flow nozzles use a curved inlet and short throat to create the pressure differential. Flow tubes use an even shapelier curved inlet and a very short tube to create the pressure differential.

Differential pressure systems are subject to fouling in wastewater situations and are therefore most appropriate for gases and clean water matrices. The pressure taps must be kept clean in order for the system to work properly.

6.8.2.4.6.7 Velocity Modified Flow Meters

These are a cross between open and closed channel devices. These meters are used to measure both water depth and velocity. Typically, the meter consists of a velocity sensing element and a depth-sensing device (such as a pressure sensor or a

bubblier). The meter is inserted into a tube, which is inserted into the pipe. These meters are useful when the pipe is submerged or buried.

As with the differential pressure systems, the velocity modified flow meter systems work well with clean matrices, but they also work well with wastewater (but not wastewater with high solids contents). These devices must be kept clean and must be installed on nearly level pipe systems to work properly.

6.8.2.4.6.8 Floats

There are three types of float methods used for estimating flow measurements; surface floats, subsurface floats and integrating floats. To determine the flow velocity, one or more floats are placed in the stream and their time to travel a measured distance is determined. These methods are simple but from an accuracy standpoint, they should be used only for estimating the discharge.

Various surface floats, such as corks and stoppered bottles, and submerged floats like oranges, measure surface velocity. The mean velocity of flow is obtained by multiplying with a coefficient, which varies from 0.66 to 0.80.

A more sophisticated version is the rod-float, which usually uses round or square wooden rods. These rods have a weighted end so that they float in a vertical position with the immersed length extending about nine-tenths of the flow depth. Velocity measured by the time of travel of these rods is taken as the mean velocity of flow. These floats are used in open channels and sewers.

To obtain better results, the velocity measurements should be made on a calm day and in a sufficiently long and straight stretch of channel or sewer of uniform cross-section and grade with a minimum of surface waves. Choose a float, which will submerge at least one-fourth the flow.

A more accurate velocity measurement is obtained by using integrating float measurements. The method is simple and consists of the release of buoyant spheres resembling ping-pong balls from the channel floor. As these spheres rise, the flow velocity carries them downstream. The time from the moment of the release to the moment when they surface and the distance traveled downstream are measured and inserted into the following equation to determine flow rate.

$$Q = DV \quad \text{and} \quad V = L / t$$

Where: Q = discharge per unit width of channel (in cubic meters per second or cubic feet per second)

D = flow depth (meters or feet)

V = terminal velocity of the float (meters per second or feet per second)

t = time of float to rise (seconds)

In flows of large depth and velocity, integrating float methods weigh two floats of different velocities of rise are used. The discharge is calculated using the relationship:

$$Q = \frac{D(L2-L1)}{t2-t1}$$

where L2 and L1 are distances traveled downstream by float 2 and float 1 respectively; t2 and t1 are times of rise of float 2 and float 1 respectively.

The integrating float method is simple and does not require any laboratory calibration. It integrates the vertical velocity profile and yields the mean velocity or discharge per unit width of the section. The method is suited to low velocity profiles and it has practically no lower velocity limit. To get better accuracy, the reach of the stream to be measured should be sufficiently long and straight and the bed fairly uniform. Use a fast rising float so that distance traveled downstream is of short length. The shape of the float should be spherical.

6.8.2.4.6.9 Salt Velocity Method

The method is based on the principle that salt in solution increases the conductivity of water. This method is suitable for open channels of constant cross-section and for flow in pipes. Sodium chloride and lithium chloride are commonly used. The basic procedure is as follows:

- Install two pairs of conductivity electrodes downstream from the salt injection point at known distances and sufficiently far apart in the stretch of the channel.
- Connect the recording galvanometer to the electrodes.
- Inject the slug of salt solution.
- The time for salt solution to pass from the upstream to the downstream electrodes, in seconds, is determined by the distance on the graph between the centers of gravity of the peak areas.
- calculate the discharge using the formula:

$$Q = AL / T, \text{ where}$$

Q = discharge in cubic meters per second

A = cross sectional area of flow, square meters

L = distance between electrodes, meters

T = recorder time for salt solution to travel the distance between electrodes, seconds.

6.8.2.4.6.10 Color Velocity Method

The color velocity method is used to estimate high velocity flows in open channels. It consists of determining the velocity of a slug of dye between two stations in the channel. This velocity, taken as the mean velocity, multiplied by the cross-sectional area of flow gives an estimate of discharge. Commercially stable dyes (see Part C.3) or potassium permanganate may be used as the coloring matter. The color velocity is computed from the observation of the travel time associated with the center of mass of colored liquid for the instant the slug of dye is poured at the upstream station to the instant it passes the downstream station, which is at a known distance from the upstream station.

With fluorescent dyes, the use of a fluorometer to detect the center of the colored mass will enhance the accuracy of the results.

6.8.2.4.6.11 Discharge

To determine the discharge (flow volume), in addition to the velocity of flow, it is necessary to determine the area of flowing water or wastewater. This applies especially to large flows in rivers, lakes, and wide and deep channels. A depth sounding is necessary at each vertical and width measurement of the cross-section of flow to determine the area of flowing water or wastewater. Sounding rods, sound weights and reels, handlines, and sonic sounders are common equipment for depth determinations. Marked cableways and bridges, steel or metallic tap or tag lines are used for width determinations.

To determine the discharge at a particular cross section, it is necessary to determine the mean velocity of flow at that section. In drag body current meters such as vertical-axis deflection vane, horizontal-axis pendulum type deflection vane and pendulum current meters, it is possible to integrate velocities at different depths in a particular section to obtain the mean velocity of flow. On the other hand, an inclinometer, drag sphere, rotating element current meters and pilot tubes measure the velocity at a point. Therefore, to obtain the mean velocity of flow at a particular vertical section, it is necessary to take velocity measurements at different depths. The various methods of obtaining mean velocities are:

- vertical-velocity curve
- two-point
- six-tenths depth
- two-tenths depth
- three point
- subsurface

Table 6.12 compares these methods in relation to application, flow, depth, velocity, measuring point(s) and accuracy.

6.8.2.4.7 Miscellaneous Flow Measurement Methods

6.8.2.4.7.1 Water Meters

An estimate of the flow can be obtained from water meter readings where an instantaneous flow rate is not critical. This technique is used in a confined area, such as an industrial plant. Water meters should be certified periodically. When using the incoming and outgoing flow for an initial estimate of the flow rate, all changes in the water quality that occur in various processes must not be overlooked. These changes may be due to water actually consumed in the process, for example, cement manufacturing, conversion of quick lime to slaked lime.

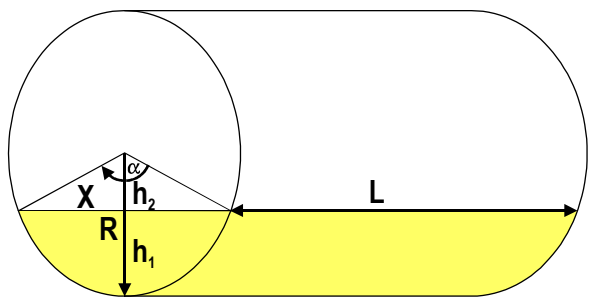
6.8.2.4.7.2 Measure Level Changes in Tank

In some instances the level change in a tank can be used to estimate flow. To accomplish this, the volume of the tank related to depth must be established; then the flow is allowed to enter and the level change with time is recorded. Figure 6.5 gives the relationship of depth to the stationary volume of a liquid in a horizontal cylinder.

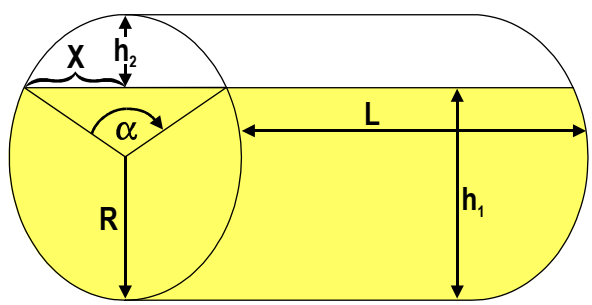
To determine the volume of a stationary liquid in a partially filled horizontal cylinder, use the following formulas

Volume = $\alpha/360\ \alpha R^2 - 2\ [1/2\ h_2\ (R^2 - h_2^2)\ 1/2]\ L$
Where: R = Tank Radius

h_1 is less than R:	h_1 is greater than R:
$\alpha = 2\cos -Lh_2/R$	$\alpha = 360 - 2\cos -Lh_2/R$
h_2 = R - depth of liquid or h_1	h_2 = Tank Diameter - depth of liquid or h_1
$X = \frac{[R^2 - h_2^2]}{2}$	$X = \frac{[R^2 - (D - R)^2]}{2}$



Partially filled horizontal cylinder where h_1 is less than R



Partially filled horizontal cylinder where h_1 is greater than R

Figure 6.5 Stationary Volume of Liquid in Horizontal Cylinders

6.8.3 Site Remediation and Waste Management Program

6.8.3.1 Sampling Objectives

Identification of sampling goals, objectives and data quality objectives (DQOs) is critical. A minimum number of surface water and sediment samples may be appropriate during the preliminary assessment phase, but may require a comprehensive suite of analytes. In contrast, a greater number of surface water and sediment samples may be required during the remedial investiga-

Table 6.12 Comparison of Various Methods to Obtain Mean Velocity

Methods Considerations	Vertical Velocity Curve Method	Two Point Method	Six-tenths Depth Method	Two-tenths Depth Method	Three Point Method	Subsurface Method
Applications	Not for routine discharge and measurements. Used to determine coefficients for application to results from other methods	Generally used	Primarily used for depths less than 2.5 ft.	During high velocities when unable to measure at 0.6 and 0.8 ft. depths.	When velocities in a vertical are abnormally distributed.	When unable to obtain soundings and depth cannot be estimated to 0.2 ft. setting
Flow depth requirements	> 2.5 ft.	> 2.5 ft.	0.3 ft. to 2.5 ft.	No depth constraint	> 2.5 ft.	> 2.5 ft.
Velocity measuring point(s)	At 0.1 ft. depth increments between 0.1 and 0.9 ft. deep	0.2 and 0.8 ft. depth below the water surface	0.6 ft. depth below the water surface	0.2 ft. depth below the water surface	0.2, 0.6 and 0.8 ft. depth below the water surface	At least 2 ft. below the water surface
Mean velocity	From vertical velocity curve	$\frac{V0.2+V0.8}{2}$	Observed velocity is the mean velocity	Vmean = C x V0.2 C = Coefficient obtained from vertical-velocity curve at that vertical for flow depth	Vmean = $\frac{\frac{\{V0.2+V0.8\}}{2}+V0.6}{2}$	Vmean = C x V observed from vertical velocity curve at that vertical for flow depth
Accuracy	Most accurate	Consistent and accurate results	Gives reliable results	If C is known gives fairly reliable results	Gives reliable results. When more weight to 0.2 and 0.8 ft. depth observations is desired an arithmetic mean may be calculated.	Gives estimate, difficult to determine

V0.2 = velocity at 0.2 ft. depth
V0.6 = velocity at 0.6 ft. depth
V0.8 = velocity at 0.8 ft. depth
Vmean = mean velocity

tion phase but only require a focused list of parameters. Compliance monitoring associated with permit requirements follows strict sampling procedures thereby necessitating thorough and compete understanding of sampling objectives.

Sampling of aqueous and non-aqueous matrices performed for, or by, the Site Remediation Program (SRP), must be pursuant to the requirements set forth in *Technical Requirements for Site Remediation*, N.J.A.C. 7:26E-3.8 and 4.5. Samples shall be collected in accordance with procedures outlined below with exceptions and additions noted as follows:

6.8.3.1.1 Site-Related Sample Locations

During the Site Investigation (SI), the objective of surface water body sampling is to determine whether site related contaminants have migrated to wetlands and surface water bodies associated with the site. During the Remedial Investigation (RI), the objectives of sampling are to further delineate and characterize contamination, as well as to evaluate the relationships among contaminated surface water, sediments, groundwater, and soil. Surface water body and wetland samples are generally discreet and biased towards depositional areas, discharge points, etc., where contaminants are

expected to accumulate, but the site- specific conditions may dictate the need for other sampling approaches. Investigations may require the use of the sample transect approach, described in NJDEP's, *Guidance for Sediment Quality Investigations, November 1998.*

6.8.3.1.2 Reference Sample Location

When investigating surface water, sediment, or wetland soil contamination in order to determine if it is linked to site operations, it is important to establish the chemical composition of upgradient sediments. These data also aid in the assessment of the site's contamination relative to the regional quality of the water body being investigated and in the development of remedial goals. The SRP recognizes that many of the State's water bodies, especially in urban/industrial settings, have become contaminated by historic point and non-point discharges, resulting in the diffuse, anthropogenic contamination of sediments at concentrations greater than natural background. Additionally, upgradient sediments can be contaminated by the site because of tidal influences. While it is difficult to distinguish between site and non site-related contamination at these settings, it is the policy of NJDEP to make a reasonable attempt to investigate the site's contribution above ambient. If potential sources of contamination are present upstream of the site, and it is believed that these sources have contributed to the contamination detected on-site, these upgradient areas should be sampled, and professional judgment should dictate how these data are to be interpreted/utilized. Note that these results will not be considered representative of true reference (i.e., natural background) conditions.

For upgradient and offsite reference locations, SRP recommends the collection of a minimum of three (3) to five (5) samples to establish a range of reference location contaminant concentrations (the larger number of samples is recommended due to sediment heterogeneity). Samples shall be collected from areas outside the site's potential influence. The samples must not be collected from locations directly influenced by or in close proximity to other obvious sources of contamination (i.e., other hazardous waste sites, sewer/storm water outfalls, tributaries, other point and non-point source discharges, etc.). If a local reference site is included in the sampling plan, it must be of comparable habitat to the study area. Upstream areas influenced by tides shall be sampled at locations determined to be within the mixing zone to delineate upstream migration of contaminants as well as upstream of any mixing zone in order to assess local ambient conditions. At a minimum, upgradient and local reference samples shall receive the same chemical analyses as site-related samples.

SRP requires, to the extent practicable, that surface water, sediment/ wetland soil, and biological samples are co-located spatially and temporally.

6.8.3.2 Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.8 and 4.5. Procedures in Section 6.8.3.1 above, shall be followed with the following additional requirements and considerations.

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely surface water migration pathways and discharge points have been identified. Aqueous samples should generally be discreet (not composited) and biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/ sheet flow runoff, dis-

charge of contaminated ground water to surface water body, landfill leachate seeps, etc.). Unless otherwise specified in the site-specific field sampling plan, surface water samples should be collected directly above sediments, near banks/other depositional areas where water current is slower and there is greater retention time for the surface water to accumulate contaminants from sediment. The site-specific field sampling plan must account for seasonal/short-term flow and water quality variation (i.e., dry vs. wet weather patterns), the need for determining flow-apportioned data, and contaminant characteristics (e.g., density, solubility). Sample volume must be adequate to allow for the measurement of both dissolved and total recoverable metals.

6.8.3.2.1 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.2.2 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination shall be targeted.

6.8.3.2.3 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

6.8.3.2.4 Determination of Contaminated Ground Water Discharge Points

The discharge of contaminated groundwater is a potential cause of continuing contaminant source to a surface water body. The determination of discharge/seep locations can be aided by the use of diffusion bags.

6.8.3.3 Non-Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.8 and 4.5 and NJDEP's *Guidance for Sediment Quality Evaluation*, November 1998. Procedures in Section 6.8.2.1 above, shall be followed, with the following additional requirements and considerations.

6.8.3.3.1 General

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely contaminant migration pathways to sediments and discharge points have been identified. Sediment/non-aqueous samples should generally be biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/sheet flow runoff, discharge of contaminated ground water to surface water body, landfill leachate seeps, etc). Sampling the surficial interval (0-6" biotic zone), specified in Section 6.8.2.1 above is required. Contaminant delineation requirements may dictate the need for subsurface sediment sampling. It is recommended that subsurface sediments be collected with a coring device where water depths permit, to best insure sample integrity. A ponar dredge (or equivalent

device) can be used provided that measures are taken to limit loss of fine sediment during dredge recovery.

6.8.3.3.2 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), of three samples are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.3.3 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination, shall be targeted areas.

6.8.3.3.4 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

Non-aqueous samples must be collected from depositional areas (e.g., inter-tidal areas along the shoreline, which are often marked by emergent vegetation and muddy or organic bottoms, as well as mudflats, etc.).

6.8.3.4 Use of Passive Diffusion Bag Samplers

Passive Diffusion Bag (PDB) samplers are currently being deployed in monitor wells as a no-purge option when prior approval for their use has been granted by the overseeing agency. Interest in PDB application to sediment/surface water sampling has been growing and research is being conducted by those first responsible for conducting the PDB monitor well research. At this time PDB sampling is an approved sampling technique on a case by case basis for deployment in stream sediments where “gaining” situations can be demonstrated. See Chapter 5, Section 5.2.1.11 and 6.9.2.5.1 for more information on PDB sampling equipment and Chapter 6 for PDB sample collection policy.

6.9 Ground Water Sampling Procedures

Return to TOC

6.9.1 Scope

These procedures describe recommended methods as well as minimally acceptable methods for obtaining representative ground water samples for organic, inorganic, residue, nutrient, bacteriological and other general chemical analyses. Ground water monitor wells, homeowners' private supply wells, and industrial or municipal supply wells are the potential sources of these samples. Temporary well points and ground water collected via direct push technology represent additional sources. The procedures described herein are to be followed by Department personnel, state-approved contract vendors, contractor personnel or anyone submitting ground water data to the NJDEP. Samples obtained in a way that does not meet these minimum criteria will not be considered as representative ground water samples and will not be accepted. In the case of state-approved vendors, unrepresentative sample collection may form the basis of non-payment for services rendered.

All ground water monitoring wells shall be constructed in accordance with current NJDEP specifications found in the, *Subsurface and Percolating Waters Act*, N.J.S.A. 58:4A-4.1 et seq., their implementing regulations (N.J.A.C. 7:9D-1.1 et seq.) and any NJDEP approved changes to these specifications including repeals, new rules and amendments. The Department's Bureau of Water Allocation administers the above Act and oversees all related licensing and permitting activities. Any deviations to the well construction or well decommissioning standards must be approved by the Bureau of Water Allocation prior to the initiation of said activities. Monitor well specifications for Bedrock Formations, Unconsolidated Formations, and Confined Formations are provided in Appendix 6.1 of this section. General guidance on the construction of temporary wells installed via direct push technology can be referenced through this manual, ASTM D6001-*96 Direct Push Water Sampling for Geoenvironmental Investigations*, and via the following Internet links: http://www.epa.gov/superfund/programs/dfa/dirtech.htm, http://epa.gov/swerust1/pubs/esa-ch5.pdf, http://geoprobe.com, and http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm.

Before any intrusion into the subsurface can begin, consideration for underground utilities must be taken. To accomplish this, the New Jersey One Call underground utility markout service must be contacted at 1-800-272-1000. They must be provided the following information: Name of caller, title, phone number, fax number, best time to call back, contractor name, contractor address, name of facility/company work is being done for, their phone number and address, the dig location, municipality, street address, nearest intersection, type of work, extent of work, start and end date. More information can be obtained by going to their website at: http://www.nj1-call.org. The local municipality, in which the work is being conducted, must also be notified in order to identify and mark out any ancillary underground utilities falling under their jurisdiction.

Additional regulations that must be complied with prior to collection of ground water samples and respective data submission to the Department include the 'Technical Requirements for Site Remediation', N.J.A.C. 7:26E and Laboratory Certification N.J.A.C. 7:18. Respectively, these regulations require: 1) purge and sample water derived from a well be monitored for pH, dissolved oxygen, temperature and specific conductance (7:26E-3.13(c) 7i., ii., iii. & iv.); 2) before **ANY** field analysis of those water quality parameters classified as "analyze immediately," those firms using LFPS instrumentation must first be certified by the Office of Quality Assurance (N.J.A.C. 7:18).

Finally, it is the policy of the Department of Environmental Protection that a sampling plan be submitted for approval before the initiation of ANY low-flow purging and sampling event.

6.9.2 Means of Sample Collection

The equipment and means utilized for specific ground water sample collection can vary greatly depending on the following factors:

- Type of well (e.g., monitor well, supply well, temporary well point)
- Depth of well
- Diameter of well casing
- Depth to water
- Contaminants likely to be encountered
- Analytes of interest
- Length of open borehole (bedrock well)
- Slot size of screen, screen type and length of screen
- Zones of infiltration
- Expected recharge rate of well
- Sampling objectives (field screening, remedial investigation, quarterly sampling, No Further Action [NFA] closeout, Monitored Natural Attenuation sampling, or filtered samples)

Based on the above considerations, the options chosen to evacuate ground water and collect a sample can generally fall into one of the five categories:

- Temporary well point/Direct Push - Ground water purged and sampled *without regard** to monitoring "stabilization."
- Low-flow purging and sampling (LFPS) - Ground water purged and sampled **within** the screened/borehole interval *with regard* to monitoring "stabilization"
- Low-Yield, Low-flow purging and sampling - Ground water purged and sampled **within** the screened/borehole interval in a well displaying uncontrollable drawdown necessitating sample collection *without regard** to monitoring "stabilization"
- Volume-averaged sample - Ground water purged and sampled **above** the well screen *without regard** to monitoring "stabilization"
- Point source grab sample - Ground water obtained as a grab sample from **within** the screened interval *without regard** to monitoring stabilization.

Refined further, below are the types of equipment associated with each of the five general categories:

- Temporary well point /Direct Push
  - ✻ Bailer[b]
  - ✻ Bladder pump[e]
  - ✻ Inertial pump[c]
  - ✻ Peristaltic pump[d]
- LFPS in the screened/borehole interval utilizing a **variable-speed**, positive-displacement pump including:
  - ✻ Bladder pump[f]
  - ✻ Gear pump[f]
  - ✻ Reciprocating piston pump[f]

- ✻ Progressive cavity pump[f]
- ✻ Submersible centrifugal pump[f]

- Low-yield LFPS in the screened/borehole interval of a well displaying uncontrollable drawdown utilizing a **variable-speed**, positive-displacement pump including:
  - ✻ Bladder pump[g]
  - ✻ Gear pump[g]
  - ✻ Progressive cavity pump[g]
  - ✻ Reciprocating piston pump[g]
  - ✻ Submersible centrifugal pump[g]
- Volume-averaged sample collected above the screened/borehole interval
  - ◇ Pump intake positioned immediately above the well screen at a depth of less than 25 feet utilizing a **variable-speed**, suction-lift or positive-displacement pump including:
    - ✻ Bailer[b]
    - ✻ Bladder pump[e]
    - ✻ Gear pump[e]
    - ✻ Peristaltic pump[d]
    - ✻ Progressive cavity pump[e]
    - ✻ Reciprocating piston pump[e]
    - ✻ Submersible centrifugal pump[e]
    - ✻ Surface centrifugal pump[a]
  - ◇ Pump intake positioned immediately above the well screen at a depth greater than 25 feet utilizing a **variable-speed**, positive-displacement pump including:
    - ✻ Bladder pump[e]
    - ✻ Gear pump[e]
    - ✻ Progressive cavity pump[e]
    - ✻ Reciprocating piston pump[e]
    - ✻ Submersible centrifugal pump[e]
  - ◇ Pump intake positioned at the top of the water column at a depth of less than 25 feet utilizing a **variable-speed**, suction-lift or positive-displacement pump including:
    - ✻ Bladder pump[e]
    - ✻ Gear pump[e]
    - ✻ Peristaltic pump[d]
    - ✻ Progressive cavity pump[e]
    - ✻ Reciprocating piston pump[e]
    - ✻ Submersible centrifugal pump[e]
    - ✻ Surface centrifugal pump[a]
  - ◇ Pump intake positioned at the top of the water column at a depth greater than 25 feet utilizing a **variable-speed**, positive-displacement pump including:
    - ✻ Bladder pump[e]
    - ✻ Gear pump[e]
    - ✻ Reciprocating piston pump[e]
    - ✻ Submersible centrifugal pump[e]
    - ✻ Progressive cavity pump[e]
- Point source grab sample
  - ✻ Passive diffusion bag sampler[h]

- ✻ Gore Sorber[i]
- ✻ Syringe sampler[j]

[a]purge only

[b]sample from top of water column only

[c]purge and sample for volatile organics only, limited to field screening

[d]purging acceptable for all contaminants however, sampling restricted to metals, Pesticides and PCBs

[e]purge and sample for all contaminants

[f]purge and sample for all contaminants including water quality indicators

[g]purge and sample for all contaminants based upon sufficient sample volume within the well to operate pump and fill all sample containers.

[h]sample for select volatiles only

[i]sample for select contaminants in coordination with manufacturer's analysis, limited to field screening

[j]sample for volatiles only, limited to field screening

**without regard* – This category of sampling technique is not conducive to accurate measurement of WQIP for determining stabilization. If collecting samples for programs regulated by Technical Requirements for Site Remediation, a variance from the requirement to provide pH, dissolved oxygen, specific conductance and temperature (N.J.A.C. 7:26E-3.13(c)7i.,ii.,iii. & iv.) must first be attained before sampling can commence.

The order in which analytical samples should be collected is as follows:

1. Volatile organic compounds (VOCs)
2. Purgeable organic compounds (POC)
3. Purgeable organic halogens (POX)
4. Total organic halogens (TOX)
5. Total organic carbon (TOC)
6. Base neutrals/acid extractables
7. TPHC/Oil & Grease
8. PCBs/pesticides
9. Total metals
10. Dissolved metals
11. Phenols
12. Cyanide
13. Sulfate and chloride
14. Turbidity
15. Nitrate and ammonia
16. Preserved inorganics
17. Radionuclides
18. Non-preserved inorganics
19. Bacteria

When several wells will be sampled of known or suspected contamination, the least contaminated well should be sampled first, and the wells then sampled in order of increasing contaminant

concentrations. Monitoring wellhead vapor readings with photo- or flame- ionization detectors can aid in determining sample order by providing information on contaminant levels in the wells. Attention to decontamination procedures must be strictly followed.

Surgical gloves must be changed between each sample location. Clean sampling equipment and any other objects entering the well should not be allowed to contact the ground or any other potentially contaminated surfaces (i.e. gasoline-fueled generators). If this should occur, that item should not be placed in the well or utilized for sampling.

For specific information on sampling procedures with a particular pump or other piece of sampling equipment refer to Chapter 5.

6.9.2.1 Temporary Well Points and Direct Push Technology

The Alternative Ground Water Sampling Techniques (AGWST) Guide is now incorporated herein. Use of the techniques listed in the 1994 version, with the exception of the screened auger (Method AGWST 1.00), remain viable alternatives to sampling ground water when "field screening" is the sampling objective. Issues of contaminant carryover downhole using Method AGWST 1.00 have rendered this alternative unacceptable. In addition, other sampling methods are available (e.g., narrow-diameter "mini" bailers) for sampling the miniature drive point. (Method AGWST2.00), therefore, sampling them with peristaltic pumps is no longer acceptable unless specifically approved on a case-by-case basis. Access to the complete guide can be attained using the following URL: http://www.state.nj.us/dep/srp/regs/agws. When referring to the 1994 AGWST Guide, all construction, decontamination, purging and sampling techniques must follow this or subsequent editions of the *Field Sampling Procedures Manual* in effect. The phrase "temporary well" is used here figuratively to consolidate the five acceptable techniques described in the AGWST Guide. They include use of a Miniature Drive Point, a Well Point, a Passively Place Narrow Diameter Point, a Direct Push Point, and use of a HydroPunch® sampler. Other commercially available devices, which have similar design and function capabilities, may be deemed acceptable for use with prior approval.

Temporary wells are typically, narrow-diameter wells, with short screens, installed by hand (shallow), drill rig, or hydraulic direct push. If the casing/screen are removed and the borehole is properly decommissioned within 48 hours of their installation, they are considered to be Category 5 Geotechnical Wells, pursuant to N.J.A.C. 7:9D-2.1(a)5. Any well remaining in the ground for more than 48 hours will be classified as a permanent well and thus will be subject to all the regulations regarding monitor well construction and decommissioning found in the "Subsurface and Percolating Water Act", N.J.S.A. 58:4A-4.1 et seq., and their implementing regulations (N.J.A.C. 7:9D-1.1 et seq.).

Temporary wells may be used for both horizontal and vertical delineation of contamination under certain circumstances; (e.g., if the sampling method does not impact sample quality and vertical profiling using direct push methods does not cause cross-contamination of samples during advancement in the same borehole). Determination of whether temporary well points may be used for delineation is made on a case-by-case basis by the SRP case team.

Direct push samplers typically cause turbid samples since there is no filter pack and the formation interval of interest is not fully developed. As such, analytical results for total metals may be biased high. Application of samplers designed with pre-attached filter packs offers a means to reduce turbidity, however, there is no guarantee turbidity will be completely eliminated. Generally, since volatile organic contaminant concentrations are not typically influenced by the presence of suspended material, the VOC values derived from this technique provide reliable field-screening data.

Temporary well points and direct push samplers typically have short screens. Therefore, the sampler will focus on a narrow zone in the aquifer. Examples of the use of temporary well points are those used to characterize a groundwater contaminant plume through vertical profiling using screening-level data. They can also be used to construct "transects" whereby temporary well points are placed at selected intervals perpendicular to the direction of plume movement. This focused approach allows for refined decision making when placing permanent monitor wells and plume delineation. In addition, advancement in direct push technology now allows for the generation of extended geophysical and hydrogeological data once strictly associated with monitor well installation and observation.

The American Society for Testing Materials discusses general technique issues in ASTM D6001-96, *Direct Push Water Sampling for Geoenvironmental Investigations*. Additional information can be found on the Internet at the following USEPA and vendor URLs:

http://www.epa.gov/superfund/programs/dfa/dirtech.htm,

http://www.epa.gov/swerust1/pubs/esa-ch5.pdf

http://www.geoprobe.com/products/tools/tools_menu.htm, and

http://www.geoinsightonline.com

http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm

6.9.2.2 Low-Flow Purging and Sampling

6.9.2.2.1 Method Summary and Application

The purpose of Low-Flow Purging and Sampling (LFPS) is to collect groundwater samples from monitor wells that are representative of ambient groundwater conditions in the aquifer. This is accomplished by setting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well. LFPS has three primary benefits. First, it minimizes disturbance of sediment in the bottom of the well, thereby producing a sample with low turbidity. Second, LFPS minimizes aeration of the groundwater during sample collection. Third, the amount of groundwater purged from a well is usually reduced as compared to conventional groundwater purging and sampling methods.

Because the method allows collection of groundwater samples with low turbidity, it was originally used for collecting samples for inorganics analysis. The method typically allows the collection of samples for total metals analysis and eliminates the need to filter the samples for dissolved metals analysis. In addition, since the method minimizes aeration of the samples, it can be used to collect samples for analysis of volatile and semi-volatile organic compounds (VOCs and SVOCs), provided that appropriate pumps are used in sample collection, as discussed below.

Advantages of LFPS are:

- Groundwater samples tend to be more representative of actual aquifer conditions with respect to mobile contaminants and turbidity
- It causes minimal disturbance of the formation adjacent to the screened interval
- It is generally less prone to sampling variability compared to other groundwater sampling techniques (e.g., bailers)
- Smaller purge volumes and associated disposal expense

- Increased sample consistency from dedicated systems and reproducibility of data due to reduced operator variability

Disadvantages of LFPS are:

- Misconceptions regarding reduced purging and sampling time
- Sampling from non-dedicated systems requires greater set-up time
- Sampling from dedicated systems requires higher initial capital expenses
- Increased technical complexity
- Increased training needs for sampling personnel
- Attractiveness of advantages may lead to improper and inconsistent application
- Typically not a "first round" sampling option
- Not recommended for wells with long screen intervals unless multiple samples are collected

6.9.2.2.2 Introduction

The following procedures are specific to LFPS of monitor wells in New Jersey. These procedures were developed in consideration of the USEPA-Region I guidance document dated July 30, 1996 (http://www.epa.gov/region01/measure/well/lowflow8.pdf) and the USEPA-Region II guidance document dated March 16, 1998 (http://www.epa.gov/Region2/desa/hsw/lowflow.txt). In addition, the U.S. Geological Survey's (USGS) Techniques of Water-Resources Investigations, Book 9, National Field Manual for the Collection of Water-Quality Data was consulted (http://water.usgs.gov/owq/FieldManual/). The reader is encouraged to review these guidance documents prior to performing LFPS. The procedures provided in the USEPA and USGS guidance must be followed except where they differ from the information provided below. Finally, three forms are provided herein to assist the sampler in recording low-flow stabilization data, calibration information and pump intake depth placement. They can be found on pages 109, 110, and 111 respectively.

6.9.2.2.3 Low Flow Policy

In the event that a responsible party is conducting a Remedial Investigation without Departmental oversight, submittal of a sampling plan is not required. However, it is *highly recommended* that the responsible party seek approval for any deviations from this guidance prior to conducting LFPS. In the event that a responsible party decides to use LFPS without submitting a sampling plan and receiving approval, it must be recognized that any deviations from this guidance may result in rejection of the data. In addition, when submitting the results of the LFPS event, the responsible party must include specific details of the LFPS techniques used which demonstrate that they were consistent with the guidance specified below. The responsible party shall also provide adequate rationale justifying any deviations from this guidance whether or not they were previously approved by the Department.

It is also Departmental policy that LFPS is not an acceptable method for any wells with screened or open borehole intervals greater than 5 feet in length **unless:** 1) multiple locations at five-foot intervals along the screen/borehole are sampled, or 2) the data quality objectives (DQOs) warrant sampling a specific zone (e.g., the shallow water table to investigate the potential for vapor intrusion inside a building) or

specific zones where sufficient geophysical (e.g., heat-pulse flowmeter, caliper and temperature logs, etc.) and hydrogeological information (e.g., tracer tests) or other evidence (e.g., stained soils or fractures noted on boring logs) that **clearly** identifies the depth(s) at which contaminants are entering the well screen or open borehole.

Once the collection of multiple samples (vertical profiling) in a well has been completed, long-term sampling of the well may require LFPS at fewer depth intervals, or even just one depth interval, depending on the data quality objectives of the sampling and the types of contamination present in the groundwater (e.g., LNAPL, DNAPL, etc).

6.9.2.2.4 Laboratory Certification (N.J.A.C. 7:18)

N.J.A.C. 7:18 requires that any environmental laboratory* submitting analytical data to the Department, regardless of quality level, must be certified by the Office of Quality Assurance. This applies to those firms using LFPS instruments associated with the "analyze immediately" category of water quality indicator parameters (WQIPs) including pH, temperature, and dissolved oxygen. Regardless of whether or not the equipment in question is rented or privately owned the requirement for certification can not be ignored. All certification documentation must accompany the instrument into the field and accompany all WQIP data submitted to the Department. (*Environmental laboratory is defined as any laboratory, facility, consulting firm, government or private agency, business entity or other person that the Department has authorized, pursuant to N.J.A.C. 7:18, to perform analysis in accordance with the procedures of a given analytical method using a particular technique as set forth in a certain methods reference document and to report the results from the analysis of environmental samples in compliance with a Departmental regulatory program).

6.9.2.2.5 Specific LFPS Considerations

6.9.2.2.5.1 Pump Intake Location

When LFPS is performed correctly, the data being collected should be a snapshot of a narrow zone along a length of well screen or fracture in an open borehole. For these reasons, it is important to place the pump intake in the zone of highest contaminant concentration or contaminant flux along the screened/open-hole interval. This is particularly important in wells constructed with more than 5 feet of well screen.

Information to be considered when selecting the pump intake depth should include: 1) evidence of soil/sediment contamination from boring logs; 2) soil/sediment sampling analytical results; 3) vertical profiles of groundwater and soil contamination developed from direct-push sampling and field-screening techniques; and; 4) lithology/stratigraphy, particularly the permeability of the aquifer materials.

Typically, the most permeable zones are selected for the pump intake location since the majority of contaminant mass will be transported through them, particularly as the plume migrates downgradient of the source area. Identification of these zones may be made from borehole geophysical data, (e.g., resistivity, fluid conductance, or natural gamma logging, etc.) and hydraulic conductivity data or grain-size analyses. The use of a series of passive-diffusion-bag samplers in a well may also help to identify the zone of highest VOC contamination. The physical/chemical behavior of the contaminants of concern should be considered when determining

the pump intake depth. For example, gasoline-related contaminants may be present near the water table while chlorinated VOCs may be present deeper in the aquifer. If a well is contaminated by both types of contaminants, both may need to be sampled, each from a discrete sampling interval.

As discussed above, LFPS is not an option in wells with screened intervals that exceed 5 feet in length, **unless** multiple sample locations at five-foot intervals along the screen/borehole are investigated. Monitor wells screened across zones of significant geologic heterogeneity or open boreholes in fractured rock may be subject to significant vertical flow. Under those conditions, use of packers to isolate specific zones should be considered.

6.9.2.2.5.2 Water Quality Indicator Parameters (WQIPs)

For groundwater investigations in New Jersey utilizing LFPS, the following parameters must be measured in order to determine when well stability has been achieved prior to sampling. Their respective measurements must fall within the stated range for three consecutive readings. If the anticipated "third" reading of any individual parameter does not fall within the stated range, then the process to achieve three consecutive readings for that parameter must be restarted. If, after four hours, stability has not been achieved for the parameters listed below, follow the recommendations in Section 3 below.

Water Level Drawdown ..... < 0.3 ft*
pH ..... ± 0.1 unit
Specific Conductance ..... ± 3%
Temperature ..... ± 3%
Dissolved Oxygen..... ± 10%
Turbidity ..... ± 10% for values greater than 1 NTU
ORP/Eh ..... ± 10 millivolts

* During pump start-up, drawdown may exceed the 0.3-ft target and then recover as flow-rate adjustments are made.

In wells with short screens (i.e., 5 to 10 ft long) or when sampling for gasoline constituents at the water table, it is much more important to limit the drawdown to less than 0.3 ft, for example, than a well with 15 ft of screen being sampled for metals only with the pump intake set in a permeable zone 5 ft or more below the water table. When sampling groundwater for VOCs and SVOCs, aerating the water by allowing it to cascade down the inside of the well should be avoided. Therefore, drawdown should not expose the screen more than 0.3 ft below the static water level in the well.

Measurements should be taken once every 5 to 6 minutes. This interval is based upon the time it takes for purge water to replace one flow-through-cell volume (generally 250 ml) and the time it takes to measure and record the data. If the purge rate decreases or if the flow cell volume is increased, the time required for purge water replacement will increase. Forms at the end of this document should be used to record drawdown and the WQIPs.

WQIP measurements must be collected in a manner that will insure integrity of the data being collected. To insure consistency of the data, consideration of the following must be made: 1) tubing diameter, length, and material of construction;

2) flow-through cell design, capacity, decontamination, and "purge-train" set-up; 3) pump selection and plumbing fittings; 4) calibration of flow-through cell probes; 5) purge rate; and, 6) water-level-measurement technique.

6.9.2.2.5.3 Purge Volume vs. Stabilization Time

In some cases, it may take considerable time to achieve stabilization of the WQIPs. In other cases, they may never stabilize. However, as provided in USEPA guidance, the following options are available if stability has not been achieved after **FOUR** hours of purging: 1) continue purging until stabilization occurs, no matter how long it takes; 2) discontinue purging, do not collect a sample and document the attempts to reach stabilization; or 3) discontinue purging, collect a sample and document the attempts to reach stabilization. In situations where WQIPs do not stabilize, the sampler must document that LFPS could not be performed and document in the report how the samples were collected.

While every effort should be taken to assure that all of the WQIPs stabilize prior to sample collection, one should keep in mind that the stabilization of some WQIPs may be more difficult to achieve than others. Also, achieving stabilization of some WQIPs may be more important with respect to some contaminant types (e.g., metals versus VOCs, etc.) than others. For example, total metals concentrations tend to increase with increasing turbidity due to sorption of metals on solids in the water. Similarly, VOC concentrations may be affected by dissolved oxygen (DO) concentrations (i.e., whether the groundwater is aerobic or anaerobic). In addition to providing information on the effectiveness of LFPS, collection of accurate DO data also aids in the evaluation of monitored natural attenuation (MNA) of VOC plumes. Similarly, temperature data can provide useful information regarding the sampling method. For example, temperature increases resulting from dissipation of heat generated by the submersible pump or from exposure of the tubing to excessive heat at the ground surface can have a significant impact on VOC concentrations in water samples.

If, for whatever reason, a WQIP is not accurately measured during the monitoring process or a certain WQIP does not stabilize, and that particular WQIP **is not** significant with respect to the type of contaminant of concern, sample collection may still proceed. For example, if DO data do not stabilize but all of the other WQIPs including drawdown and turbidity stabilize and samples will be collected for metals only, then the samples may be collected. However, any WQIPs that are affected by field conditions or instrument malfunction, must be discussed in the text of the report in order to alert the end-user of potential data bias. If questions arise regarding when stabilization occurs, the sampler should contact the Department's assigned case manager for the site, if any, either prior to (preferably) or when performing LFPS.

6.9.2.2.5.4 Tubing

The inside diameter (ID) of tubing should be no greater than three-eighths of an inch (3/8-in). Quarter-inch (1/4-in) tubing is preferred. Larger tubing diameters reduce flow velocity resulting in a corresponding increase of pump speeds to maintain flow. Increased pump speed will, in turn, elevate the potential for turbulent flow across the screened interval and this may affect the quality of the water being sampled. Conversely, any reduction in flow velocity may allow air to become

trapped in the tubing, which may ultimately affect air-sensitive parameters or allow particulates to settle, which may affect turbidity values.

The length of tubing, from the top of the well casing to the flow-through chamber, should be the shortest length manageable. Attention to this detail will help ensure that: 1) exposure to ambient temperature, direct sunlight, and bubble formation are kept to a minimum, and 2) deposited solids or air bubbles will less likely be trapped in tubing bends and re-mobilized after accidental movement. Occurrence of any one or combination of these factors can cause variations in WQIP measurements, which could increase stabilization time. Therefore, tubing must be completely full of water at all times.

If the sampling plan calls for multiple sample locations within the well screen, sampling should proceed from the top location to the bottom location. This will require that additional tubing be coiled at the surface to allow for pump relocation to the next deeper sampling location. In these instances, the coiled tubing must be protected from ambient conditions and the ground surface, in order to avoid impact to the WQIPs and sample data.

The tubing's material of construction must be either Teflon® or Teflon®-lined polyethylene up to the flow-through cell. This is consistent with collection of any groundwater sample. Tubing downstream of the flow cell may be constructed of a lower-quality, more flexible material. However, when sampling for metals analysis only, the tubing may be constructed of flexible polypropylene or polyethylene.

Tubing "reuse" is not recommended when sampling well to well since decontamination of tubing is difficult and time consuming. If tubing is to be reused, it must undergo a rigorous decontamination procedure, which must include a hot water wash/hot air drying process. In addition to the hot water wash/hot air drying, separate decontamination solutions of acetone and nitric acid may have to be pumped through the tubing for 15 minutes, followed by copious amounts of distilled, deionized water rinses. The cost of labor associated with decontamination, including the special handling of cleaning solvents and acid, often exceeds the cost of simply discarding the old tubing and using new tubing for each well. If a decision is made to reuse tubing, then one of the following requirements in the USGS, *Water-Quality National Field Manual,* must be considered: 1) Collect additional field blanks if VOC concentrations in the last sample collected through the tubing are greater than 500 µg/L, or 2) The tubing should be replaced, rather than cleaned, if VOC concentrations in the last sample exceed 700 µg/L.

6.9.2.2.5.5 Flow-Through Cell

Typical flow-through cell design is not complicated and almost all on the market today have common shared features. Cells should be transparent in order to "see" the physical condition of the purge water or air bubbles passing through the system. Highly turbid or iron bacteria-laden water can be visually monitored for change as the purge progresses. The cell must be sealed against unwanted exposure to the atmosphere, thus insuring accurate measurement of air-sensitive parameters (dissolved oxygen, pH, etc.). The total capacity of the cell must be small (300-1,000 ml) in order to maintain a desirable turnover rate of water coming into the cell to ensure real-time data integrity. The in-line design must allow for purge

water to enter the flow cell from a bottom port and exit at the top. The discharge may be fitted with a check valve.

Upon initial pump startup, it is good practice to not connect the pump discharge line to the flow-through cell. This will allow the sampler time to monitor drawdown, stabilize the flow rate and prevent fowling of probes by bacteria, sediment, or NAPL. Once drawdown measurements indicate that the flow rate has been controlled and a few minutes (<10) have been allowed to clear any unwanted material, the pump discharge line can then be connected to the flow cell.

Flow cell decontamination is important, not only to reduce the potential for cross contamination, but also to ensure data integrity and consistent instrument performance. The cell and probes should be rinsed with distilled/deionized water between each monitor well as accumulation of suspended material may impact probe performance. If they are exposed to contaminants, use a mild detergent or laboratory glassware cleaning solution. Flow cell exposure to high levels of contamination may damage probes and require their repair by the manufacturer. Since LFPS is NOT normally a first-round sampling option, knowledge of contaminant levels will generally be known prior to the cell's exposure to purge water.

The location of the flow cell or cells in relation to the sample port is critical. Samples for turbidity measurement, general chemistry and laboratory analysis must be collected ahead of the flow cell. When two cells are used in series, the dissolved oxygen probe must be located in the first cell.

Set up the flow-through cell in a location which will cause minimal fluctuation of the flow rate due to elevation changes in the sample tubing as the tubing is disconnected from the cell prior to sample collection. It is also important to locate the flow-through cell as close as possible to the well head in order to minimize the length of tubing needed between the well head and flow-through cell. The flow-through cell must be protected from ambient conditions and the ground surface. See Figure 6.6.

6.9.2.2.5.6 Pump Selection

Pumps used for monitoring WQIPs must be submersible, positive-displacement pumps. Examples of acceptable positive-displacement pumps include bladder, variable-speed submersible-centrifugal, reciprocating-piston, progressive-cavity, and gear pumps. The pump discharge must be fitted appropriately to receive either 1/4 or 3/8-inch inside-diameter (ID) Teflon® or Teflon®-lined polyethylene tubing.

Peristaltic pumps are suction-lift pumps, which can create a negative pressure gradient. Therefore, their use is not appropriate when collecting groundwater samples for analysis of organic compounds. However, peristaltic pumps may be used for the collection of groundwater samples for analysis of inorganic compounds. It should be kept in mind, however, that sampling with peristaltic pumps may affect the stabilization of some WQIPs including dissolved oxygen, pH and redox potential. Since these WQIPs can be affected by the peristaltic pump, this pump should not be used when these data are to be used to evaluate the effectiveness of Monitored Natural Attenuation of groundwater.

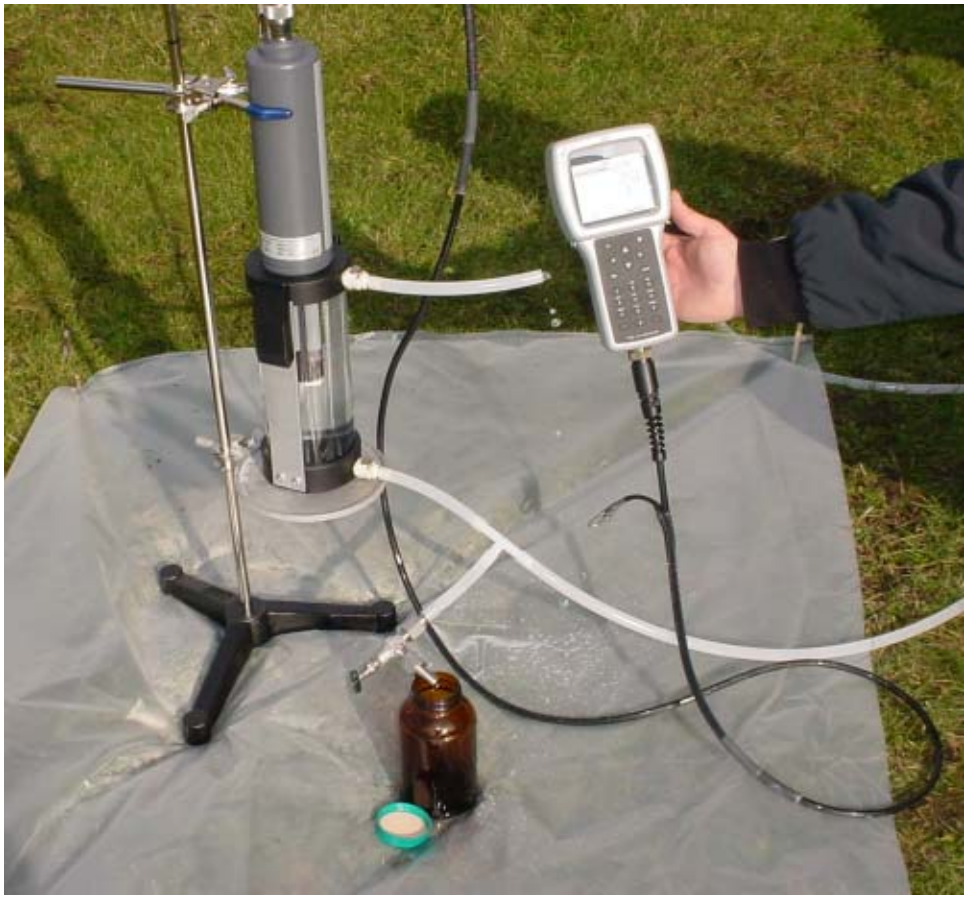


Figure 6.6 Illustration of Flow Cell with stand. (Photograph by J. Schoenleber)

Two basic collection scenarios have a bearing on pump selection. These include: 1) a permanently installed pump system, or 2) a portable (well-to-well) pump installation. Bladder pumps can be used for either scenario, however, only those with disposable bladders and easily cleaned parts are suitable when sampling on a well-to-well basis. Variable-speed submersible-centrifugal pumps, gear or progressive-cavity pumps can be used for either scenario as long as they are constructed of easy to clean stainless steel/Teflon® parts. Pumps constructed with impellers, helicoils, or gears, which are difficult to clean or are constructed of unacceptable plastic parts, are not suitable for sampling. In addition, when conducting LFPS on a portable basis, the power or gas supply line should be isolated from the sample tubing. Power supply and sample tubing lines that form a single unit do not allow for easy decontamination and are not recommended.

6.9.2.2.5.7 Plumbing Fittings

A check valve should be incorporated into the tubing train or flow cell discharge to eliminate accidental drainage and subsequent aeration of the flow cell. More importantly, a check valve will prevent a back-surge of purged water being reintroduced at the screen interval of the well should the power source or pump experience mechanical failure. A back-surge of purge water into the screened interval of the well may result in variability of the WQIPs and create analytical bias. In order to avoid the need to decontaminate the check valve, it may be placed on the discharge side of the flow cell or installed immediately above the pump discharge. Some flow-through cells have check valves built into the unit. By design, bladder pumps also have a check valve built into their construction.

A ¼- or 3/8-inch ID barbed “T” or “Y” fitting, placed ahead of the flow cell, may be used to establish the line which will receive a needle valve for turbidity, general

chemistry and analytical sample collection. The “T” or “Y” fitting used should be constructed of Teflon® or stainless steel and decontaminated between each use, if used for analytical samples. The fitting may be constructed of polyethylene and decontaminated between each use if it is only used to sample for turbidity and general chemistry parameters. If analytical samples are collected through the “T” or “Y” fitting and needle valve, then those parts must be incorporated into the field blank collection technique.

When collecting a sample at the port ahead of the flow cell, a flow control valve (stainless-steel needle valve [preferred] or stainless steel/Teflon ball valve [optional]) must be used to prevent backpressure and air bubbles from forming in the tubing (see http://water.usgs.gov/owq/FieldManual/chap4_rpt.pdf, page 84). The “needle valve” offers versatility as it can be used for collection of turbidity, general chemistry **and** analytical samples. It can be used with Teflon® tubing and can be used to control sample flow rate because the design significantly reduces any backpressure gradient. Like all other sampling equipment, the “needle valve” must be decontaminated before use at any well. See Figure 6.7.

Figure 6.7 Closeup of Needle Valve. (Photograph by D. Dibblee)

6.9.2.2.5.8 Calibration of Probes

> Calibration of the probes used to monitor water quality indicator parameters must take place **in the field prior** to the day’s events. The Office of Quality Assurance must certify the *environmental laboratory* (see Section 6.9.2.2.4) using probes for pH, dissolved oxygen and temperature measurement.

There are no exceptions to these rules. Probe calibration is critical to the accurate and precise measurement of WQIPs.

For warranty purposes, **all** manufacturers’ instructions for proper care and calibration must be followed. Solutions for probe calibration must be held to the temperature of the liquid (groundwater) being measured as temperature correlation is critical in calculating conductivity, dissolved oxygen and pH. Tables and equations to compensate for the difference between ambient groundwater and calibration solution temperature are sometimes provided in the operating manuals or with the calibration solutions. Some instruments are designed with internal features to

compensate for this difference in temperature. The respective difference between calibration of conductivity and specific conductivity requires compensation for groundwater temperature at the time of calibration vs. solution temperature adjusted to 25°C at the time of calibration. For dissolved oxygen, the flow cell itself must be maintained at the temperature of groundwater during calibration. All efforts made to account for proper temperature control of solutions during calibration must be reported to the end user. All steps must be recorded in the field notes. No sampling shall commence until all instruments are calibrated and operating properly. See the "Tips" section below for further discussion on Temperature of Calibration Solutions.

6.9.2.2.5.9 Water Level Measurements

The depth to the top of the water column must be recorded prior to pump installation and/or prior to purging. If the **total** depth of the well needs to be determined (e.g., to verify the correct well designation and/or to determine if silt has accumulated in the bottom of a well), it should be measured at least 48 hours prior to sample collection or after the sample has been collected and the pump removed. Total depth measurements must never be taken immediately before purging as this may cause the re-suspension of solids in the well and prolong the purge time.

Once the initial water-level measurement has been recorded and the pump installed, suspend the water-level probe in the well at the point at which drawdown is equivalent to a 0.3-foot drop. Record water levels simultaneously with WQIP measurements once every five minutes.

Water-level-measurement devices, which may impart some disturbance to the water column (i.e., stainless steel "popper" or coated tape), are not acceptable.

6.9.2.2.5.10 Pump Installation

LFPS pump installation can be divided into two general collection scenarios: permanent and portable (well to well). Permanent pump installation is the most desirable. Among other advantages are improved consistency in data acquisition and reduced long-term labor, preparation and material costs. However, permanent installation is more typically associated with long-term monitoring due to the high initial capital investment required.

The more common practice is to use a pump on a portable or well-to-well basis. While initial capital investment is comparatively less than that of a permanent installation, this practice requires close attention to quality control aspects of pump selection, preparation and decontamination.

Once pumps have been properly decontaminated and fitted with appropriate tubing, installation of the pump can begin. Ideally, pumps should be installed 24 to 48 hours prior to initiation of purging. However, this is not always practical, especially when site security can not be guaranteed. In addition, wells constructed with flush-mount casing are difficult to protect from storm water or infiltration of other contaminants during the extended period monitor wells are open.

Pumps must be installed in such a manner as to insure any disturbance in the well is kept to an absolute minimum. Once pumps reach the top of the water column, their descent should proceed very slowly through the water column. The actual

level where the pump intake is to be suspended must be predetermined. Under no circumstance should the pump make contact with, or be “bounced” off, the bottom of the well.

One helpful method to insure proper intake location is to accurately measure and pre-cut the tubing for each individual well prior to site activity. A mark can be made on the tubing, which coincides, with the top of the well. Cutting the tubing off-site in a controlled setting is most desirable. Tubing can be wiped down with paper towels, moistened with distilled/ deionized water, labeled and then sealed into plastic bags until needed. If this practice is used, be sure to allow enough tubing to account for the distance from the top of the well casing to the flow cell.

6.9.2.2.5.11 Purge Rates

Control over the purge rate is one of the most critical aspects of this technique. Once the pump is set within the screened interval at the desired location, a clean electronic water-level-monitoring device is lowered approximately 0.3 ft into the water column. Start the pump at a speed that results in a flow rate in the range of 100 to 500 ml/min. Pump the initial purge water to waste in order to prevent any fouling of the flow-through cell. *With the pump running*, connect the tubing to the cell. Make sure that all air is purged from the tubing and flow cell as the system fills with purge water. For LFPS, the pump speed must remain constant such that flow rates never exceed 500 ml/min and, once stabilized, the flow rate must not be varied, even during sample collection. If drawdown continues to exceed 0.3 ft., reduce the pump speed until the drawdown has stabilized but do not adjust pump speed to a flow rate below 100 ml/min. Flow rates below this level may induce pump stalling and undo the effort to reach stabilization. If drawdown does not come under control at 100 ml/min, then a field decision should be rendered as to how far to allow drawdown to continue until sample collection. At no time should evacuation allow any portion of the well screen to be exposed (for wells screened below the water table) or bring the well to dryness.

Adjustments to pump speed are best made during the first 15 minutes. Once a “feel” for the purge rate is obtained, begin recording well stabilization indicators. Any significant change to purge rates after this time may negatively impact well stabilization measurements.

Purge rates are best monitored by measuring the flow from the discharge side of the flow cell with a graduated cylinder. Record all of the required WQIPs once every 5 minutes. Once stability has been attained and recorded, begin sample collection

6.9.2.2.5.12 Sampling

Once WQIPs have stabilized, or a 4-hour time decision has been rendered, sampling can proceed. Do not adjust the flow rate; maintain the same pumping rate during sampling that was used to purge the well. Collect the sample directly from the needle valve at the sample port. The needle valve allows for sample collection with significantly reduced backpressure and turbulence and offers the best means for sample collection without affecting water quality. It also allows for monitoring using the flow-through cell during sample collection, thereby allowing a final WQIP measurement to be recorded immediately after sample collection. This is the

preferred method, especially if volatile organic compounds are the parameters of concern. Any exceptions to this technique must first be approved in writing from the NJDEP on a case-by-case basis before commencing sampling operations.

If higher than expected water temperatures are being observed, evaluate whether the submersible pump is overheating. If the pump motor is not suspected, check the system for any exposure to direct sunlight, especially during warmer periods of the year.

6.9.2.2.5.13 Pump Decontamination

The pump forms one of the two key elements of sampling equipment (tubing is the other). The importance of proper pump decontamination is especially true when pumps are rented and utilized on a well-to-well basis. Never assume that rented pumps have been thoroughly cleaned. **Pumps constructed with plastic parts, or sealed inner workings that are inaccessible to direct handling are not an option for LFPS well-to-well consideration because of their limited ability to be decontaminated thoroughly**.

Most bladder pumps can not be easily decontaminated in the field due to their unique construction. For that reason, bladder pumps are not employed on a well-to-well basis **unless** they are constructed with easy to clean parts and *disposable* bladders. Bladder pumps are best suited for dedicated (permanently installed) scenarios. Another popular pump, the variable-speed, 2-inch diameter submersible, is more adaptable for well-to-well sampling; however, close attention to decontamination is warranted. One manufacturer, Grundfos®, clearly states in the operational handbook that the pump must be completely disassembled, including removal of the motor shaft from the stator housing, and all components within the impeller housing (See Figure 6.8). Care must be taken upon reassembly to insure that the cavity housing the motor shaft is *completely* refilled with distilled/deionized water. Care must also be taken with this pump during periods of cold weather to avoid freezing of the coolant water. Proper decontamination not only helps to ensure more reliable data; it also prolongs the life of any pump.

6.9.2.2.5.14 Field Blank Collection

When employing LFPS techniques, collection of the field blank must follow the same general rules for all groundwater sampling equipment. This includes the requirement that “all” sampling equipment, which comes in contact with the sample, must also come into contact with the field blank water. To overcome some of the difficulties that manual field blank collection through the inside of a pumping system creates, the following procedure is strongly recommended. Fill a 1000-ml decontaminated, graduated glass cylinder with method blank water supplied by the laboratory performing the analysis. Place a properly decontaminated pump into the graduated cylinder with sample tubing and plumbing fittings attached. Activate the pump and collect the required field blank samples. As the water is removed from the cylinder, replace it with additional method blank water. This procedure will require that the laboratory supply larger volumes of field blank water i.e., bulk water in liter or 4-liter containers. The traditional requirement that field blank water be supplied in the same identical containers as the sample being collected can not be practically satisfied when using LFSP. The identical bottle-to-bottle field blank requirement is waived for this sampling technique procedure only.

Figure 6.8 Grundfos® Pump being prepared for decontamination (Photograph by J. Schoenleber)

6.9.2.2.6 Tips

6.9.2.2.6.1 Temperature Measurement and Submersible Pumps

Variable-speed submersible pumps such as the Grundfos Redi Flo 2â pump use water to cool the motor during operation. Sometimes, reduced flow rates may result in insufficient cooling of the motor and may elevate the temperature of the water to a point where it may begin to affect sample integrity. If the pump is used in low-yielding, two (2)- or four (4)- inch-diameter wells, temperature increases that do not stabilize may result. If this is observed, a field decision must be made to either discontinue or continue with LFPS. If all other WQIPs have stabilized, then collecting the sample and qualifying the water-quality data accordingly may be acceptable. If the temperature increase continues and eventually exceeds 40% of the initial recorded temperature (Celsius) and other WQIPs have not stabilized, sampling should be discontinued. Turning the pump off and on to control overheating is not acceptable. Always keep in mind that elevated temperature has a direct relationship with dissolved oxygen, specific conductance and, to a lesser degree, pH measurement. Higher temperatures may also reduce the concentrations of volatile organic compounds in groundwater samples due to their relatively high Henry's Law constants. If sampling with submersible pumps continues to result in elevated water temperature, other sampling alternatives should be discussed with the appropriate regulatory program.

When using some submersible pumps in large-diameter wells (six inch and greater), overheating of the motor, followed by mechanical shutdown and possible motor damage, may occur. This is the result of water being drawn to the pump intake in a more horizontal flow pattern which diminishes the design feature that

normally moves cool water vertically across the motor (stator) housing. The use of specially designed shrouds may overcome this condition.

6.9.2.2.6.2 Control of Pump Speed

In order to achieve the high turning speeds, low-speed startup torque is generally lacking in some submersible pumps including the Grundfos[â] Redi Flo 2 pump. When attempting to control initial drawdown and/or sample flow rates, it is possible for the pump to cease pumping. Then, if a check valve has been installed, the pump may not have enough torque to overcome the head pressure when attempting to restart it. Sometimes, turning the pump to the highest speeds will overcome this situation or sometimes the pump may have to be pulled from the well and reinstalled. Neither of these corrective measures is conducive to LFPS. To avoid this scenario, make sure the control box comes equipped with a “ten turn pot” frequency adjustment knob. This will allow significantly greater control over pump speeds and the risk of losing pump flow will be reduced.

6.9.2.2.6.3 pH

Monitoring for stabilization of pH in groundwater is relatively straightforward and rarely requires serious troubleshooting. When calibrating for pH, do a two-point calibration, at a minimum. The calibration range should bracket the anticipated pH. If the pH is unknown, then a three-point calibration must be made. The temperature of the buffer solutions should be as close to the temperature of the groundwater as possible. If the probe does not calibrate properly, check to make sure that the probe’s electrical contact points are dry. As with preventative maintenance of any probe, make sure that the pH probe is rinsed with distilled/deionized water between use and cleaned periodically per the manufacturer’s specifications. Overnight storage generally requires placement of the probe into a 2-molar (M) solution of potassium chloride. This solution may cause an unwanted build up of salt, therefore, frequent rinsing may be necessary.

6.9.2.2.6.4 Temperature of Calibration Solutions

Correct field measurement of dissolved oxygen, conductivity and pH requires tight control over calibration solution temperature. Proper calibration calls for solution temperatures of these parameters to be the same as the groundwater being measured (http://water.usgs.gov/owq/FieldManual/Chapter6/6.2.1.html#HDR6.2.1.CAL1). This may be difficult to achieve when field sampling well to well as groundwater temperature can vary between wells based on depth, local setting (asphalt vs. open field) and other atmospheric and hydrogeological factors. In addition, it is logistically difficult to bring solutions to groundwater temperature at the point of pump intake without first installing the pump, collecting purge water and allowing sufficient time to bring calibration solutions to appropriate temperatures.

For the purposes of LFPS in New Jersey, calibration solution temperatures and the flow-through cell itself must be maintained at approximately 54° F (12° C ± 2° C) during calibration. When ambient conditions warrant, this will require the suspension of the solutions and flow-through cell in a container/bucket of water at the aforementioned temperature. When calibrating for dissolved oxygen, always make sure the cell is vented to the atmosphere by attaching short pieces of tubing to the inlet and outlet fittings while the cell is submerged.

LOW FLOW SAMPLING
DATA SHEET

SHEET _____ OF _____

SITE: _____
DATE: _____
WEATHER: _____

CONSULTING FIRM: _____
FIELD PERSONNEL: _____

MONITOR WELL #: _____ WELL DEPTH: _____
WELL PERMIT #: _____ WELL DIAMETER: _____ inches

SCREENED/OPEN INTERVAL: _____

PID/FID READINGS (ppm):
BACKGROUND: _____
BENEATH OUTER CAP: _____
BENEATH INNER CAP: _____

PUMP INTAKE DEPTH: _____ ft below TOC
DEPTH TO WATER BEFORE PUMP INSTALLATION: _____ ft below TOC
MAKE/MODEL OF PUMP: _____

TIME	PURGING	SAMPLING	pH (pH units)		SPECIFIC CONDUCTIVITY (mS/cm)		REDOX POTENTIAL (mv)		DISSOLVED OXYGEN (mg/l)		TURBIDITY (NTU)		TEMPERATURE (degrees C)		PUMPING RATE (ml/min)	DEPTH TO WATER (ft below TOC)
			READING	CHANGE*	READING	CHANGE*	READING	CHANGE*	READING	CHANGE*	READING	CHANGE*	READING	CHANGE*		
				NA		NA		NA		NA		NA		NA		

COMMENTS:

*INDICATOR PARAMETERS HAVE STABILIZED WHEN 3 CONSECUTIVE READINGS ARE WITHIN: ±0.1 for pH; ±3% for Specific Conductivity and Temperature; ±10 mv for Redox Potential; and ±10% for Dissolved Oxygen and Turbidity.

Field Instrument and Calibration Data Sheet

Site: _____

Field Personnel: _____

Date: _____ Start Time: _____ Stop: _____

	Meter (make/model)	Probe
DO		
pH		
Spec. Cond.		
ORP		
Turbidity		

Dissolved Oxygen		Turbidity		ORP	
		Standard	Reading		
Water Temp		D.I. Water		Standard Temp.	
Baro. Pres.				Standard Conc.	
Saturation				Initial Reading	
Init. Mtr. Rd.				Meter reset to	
Mtr. reset to					
O_2 Satur. %					

Specific Conductance

	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1					
Standard #2					
Standard #3					
Standard #4					

pH Calibration

Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4					
7					
10					

Monitor Well Information in Support of Pump Intake Depth Placement

Sheet _____ of _____

Monitor Well	Screened/Open Interval			Intake Depth(s) (ft TOC)	Rationale for Pump Intake Depth(s)*
	Top (ft TOC)	Bottom (ft TOC)	Length (ft)		

ft = feet

ft TOC = feet below Top of Casing

* If necessary, attach supporting documentation (e.g., boring logs, construction diagrams, soil sampling data, etc.).

During the purge phase, record the difference between the stabilized temperature and the temperature of the calibration solutions. This information must be presented to the end user. If the sampling event is extended for two or more days, appropriate adjustments can then be made to more accurately reflect the groundwater temperature during calibration.

6.9.2.3 Low-flow Purging and Sampling for Low-Yielding Wells

The principal focus of water supply well installation is well-yield. In contrast, the principal focus of monitor well installation is water quality; well-yield is of secondary importance. In an attempt to locate and delineate ground water contamination, monitor wells are frequently installed in low-yielding water-bearing zones.

Low-yield wells present challenges with respect to representative ground water sample collection. The removal of water by bailers draws down the water-level in the well in slug-type increments. Peristaltic pumps draw water out of the well by vacuum (negative pressure) which may result in degassing and VOC loss. The operation of variable-speed submersible pumps at low-flow rates may result in heating of the sample as it flows around and through the pump, which may also lead to degassing and VOC loss.

Wells that yield less than 0.1 Lpm (100ml/min) frequently incur significant drawdown during well purging. If drawdown occurs across the screened interval or open borehole of a well, VOC loss may result. The increased stress on a well caused by significant drawdown may also result in an increase in well water turbidity. NJDEP recognizes that the use of sampling methods for LFPS discussed above may be impractical if drawdown cannot be limited. In an effort to facilitate the collection of a representative ground water sample from low-yielding wells, NJDEP will allow special sampling procedures to be used. This may include sample collection without regard to monitoring water quality indicator parameters associated with well stabilization.

At a minimum, water quality data, well construction data, water-level data, and accurate well-yield data for each low yielding well will need to be submitted to the Department prior to the formulation of an acceptable sampling procedure. Since sample collection may begin almost as soon as purging is initiated, it is imperative that the exact interval where the sample will be collected along the screen be predetermined. Aside from the considerations for monitoring drawdown and WQIP, all other aspects of LFPS may be found in the section above. The owner of the well shall also propose possible explanations for the low-yield of the well(s). Once the aforementioned information has been received, the Department will work with the well owner to formulate an acceptable sampling plan. The sampling plans will be approved on a case-by-case basis and will be well specific. Implementation of any special sampling procedure shall not be undertaken without prior NJDEP approval.

6.9.2.4 Volume-Averaged Purging and Sample Collection

Application of water supply well construction practices to remedial investigations often resulted in monitor wells with open boreholes or screens of up to twenty-five feet in length. Previous NJDEP guidance specified that the standard well purging procedure was to calculate, in gallons, one volume of standing water within a monitor well and purge three to five times that amount. Over the past decade, much information has shown that this procedure may have produced data of questionable value. Today, the general consensus is that ground water contaminants in a heterogeneous subsurface often flow within thin or narrow zones of higher permeability. Purging large volumes of water from wells with long screens situated in a heterogeneous aquifer

creates a situation where ground water in the contaminant-bearing zone may be diluted by uncontaminated water entering the well from one or more “clean” zones. Utilizing poor well development techniques following well construction may acerbate this dilution process in wells with long screens. The resulting condition is responsible for what is now acknowledged as a volume-averaged sample.

It should be noted that data generated from volume-averaged sampling can provide useful information regarding the contamination present in ground water. Indeed, volume-averaged sampling has been considered to be a conventional method of sampling monitor wells for years. If contaminant concentrations are not diluted below method detection limits, use of the method allows identification of the contaminants present in the ground water. A properly executed remedial investigation using this method can be used to monitor plume movement. The information generated, however, may fall short when evaluating the extent of a plume, true contaminant loads and, ultimately, the information needed to design a remedial action. Another example, where data generated under volume-averaged conditions remains valid, is potable sampling used for contaminant identification during homeowner/residential well investigations. This sampling method is a cost-effective means of determining whether contaminants have impacted potable wells and, if so, the potential level of risk to the well owners.

Sample collection equipment and the procedures for their use, when employing volume-averaging methods, are discussed in Chapter 5.

Because volume-averaged sampling involves purging a specified volume of water (i.e., 3 to 5 well volumes) and does not involve setting a pump intake in a specific screened or open borehole interval, there is no basis to justify the recording of any water quality indicator parameters typically monitored during LFPS. During a volume-averaged sampling event, the pump intake location can be set either immediately above the well screen or at the top of the water column. If the intake location is immediately above the well screen, and there is more than three feet of standing water above the pump, then the pump must be a positive-displacement pump since the sample will have to be collected through the pump. If the intake location is at the top of the water column and the depth of water is less than twenty-five feet, either a positive-displacement or suction-lift pump may be utilized. If a suction-lift pump is utilized for purging, samples must be collected by another means, typically via bailer.

Not all wells respond similarly to purging. Thus, the five ground water sampling categories listed at the beginning of this section were developed to match the best sampling technique to the well’s design and the sampling objectives. Generally, **every** reasonable effort must be made to keep pumping rates low to avoid over-pumping or pumping the well to dryness. To accomplish this, pump rates may be adjusted and pumping times extended in order to remove the desired volume of water. Samples should be collected within two hours of purging. In no case should the time of sampling exceed 24 hours after purging. The evacuation rate of a monitor well should never exceed that of the rate used to develop the well to avoid altering the hydrogeological properties of the aquifer in the vicinity of the well. When sampling for VOCs, purging the well to dryness is unacceptable.

In some volume-averaged situations, evacuation of three-to-five well volumes may not be practical in wells with slow water-level recovery rates. If a well has been pumped to near dryness at a rate less than 0.5 gallons per minute, the well should be allowed to recover completely before sampling. If necessary, sampling within the two-hour limit may be exceeded to allow the well to recover sufficiently for sampling. In no case should the time of sampling exceed 24 hours after purging.

There are several reasons why the well should not be pumped below the level at which the ground water enters the well. First, water entering the well at the top of the well screen may cascade down the side of the screen. This cascading effect may aerate the ground water to be sampled, thus resulting in the loss of volatile organic compounds. Secondly, pumping to dryness can cause dehydration of the saturated zone; again, volatiles may be lost due to aeration within this zone. Additionally, other contaminants may adsorb to formation materials where a dehydrated zone is created. Finally, exposure of the filter pack to atmospheric conditions may have long term effects. As a result, samples collected upon the recharge of a well pumped to dryness may not accurately characterize ground water quality due to one or more of these effects.

There are many methods that may be used for well evacuation. Not all methods are acceptable under all conditions. The depth to the water table usually dictates the selection of an evacuation method. The preferred and most commonly used methods involve the use of a surface centrifugal or peristaltic pump when the depth to water is less than twenty-five feet, and, a submersible centrifugal pump when the depth to water is greater than twenty-five feet.

It is paramount to ensure that the evacuation procedure does not cause cross contamination from one well to the next. Therefore, the preferred method employs dedicated tubing and pumps. Since in many cases it may not be practical to dedicate a pump to a specific well, it is permissible to decontaminate this equipment between wells, if approved methods are used (refer to Chapter 2 of this manual). Tubing should always be dedicated to each individual well. Cleaned equipment entering the well should not be allowed to contact the ground or be compromised by any other potentially contaminated source (i.e., gasoline-fueled generators, purged ground water, surface water, vehicle exhaust, etc.). If this should occur, the compromised item should not be placed in the well or utilized for evacuation.

Prior to evacuation, check the well for floating product. The disposal or discharge of floating product or hydrocarbons, and the discharge of highly contaminated water may require special purge water collection and disposal procedures. During evacuation, drawdown should be kept to a minimum to avoid “overpumping” the well. However, if volume-averaged sampling is the objective, the pump intake or tubing shall be lowered if the water level drops and to ensure that all static water will be removed from the well prior to sampling. Regardless of the evacuation procedure used, the evacuation rate should not exceed that of well development. Overpumping will cause a “redevelopment” of the well resulting in collection of a turbid sample.

6.9.2.5 Point Source (No-Purge) Sampling

Point source sampling is a technique that utilizes a device specifically designed to obtain a grab sample of limited volume within the screened interval without the aid of, or disturbance caused by, well purging prior to sample collection. There are very few of these devices that are available on the market today, and the few that are must first be approved for use through an approved sampling plan. This is mainly due to their inherent design or function limitations, which restricts their broad application. Generically, these devices are only approved for use once the contaminants of concern have all been identified and the specific zone of contaminant flow in the screened interval/open borehole of the well has also been positively identified. This implies that these devices are more likely to be approved for operation and maintenance sampling where point source quarterly sampling supplements annual sampling performed using a pump for confirmation purposes. There may, however, be instances where deployment of multiple passive diffusion bag samplers in one well may be instrumental in determining the zone of contaminant flow. See below for a description of those devices approved for this technique and their associated advantages and disadvantages.

6.9.2.5.1 Passive Diffusion Bag Samplers (PDBS)

6.9.2.5.1.1 Introduction

For the purposes of this guidance, the intended application of Passive Diffusion Bag Samplers (PDBS) is for long term monitoring of volatile organic compounds (VOCs) in ground water at well-characterized sites. This section of the Field Sampling Procedures Manual was prepared using guidance from the following documents:

1. "*User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells"*, United States Geological Survey (U.S.G.S.) Water Resources Investigations Report 01-4060, March 2001,

2. "*Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater*", Interstate Technology and Regulatory Council (ITRC) 2004 Publication (issued by the ITRC Diffusion Sampler Team)

It is recommended that anyone considering using PDBS in the State of New Jersey review both documents referenced above to obtain additional detail on theory, construction, deployment and data considerations. Both of these documents can be accessed via the Internet at the *Interstate Technology and Regulatory Council* (ITRC) *Diffusion Sampler Information Center* Website at http://diffusionsampler.itrcweb.org

Once it has been demonstrated that PDBS are appropriate for the intended application (see the discussion under "Theory" below), and regulatory approval has been granted, PDBS may replace the existing sampling method used for long term monitoring applications. Due to potential variations in lithology, well construction, and contaminant distribution, the use of PDBS must be evaluated and approved on a well-by-well basis (i.e. approval to use samplers at one well does not imply it is appropriate or acceptable for all wells at the site). The use of PDBS has been approved by the NJDEP at sites within NJ, and generated data may be used for compliance monitoring and/or to demonstrate that clean-up objectives have been achieved for site closure. When data are needed to document site closure, it is necessary to document that the PDBS interval used during the sampling program is still appropriate, and that data being submitted to close the site represents a worst-case scenario. This shall be accomplished by re-profiling the well using PDBS. A less desirable but acceptable alternative would be to take a conventional ground water sample to document that ground water contaminant concentrations within the well have decreased to levels that are acceptable for site closure.

Advantages

- No purging (purge water associated with conventional sampling is eliminated).
- The devices are relatively inexpensive and disposable.
- PDBS are easy to deploy and recover, which reduces both sampling costs and operator error.
- Purging stabilization criteria do not need to be measured which reduces time and associated cost.

- The stainless steel weights and Teflon® coated wire rope are the only equipment to be decontaminated. Based on site conditions and sampling frequencies, equipment may be dedicated to a well, which reduces the need to decontaminate equipment between sampling events.
- Quick deployment and recovery is a benefit when sampling around high profile areas such as business establishments and schools, and in dangerous areas like roadways and parking lots.
- Multiple PDBS can be deployed along the screened interval or open borehole to detect the presence of VOC contaminant stratification.
- PDBS can provide samples for accurate Dissolved Oxygen measurement.
- Since alkalinity conditions in the well are not transferred across the membrane, effervescence associated with HCl preservation is avoided.

6.9.2.5.1.2 Limitations And Concerns

- PDBS provide a time-weighted VOC concentration that is based on the equilibration time of the particular compounds, usually 1 to 4 days. This is a limitation if the sampling objective is to obtain a grab sample representative of contaminant concentrations in the well at the exact time of sample collection.
- PDBS have a limited detection capability (only VOCs).
- PDBS work best when there is unrestricted horizontal movement of ground water through the well-screen or open hole. Due to improper well construction and/or inadequate well development, the filter pack and/or screen of a well could be less permeable than the surrounding formation. Under ambient flow conditions, ground water flow through the well would be restricted and PDBS may not be able to provide a representative sample. In such cases, a conventional pumped sample may better represent ground water quality in the formation.
- PDBS represent a point sample within the well/open borehole. Contamination, migrating horizontally above or below the targeted depth interval, may not be detected by the sampler.
- Membrane limitations restrict accurate pH, specific conductance and temperature data.
- In some cases, biofouling of the bag could inhibit sampler performance. However, biofouling of the membrane has not been observed during field testing of PDBS for in-well deployment timeframes of up to three months in duration.

6.9.2.5.1.3 Theory

PDBS have proven effective in detecting VOCs in ground water. The function of the sampler is based on the *Law of Diffusion,* which states that compounds tend to migrate from areas of higher concentration to areas of lower concentration. PDBS are suspended within the screened interval or open borehole of a ground water monitoring well. VOCs in the well water will diffuse across the semi-permeable

polyethylene membrane into the distilled water of the sampler until the concentration inside and outside of the bag reach equilibrium. It is necessary to consider several factors that affect the ability of PDBS to obtain a representative sample. These factors include well construction, lithology, contaminants of concern, the potential for contaminant stratification, and vertical flow within the well. All proposals to use PDBS must include an evaluation of these factors, which are discussed in greater detail in the following sections of this guidance. In addition, it also may be necessary to evaluate how PDBS results compare to results from more conventional ground water sampling techniques to determine if the method is appropriate for the well. More conventional ground water sampling techniques would include purging 3-5 well volumes and sampling with a bailer, or low flow ground water purging and sampling.

6.9.2.5.1.4 PDBS Construction

PDBS are made of 4-mil. low-density polyethylene (LDPE) flat tubing that is filled with laboratory grade (ASTM Type II) deionized water and sealed at the ends. Samplers range in length from about 18 to 20 inches and hold up to 350 ml of water. The samplers can be outfitted with a protective polyethylene mesh sleeve to protect the bags against abrasion and tears during deployment and recovery. The addition of this outer protective mesh covering does not affect sampler performance (i.e. does not enhance or inhibit the transfer of VOCs across the polyethylene membrane). While use of the protective cover may be beneficial, it is not specifically required. Currently, there are two variations of PDBS available. One sampler is **pre-filled** by the vendor and shipped to the sampling location for deployment. The second type is shipped **unfilled** to the sampling location and must be filled in the field with ASTM Type II distilled water prior to deployment. Vendors can usually modify the length and width of a sampler to meet specific sampling requirements. A list of equipment vendors for PDBS can be found at the USEPA Internet Website “reachit” http://www.epareachit.org. The PDBS are suspended in the screened interval of a well at a pre-determined depth via Teflon® -coated stainless steel wire or low-stretch braided, polyester rope (please see “Deployment” section for additional requirements regarding the use of braided polyester rope). In most cases, the samplers are neutrally buoyant. Sufficient weight must be attached to the bottom of the deployment line to keep the samplers positioned at the desired location within the screened interval/open borehole of the well. Equipment vendors can supply stainless steel weights that can be easily decontaminated and re-used.

6.9.2.5.1.5 Contaminant Detection Capabilities

PDBS are capable of detecting most VOCs in ground water, however, some highly water soluble VOCs such as methyl-*tert*-butyl ether (MTBE), and acetone have shown poor correlation in lab tests (i.e., greater than 11% difference between concentrations inside and outside the PDBS). For that reason, use of PDBS is not recommended for sampling ground water where those parameters are the contaminants of concern. Parameters showing good correlation in lab tests and recommended for sampling with PDBS are identified in Table 6.13. Since PDBS have a limited detection capability (i.e., VOCs), they are not recommended for initial investigations where there is not a thorough understanding of the contaminants present. PDBS should generally be used at a site *after* the contaminants of concern

have been thoroughly documented and are determined to be compatible for their use.

Table 6-13. Passive Diffusion Bag Samplers (PDBS)		
Lab Tested VOCs that Displayed Good Correlation (i.e. less than 11% difference between concentrations inside and outside the PDBS)		
Benzene	BDC Methane	Bromoform
Chlorobenzene	Carbon Tetrachloride	Chloroethane
Chloroform	Chloromethane	2-Chlorovinylether
DibromoChloromethane	DibromoMethane	1,2-DiChlorobenzene
1,3-DiChlorobenzene	1,4-DiChlorobenzene	Dichlorofluoromethane
1,2-Dichloroethane	1,1-Dichlororethene	cis-1,2-Dichlororethene
trans-1,2-Dichloroethene	1,2-Dichloropropane	cis-Dichloropropane
Ethyl dibromide	trans-1,3-DCPE	Ethylbenzene
Naphthalene	Toluene	1,1,1-Trichloroethane
1,1,2-Trichloroethane	Trichlororethene	Trichlorofluoromethane
1,2,3-TCPA	1,1,2,2-PCA	Tetrachloroethene
Vinyl Chloride	Xyene	

PDBS are deployed at specific depth intervals and, therefore, it is necessary to know what contaminants are present within the aquifer at the location of deployment. Historic sampling data (from the wells where the use of PDBS is being proposed) must be submitted along with a discussion regarding the ability of the PDBS to detect contaminants of concern.

Note: Compounds that displayed poor correlation in testing and are not recommended for sampling with PDBS include MTBE, Acetone, Styrene and MIBK.

6.9.2.5.1.6 Well Construction Considerations

PDBS work best when there is horizontal movement of ground water through the well-screen or open hole. As such, well construction has a significant effect on the ability of the well to provide a representative sample. If the well has been constructed with a filter pack that is less permeable than the surrounding formation, ground water flow lines will be diverted around the well resulting in well water that may not be representative of formation water. Inadequate or inappropriate well development could create a similar condition, which diminishes the ability of PDBS to operate as intended. Under these circumstances, it may be necessary to use a pump to draw formation water into the well. Well construction specifications (i.e., construction material, well diameter, total well depth, screen length and depth interval, screen slot size, and filter pack, etc.) must be submitted with any proposal to help evaluate the appropriateness of using PDBS in a well. Since it is common for proposed well installation specifications to be modified in the field due to drilling difficulties, borehole cave-in or lack of desired well construction materials, it is necessary to use “as built” well diagrams to help assess the appropriate depth for PDBS deployment. Occasionally wells are constructed with a “sediment trap” or “sump”, which is an added length of blank casing attached to the bottom of a

well screen. Sumps are intended to provide an area where sediment can accumulate without obscuring the well screen. For wells that have sumps below the well screen, care must be taken to account for the added depth when determining PDBS position in the well.

6.9.2.5.1.7 Contaminant Stratification/Multiple Sampler Deployment

Contaminants do not always flow uniformly through an aquifer. Studies presented in Part 2 of the U.S.G.S. Water Resources Report, *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells*, demonstrated that it is not uncommon to see a high degree of chemical variability along the vertical portion of even a 10-foot well screen. A sample from PDBS represent a point sample from the section of screened interval or open borehole where the sampler is positioned. Because of this, PDBS have the ability to detect contaminant stratification. If multiple samplers are deployed along the screened interval or open borehole of the well, they can provide valuable information on the vertical stratification of contaminants within the well. Contaminant stratification within a well may indicate the presence of preferential flow zones in an aquifer. Identifying zones of preferential flow and contaminant transport in an aquifer can be useful when refining a site conceptual model, modeling contaminant fate and transport, or optimizing the performance of remedial systems. Since use of PDBS does not require well purging, field parameters such as pH, dissolved oxygen, temperature, and specific conductance are not measured to assess the adequacy of purging, however, these parameters may still provide useful information. In some cases the Department may still require field parameter data to be collected. It should also be noted that the *New Jersey Technical Requirements for Site Remediation* (N.J.A.C. 7:26E-3.13(c)7) requires field parameter data to be collected and submitted and with all ground water sampling data. Therefore, if PDBS sampling data is submitted without collecting field parameter data, a variance must be requested to obtain relief from these reporting requirements. Procedures for requesting a variance from requirements of the *New Jersey Technical Requirements for Site Remediation are* described in N.J.A.C. 7:26E-1.6(d).

If contaminants are migrating through the aquifer above or below the depth where the sampler is positioned, the PDBS may not detect them. It is, therefore, necessary to vertically profile a well using multiple PDBS to identify the presence of contaminant stratification and to document the most appropriate depth interval for future sampler deployment. Initially, any well having greater than 5 feet of well screen or open borehole must deploy multiple PDBS at the midpoint of every 5 feet of saturated screen or open hole to evaluate the potential for contaminant stratification. For example, a 10-foot well-screen or open borehole would have one sampler set at the midpoint of the upper 5 feet of screen/open hole and one sampler set at the midpoint of the lower 5-feet of screen/open hole. Although vertical profiling is only required on the initial sampling round, it must be recognized that for long-term monitoring applications it should be conducted periodically to document that conditions have not changed and that the sampling interval remains appropriate. The frequency of confirmation should be negotiated with the NJDEP Case Team for individual sites and will be based on the length of the monitoring program, historic data trends, fluctuations in ground water elevation, contaminant distribution, and fate and transport factors. In applicable instances, appropriate field

screening techniques at a Data Quality Level 2 (see Chapter 7, *Field Analysis*) may be substituted for fixed laboratory data in reaffirming the original vertical profile.

6.9.2.5.1.8 Vertical Flow Within the Well

As previously mentioned, in some instances vertical flow can be present within the well. This condition is more common in bedrock aquifers, but it can also be present in unconsolidated formations where the screened interval of the well intersects zones of differing hydraulic head. It must also be recognized that the potential for vertical flow within the well increases as the length of well screen or open borehole increases. If vertical flow is occurring in a well, the VOC concentration in PDBS will be more representative of the water flowing vertically past it from another portion of the aquifer rather than from ground water quality in the adjacent formation. If vertical profiling is conducted in a well using multiple PDBS and the results indicate all samplers have similar concentrations regardless of depth, the presence of vertical flow within the well should be suspected. In these cases, it is necessary to know where the water is coming from and where it is going. This can be accomplished by using a borehole flow meter to take readings at multiple intervals within the well screen or open borehole. These data can be used in conjunction with vertical profiling to provide a better understanding of contaminant distribution within the aquifer. It will also help to ensure that generated data are not misinterpreted. If vertical flow is suspected in an unconsolidated well having greater than 10 feet of well screen, flow testing should be conducted. The recommended frequency of flow measurements along the screened interval or open borehole is one measurement every 2 feet.

6.9.2.5.1.9 Comparison of PDBS Results with Conventional Sampling Methods

When evaluating the appropriateness of PDBS use at a particular well, a common approach is to do a side-by-side comparison with a conventional sampling method. However, it must be kept in mind that no sampling method currently available is without faults or biases. When pumping a well during sampling, conditions within the well are immediately modified. This action could clearly bias a sample since contaminants could be drawn into the well from locations that would not naturally flow into the well. As such, results from pumped samples and passive samples could differ significantly. If results from PDBS do not correlate well with results from pumped samples, it does not necessarily mean the bags are inappropriate for the intended application. Poor correlation between sampling methods means that additional work needs to be conducted to identify the reason why the samples do not correlate well. Often this type of evaluation results in a better understanding of ground water flow and contaminant distribution, which ultimately helps to improve the site conceptual model. In wells where there are only minor variations in concentration data and ground water elevation data over time, comparison of PDBS and historical sampling results may provide enough information to determine whether PDBS are appropriate for the application. For wells that have demonstrated considerable variability in contaminant concentrations and ground water elevation over time, a side-by-side comparison (i.e. using both methods in the same well during the same sampling event) would be more appropriate to ensure the data reflect the same sampling conditions.

6.9.2.5.1.10 Use of PDBS in Sentinel Wells

PDBS are not recommended for monitoring sentinel wells if the saturated length of well screen exceeds five feet unless multiple samplers are used every sampling round. This is due to the uncertainty associated with the depth at which a contaminant front will arrive at a sentinel well. If the PDBS is positioned above or below a discrete zone where the contaminants are migrating, the impact may not be detected. To avoid missing the contaminant impact, sentinel wells with saturated screens/open boreholes in excess of five feet must be vertically profiled every sampling round. This would involve deploying one PDBS at the midpoint of every five feet of saturated screen or open borehole.

6.9.2.5.1.11 Procedures for PDBS Use (Deployment/Retrieval)

PDBS can be obtained pre-filled from a vendor, or they can be obtained empty and filled in the field prior to deployment. In both cases, the PDBS must be filled with laboratory grade ASTM Type II distilled water. As with all ground water sampling approaches, plastic sheeting should be laid out on the ground surface at the sampling location to provide a contaminant free surface to assemble and prepare the samplers for deployment. PDBS can be placed inside a protective polyethylene mesh sleeve (available from current vendors) to protect the bags against abrasion and tears during deployment and recovery. The use of the outer protective mesh covering is not required, however, if a sampler tears during retrieval, another PDBS must be prepared and deployed for an additional 2-week equilibration period. A list of vendors can be "searched" for using the USEPA "reachit" website (http://www.epareachit.org.)

6.9.2.5.1.11.1 Weights and Deployment Lines

Since PDBS are neutrally buoyant, they must be attached to a weighted line to keep them positioned at the desired sampling depth over time. Weight construction must be stainless steel, which can be reused after thorough decontamination per acceptable decontamination procedures (See Chapter 2, *Quality Assurance*). Teflon® coated stainless-steel wire is preferable for deploying the samplers in the well. Teflon® coated stainless-steel wire can also be reused after proper decontamination. As an alternative to Teflon® coated stainless steel wire, synthetic rope may be used as the deployment line for single-use applications if it is low stretch, non-buoyant, and sufficiently strong to support the weight of the sampler(s). An example of acceptable rope would be uncolored (white) 90-pound, 3/16-inch braided polyester. Extreme care must be exercised when using rope as a deployment line in deep wells due to the potential for the deployment line to stretch, which may result in improper location of the PDBS within the well screen or open hole of the well. Deployment lines consisting of material other than Teflon® coated stainless steel wire may not be used in another well and must be properly disposed of after a one-time use. The deployment line and PDBS must not contact non-aqueous phase liquid (NAPL) during deployment or retrieval, which could lead to carry-over of contamination and degradation of the polyethylene membrane. Under no circumstances can PDBS be re-used.

Before sampler deployment, measure the total well depth and compare it with the reported depth to the bottom of the well from *as-built* well construction diagrams to evaluate whether sediment has accumulated in the bottom of the

well. In some cases wells are constructed with *sediment traps* or *sumps*. It is important to identify and account for the presence of these structures when measuring the placement location of the sampler on the deployment line. Wells with depths or construction details vastly different from the as-built diagrams may indicate that there is a problem with the well or that the well is misidentified. In these cases, the well designation and location should be verified to find the source of the error. The preferred deployment method is to have the weight attached to the end of the deployment line and position the line so that the weight rests on the bottom of the well with the line taut above it. The PDBS are attached directly to the deployment line at a depth interval corresponding to the targeted sample location within the screened interval. As previously mentioned, sufficient weight must be added to the PDBS deployment line to counterbalance the buoyancy of the PDBS. This is particularly important when deploying multiple PDBS. If there is uncertainty regarding the length or depth of the well screen/open borehole, an independent method of confirmation must be employed, such as video imaging.

6.9.2.5.1.11.2 Measuring and Attaching the PDBS to the Deployment Line

It is usually easier to measure the placement of the PDBS on the deployment line from the bottom of well. In this case, calculate the distance from the bottom of the well (or top of the sediment) up to the desired interval in the well where the PDBS will be suspended. For example, a well having 5 feet of screen may deploy a single bag positioned at the midpoint of the saturated-screened interval or open borehole. If the top of the well screen is 55 feet below the top of casing (btoc), and the measured total depth of the well is 59 feet btoc, then the bottom of the well has been filled with 1 foot of sediment. In this case, the middle of the PDBS should be set at 57-feet or 2-feet from the bottom of the well. Measure up 2 feet from the bottom of the weighted deployment line and position the midpoint of the sampler there. Provide attachment points in the deployment using loops in the line at appropriate points or movable clamps with rings. Attach the PDBS to the deployment line with cable ties, stainless steel clamps, or simply tie in a way that prevents slipping of the sampler bag along the wire/rope. Care should be taken to eliminate sharp points or ends of clamps or cable ties to decrease the potential for PDBS punctures or tears.

For wells that are screened across the water table, PDBS must be placed at least 2 feet below the water column in the well. Extreme care must be taken to ensure that no part of the sampler bag will be exposed above the water table during the equilibration period. Since VOCs can diffuse into and out of the PDBS, VOCs from ground water that diffuse into the bag could diffuse out of the top of the bag into ambient air. If this condition were observed prior to retrieval of the PDBS, it would be necessary to re-suspend the sampler at least 2 feet below the water table and wait for an additional 2-week equilibration period. For areas where there are large tidal influences or significant fluctuations in ground water elevations, historic ground water elevation data must be reviewed to determine the appropriate depth to set the PDBS so it will not be exposed to ambient air during the equilibration period.

If the well screen or open borehole intersects zones of varying hydraulic head and /or variable contaminant concentrations, vertical flow may occur in the well.

Under these conditions, VOC concentrations in the PDBS may not be representative of ground water quality in the formation immediately adjacent to the sampling interval. Sample concentrations may reflect the concentration of VOCs flowing vertically past the sampler from other parts of the formation, which could provide misleading information. In this case, use of a borehole flow meter in combination with vertical profiling of the well would be needed to define the zones where contaminated ground water is entering and exiting the well.

6.9.2.5.1.11.3 Equilibration Time

The sampler is positioned at the desired depth interval in the well by attachment to a weighted deployment line and left to equilibrate with the water in the well. Many VOCs equilibrate within 48 to 72 hours; however, the minimum recommended equilibration period for PDBS is 2 weeks. This is to allow the formation water and well water to re-stabilize after deployment of the samplers, and to allow diffusion between the stabilized well water and the PDBS to occur. In low-yielding formations, additional time may be required for the well to re-stabilize. If quarterly sampling is being conducted, it is acceptable to leave PDBS in the well for up to three months so that samplers can be retrieved and deployed for the next monitoring round during the same mobilization. Unfortunately, data are currently unavailable to support longer deployment periods (i.e., semi-annual or annual). Leaving samplers in a well for longer than 3 months is not recommended. If future data become available which demonstrate longer deployment timeframes are appropriate, this condition will be re-evaluated.

6.9.2.5.1.11.4 Sample Retrieval

After the appropriate equilibration period (discussed above), the PDBS is/are removed upward and out of the well using the deployment line. If multiple samplers are being retrieved from a single well, care must be taken to ensure the vertical placement of the sample within the well is accurately recorded on each sample vial and in the field-sampling logbook. When retrieving multiple samplers from a single well, only one PDBS should be removed and processed at a time. The remaining samplers should be suspended in the well until they can be processed to isolate them from exposure to ambient weather conditions and direct sunlight. Once a sampler is removed from the deployment line, the sample water must be immediately transferred into appropriate pre-labeled, VOC vials. All sampling information (e.g. site, well designation, sample ID, date and time of collection, depth interval, etc.) must be recorded before removing the next PDBS from the deployment line. If a protective outer covering is used during deployment, remove the PDBS bag and dry excess water from the bag using a lab wipe. PDBS water can be transferred to VOC sample vials using several available options depending on the equipment vendor and selected materials. One option is to carefully cut the PDBS bag at the top corner using decontaminated scissors or razor blade and carefully decant the sample into the VOC vials. Some PDBS models are equipped with a removable end cap that can be removed to allow the sample to be gently poured into VOC sample vials. Other equipment options include a small lab-cleaned straw that has a sharpened end. The straw is used to pierce the bag at the bottom and the sample is decanted though the straw into sample vials. In all cases, care must be taken when transferring the sample since the bags themselves are not rigid and can bend or collapse during handling.

Collected samples must be placed immediately in a sample cooler that is **already** full of ice or ice packs such that samples are **immediately** chilled and stored at a temperature of 4°C, in accordance with existing NJDEP ground water sampling protocols.

6.9.2.5.1.11.5 Quality Assurance/Quality Control Samples

"Duplicate/blind duplicate" samples should be collected at a rate of 10 percent of the total number of samples collected. A duplicate/blind duplicate sample must be obtained from the same bag as the original sample. Sample volume consideration must be accounted for when collecting matrix spike and matrix spike duplicate (MS/MSD) samples. If the lab requires three 40-ml vials for each sample location, then a total of nine 40-ml vials will be required to cover the sample plus MS/MSD requirement. That means a minimum (no spillage) of 360 ml must be obtained from the targeted location. Deployment of two bags at the same sampling interval may be necessary to obtain these required QA/QC samples. If the well is 2 inches in diameter, two bags placed side-by-side at the same sampling interval may not fit down the well. In this case, a larger bag (capable of holding more than 360 ml of water) may need to be ordered from the vendor and deployed to provide sufficient sample volume to meet QA/QC requirements. Another option is to speak with the lab to identify the minimum sample volume they need to conduct the required analysis. Often, labs will require more water than necessary to be collected for analyses. This is typically to account for potential loss of sample volume due to spills or vial breakage during shipment and/or during sample preparation in the lab. (Note: The ITRC Diffusion Sampler Team has worked with Columbia Analytical Labs and USEPA Lab representatives to generate a *Minimal Volume Document* that identifies the least amount of sample volume required to do conventional sample analysis. Although this document uses standard analytical protocols, labs must be contacted to ensure they are comfortable with the approach.)

6.9.2.5.1.11.5.1 Blanks for Lab filled PDBS

For PDBS that are filled in a lab and shipped to the site, a modified PDBS trip/equipment blank must be taken during deployment of the samplers. The purpose of this blank is to identify potential biases in sample quality resulting from water used by the lab to fill the samplers, sampler materials, and environmental conditions that the samplers were exposed to during storage, shipment and deployment. This blank is obtained by ordering an *extra* PDBS, which is shipped to the site in the same container and handled in the same manner as all of the other PDBS that will be deployed during the sampling event. Throughout the deployment event, the "extra" PDBS must travel in the same container as the other samplers that are being deployed. Once all samplers have been deployed, a sample must then be taken from the *extra* PDBS. Open this PDBS and transfer a sample into a VOC vial in the same manner as will be used to obtain samples from all of the other PDBS when they are retrieved after the equilibration period. This sample must be processed (i.e. if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4º Celsius and sent to a NJ-certified lab for analysis. Once the sample water is transferred to the 40-ml VOC vials, the regularly required complement of QC samples and

chain-of-custody requirements that applies to all ground water sampling protocols is followed. This type of blank must be collected at a rate of one per sample shipment. If there is more than one sampling crew, and samplers are being transported in separate containers, one modified trip blank (i.e. *extra* PDBS) must be taken for each sampler container.

6.9.2.5.1.11.5.2 Blanks for Field Filled PDBS

Some samplers available from equipment vendors are designed to be filled in the field prior to deployment. If PDBS are field-filled, they must be filled with ASTM Type II deionized water. It is also necessary to take a *modified trip/equipment blank* for this type of sampler. This blank is intended to detect any sample bias due to the quality of the fill water, PDBS material or, if applicable, the environmental conditions they may potentially be exposed to during transport to the deployment location. If these types of samplers are filled at a location other than the wellhead where they will be deployed, the blank should be taken in the same manner as the one described above for lab-filled PDBS. While the lab-filled blank comes pre-filled, the field-filled blank is initially empty and must be filled by the sampling crew using the same procedure that will be used to fill all of the other samplers that are deployed at the site (e.g., if other samplers are filled using a funnel, follow the same procedure to fill the trip/equipment blank sampler). After filling the sampler, seal it as you would all other samplers and place it in the same container as the other samplers for transport to the deployment location. As discussed above, once all samplers have been deployed, a sample must then be taken from the *extra* PDBS. Open this PDBS and transfer a sample into a VOC vial in the same manner as will be used to obtain samples from all of the other PDBS when they are retrieved after the equilibration period. This sample must be processed (i.e. if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4º Celsius and sent to a NJ-certified lab for analysis. Once the sample water is transferred to the 40-ml VOC vials, the regularly required complement of QC samples and chain-of-custody requirements that applies to all ground water sampling protocols is followed. This type of blank must be collected at a rate of one per sample shipment. If there is more than one sampling crew, and samplers are being transported in separate containers, one modified trip blank (i.e. *extra* PDBS) must be taken for each sample container.

6.9.2.5.1.12 Data Reporting Requirements

To use PDBS as a replacement sampling technology for long term monitoring, it is necessary to demonstrate that the use of PDBS is appropriate at each well. In addition, it is important to document that the sampling method was performed in accordance with NJDEP guidance. To meet these objectives, a PDBS Data Checklist (see page 126) must be completed for each well where PDBS are deployed. This checklist must be submitted with the analytical results for each sampling round. In addition, a narrative must that describes the site, the well, and procedures that were used to deploy and retrieve PDBS must accompany the checklist and submitted analytical data. The narrative should also include any problems encountered during PDBS deployment and retrieval and the steps taken to address the problems.

New Jersey Department of Environmental Protection

Checklist for the Submission of Sampling Data for Passive Diffusion Bag Samplers (PDBS)

1. Site: _____
2. Location: _____
3. Well Designation: _____
4. Well Permit Number: _____

5. Type of Well: ☐Monitoring ☐Extraction ☐Residential ☐Public Supply ☐Irrigation ☐Other
6. Well Surface Finish: ☐Stick Up ☐Flush Mount
7. Location of Measuring Point: ☐Top of Casing ☐Other (specify) _____
8. **NOTE:** PDBS represent a point sample within the screened interval or open hole of the well. It is critical to know the exact depth within the well where the PDBS is deployed. Well construction specifications, which are typically used to determine where to set the PDBS in the well, are measured in feet below ground surface (fbgs). If the depth interval for PDBS deployment is measured from the reference point identified above, the difference between this reference point and the ground surface must be measured and accounted for to determine the proper depth interval to set the PDBS. Please identify below, any differences between the measuring point identified above and actual ground surface at the well head.

   Distance between measuring point and ground surface (ft.) _____
9. Total Well Depth (fbgs) _____
10. Screened interval/open hole (fbgs) _____
11. Well Casing: Diameter: _____ Material: ☐PVC ☐Carbon Steel ☐Stainless Steel
12. Well Screen (or open hole diameter): Diameter: _____ Material: ☐PVC ☐Carbon Steel ☐Stainless Steel
13. Screen Size (slot) Screen Slot Size _____

14. Date and Time of Deployment Date: _____ Time: _____
15. Depth to Ground Water Depth to ground water at time of deployment _____
16. Date and Time of Retrieval Date: _____ Time: _____
17. Depth to Ground Water Depth to ground water at time of retrieval _____
18. Type of Deployment Line Used Diameter: _____ Material: _____

19. Material and Mass (oz.) of PDBS Weight _____ (stainless steel recommended)
20. Type of PDBS Used
    - ☐Lab Filled (Modified Trip Blank must be taken at time of deployment)
    - ☐Field Filled (Modified equipment blank of fill water must be taken at time of deployment. If PDBS isn't filled at well head, blank must travel with samplers until last sampler is deployed. Blank is then taken.)
21. Dimensions of PDBS Length (in.) _____ Diameter (in.) _____ Filled _____
22. Position of PDBS Weight
    - ☐Attached to bottom of PDBS and suspended in well
    - ☐Attached to bottom of deployment line and suspended in well
    - ☐Attached to bottom of deployment line and resting on bottom of well (preferred)
23. Position of PDBS in Well Screen (ft. from measuring point to center of PDBS)

1st PDBS	2nd PDBS	3rd PDBS	4th PDBS
_____	_____	_____	_____
5th PDBS	**6th PDBS**	**7th PDBS**	**8th PDBS**
_____	_____	_____	_____

24. If the saturated portion of the well screen or open hole is greater than 5 feet, has the well been vertically profiled to assess the potential for contaminant stratification?
    - ☐ **No**, this well is being profiled during this sampling round
    - ☐ **Yes**, this well was profiled already. Date when well was profiled: _____
25. If the saturated portion of the well screen or open hole is greater than 10 feet, has the well been flow tested to assess the potential for vertical flow to be present within the well?
    - ☐ **No**, flow testing has not been conducted in this well
    - ☐ **Yes**, flow testing of this well was conducted. Date of testing: _____

      Type of flow meter used: _____

      Measurements taken every _____ feet **[Please Attach Results]**
26. Weather Conditions During Deployment Temp. _____ Wind _____ ☐Sunny ☐Overcast ☐Raining ☐Snowing
27. Weather Conditions During Retrieval Temp. _____ Wind _____ ☐Sunny ☐Overcast ☐Raining ☐Snowing

28. Field Sampling Technician: Name(s) and Company (please print clearly)

Name	Company

6.9.3 Sampling Private Homeowner Wells (a.k.a. Public Non-Community/Non-Public/Domestic Wells)

Domestic wells usually provide only limited useful information for ground water investigations. This is due to the fact that adequate geological information relative to the well's placement and construction is not available. Also, domestic wells usually have long well screens, which may cause dilution of the contaminants being investigated (volume-averaged sample). However, domestic wells do provide useful information regarding contaminant identification and exposure levels to those using the well water.

When sampling these types of supplies, conduct an initial survey to get a general overview of the water system and its operation. Note how the configuration of the system relates to the type of sample that you want to collect (raw water, finished/treated water, or an intermediate sampling point). Inquire as to whether any treatment units are installed on the system. Softening (pH adjustment), iron removal, turbidity removal, chlorination, are often used; these may give misleading analyses depending upon the parameters of interest. Home carbon filters used for the removal of organics are increasingly popular. Basement and outside faucets may by-pass such treatment systems. Always collect sample from the cold water faucet with the aerator removed. Should a raw water sample be desired, sample as close to the well head as possible and upstream of the storage tank or any treatment system. Important considerations to record are:

- Well driller and date drilled
- Construction of well and casing depth
- Well and pump location
- Well depth and pump capacity (if available)
- Storage tank capacity
- Treatment or conditioning unit (if any)
- Plumbing arrangement
- Possible sample collection points
- Distance of well to any septic systems or underground storage tanks
- Aesthetic information (color, odor, observed suspended material)

Well construction information should be verified, if possible, by obtaining drilling logs that were submitted to the NJDEP with the Monitor Well Record which are maintained by the Bureau of Water Allocation.

When collecting a sample from an operating domestic well, it is essential to evacuate standing water in all plumbing lines and water storage tanks. Running the water for a minimum of fifteen minutes before collection is a good rule of thumb (unless a first-draw *System Sample* is desired), however, a longer period of time may be desirable. Listen for the pump to turn on. This is a good indicator that the tank and plumbing are being evacuated.

Home faucets, particularly kitchen faucets, usually have a screen (aerator) installed on the discharge. The screen must be removed prior to sampling for bacteria, or for volatile organics, since the screen tends to aerate the water and some organics may be lost. Also, when sampling for bacteria, do not take a sample from a swivel faucet since the joint may harbor a significant bacterial population.

Note: Homeowners' plumbing systems should not be tampered with in any way, except for removal of the faucet screen (aerator) with permission of the homeowner. Under no circumstances shall a pump be pulled from a homeowner's well unless the removal is authorized by the homeowner and is carried out by a licensed pump installer. Pump installers are trained professionals

with experience in the electrical and plumbing aspects of well pumps. In addition pump installers are trained in the proper chlorination of wells after work is completed and will advise homeowners of any precautions to take to avoid excess rust from entering their system.

For long term monitoring projects which include sample collection from domestic wells, a specific tap or faucet should be designated as the target sample access point for consistency and data comparability of future samples.

6.9.4 Sampling Point of Entry Treatment (POET) Systems

Treatment systems are typically installed either on a temporary or permanent basis in residential homes, schools and businesses where contamination has been positively identified at levels exceeding Safe Drinking Water Standards. These Point of Entry Treatment (POET) systems are designed to remove contaminants via filtration through carbon or other media and subsequently the water quality must be monitored on a routine basis to ensure the treatment system is functioning properly. POET systems are generally installed with multiple sampling locations in order to provide the information necessary to determine operating efficiency and to decide when the filtering media must be replaced. The same purging/sampling considerations apply to private homeowner wells discussed above as to POET systems. However, since POET systems are normally installed after home construction, there is an opportunity to control the type of sampling port. Standard gate valves (commonly termed garden faucets) have a tendency to aerate the sample, especially when the valve is only slightly opened to control flow rates. For analyses measured at the parts per trillion level, this aeration may bias the results. To control sample flow rates and assist in reducing aeration bias install ball valves at sample ports. Select ball valves with Teflon^{Ò} or PVC internal components and non-toxic lubrication. Depending on plumbing dimensions (1/2 or 3/4 inch diameter pipe), valves should be fitted with an outlet of smaller dimension to further control flow.

6.9.5 Sampling Industrial Wells

When sampling industrial wells, it is desirable to sample as close to the well source as possible. Samples should be taken directly from the well head whenever possible. This will eliminate treatment interference, possible changes in quality within the lines, and mixing of water from other wells, etc.

Large capacity wells, which are *on-line* during the visit, can be sampled immediately. Wells, which are *off-line*, must be pumped to waste prior to sampling. Pumping fifteen minutes or more is suggested. Access to municipal well systems and well houses, etc. requires the assistance of a water department employee. Prior notification is essential.

6.9.6 Sampling Municipal and Industrial Wastewater

Sampling of municipal and industrial wastewater is performed for a number of reasons: to determine compliance with Federal, State or local standards, to verify reported self-monitoring data, to assist in determining discharge or user fees based upon wastewater strength, to verify the sampling technique and monitoring points of regulated parties, and to aid in determining the sources of prohibited or unwanted wastes. The most difficult type of sampling to perform is the collection of background information for future use; sometimes the correct information will be obtained and sometimes it will be missed. The collection of background information is critical. Information that may be gathered includes flow rate and totalizer readings, pH, TSS, treatment plant configuration and operating status.

When sampling wastewater, one must take into consideration that good sample results depend on a number of factors, including sample representativeness, proper sampling technique and proper preservation. A location for sample collection should be chosen where uniform wastewater quality and thorough mixing exist. Wastewater influent samples should be collected at a point upstream of any recycle, supernatant or return lines; wastewater effluent samples should be collected after the final treatment process. Take into consideration that the representativeness of samples may depend on timing; for example, influent samples collected at a municipal treatment plant with a substantial collection system may represent discharges into the system that occurred hours ago. In addition, be cognizant that many sampling locations present safety hazards, ranging from confined spaces, elevated platforms, unsteady equipment or surroundings, airborne pollutants, and biological hazards that may include infectious disease agents, ticks, poison ivy and snakes to chemical hazards such as corrosive liquids, heavy metals and potentially explosive atmospheres. Wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

Samples may be collected as grabs or composites, depending on the purpose of the sampling, regulatory requirements or site conditions. Grab samples are single samples collected at neither a set time or flow rate. It may be advantageous to collect grab samples if wastewater flow is not continuous, if the wastewater's character varies or is not consistent, or if there is a need or desire to determine if a composite sample of the wastewater would obscure extreme conditions of the waste. In addition, some parameters, specifically dissolved oxygen or other dissolved gases, total and fecal coliform and other bacteria, pH, temperature, oil and grease and petroleum hydrocarbons, purgeable organics, and available and residual chlorine sulfite may only be collected as grab samples.

Composite samples may be collected in six different ways depending on sample volumes collected and at what frequency sample collection occurs. Composite samples may be collected as follows: constant sample volume/consistent time intervals, constant sample volume/time interval between samples is proportional to wastewater flow, constant time intervals/sample volume is proportional to the wastewater flow rate at the time of sample collection, constant time interval/sample volume is proportional to total wastewater flow since the last sample was collected; continuous sample collection or pumping rate, and continuous sample rate is proportional to wastewater flow. If flow rates at the time of sample collection are within (+/-) fifteen percent of the average flow, sample compositing based on constant sample volumes and constant time intervals is generally representative, however, the method is not considered to be the most representative for highly variable flow or concentration conditions. During sample compositing, a minimum of eight individual samples should be collected, if at all possible, and each individual aliquot should be a minimum of 100 milliliters. During six-hour composites, a facility should collect an aliquot at least once each half-hour.

Composite sampling may be conducted manually or by the use of an automatic sampler. The most common automatic samplers use either a vacuum pump or a peristaltic pump to draw the sample into the unit. A unit with a vacuum pump may be able to draw the sample at a higher velocity and from a cross-section of the wastestream. However, it may also bias the solids concentration in the collected sample if the unit operates first by filling a reservoir, then by wasting excess sample material before draining the remainder into the sample container. A unit with a peristaltic pump discharges a measured sample volume into the sample container, so less solids separation and associated sample bias should occur. However, peristaltic pump units generally sample from only one point in the wastestream. Automatic samplers operating with a suction-lift and without a

detachable gathering system are practically limited to operation at heads at or under 25 feet due to internal friction losses and atmospheric pressure. Automatic samplers should be capable of rapidly purging the intake system prior to and immediately after collection of an aliquot. The transport lines for the units should also be at least 0.64 centimeters (0.25 inches) in diameter to prevent clogging. It should be recognized that the transport lines might build up growths, which may periodically slough off and contaminate sample material if left uncleaned or unnoticed. Samplers should have an intake velocity of between two and five feet (0.6 to 1.5 meters) per second. Units with an intake velocity under two feet per second may leave solids behind in the tubing, while those with intake velocities over this range may draw in large pieces of suspended material; either case may yield erratic analytical results. One reference consulted recommended determining the suspended solids concentrations obtained from an automatic sampler and comparing it with a mean of a minimum of six simultaneously collected manual grab samples. The obtained ratio (automatic: grab) for a municipal treatment plant influent should be 1.6 to 2.0 and, for a municipal treatment plant effluent, the ratio should be 0.9 to 1.3. Samples should be kept near 4° C during compositing; if the sampler does not have an integrated refrigeration unit or ice compartment, it may be placed on ice in an ice chest that has been laid on its end. *Standard Methods for the Examination of Water and Wastewater* recommends the addition of chemical preservatives at the start of composite sample collection, so that all sample portions are preserved as soon as they are collected.

Units to be used for collecting samples to be analyzed for trace organics must be free of Tygon tubing, which may be a source of phthalate ester contamination, and of other sources of contamination such as plastic or rubber compounds. The collection of a field blank must include the automatic sampling equipment.

When sampling wastewater, any equipment coming in contact with the sample material must be clean (see Chapter 2, *Quality Assurance*). It is preferable to collect samples directly into the containers in which they will be submitted for analysis, if at all possible. If a bucket or sampling device is to be used for collecting samples that will be analyzed for metals, do not use a metal device. Some parameters, such as oil and grease, petroleum hydrocarbons, volatile organics, and base neutral/acid extractable organics should not be collected except in the final sample container, if at all possible. Any device or bottle coming into contact with the sample material should be rinsed with the liquid two or three times, unless the bottle is pre-preserved, contains a dechlorinating agent, has been rinsed with acid, acetone, or hexane, or the sample is to be analyzed for oil and grease, petroleum hydrocarbons or microbiological parameters. Sampling devices should face upstream, and samples should be collected centrally (at a 0.4 to 0.6 times the depth from the bottom of the wastestream and in the center of the channel). Collecting samples at this depth avoids skimming the surface of the wastestream, where the concentration of lighter-than-water materials will be highest, and lowers the possibility of sampling bed loads in situations where solids separation is a concern.

When sampling from a valve or a faucet, flush the sampling line first, taking into consideration the line diameter, length of pipe to be flushed and velocity of flow. When sampling wastestreams that are under pressure, regulate the flow rate in the sampling line to not less than 500 milliliters per minute after first flushing the line at a rate high enough to remove sediment and gas pockets. If it is believed that dissolved gases will be released from solution due to the drop in pressure, a notation should be made. If samples are to be collected from a wastestream that is at an elevated temperature, they must be collected through a cooling coil.

The importance of the use of proper containers and proper sampling and preservation techniques cannot be overly stressed. A material with a pH of 6.5 or less, and a low buffer capacity, may

experience a significant pH change if shaken. In addition, samples stored in plastic containers may experience a change in pH due to the permeability of the container walls to gases like carbon dioxide. With a change in the carbon dioxide, pH, and alkalinity balance, calcium carbonate may precipitate out and the concentrations of total hardness and calcium may drop. A change in the concentrations of carbon dioxide and dissolved oxygen and changes in pH and temperature may change the concentrations of inorganic parameters such as manganese, iron, alkalinity and hardness. If air contact will change the concentration or characteristics of a constituent, it is recommended that the sample bottle be completely filled and secured from air contact. If the sample will require mixing, if the sample will be completely consumed during analysis (such as oil and grease and petroleum hydrocarbons), or if microbiological parameters are to be analyzed, the bottle will not be able to be completely filled. If a preservative has already been added to the bottle, do not overfill the container. Containers should be completely filled for the following analyses: purgeable organics, hydrogen sulfide, free and residual chlorine, pH, hardness, ammonia, dissolved oxygen and oxygen demands, sulfite, acidity, alkalinity, ferrous iron, and for most organics. For samples requiring shipment, allow a one to ten-percent airspace for thermal expansion except for VOC, BOS and DO samples. This airspace will most likely not compensate for accidental sample freezing, however, microbiological activity may be responsible for changes in the nitrate/nitrite/ammonia concentrations of a wastewater, may reduce phenol concentration, may cause the reduction of sulfate to sulfide, reduce biochemical oxygen demand, and reduce residual chlorine to chloride. Due to oxidation, sulfite, sulfide, iodide, cyanide and ferrous iron concentrations may decrease. Hexavalent chromium may be reduced to chromic ion. Color, odor and turbidity may change in quality. Silica, sodium and boron may be leached out of glass containers. Some cations may be lost by adsorption onto, or in ion exchange with, the glass walls of sample containers.

Individuals, who are required to choose dilutions for biochemical oxygen demand or coliform bacteria analyses, may find Table 6.14 to be helpful:

6.9.7 Public Community Water Systems

Sampling Definition: Systems for provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serve at least 25 individuals at least 60 days out of the year.

6.9.7.1 Source Sample (Raw Water)

6.9.7.1.1 Ground Water

Samples from a well supply should be collected as close to the well head as possible (before any treatment) preferably from a designated raw water sample tap. The sampler is cautioned to remember that well pumps and casings can contribute to sample contamination. If a well pump has not run for an extended period of time

Table 6.14 Suggested Biochemical Oxygen Demand Dilutions

Sample Type	Dilutions
Raw Sewage	1 - 2 - 5%
Secondary Effluent	5 -10 - 25%
	or 2 - 5 - 10%
Tertiary Effluent	5 -10 - 25%

Suggested Coliform Dilutions

Sample Type	Dilutions
Raw Sewage	10-4, 10-5, 10-6
Disinfected Effluent	1, 10-1, 10-2

Dilutions	MPN Range	
10, 1, 10-1	2.0	1,600
1, 10-1, 10-2	20	16,000
10-1, 10-2, 10-3	200	160,000
10-2, 10-3 10-4	2,000	1,600,000
10-3, 10-4, 10-5	20,000	16,000,000
10-4, 10-5, 10-6	200,000	160,000,000

prior to sampling, the water collected may not be representative of actual water quality. The sample may be collected immediately (after flushing the sample tap) if the well has been running continuously. If the pump has turned off or is running intermittently, run the pump for a minimum of 30 minutes.

6.9.7.1.2 Surface Water

Samples collected from a surface water supply are to be collected before the water receives any treatment and should be representative of the water entering the intake structure. The actual sampling location may be downstream of the low lift pumps or at the intake structure. This sample is NOT to be collected along the banks of a river, lake, or reservoir.

6.9.7.2 Plant Delivered Sample (Finished Water)

This sample is to be collected at a location downstream of all water treatment and must be representative of the finished product leaving the treatment facility. Only proper spigots are to be used and they must be flushed prior to sampling.

6.9.7.3 Point of Entry Sample

This sample is to be collected at a point of entry into the water distribution system representative of a particular source after the application of any treatment.

In many cases this may be a plant-delivered sample (if no other sample tap is available) or a meter pit sample tap where water purchased in bulk from another water supply enters a distribution system.

6.9.7.4 System Sample

A system sample is a sample collected from the water distribution system. A FIRST DRAW sample is water that immediately comes out when a tap is first opened. This type of sample is useful when evaluating whether plumbing materials are contributing lead or other contaminants to the water supply. A FLUSHED SAMPLE is collected after the piping has been evacuated and should be representative of the water flowing in the public water main.

When collecting a FLUSHED sample, allow the spigot to run long enough to obtain a representative sample. A good rule of thumb is to allow the water to flow until the water in the service line (the pipe that carries tap water from the public water main to a home or building) has been replaced at least twice. A convenient flow for sampling is usually about a half-gallon per minute. (To estimate flow, use a gallon jug and time the fill rate.) For a flow of a half-gallon per minute, the jug should be half full in one minute or completely full in two minutes). Since 50 feet of 3/4-inch service line pipe contains over one gallon (3.8 liters), 4 or 5 minutes of running time would be necessary to replace the water in the line twice.

Samples should not normally be collected from fire hydrants, drinking fountains, or from spigots that contain aerators or screens. If aerators or screens are present, they should be removed with care. Do not sample from taps that are surrounded by excessive foliage (leaves, flowers) or taps that are dirty, corroded, or are leaking. Never collect a sample from a hose or any other attachment to a faucet. Be sure that the sample container does not touch the faucet.

6.9.8 Ground Water-Level Measurements

Pursuant to N.J.A.C. 7:26E-3.7(e)3, if ground water contamination is confirmed, a ground water remedial investigation must be performed. The person responsible for conducting the investigation

must collect a minimum of two rounds of synoptic static ground water-levels at a minimum of thirty (30) calendar days apart, pursuant to N.J.A.C. 7:26E-4.4(h)3ii2. By measuring the depth to ground water in networked monitoring wells or piezometers, the direction of ground water flow can be determined.

Various measuring devices and methods can be used to determine well depths, depths to ground water, as well as product thickness, if any. However, all ground water-level measurements should be made from the same marked reference point at the top of the inner well casing. A surveyor licensed in New Jersey must mark the reference point. If no discernable survey mark is observed on the inner casing, the ground water-level measurement should be read from the highest point of the inner casing. If no survey mark is observed on the inner casing, it should be noted with the ground water-level data and the highest point of the casing must be marked for future reference. Measurements should be made three to four times to confirm the measurement. Each time a measurement is made it should be determined to the nearest one-hundredth of a foot (0.01). All well measurements should be performed the same day, and prior to the evacuation of any wells which may influence ground water elevations in the area of the investigation. The key to accurate readings by any method is proper collection of the measurements. Measurements should be collected from the same survey point, and to avoid any procedural differences, preferably by the same person and measuring tape. The following is a discussion of some of the equipment and techniques used to measure ground water-levels in monitoring wells and piezometers.

6.9.8.1 Steel Tapes

Ground water-level measurements can be obtained using a steel tape. Tapes are typically a quarter-of-an-inch-wide steel band mounted to a hand-wound reel. Measurements are obtained by first applying either water indicator paste or chalk to the bottom two feet of the tape and then lowering the tape to a predetermined depth close to the anticipated ground water depth. The referenced stopping point should be recorded and the tape brought back to the ground surface. The difference between this point and the area on the tape where the paste/chalk has been washed off is the depth to ground water from the surveyed reference point at the top of the inner well casing. The tape can only be lowered to the predetermined stopping point and then retrieved. If the tape is lowered past this point and then retrieved, it will result in a false ground water-level measurement. For this reason, and the fact that the chalk or paste may impact ground water quality analyses, the Department does not recommend the use of this method in monitor wells.

6.9.8.2 Electronic Ground Water-Level Indicators

A commonly used device is the electronic ground water-level indicator. These units usually have a cable divided into incremental measurements of 0.01 feet and two conductors forming a probe. When ground water is encountered, the circuit is completed and a light, meter or audible buzzer is activated. The depth to ground water is then measured from this point to the reference mark on the inner casing of the monitor well. Occasionally, the cable may need to be raised and lowered a few times in order to obtain an accurate reading. Not all electronic ground water-level indicators are incremented every 0.01 feet, as some older cables may be incremented every 5 feet, every foot or every tenth of a foot. If the cable is not marked in hundredths of a foot, an engineering ruler that is marked every hundredth of a foot must be used to take the measurement

6.9.8.3 Helpful Hints

The accuracy of ground water-level measurements collected from electronic ground water-level indicators can be affected by several factors. The following is a discussion of some helpful techniques that may be considered when using these units.

Most electronic ground water-level indicators produce both an auditory and a visual response when the ground water surface is contacted. Weak batteries in these units frequently produce weak or gradual auditory and/or visual responses, making it difficult to accurately determine when the probe of the unit has come in contact with ground water. As such, it is recommended that electronic ground water-level indicators be tested before they are brought out into the field. Note that electronic ground water-level indicators will not respond to distilled water, so distilled water should not be used to test these units.

Wells that are not plumb may result in probe contact with the side of the well casing providing a false measurement. Once the probe has come in contact with ground water in the well, water may be trapped by capillary action between the probe and the well casing. If this happens, the unit may continue to signal even after the probe has been raised above the ground water surface. The deeper the well, the more likely this problem may occur. To correct this, the cable should be raised several feet above the water and shaken to remove water from the probe. A new ground water-level measurement should then be collected. If the signals from the unit are not abrupt or reproducible, the probe may need to be reeled up to the surface and dried off before re-attempting another measurement. Accumulation of sediment, organic material, or floating debris on the probe may also result in gradual or non-reproducible readings.

Wells that are constructed with metal inner casings may lead to difficulties in collecting reproducible ground water-level measurements because the inner sides of the well casing are conductive. In some cases, a rubber grommet or metal centralizer may need to be placed on the probe so that the probe is not allowed to come in contact with the inner casing.

Ground water-level-measuring equipment should be properly decontaminated between wells and piezometers to avoid cross contamination. In certain circumstances sensitive components of an interface probe may be compromised by the use of standard decontamination solvents. Alternative solvents may be used upon approval of a Site Remediation Program Case/Site Manager.

Once a well has been located and properly identified, the field measurements listed below should be noted in a field logbook. Be certain that the proper well is being measured. The misidentification of a sampling point in the field will result in erroneous data that may result in incorrectly constructed contour maps.

◇ Field Observations

- Diameter of protective outer casing
- Security and integrity of the well
- Well number & well permit number
- Inner diameter and construction material of the inner well casing
- Total depth of the well from the top of the inner casing or surveyor’s mark, if present (measured to 0.01 foot)
- Depth from the top of the inner casing to ground water (recorded to 0.01 foot accuracy)
- Thickness of floating product, if any
- Calculation of the linear feet of water in the well by subtracting the depth to ground water from the total depth of the well.
- Calculation of the water table elevation in the well by subtracting the depth to ground water from the top-of -casing elevation.

Note: Ground water-levels should be obtained from all wells prior to sampling the first well, thus avoiding interference problems. This also allows one to determine if any well, upon inspection, is damaged or may pose a problem prior to sampling a well.

6.9.8.4 Ground Water Level and Non-Aqueous Phase Liquid (NAPL) Measurements

Monitoring points with Light Non-aqueous Phase Liquids (LNAPLs) can pose a problem when measuring the level of ground water. Floating LNAPLs can depress the ground water-level in a monitoring well or piezometer and distort the measurement. Therefore, the corrected depth (CD) formula shown below should be applied to ground water-level measurements in monitoring points where LNAPLs are present:

- CDTW = Static DTW – (PT x G)
- CDTW = Corrected Depth to Ground water
- DTW = Depth to Ground Water (Static)
- PT = Measured Product Thickness
- G = Specific Gravity (density of free product / density of water)

When an LNAPL thickness is measured in a monitoring well it will usually exhibit an apparent thickness rather than an actual thickness. This apparent thickness is caused when LNAPL from within and above the capillary fringe migrates into the monitoring well causing the ground water-level to become depressed below the surrounding capillary fringe area. As a result, LNAPL will continue to flow into the well until equilibrium is reached causing an apparent LNAPL thickness, which is greater than the actual thickness**.** In addition, LNAPL thickness can be affected by fluctuations in the water table. In some cases, an LNAPL's thickness may decrease when the water table rises, while its thickness increases as the water table drops. In other cases, fluctuating water tables may cause sudden appearances and disappearances of LNAPL layers.

Below are examples of some of the equipment and techniques used to measure ground water-levels and/or NAPL thickness in monitoring wells. Since electronic ground water-level indicators will not work in these situations, alternate methods must be used. Clear bottom-fill bailers and interface probes offer two alternatives.

6.9.8.4.1 Clear Bailer

Once the surface level of the LNAPL layer has been determined, a clear bailer can be lowered into the well and slowly into the product, being careful not to submerge the bailer. The bailer is raised and the product thickness measured. Once the product thickness is known, the depth to ground water may be determined. This method has inaccuracies because successful use of the bailer is dependent upon the expertise of the operator and assumes the check valve does not leak upon retrieval. However, due to difficulties associated with the Interface Probe, use of the clear bailer is the preferred method to identify and estimate thickness of floating product in monitor wells.

6.9.8.4.2 Interface Probes

This probe uses an optical sensor to determine if the probe is in NAPL and a conductivity sensor to determine if the probe is in water. When using this probe, each phase can be measured independently, including Dense Non-aqueous Phase Liquids (DNAPLs) that may be present at the bottom of the well. The hydrocarbon/air interface reading should be measured first upon going from air to the LNAPL surface to prevent dripping hydrocarbons from enhancing the thickness reading. The hydrocarbon/water reading is best collected when moving up from the water to the hydro-

carbon layer to prevent hydrocarbons from coating the conductivity probe which would also enhance the hydrocarbon thickness reading. Lowering the probe quickly through the LNAPL layer minimizes the contact time of the probe within the hydrocarbon phase.

Experience has determined that the optical sensor on Interface Probes may become damaged if solvents are used to clean product from the probes. Additionally, the optical sensor may become smeared when used to measure product, rendering pinpoint accuracy to an estimate at best. In either case, close attention to decontamination procedures will improve accuracy, operational life and reduce the risk of cross contamination with other wells.

6.9.9 New Well Construction and Stabilization

After well construction and development, the length of time for ground water conditions to become representative of aquifer conditions at and near the monitor well (the stabilization period) will vary depending on site hydrogeologic conditions and the drilling, construction and development methods. Ground water flow velocities are typically less than one foot per day and natural flushing rates are generally slow. If a monitor well is drilled, installed and developed so that a 14-foot radius around the well was impacted by drilling fluids, for example, and a natural ground water flow rate was one foot per day, it would take 14 days for unaffected ground water to reach the well. Sampling a monitor well immediately after development will generally not be representative of the static ground water quality conditions at the horizontal and vertical location of the monitor well's intake interval. Therefore, all newly constructed and developed, or redeveloped monitor wells must be allowed to stabilize and equilibrate with the aquifer for a minimum of two weeks prior to sampling.

6.9.9.1 Well Development

Following construction, well development is necessary to remove drilling fluid and construction residues remaining in the borehole or surrounding aquifer and restore the hydraulic properties of the formation immediately surrounding the screened interval. Only a licensed well driller can carry out well development in the state of New Jersey (N.J.A.C 7:9D-2.11(b)) ["Subsurface and Percolating Waters Act", N.J.S.A. 58:4A-4.1].

Installation and construction of monitor wells may themselves alter the quality of ground water in the surrounding aquifer. Site-specific subsurface conditions should be used to determine the appropriate well development techniques. Many times, a combination of the techniques mentioned below will be necessary to produce a properly developed monitor well. Also discussed are certain outcomes inherent to the well development techniques that can be mitigated by following the 14-day stabilization period.

Since construction of monitor wells is merely an extension of water supply well construction techniques, the chosen well development technique is not often given appropriate weight in the overall decision process. This miscalculation can be compounded when constructing a well in a low-yield hydrogeological setting. More often than not, a submersible pump is lowered into a well and pumping is continued until the well water clears. This one-directional, high-stress flow is not effective in proper well development since overpumping causes sand grains to bridge openings in the formation and filter pack.

Once the well is put in service, agitation by pump cycling (dormancy followed by purging and sampling) can break down the bridges, causing reduced permeability and sand pumping. Effec-

tive development requires movement of water in both directions through the screen openings. Reversing flow during well development helps break down the sand bridges. See Figure 6.9 below.

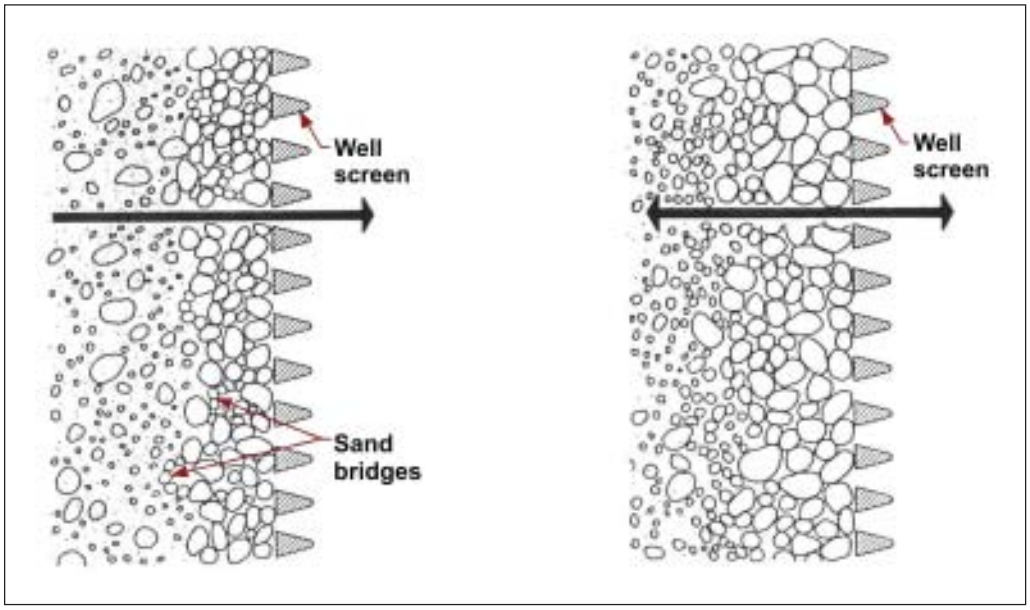


Figure 6.9. On the left, overpumping has formed sand bridges, which eventually collapse reducing the permeability of the filter pack. On the right, bi-directional flow-through the screen and filter pack removes the bridges (illustration published with permission of Johnson Screens, from *Groundwater and Wells*).

In the screened portion of the well there may exist an area that, relative to other areas across the screen, has higher permeability. Once pumping is commenced, this particular area begins to yield water, thus reducing the influence of pumping on other areas in the screened interval. This condition or *piping effect*, as it has sometimes been termed, can be minimized if more attention is given to proper well development. As stated above, the most desirable technique causes the movement of water across the screen in two directions rather than the unidirectional movement afforded by using only a submersible pump. Use of a surge block in tandem with a pump may be one method to avoid the *piping effect*, and create a monitor well capable of delivering a better ground water sample.

6.9.9.2 Other Considerations

- High-velocity air jetting or air-lift development methods may introduce air into the aquifer surrounding the monitor well, and this air has the potential for altering ground water quality, particularly volatile organic compounds and dissolved oxygen. Since air may become entrapped in filter pack materials, these well development methods are not acceptable in wells installed with screens and filter packs.
- Over-pumping of a monitor well for development may draw ground water to the monitor well from considerable distances and draw ground water of quality not representative of the horizontal and vertical location of the monitor well, especially in anisotropic and/or bedrock aquifers.
- Organic drilling fluid residues and inorganic residues of bentonite have been found to remain in and near wells, even after proper development, and these residues have been found to affect water quality including chemical oxygen demand of ground water samples for up to 100 days after completion of development. The Department only approves the use of organic drilling fluids on a case-by-case basis.

- Non-aqueous phase liquid contaminants may be pushed away or drawn to a monitor well location during development depending on the development method selected. The process may smear soil and sediment, thus permanently undermining the intention of obtaining representative ground water samples.
- Suspended, construction-induced sediment, which is not completely removed by development, may affect the quality of ground water samples obtained from the well.

Ground water pollution investigations in New Jersey often base expensive site related investigation and remedial action decisions on initial (first sampling event after construction) ground water sample analyses. Therefore, before ground water samples are collected, a complete understanding of the monitor well's design, construction and development, and aquifer characteristics is necessary in order to properly interpret analytical results.

6.9.10 Filtering Ground Water Samples

In order to assure the quality of data generated from the analysis of ground water samples, critical sample handling procedures must be addressed. An important consideration is sample filtration. However, because the objectives of specific monitoring programs may vary, it is difficult to establish a standard for filtering that will apply to all situations.

The NJDEP requires metals analysis to be performed on unfiltered ground water samples pursuant to the requirements of the Safe Drinking Water Act and the Clean Water Act. The purpose is to obtain a representative sample as it actually occurs in the aquifer and to maintain consistency in sample handling for samples collected for both inorganic and organic analysis. Filtration is recommended only when dissolved metals (0.45 microns or larger) data is needed for evaluation against the NJDEP and USEPA surface water quality criteria for discharge of ground water to surface water. Otherwise, filtration should only be allowed after approval of the sampling objectives, method, filter type and size by the NJDEP under an approved oversight document. There are numerous articles in the scientific literature discussing the various problems with sample filtration relative to obtaining accurate, representative samples.

Studies have also shown the ineffectiveness of bailers for collection of representative metals samples. Inconsistent operator usage, together with high purge rates can result in excessive turbidity. For these reasons, the Site Remediation Program recommends that low-flow purging and sampling (LFPS) methods be used to collect ground water samples for total metals analysis where ground water is turbid, rather than collecting samples for both total and dissolved metals analysis.

If a particular case demands consideration of dissolved metals, both filtered and unfiltered samples should be collected for analysis. The regulatory document, i.e., NJPDES permit, ACO, or approved quality assurance project plan (QAPP) should be consulted for monitoring requirements.

The differences obtained as a result of sample handling (filtered vs. non-filtered) are dependent on the type of association between the specific inorganic ion and the particulate matter. Studies show that when an inorganic ion is not closely associated with particulate matter (i.e., sodium), the differences between total and dissolved concentrations are small and random.

If filtering is to be performed, the sample should be split into two portions, one for filtration and the other for immediate preservation and subsequent analysis for total metals concentration. By analyzing the two fractions separately, differences between dissolved and total metals can be compared.

The decision whether to filter metal(s) samples will be based on the physical quality of the samples, the objective of the monitoring program and the policy of the Program within the NJDEP controlling the specific event. If filtering is allowed and chosen, it is imperative that it be per-

formed in a manner that will preserve the integrity of the sample and allow consistent reproduction of the technique.

6.9.10.1 Total Metals Sampling

Analyzing for total metals concentrations provides an element of consistency when comparing data and evaluating water quality. Also, both the National Primary Drinking Water Standards (NPDWS) and the National Secondary Drinking Water Standards (NSDWS) for metals are based on total metals concentration. An assessment of water quality must take this into account.

The difference between dissolved and total metals can be attributed to the absorption or adsorption of various metals species onto fine-grained particles (i.e., silt, clay). There has been a general assumption that water and soil are the only distinct constituents of an aquifer system; there is also a false assumption that water and completely solvated solutes are the only constituents of the system that are mobile. In fact, components of the solid phase in the colloidal size range may be mobile in subsurface environments. The colloidal state refers to a two-phase system in which one phase in a very finely divided state is dispersed through a second. In ground water, colloidal particles are generally smaller than ten micrometers (10 µm) in diameter. In unconsolidated aquifers, mobile colloids are usually those in the range of 0.1 to 1.0 µm. Since the clay fraction is defined as being two-micrometer (2 µm) and smaller, not all clay colloids are mobile. But even the larger clay particles have colloid-like properties.

There are two distinct types of colloidal matter, inorganic and organic, which exist in an intimate intermixture. The inorganic fraction is present almost exclusively as clay minerals of various kinds; the organic portion is represented by humus. These colloidal particles can adsorb organic and inorganic contaminants and stabilize them in the mobile phase of the aquifer. Association of contaminants with mobile colloidal particles may enhance the transport of highly adsorbed pollutants, or deposition of colloidal particles in porous media may decrease permeability and reduce contaminant transport.

An objective of many sampling episodes is to assess water movement in an aquifer. Analysis of total metals concentrations are useful in the event of a change in the aquifer (i.e., pH decrease) that would cause adsorbed ions to become dissolved, thereby raising the total metals concentration.

Note: Unfiltered sample results should be reported as total metals. Acidification of an unfiltered sample will dissolve some particulate matter, thereby raising the original metals content by releasing adsorbed metals into solution.

6.9.10.2 Trace Metals Sampling

The following guidelines will apply to samples collected for trace metal analysis of ground water:

- For new investigations, that is, when ground water quality is uncertain, samples must be unfiltered for the initial round of samples. As stated above, the SRP recommends sampling for total (unfiltered) metals analysis using LFPS methods. Unfiltered samples will represent “worst case” with respect to metal content. Thus, if no significant concentrations are detected, further sampling for metals normally will not be required.
- If metal concentrations significantly above ground water standards are confirmed, two samples may then be collected from each well: one sample filtered according to the NJDEP procedures and a second unfiltered sample.

Note: The Safe Drinking Water Act program does not allow filtered samples.

6.9.10.3 Dissolved Metals Sampling

The effect of filtration on inorganic ion content must be considered. The aeration that occurs during filtration may increase the oxidation-reduction potential of the water through the introduction of oxygen. This, in turn, may change the valence state of some inorganic ions, which then could lead to the loss of dissolved analytes through precipitation (i.e., oxidation of ferrous ion to ferric ion after aeration). This same effect occurs during sample transport if the sample is not immediately preserved. For this reason, transport of the sample to a laboratory for subsequent filtration and preservation is not permitted.

In addition, the filtering apparatus itself may adversely affect the quality of the sample. The filter paper and filter cake that accumulates during filtration could absorb dissolved metal ions resulting in lower than actual dissolved metals concentration in the filtrate and the filter itself may leach inorganic compounds, raising the concentration in a water sample. Also, the filtration apparatus and procedures, especially if performed by an unskilled technician, are an additional source of error potentially affecting the quality of the sample. In general, handling samples between collection and analysis should be minimized.

Note: If the results of metals analyses are to be reported as dissolved metals concentration, samples must be field filtered immediately after sampling and prior to preservation.

6.9.10.4 Filtering Procedures for Dissolved Metals Analysis

A device made of polyethylene, polypropylene or borosilicate glass should be used when filtering ground water samples for metals. The apparatus should be pre-cleaned by rinsing with a 10% HNO3 solution, followed by a demonstrated analyte-free deionized water rinse, and should be cleaned in the same manner between samples. Also, a field blank must be collected for this apparatus.

When filtration is performed, it must be done immediately upon sample collection and prior to preservation. The sample may not be transported to the laboratory for filtration and preservation nor may it be preserved prior to filtration. The sample should be collected, filtered, preserved, placed on ice and shipped to the laboratory for analysis.

Filtration is best accomplished using an in-line filter apparatus equipped with an ungridded, 0.45-micron pore-diameter filter. If the use of an in-line filter is impractical, pressure filtration may be performed. Vacuum filtration of ground water samples, a third alternative, is the least preferred method of filtration. Care must be taken to strictly follow the manufacturer's recommended procedures if vacuum filtration is used. All filter apparatus should be laboratory cleaned and dedicated. Disposable filters are acceptable. Caution must be used when filtering samples as to prevent the "filter cake" from becoming too thick during filtration. After filtration, samples must be preserved immediately with nitric acid to a pH less than 2.

While total metals analysis may bias the metals concentrations higher than what is actually mobile in ground water, dissolved metals analysis of samples filtered with a 0.45-micron filter may also bias the sample results. Some investigations show that use of a 0.1-micron filter is more appropriate for determining the concentrations of dissolved metals.

6.9.11 Sampling for Light, Non-Aqueous Phase Liquids (LNAPLS)

LNAPLS are generally considered to be low density, immiscible organics including gasoline, petrochemicals and other chemicals that have specific gravities less than water. They are likely to

be present in aquifers as a separate phase because of their low solubility in water. These chemicals tend to float on the water surface in a water table environment and commonly occupy the capillary fringe zone above the water table. For this reason, if product (LNAPL) is suspected to be floating on the water table, all shallow wells installed in the area under investigation must be screened across the water table.

In a confined aquifer, these chemicals are found along the upper surface of the permeable material and also within the overlying confining layer. When immiscible organics with a specific gravity greater than water are the contaminants of concern or if contaminants are suspected in more than one stratified layer in the well column, sampling procedures must be modified. It may be necessary to lower the bailer used for sample collection to a particular depth in the well, or to utilize a double check valve bailer.

Sampling procedures for LNAPL differ substantially from those for other pollutants. If more than one distinct LNAPL layer is present in a well, each layer should be sampled. Samples should be analyzed for chemical composition (i.e., for VOCs and base-neutral extractable compounds, etc.) and physical parameters (e.g., specific gravity, water solubility, vapor pressure of the liquid, and Henry's Law Constant, etc.). Gas-chromatography (GC) *fingerprinting* may also be used to characterize the LNAPL as gasoline or diesel fuel, etc.

After the well is initially constructed it should be developed and pumped to remove stagnant water, then it should sit idle for at least two weeks to allow the water-level to fully stabilize and the floating layer to stabilize.

Measurement of the thickness of the floating layer may be accomplished by using a water indicator paste/gel with a weighted steel tape to determine the depth to the top of the floating layer and to the water surface. The difference between these two readings is the thickness of the floating layer. Measurement of the thickness of the floating layer may also be accomplished by using an interface probe or clear Teflon bailer, if the product thickness is less than the length of the bailer. Electric water-level sounders will not work properly for these determinations.

Prior to purging ground water from the well, a sample of the floating layer may be obtained using a bailer that fills from the bottom. Care should be taken to lower the bailer just through the floating layer but not significantly down into the underlying ground water. After following typical evacuation procedures discussed previously in this section, a sample of formation water may be obtained from the well.

6.9.12 Sampling for Dense, Non-Aqueous Phase Liquids (DNAPLs)

DNAPLs include chlorinated solvents and other chemicals that have specific gravities greater than water. They are likely to be present in aquifers as a separate phase because of their low solubility in water. DNAPL chemicals tend to migrate downward through the unsaturated zone and the saturated zone due to their high density. If the volume of DNAPL chemical introduced into the subsurface is larger than the retention capacity of the vadose and saturated zones, a portion of the DNAPL will spread out as a layer of free liquid on the bottom of the aquifer or on lower permeability beds within the aquifer.

Measurement of the thickness of DNAPLs (and LNAPLs) must be performed prior to purging (evacuating) the well. Measurement of the DNAPL may be accomplished by using a water indicator paste/gel with a weighted steel tape (if no LNAPL is present) to determine the depth of the top of the DNAPL and the bottom of the well. The difference between these two measurements is the thickness of the DNAPL in the well. An interface probe may also be used to measure DNAPL thickness in the well.

Prior to purging a monitor well, a sample of the DNAPL may be obtained using a dual check valve bailer or a bladder pump. If both LNAPLs and DNAPLs are present in a well it may be necessary to purge the well of one casing volume of water prior to sampling the DNAPL provided that efforts are made not to disturb the DNAPL in the bottom of the well. This can be accomplished by setting the pump intake of the submersible or suction-lift pump several feet above the DNAPL.

Samples should be analyzed to determine the chemical composition of the DNAPL and its physical properties (e.g., specific gravity, water solubility, equilibrium vapor pressure of the liquid and Henry's Law Constant, etc.). Gas-chromotrgraphy (GC) "fingerprinting may also be used to characterize the DNAPL as TCE or coal tar, etc.

◀ Return to TOC

6.10 Biological Sampling Procedures

6.10.1 Phytoplankton Sampling

6.10.1.1 Sample Site Location

Locate sampling stations as near as possible to those selected for chemical and bacteriological sampling to ensure maximum correlation of findings. These locations will depend upon the physical nature of the water body. In streams or rivers, stations should be established both upstream and downstream of a pollution source or major tributary. Stations should also be set up on either side of the river so as to account for unequal lateral mixing. Slow moving sections of streams generally contain more phytoplankton than slower moving segments. If there are any lakes, reservoirs, or backwater areas (i.e., potential phytoplanton sources) upstream of sampling stations, notes on their nature and location should be included in the sampling log.

Sampling stations in lakes, reservoirs, estuaries and the ocean should be located along grid networks or transect lines, aligned so as to provide the most representative sampling. Points of interest should include intake and discharge areas, constrictions within the water body, and major bays and tributaries off of the main basin. In tidal areas, the effects of tidal oscillation should also be taken into account when determining sampling frequency. When locating stations for a *red tide* survey in estuarine or coastal waters, note where and when the blooms tend to occur.

6.10.1.2 Sampling Depth

Rivers, streams, shallow bays and coastal waters are usually well mixed so that only subsurface sampling is necessary. In lakes, reservoirs, as well as deeper coastal waters, plankton composition and density may vary with depth; thus sampling should be done at several depths determined by the depth of the thermocline, the euphotic zone if applicable, and overall the depth at the station. In shallow areas (1-2 meters) subsurface samples (to a depth of 1M) are usually sufficient. In deeper lakes and reservoirs, samples should be taken at intervals of 5M or less to the thermocline. In estuarine and coastal waters 2-10M deep, subsuface, mid-depth and near bottom samples are recommended. Offshore samples should be collected at intervals of 5M or less to the bottom of the thermocline, and near the bottom where depletion of oxygen by decaying blooms is critical; larger sample volumes of at least one liter are needed because these waters are typically low in productivity.

6.10.1.3 Sampling Procedure

Sample size, preservation and storage are dependent upon certain variables. Refer to Chapter 2, *Appendix 2.1* for details.

If analysis is limited to species composition clear polyethylene or glass bottles may be used. If chlorophyll analyses is requested, amber bottles are recommended. Clear or translucent glass or plastic bottles may be used provided they are covered with aluminum foil so as to shield out light.

Freshwater samples for species composition analysis should be preserved with a solution of neutralized formalin (5 ml neutralized buffer with formalin/100 ml of sample). Estuarine and marine samples are to be preserved with Lugol's solution (60 g KI + 40 g iodine crystals in 1,000 ml distilled water) at a rate of one (1) drop Lugol's solution to 100 ml of sample adding more periodically to maintain the color of weak tea. In special studies glutaraldehyde may be used (6-drops/25 ml of sample). All preserved samples should be stored in the dark immedi-

ately so as to prevent the degradation of the phytoplankton, or the preservative if Lugol's solution is used.

All species composition phytoplankton samples should be fixed (preserved) except where primary productivity and phytoplankton populations must be studied in extensive detail. When collecting live samples, leave at least a four-cm air space in the bottle and chill to 4 ºC (e.g. in a cooler with ice) during transit storage. For delicate flagellated species do not refrigerate sample bottles. Maintain in-situ temperature by storing them out of direct sunlight, in an ice chest, with some of the ambient water. Surface samples in streams, rivers, shallow estuaries and coastal water can be collected simply by inverting the sample bottle, immersing it up to one (1) meter below the water surface and slowly filling it as it is removed from the water. A Kemmerer sampler may also be used, holding it in a horizontal position and closing it manually.

Samples collected for Chlorophyll analysis shall not be fixed preserved. Chlorophyll samples shall be preserved by chilling to 4°C. If species composition analysis is necessary, then it shall be collected in a separate sample bottle, or fixed preserved by laboratory staff after the aliquot for chlorophyll analysis is removed from the sample container.

When deeper samples are needed, use of a Kemmerer, Water Bottle, Van Dorn or Juday samplers are standard. All of these devices basically consist of a metal or plastic hollow cylinder with remotely activated stoppers at either end. The sampler is lowered to a desired depth with a graduated line. Once at the desired depth, a heavy brass slug or messenger, attached to the line, is released. It slides down the line, strikes the release mechanism on the sampler which pulls the stoppers tight against the open ends of the cylinder, trapping the sample of water inside. The sampler is then withdrawn and the water emptied into the sample container via a small spigot or tube in one of the stoppers. Use only non-metallic samplers when metal analysis, algal assays, or primary productivity measurements will be performed on the sample.

Sample bottle labels should identify the body of water sampled and list the date of collection, collectors name, preservative if present, and the type of biological analysis desired (determination of dominant or bloom species, total cell count, etc). It is important that labels clearly identify live plankton samples as being unpreserved.

6.10.2 Zooplankton Sampling

6.10.2.1 Sample Site Location

The procedures outlined for phytoplankton sampling can be applied.

6.10.2.2 Sample Depth

The same procedure as phytoplankton for rivers and streams but in lentic environments sample at one (1) meter intervals from the surface to the lake bottom; since these organisms are not confined to the euphotic zone.

6.10.2.3 Sampling Procedure

Zooplankton analysis requires larger volume samples than phytoplankton, at least six (6) liters in moderately and highly productive waters. For appropriate preservation requirements refer to Appendix-A.

6.10.3 Macrophyte Sampling

Field observations are very important when analyzing macrophyte populations. The sampling person must estimate the percentage of the lake's surface area, and bottom area if possible, over

which macrophyte growth occurs and the dominant form or forms for any samples taken.

When taking a macrophyte sample, an entire plant of each kind encountered should be collected if at all possible. If this is not possible, as much of the plant as can be collected should be taken, and care should be taken to include any reproductive structures present, complete leaves, and a section of stem showing branching pattern, if any. Specimens can be placed in plastic bags or containers without special preservatives, although completely aquatic species should be kept moist; refrigeration is recommended unless otherwise specified. If the samples cannot be examined within 3 days, it is recommended that they be preserved with a 5% solution of formalin.

6.10.4 Macroinvertebrates

6.10.4.1 Hester-Dendy Artificial Substrates

6.10.4.1.1 Sampler Placement

These multiple-plate samplers consist of eight large tempered plates separated by seven small plates, exposing one square foot of surface area. A hole is bored through the center of each plate. Plates placed alternatively on a galvanized eyebolt, threaded rod or nylon cord and secured. Samplers may have a brick attached to one end to anchor the sampler to the bottom for use in shallow streams, or they may be suspended from anchored floats in lakes and deep rivers. Used throughout, artificial substrates provide consistency of habitat in order to facilitate comparison among stations. Samplers are usually placed at equal intervals across a stream. However, species colonization is greatly affected by current velocity. When conducting a survey, care should be taken to place substrates at locations having similar flow characteristics. Three samplers are routinely placed at each sample site, although more samples may be necessary to satisfy particular statistical criteria. When using brick-anchored samplers, additional rocks are often necessary to secure the sampler in an upright position. Care should be taken not to block the plates with the rocks and thus limit colonization. Sampling devices should be placed as inconspicuously as possible, since they are prone to removal by the public. They should be secured with strong nylon line (not attached to the anchor line itself). In deeper waters, suspended samplers should be placed within the euphotic zone (i.e., shallower depths where light penetrates) usually less than 2 meters.

6.10.4.1.2 Sampler Retrieval

The samplers should be removed after a six-week colonization period. Gently remove the sampler from the water in order not to dislodge the organisms, and immediately place the sampler in a plastic tub or bucket. Anchors attached to the substrate should not be placed in the tub until any organisms on the anchor are removed and discarded. Add a small amount of water to the tub and wash the easily removable material from the plates. Then gently scrape the top and bottom of each plate into the tub removing the plates as cleaned. Scalpel, spatula or soft toothbrushes are useful cleaning tools. Pour the sample slurry through an U.S. Standard No. 30 sieve. Additional water may be used to completely clean the tub. Pass this through the sieve as previously described. Transfer the sample material from the sieve to the sample jar(s) using forceps or a stream of water from a wash bottle. Fill each jar no more than half full. Work directly over the tub so that any spilled materials can be recovered. Finally, inspect the tub for any remaining organisms and transfer them to the sample jar(s).

Water-resistant paper should be used for sample labels and all information written with a soft lead pencil. Include sample (log) number, water body, station, sample number, sample device, and other pertinent information. Record the sample number in a bound notebook together with other environmental information. Place the label inside the sample jar. An external label is helpful in identifying the sample in the laboratory. See below for preservation. Any samplers thought to be contaminated by oil, grease, toxins, etc. should not be reused. All other samplers are to be washed thoroughly in the laboratory before reuse.

6.10.4.2 Surber or Square Foot Bottom Sampler

6.10.4.2.1 Sampler Placement

This sampler consists of a strong close-woven fabric (0.595-mm opening) approximately 69-cm (27 in.) long held open by a square foot metal frame hinged at one side to another frame of equal size. The sampler is generally used in procuring samples in fast-flowing streams less than 1m deep. It can also be used in pools where the water depth is wadeable. Three replicate samples are usually obtained at each sampling station.

Carefully place the sampler in position with the net opening facing upstream, using the current to hold the net open, while standing downstream and to the side of the sampling area. By imbedding the separate 2 or 4-inch extensions of the horizontal frame, the sampled area will be more effectively isolated. When taking replicate samples, always work across or in an upstream direction. Dislodge the rocks, stones, and other bottom material within the frame to a depth of at least 2 inches and collect them in the net.

6.10.4.2.2 Sampler Retrieval

Remove the sampler and empty the contents into a plastic tub. Carefully inspect the larger rocks and stones removing any organisms clinging to them, and discard the stones when cleaned. Also carefully inspect the net and remove any organisms remaining. After the larger materials have been inspected and removed, add a small amount of water to the tub and pour the slurry through an U.S. Standard No. 30 sieve. This may have to be repeated several times in order to completely empty the tub. Follow the same techniques described under Hester-Dendy retrievals in transferring the sample to the sample jars and in labeling. See below for preservation.

6.10.5 Grab Samplers

The Ponar, Peterson, and Ekman grab are the most commonly used grab samplers. The Ponar is similar to the Peterson, except that it has side plates and a screened top to prevent sampling loss. The Ekman grab is useful in sampling silt and muck in water with little current. Extreme care must be employed when locking open the jaws of the samplers, as premature tripping will squash or sever fingers or hands. Handling by the attached line is recommended with an open sampler. Carefully lower the grab to the bottom so as not to agitate the substrate prior to sampling. Slacken the rope to trip jaws (the Ekman grab employs a messenger, which is released by the operator) and retrieve the sampler. Place it in a plastic tub or large screened bin and carefully open the sampler jaws to release the sample. The sample should be discarded if sticks or stones have obstructed the jaws or if there is incomplete closure for any other reason. Inspect the larger debris for organisms and discard the debris when cleaned. Filter sample through a #30 sieve to remove smaller particles. Then transfer, label and preserve the sample as described in Chapter 2, *Appendix 2.1*.

A Mason jar, or any glass or plastic wide mouth container can be used for macroinvertebrate samples. All macroinvertebrates are preserved in 5% formalin (5 ml formalin/100 ml of water from which the organism was taken), with 95 % ethanol, or isopropyl alcohol.

Equipment List for Macroinvertebrate Sampling Using Surber, Square-Foot, Hester-Dendy or Grab Samplers

- U.S. Standard No. 30 Sieve
- Plastic Trays
- Brush
- Forceps
- Gloves
- Mason Jars
- Boots
- Formalin
- Labels
- Squeeze Bottle

6.10.6 Periphyton Sampling

6.10.6.1 Artificial Substrates

6.10.6.1.1 Sampler Placement

Samples are collected using standard 25 x 75 mm (1 x 3in) unfrosted glass microscope slides as artificial substrates mounted in a floating rack. Eight slides are to be placed at equal intervals in the sampler and secured with monofilament fishing line. The sampler is then attached several feet downstream of a large anchored float. The sampler should be secured so that the slides are parallel with the current. The large float helps to deflect floating materials, which would otherwise cover the slides and reduce photosynthesis. It also forms an eddy, which may be more conducive for periphyton colonization than a faster current. In shallow streams, the sampler may be tied directly to a brick and placed directly on the stream bottom. This is especially advantageous in areas where floating samples may be disturbed or removed by the curious. Care should also be taken to place the samples in well lighted stream segments so that light intensity will be similar at all stations in a survey.

6.10.6.1.2 Sampler Retrieval

A two-week exposure period constitutes the optimum exposure period. Upon retrieval, three slides should be immediately processed for chlorophyll A determinations. If it is impossible to begin immediately (while rowing a boat for example) place the sampler in a bucket or tub and cover, since exposing the slides to direct sunlight will result in a rapid deterioration of chlorophyll.

To process chlorophyll, scrape three slides clean as soon as possible with a razor blade or rubber policeman, being careful not to touch the surfaces with your fingers. Place the scrapings from each slide into separate 120 ml amber jars (with polyseal caps) and then, using an eyedropper, rinse each slide with a small amount of 90% acetone. Twenty to thirty milliliters to a maximum of fifty milliliters should suffice. The remaining slides, to be used for species composition determination, should be placed in separate clear glass jars filled with 5% formalin.

Seal jars tightly and label appropriately including station, sample number, date, and collector's name. Place samples in an ice chest for transport to the laboratory. Process the slides used for chlorophyll analysis (and later, ash-free weight) first since chlorophyll degrades rapidly and, if a slide is broken or contaminated the extra slide can be substituted.

Equipment List for Placement and Retrieval of Diatometers for Periphyton Sampling

- Boots
- Knife
- Labels
- Gloves
- Bricks
- String
- Diatometers
- Plain Glass Slides
- Nylon Monofilament
- Wide Mouth Amber Bottles
- Razor Blades or Rubber Policemen
- 90% Acetone (for chlorophyll A samples)
- 5% Formalin (for taxonomic ID samples)

6.10.6.2 Natural Substrates

If differences between substrates at the various study stations are not great, it is often advantageous to sample the natural substrates available. To do this a rubber sheet with a 10-cm2 space cut out of its center is placed on a rock, piece of wood or large plant stem or leaf taken from the water. A small amount (about 1 ml) of acetone solution (90% acetone, 10% distilled water) is sprayed on the area exposed by the cut out section of the rubber sheet. This area is then scrubbed with a toothbrush, which is repeatedly rinsed off with the acetone solution into an amber jar. The scrubbing and rinsing continues until the exposed area of substrate and toothbrush are clean. Approximately 20-30 ml of acetone solution is needed per sample.

For chlorophyll and ash-free weight determinations, 3 replicates per station are required, each taken from a separate substrate unit (e.g., 3 separate rocks or logs). For species composition analysis, substitute water for acetone and add enough formalin to the sample jar to make a 5% solution. One composite sample should be sufficient, made from scrapings from each of the substrates used for chlorophyll sampling. Label all jars with the station designation, date, preservative used, area of substrate cleaned, and operation to be performed.

6.10.7 Rapid Bioassessment (RBP) Techniques*

Rapid bioassessment provides an efficient tool for screening, site ranking and trend monitoring regarding quality of the State's waters. The methods currently in use pertain to lotic waters (i.e., streams and rivers). * from USEPA 1999, *Rapid Bioassessment Protocols for Use in Streams and Rivers*, Second Edition. EPA 841-B-99-002. Washington, D.C.

6.10.7.1 Benthic Macroinvertebrates

Benthic RBPs usually employ direct sampling of natural substrates, as do Surbers and grab samplers; under certain conditions, however, such as in large rivers, the use of artificial substrates may be more appropriate for RBP analysis. The collection procedure should provide

representative samples of the macroinvertebrate fauna from comparable habitat (substrate) types at all stations in a particular survey. Either single or multiple habitat samples can be employed depending on which is more suitable for a particular survey. A riffle/run habitat, with rock substrate, will generally provide the most diverse community of major macroinvertebrate groups. If the stream or river is non-wadeable or has an unstable substrate, fixed structures (e.g., submerged boulders, logs, bridges, and pilings) can provide suitable habitat.

D-framed or rectangular framed, 500 – 900 mm mesh "kick" nets can be employed as either single or multiple habitat samplers.

6.10.7.2 Single Habitat Sampling

A 100 m reach representative of the characteristics of the stream is chosen, and whenever possible, upstream of road or bridge crossing.

A composite sample is taken from individual sampling spots in the riffles and runs in the stream reach. A minimum of $2m^2$ composited area is sampled.

Sampling begins at the downstream end of the reach and proceeds upstream. 2 to 3 *kicks* are sampled at various velocities in the reach. A *kick* is a stationary sampling accomplished by positioning the net on the bottom of the stream and disturbing one square meter upstream of the net. The substrate can be disturbed using the heel and toe of the boot, or rubbed by hand for larger substrate particles. Several kicks will make up the composite sample.

Empty the composite sample into a sieve or sieve bucket and mix to ensure a homogeneous composite. Place the sample into a sample jar of at least one liter, and label with the site name, location, date, and sampler(s) name. Preserve the sample with 95 % ethanol, or isopropyl alcohol, or 5 % formaldehyde.

6.10.7.3 Multi-habitat Sampling

For sampling low gradient streams or streams with variable habitats, a multi-habitat sampling approach is required.

A 100 m reach representative of the characteristics of the stream is chosen, and whenever possible, upstream of road or bridge crossing.

Sampling begins at the downstream end of the reach and proceeds upstream. Habitats are sampled in their approximate proportion to their representation of surface area in the reach. In low gradient streams, snags, vegetated banks, submerged macrophytes, and gravel/ sand are habitats that support fauna. A total of 20 *jabs* or *kicks* should be sampled over the length of the reach. A *kick* is a stationary sampling accomplished by positioning the net on the bottom of the stream and disturbing one square meter upstream of the net. The substrate can be disturbed using the heel and toe of the boot, or rubbed by hand for larger substrate particles. A *jab* consists of forcefully thrusting the net into a productive habitat for a linear distance of 0.5 m. Then, sweep the area with a net to ensure macroinvertebrates, that have disengaged from the substrate, are collected. A minimum of 2 m^2 composited area is sampled

Empty the composite sample into a sieve or sieve bucket and mix to ensure a homogeneous composite. Place the sample into a sample jar of at least one liter, and label with the site name, location, date, and sampler(s) name. Preserve the sample with 95 % ethanol, or isopropyl alcohol, or 5 % formaldehyde.

6.10.7.4 Periphyton

Benthic algae (periphyton) are primary producers and important foundation of many stream food webs. Periphyton also stabilize substrata and serve as habitat for many other organisms. Their characteristics are affected by physical, chemical, and biological disturbances that may occur in the stream reach.

Equipment:

- stainless steel teaspoon, toothbrush, or similar brushing and scraping tools.
- section of 3” diameter or larger PVC pipe fitted with a rubber collar at one end
- white plastic or enamel pan
- petri dish and spatula
- forceps, suction bulb, and disposable pipets
- DI water
- 125 ml wide mouth sample jars
- labels
- preservative (Lugol’s solution, 4% buffered formalin, “M3” fixative, or 2% glutaraldehyde)
- cooler with ice

Establish the sampling reach as per benthic macroinvertebrates above

Collect samples using techniques for specific substrate types:

Removable substrates (hard): gravel, pebbles, cobble, and woody debris. – Remove representative substrates form the water; brush or scrape a representative area of algae from the surface and rinse into sample jar.

Removable substrates (soft): mosses, macroalgae, vascular plants, root masses. – Place a portion of the plant in a sample container with some water. Shake it vigorously and rub gently to remove algae. Remove plant form sample container.

Large substrates (not removable): boulders, bedrock, logs, trees, and roots. - Place PVC pipe with a neoprene collar at one end on the substrate so that the collar is sealed against the substrate. Dislodge algae in the pipe with a toothbrush, or scraper. Remove algae from pipe with pipette.

Loose sediments: sand, silt, fine particulate organic matter, clay. – Invert petri dish over sediments. Trap sediments in petri dish by inserting spatula under dish. Remove sediments from stream and rinse into sampling container. Algal samples from depositional habitats can also be collected with spoons, forceps, or pipet.

Place samples collected from all substrate types into a single watertight, unbreakable, wide mouth container. If a single habitat is sampled, collect from several areas. A composite sample measuring four ounces (125 ml) is sufficient. Add preservative, and place label on outside of container with pertinent information.

Transport samples on ice and in the dark.

Return to TOC

6.11 Toxicological Sampling (Toxicity Test or Bioassay)

6.11.1 Dilution Water Sample Collection and Handling:

Dilution water is acceptable for use in a bioassay provided healthy test organisms survive in it through the acclimation period without showing any signs of stress, including but not limited to, abnormal behavior or discoloration.

Dilution water samples shall be representative of the receiving water system which the effluent is discharged into. Samples shall be collected in the following manner:

In non-tidal waters, dilution water samples shall be collected from a location as close as possible to, but upstream of, the effluent-mixing zone.

In estuarine waters, dilution water samples shall be collected from a location as close as possible to, but upstream of, the effluent mixing zone. Samples shall also be collected during the outgoing tide up to and during low slack tide.

In marine waters (that is, tidal saltwater), dilution water samples shall be collected from a location outside the influence of the effluent being tested.

The sampling location shall be such that the salinity of the sample shall be within the salinity range for receiving water immediately outside of the effluent mixing zone.

When samples are collected from streams or rivers, an integrated sample shall be collected. This is a sample that is collected from bottom to top of the water column so that the sample collected is proportional to flow. If only a grab sample can be taken it should be collected at mid-depth in midstream.

When samples are collected from reservoirs or lakes, the effects of seasonal stratification, runoff, and previous rainfall upon the chemical/physical characteristics of the water shall be considered.

If the receiving water has a natural pH below 5.0 units, then the dilution water samples shall be adjusted to pH 5.0 prior to their use in test organism acclimation and/or toxicity test.

If the receiving water is influenced immediately upstream of the effluent outfall by other point sources of pollution so as to disqualify its use as dilution water, (in accordance with the NJPDES permit), then the dilution water sample(s) shall be obtained from a location just above the other point sources in the case of streams, or outside the zone of influence of other point sources in the case of other water bodies.

If acceptable dilution water cannot be obtained from the receiving water at any location because an effluent is discharged into the receiving water headwaters, then some other unpolluted water, meeting the following requirements, shall be used as an alternate in the following order of preference:

Another surface water or ground water having a natural quality similar to that of the receiving water prior to its pollution may be used; or

Reconstituted or artificial freshwater or saltwater having a natural quality similar to that of the receiving water prior to its pollution may be used; and

Substitute dilution water shall have a total hardness, total alkalinity, salinity and specific conductance within 25 percent and a pH within 0.4 units of the receiving water prior to its pollution, but not less than 5.0 units.

Alteration of dilution water samples shall be limited to the following:

Filtration is conducted through screening made of a non-toxic material. This screening shall have a mesh of 2 mm or larger if sample is to be used for fish testing or 0.45 microns or larger for zooplankton and macrocrustacean testing.

Adjustment of the salinity of dilution water samples shall only by either the addition of laboratory pure water to lower the salinity or by the addition either a hypersaline brine or artificial sea salts to raise the salinity made in accordance with N.J.A.C. 7:18 9.5(a)6.

Sample collection and transport containers shall meet the requirements listed in Appendix 3-1. Prior to sample collection, containers shall be pre-rinsed with the dilution water and then filled so that there is little or no air in the container neck or cap.

Dilution water sample storage shall be in covered containers constructed of non-toxic materials as specified in N.J.A.C. 7:18-7.3(a)13.

Dilution water samples shall not be stored for more than 150 hours and should be collected as close as possible to the time of testing.

6.11.2 Effluent Samples Shall be Collected and Handled in the Following Manner.

Unless otherwise specified by the Department, the effluent sampling location shall be the same as that specified in the applicable permit. The Department may specify an alternate sampling location when the following conditions prevail:

- When there is better access to the effluent at a point located between the final treatment and the discharge outfall. That point shall be the sampling point, or
- When the chlorinated effluent is dechlorinated prior to discharge and the purpose of the test is to determine the toxicity levels of the dechlorinated effluent. The sampling point shall be located after dechlorination.

The following sampling procedures shall be adhered in order to insure a representative effluent sample:

If the facility discharges wastewater continuously, the following procedures shall be used: Twenty-four hour composite samples consisting of equal volumes collected at least once every hour or a flow proportionate 24 hour composite sample shall be collected and used to set up a single toxicity test. This procedure is repeated for the duration of toxicity tests or; the effluent shall be pumped directly and continuously into the dilutor system of the toxicity test, for the duration of the test.

If the facility discharges wastewater intermittently, one of the following procedures shall be used:

When the effluent is discharged continuously only during a single work shift, or two successive work shifts, at least one composite sample, of sufficient volume to set up the toxicity test, shall be collected;

When a facility retains the wastewater during a work shift, then treats and releases it in a batch discharge, a grab sample shall be collected during the discharge period. Sufficient volume of sample shall be collected for the set up and renewal of the toxicity test during the hours intervening between effluent discharges. Use caution when collecting these samples as wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

When a facility discharges wastewater to an estuary only during an outgoing tide, a single grab sample or composite sample (as specified by the Department in the NJPDES permit), of sufficient

volume to set up the toxicity test shall be collected on the outgoing tide. This procedure is repeated for the duration of the toxicity test.

Effluent samples shall be chilled during or immediately after collection for transport to the lab.

Alteration of samples shall be limited to:

Filtration through Teflon® or No. 316 stainless steel screening having a mesh of 2mm or larger. Screening constructed of unplasticized polyethylene or polypropylene may be substituted provided the screens are discarded upon the completion of a bioassay.

Introduction of dry artificial sea salts or hypersaline brine for the purpose of adjusting the effluent test concentration.

Using a dechlorinating agent to reduce the level of chlorine in an effluent sample. Any adjustments made shall be consistent with N.J.A.C. 7:18-9.5(b)6.

All sampling equipment shall be constructed of approved materials in accordance with N.J.A.C. 7:18-7.3 and cleaned in using the methodology in accordance with N.J.A.C. 7:18-7.4(c). Prior to sample collection, containers shall be pre-rinsed with the effluent and then filled, using the specified procedures, so that there is no air space in either the neck or cap.

Unless the purpose of the bioassay is to ascertain the persistence of the toxicity of an effluent, testing shall begin within 24 hours of the collection of an effluent.

6.11.3 The Following Chain of Custody Procedures Shall be Employed in Collecting and Handling Composite or Grab Samples:

Only clean or new containers, previously rinsed with the material being sampled shall be used for taking composite or grab samples.

Tie-on affixed labels with an identification number shall be used for labeling all samples.

After a sample has been collected, the appropriate information as to identity of the sample shall be written on the label and the label affixed. The label shall remain affixed until the test has begun and the surplus has been discarded.

Immediately upon delivery of a sample to the laboratory, the sample collector shall complete the appropriate chain of custody section of the sample report form or chain of custody form.

The chain of custody form shall list at a minimum the following information:

- Sample number;
- Description of samples;
- Specific location of sample collection;
- Identity of person collecting the sample;
- Date and time of sample collection;
- Date and time of custody transfer to laboratory (if the sample was collected by a person other than laboratory personnel);
- Identity of person accepting custody (if the sample was collected by a person other than laboratory personnel);

Date and time of initiation of analysis. Identity of person performing analysis; and Name of the laboratory performing the analyses.

Appendix 6.1
Monitor Well Construction and Installation

A.6.1.1 Introduction

Monitor wells are installed to collect groundwater quality data, hydrologic information and determine ground water flow direction. They can be installed either permanently or temporarily. The types of wells used for remedial investigations include Category 3 Resource Evaluation Wells which include monitoring wells, air-sparging wells, soil vapor extraction (SVE) wells, recovery wells and temporary wells installed for environmental remediation projects (see N.J.A.C. 7:9D-2.1(a)3). Category 5 Geotechnical Wells include test borings, probe holes and borings involving use of direct-push methods (see N.J.A.C. 7:9D-2.1(a)5).

Their method of installation and construction can greatly impact the quality of ground water samples collected from them. For example, temporary wells that are driven or pushed do not always have filter packs, which may result in samples with high turbidity levels. This artifact would have to take this into consideration if samples are to be collected for metals analysis. The following text describes different methods of well drilling and monitor well construction with considerations for their use and possible impacts on ground water samples. All wells must be installed by a New Jersey-licensed well driller of the appropriate class, pursuant to N.J.A.C. 7:9D. Prior to installing a well, the well driller must obtain a well drilling permit from the Bureau of Water Allocation (BWA, 609-292-2957), pursuant to N.J.A.C. 7:9D-1.11. Within 90 days of completing a well, the well driller must submit a well record to BWA, pursuant to N.J.A.C. 7:9D-1.15.

The drilling methods described below also are applicable to the collection of subsurface soil samples. Profiles of subsurface conditions encountered and well installation details must be recorded on logs, preferably by a qualified geologist and submitted with the completed well record to the Bureau of Water Allocation. The information recorded must include that specified at N.J.A.C. 7:26E-3.6(a)2, at a minimum, and should be consistent with applicable standard protocols including those of the American Society for Testing and Materials (ASTM). See also Section 6.2.3, *Soil Log* and Section 6.2.3.5, *Soil Classification.*

A.6.1.2 Conventional Well Drilling Methods

A.6.1.2.1 Hollow-Stem Augers (HSAs)

Wells can be installed in unconsolidated formations using solid-stem or hollow-stem augers (HSAs). The augers are advanced by rotation and the drill cuttings are brought to the surface by travelling up the outside of the auger flights in a screw-like manner. HSAs have the advantage of allowing the well to be installed inside the hollow stem of the auger, which prevents the borehole from collapsing. Upon reaching the planned well depth, the casing and screen are placed inside the HSAs and the flights are individually removed while the annular space around the well is filled with the filter pack and grout, as appropriate. Conversely, solid-stem augers must be completely removed from the borehole before well installation, which can lead to collapse of the borehole. For this reason, solid stem augers are seldom used for installation of monitor wells.

HSAs come in a variety of sizes and allow collection of soil samples utilizing split spoons or Shelby tubes. Samples are collected ahead of the augers for determining soil/sediment type, stratigraphy, the depth to the water table and for collecting soil samples for chemical analysis. During this process, the standard penetration test (SPT, ASTM Method D 1586) can also be

performed. The HSA method also has an advantage over mud-rotary drilling techniques in that drilling mud is not used. Drilling mud can contaminate the soil samples or and potentially reduce the yield of the wells.

A disadvantage of the method is that HSAs cannot be used to drill into competent bedrock or through large boulders. Also, “heaving or running sands” can be forced up inside the augers as a result of strong vertical groundwater gradients, which can hamper efforts to collect soil samples or complete well installation. Furthermore, the maximum depth achievable using HSAs, which is generally shallower than other methods is dependent not only on the ability of the rig (e.g., horse-power, rig-torque, weight of augers etc.) but also the lithology of the material drilled.

A.6.1.2.2 Rotary Drilling

Rotary drilling methods include direct rotary and reverse-circulation rotary. Direct rotary is more commonly used in environmental investigations whereas reverse-circulation rotary is used in drilling large-diameter water supply wells. In direct rotary drilling the borehole is advanced by rotating the drill pipe (rods) and bit to produce a cutting action. The cuttings are removed from the borehole by continuous circulation of a drilling fluid. The fluid or “mud” is pumped down the inside of the drill pipe and is circulated back to the surface on the outside of the pipe. The fluid removes the drill cuttings from the borehole and cools and lubricates the bit. Mud used during direct rotary consists of additives (e.g., bentonite) water or air.

Reverse-circulation rotary drilling is similar to direct rotary except the drill rigs are larger and the flow of the drilling fluid is reversed. The drilling fluid moves upward inside the drill pipes and circulates back to the borehole via settling pits. The drilling fluid returns to the borehole via gravity and moves downward in the annular space between the drill pipe and borehole wall. Drilling fluids for reverse circulation rotary are generally water and any suspended particles picked up from the surrounding formations

Mud-rotary methods can be used to drill in both unconsolidated and consolidated (bedrock) formations. In addition, drilling mud stabilizes the borehole and limits the potential for borehole collapse. Disadvantages of using the mud-rotary method include the difficulty in determining the depth to the water table, the potential for drilling mud to impact soil samples and dragging of contamination into deeper zones since the drill cuttings are re-circulated in the borehole. Wells installed using this method typically take longer to develop (see below) than wells installed using the HSA or air-rotary methods due to the invasion of mud filtrate into the formation.

In air-rotary drilling, compressed air is directed down the inside of the drill pipe. As in mud-rotary drilling, air removes the cuttings and lubricates the bit. However, since air has no viscosity, it cannot be used to stabilize a borehole therefore, casing must be advanced in unconsolidated formations to keep the borehole open. This is why air rotary methods are best suited for drilling in bedrock formations. The percussion-type air-rotary “hammer” bit provides the best penetration rate when drilling bedrock consisting of crystalline rock. However, when drilling above the water table, an air-rotary bit can grind the soil and bedrock to a fine powder which is blown out of the hole with air and which has the potential to be inhaled. Therefore, drilling above the water table using air-rotary methods requires the addition of potable water to the borehole for dust control. In addition, the air compressor should be of the oil-less variety or have a filter to prevent any oil from entering the borehole.

A disadvantage of using rotary methods while drilling in unconsolidated formations is the requirement of pulling the drill pipe out of the hole each time that a split-spoon soil sample is collected (and the SPT is performed). This can add up to a considerable amount of time when deep wells are

being installed or when continuous split-spoon sampling is being performed. As stated above, split spoons used to collect soil samples can become contaminated when they are advanced down a mud-filled borehole.

A special type of rotary drilling is bedrock coring, wherein a special core bit and barrel are used to retrieve relatively undisturbed core samples of the bedrock. Coring allows better characterization of bedrock lithology and other features including orientation of fractures and bedding planes, which can control contaminant migration. Core barrels can either be unoriented or oriented. An oriented core is scribed with respect to magnetic north. Although more expensive than collecting an unoriented core, this method gives the true orientation of the features encountered in the core. Logging of rock core should be consistent with N.J.A.C. 7:26E-4.4(g)5. See the section on coring in Chapter 6, Section 6.3.4, *Core Logging*.

A.6.1.2.3 Drilling Fluids

Drilling fluids are generally air (air-rotary) or bentonite and/or water (mud-rotary). Water added to a borehole must be of potable quality. The source of the potable water used during the installation (and development) of monitor wells should be documented (e.g., in the Remedial Investigation Report).

Bentonite is high swelling clay with sodium montmorillonite as its primary clay mineral. Bentonite is added to water to increase the viscosity of the drilling fluid so that drill cuttings can be removed from the borehole more effectively. At the same time, the viscosity must be low enough to allow cuttings and coarse-grained particles to settle out once they are circulated out of the hole. Bentonite also adds weight to the drilling fluid, which helps to maintain borehole stability.

While all drilling fluids have the potential to impact groundwater quality to some extent, the use of polymer-based drilling muds (e.g., Revert®) can significantly impact the quality of water samples collected from wells. Biologic activity related to the decomposition of these compounds can cause a long-term variation in the quality of the water sampled from the well (EPA, 1991, and Barcelona, 1983). Therefore, use of polymer-based drilling muds is not acceptable unless specific approval is first obtained from the SRP case/site manager or geologist.

A.6.1.3 Specialized Drilling Methods

A.6.1.3.1 Sonic Drilling

A resurrected and fastly becoming popular drilling technology used in the environmental field is sonic drilling, which is sometimes called rotosonic drilling. The method involves driving a core barrel using vibration, rotation and a downward force to collect soil samples. A sonic drill rig looks and operates very much like a conventional top-drive rotary or auger rig. The main difference is that a sonic drill rig has a specially designed, hydraulically powered drill head or oscillator, which generates adjustable high-frequency vibrational forces. The oscillator uses two eccentric, counter-rotating balance weights or rollers that are timed to direct 100 percent of the vibrational energy at 0 degrees and 180 degrees. There is an air spring system in the drill head that insulates or separates the vibration from the drill rig itself. The sonic head is attached directly to the drill pipe or outer casing, sending the high-frequency vibrations down through the drill pipe to the bit.

A core barrel is advanced using vibration, rotation, and downward force to collect continuous soil cores up to 20 feet in length. The bit at the end of the core barrel contains carbide teeth allowing the core barrel to be advanced through most overburden, soft bedrock, and minor obstructions such as bricks and boulders. Once the core barrel has been advanced, a secondary or “over-ride “ casing is advanced down to the same depth as the inner core barrel. The over-ride casing keeps the

borehole from collapsing while the inner core barrel is removed. Once the core barrel is removed, the soil core is pushed out of the core barrel through the use of vibration and either air or water pressure. Soil core diameters are dependent on the size of core barrel used and range from 3 to 12 inches. The use of multiple over-ride casings of increasing diameter allow the borehole to be telescoped down through multiple confining units. Continuous soil cores to over 400 feet have already been installed in New Jersey using this method. The setup used in sonic drilling makes this drilling method amendable to collecting soil cores and installing wells in angled boreholes. With only the bottom of the inner and outer core barrel exposed to the aquifer at any given time, determining the location of the water table can be difficult.

When using this drilling method to collect soil cores that will be used to obtain soil samples for VOC or SVOC analysis, two issues of concern must be addressed: heating of the soil core during drilling, and disturbance of the core during drilling, extraction and handling.

While this drilling method has the capability of drilling through and providing samples of coarse gravels, boulders and tight clays, these situations will result in slow drilling or advancement of the core barrel. The result is a hotter core barrel and a longer contact time between the core barrel and the encased soil core. The aforementioned conditions will increase the probability that the sonic method will raise the temperature of the soil core and facilitate VOC and SVOC loss. If heating of the soil core is a concern, the following procedures should be implemented:

- Collect soil cores in shorter runs. While some sonic rigs have the capability of collecting 20 feet of soil core at a time, the process of collecting the longer core results in the core being in contact with the core barrel for a longer period of time and consequently absorbing more heat from the core barrel itself.
- Add water between the inner core barrel and the outer override casing. This water would reduce friction and adsorb heat between the inner core barrel and the outer over ride casing.
- Maximize drilling advance rate. The faster the core barrel is advanced, the less likely the core barrel will heat up, and the less contact time the soil core has with the core barrel. Drilling with a 3-inch diameter core barrel and a 5-inch diameter override casing, instead of the standard 4-inch core barrel and 6-inch over ride casing, may increase advance rates and reduce the potential for soil core heating. If a significant decrease in drilling advance rate is observed, stop drilling and remove what soil core has accumulated in the core barrel. Resume drilling through the resistant material (gravel, boulder, hard clay, etc.). When the resistant material has been penetrated and the drilling advance rate increases, stop drilling and remove what material has accumulated in the core barrel. Wash down the core barrel with cool water to cool the core barrel and associated casing, and resume drilling.

Disturbance of the soil core is most likely to occur during removal of the soil core from the core barrel. The soil cores are usually vibrated out of the core barrel into plastic bags approximately 5 feet in length. As the plastic bags are a little larger than the soil core itself, fragmentation of the soil core may occur as the core is extruded into the bag or while the bagged core is being moved in an unsupported manner. Soil conditions that are prone to disturbance include wet or dry zones that contain little or no fines, and well graded sands that contain significant volumes of water.

If integrity of the soil core is of concern, the following procedures should be implemented:

- Measures should be taken to ensure that the core, from the time it is extruded from the core barrel, is rigidly supported through the use of some type of cradle or carrying device.
- The core should not be removed from its cradle until all sampling of the core has been completed. Acrylic liners are available for some core sizes and can be used to hold the core together upon removal from the core barrel.

- If the soil is to be sampled for VOCs, acrylic liners must be used.

Sonic drilling has been approved for:

- geologic profiling through the production of soil cores;
- collection of insitu ground water grab samples during borehole installation;
- well installation and;
- sampling of the soil core for metals, PCBs, and pesticides.

Sampling of the soil core for VOCs or SVOCs must be approved on a case by case basis. Proposals for VOC or SVOC soil core sampling must include provisions to minimize core fragmentation and heat generation, such as:

- the use of acetate liners in the core barrel so that the soil core does not have to be extruded out of the core barrel;
- limiting the length of soil core generated during a given downhole run and;
- implementing practices to reduce the residency time of the soil core in the core barrel. For the analysis of SVOCs, the use of the acetate liners is not required.

The large diameter of the core barrel enables ground water sampling equipment to be placed inside the core barrel so that discrete depth groundwater samples can be collected during borehole advancement. If a well is to be installed in the borehole, the sandpack and grout are placed as the core-barrel and over-ride casing(s) are selectively vibrated out of the ground. The vibratory action reportedly facilitates the settlement of the sandpack and grout. Upon completion, no casing is left in the ground other than the well casing and screen.

Another application of the sonic method involves vibratory direct push installation of monitor wells without drilling a borehole. However, knowledge of the local stratigraphy (depth of confining layers, etc.) and depth to water should be known before the wells are installed. Therefore, soil sampling using sonic methods or other, conventional, methods (e.g., split-spoon sampling) should be performed prior to installing wells using the sonic method. This method does not allow or require installation of filter pack and grout filling of annular space. Approval to install wells in this manner should first be obtained from the SRP case/site manager or geologist.

The ability to quickly install deep borings and wells, while generating a large-diameter continuous soil core, makes this drilling technique invaluable when continuous soil sampling is needed to assess deep or complex geological situations. However, sonic drilling's high cost, relative to other drilling methods, may be prohibitive for small projects or shallow boreholes. The higher cost of the drilling method should be weighed against the cost savings incurred due to its faster drilling rate and high quality of the soil core produced.

A.6.1.3.2 ODEX® Method

In situations where boreholes cannot be stabilized, conventional drilling methods may not be adequate for drilling soil borings or installing monitor wells. In these situations, the ODEX® method can be used to simultaneously drill and case a borehole. This method involves use of an eccentric bit, along with a conventional rotary hammer, to drill a borehole of slightly larger diameter than the casing (See Figure 6.10). The bit retracts to allow its passage through the casing. Once below the casing, the bit is expanded and used to drill a slightly larger borehole. The bit can be retracted and retrieved through the casing to allow collection of soil and/or rock samples.

A disadvantage of the method is the fact that installation of the casing is only temporary. (The Department does not allow installation of permanent casing in monitor wells using this method.) It

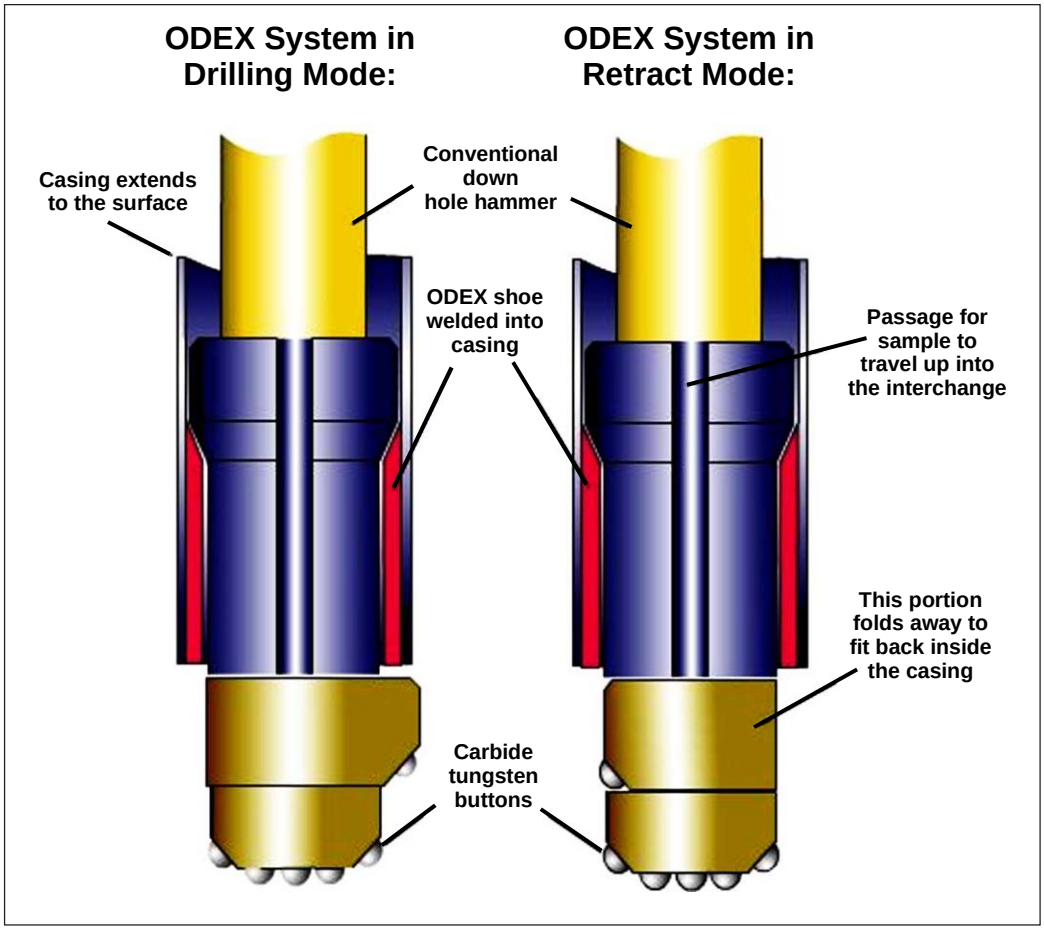


Figure 6.10 ODEX® System. Source: http://www.midnightsundrilling.com/ODEX_system.html

cannot be grouted in place. This means that conventional methods must be used to install and grout outer casing when installing monitor wells in confined aquifers. Another disadvantage of the method is the potential for rock cuttings to jam the bit and not allow it to be retracted and, therefore, retrieved through the casing.

A.6.1.3.3. Direct-Push Drilling

Direct-push technology was first developed in the geotechnical industry using cone penetrometer testing (CPT) methods to obtain information on soil/sediment type, stratigraphy and the depth to groundwater without collecting actual soil samples and installing monitor wells. The method involves pushing rods into the subsurface under a constant weight while recording such parameters as sleeve friction stress, tip stress and pore pressure. The method has been expanded in the environmental industry to include the investigation for hydrocarbons (e.g., the fuel fluorescence detector or FFD® developed by Handex and the Laser Induced Fluorescence (LIF) Probe used in the SCAPS system), and natural gamma and resistivity logging tools. These methods provide only screening-level data quality. However, they allow the collection of numerous data points in one mobilization without generating any soil cuttings, which would otherwise have to be characterized and disposed of.

A variation of the method involves hydraulically pushing hollow rods into the subsurface for the purpose of collecting soil and/or groundwater samples (e.g., Geoprobe®). The method can be used

to install small-diameter wells used to collect groundwater samples. These wells are usually installed for temporary use and subsequently retrieved. (i.e., Category 5 *Geotechnical Wells*). Wells installed to a depth of 50 feet or less and that remain in place 48 hours or less do not require boring permits. Wells installed to depths greater than 50 feet or that remain in place longer than 48 (i.e., Category 3 *Resource Evaluation Wells*) hours require well drilling permits and completion of well abandonment reports when decommissioned; these wells must be decommissioned using an approved grout material.

Advantages of the direct-push method include the relatively quick collection of groundwater samples and, when used along with a mobile laboratory, collection of data in "real" time. The method allows for collection of multiple samples in a day with the potential for achieving contaminant delineation in one mobilization of the field equipment. The data can also be used to select locations of permanent monitor wells.

Disadvantages of the method include the fact that the data quality achieved are often suitable only for screening purposes. Direct-push methods typically result in very turbid samples since an oversize borehole is not produced and a filter pack is not used. Turbid samples can produce higher metals concentrations in groundwater samples since metals are typically adsorbed onto soil particles. Use of direct-push methods can also cause cross-contamination since contamination from shallow zones may be driven down to deeper zones. Due to the narrow diameter of the direct-push rods, samples are often collected with peristaltic pumps. When samples are collected for volatile organic compounds (VOCs) using peristaltic pumps, some of the volatiles may be lost due to the pressure drop produced by the suction lift. In such cases, the VOC data must be qualified accordingly. For this reason, use of the peristaltic pump for collecting groundwater samples for VOC analysis is not recommended and approval for its use should first be obtained from the SRP case/site manager or geologist.

Another disadvantage of using direct-push technology for collecting groundwater samples is the potential to breech confining units. To prevent this, soil sampling using direct-push technology or conventional split-spoon sampling techniques should first be performed to identify the presence, depth and lateral extent of confining units. Pushing through confining units should be avoided if the presence of dense, non-aqueous-phase liquid (DNAPL) or very soluble compounds such as MTBE are suspected or the contaminant plume appears to be diving in the aquifer.

For additional information on well drilling methods, please refer to the, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, (EPA, 1991).

A.6.1.4 Monitor Well Design And Construction Considerations

Well construction specifications for unconsolidated, confined and bedrock aquifers are provided in this Appendix. As provided in N.J.A.C. 7:9D, most wells used in the investigation of contaminated sites are Category 3 wells (resource evaluation wells including monitoring wells, air sparging wells, soil vapor extraction wells, recovery wells, and wells or well points installed for environmental projects) and Category 5 wells (geotechnical borings including test borings, probe holes and those involving direct-push technologies). Requirements for the construction and maintenance of all Category 3 wells are provided at N.J.A.C. 7:9D-2.4. Specific requirements for the installation of Category 5 geotechnical borings are provided at N.J.A.C. 7:9D-2.6. Any proposed deviations from these construction standards must be approved by the BWA, pursuant to N.J.A.C. 7:9D-2.8.

The following is a discussion of different aspects of monitor well construction.

A.6.1.4.1 Well Diameter

Well construction varies depending on the intended use of the wells. Most permanent, overburden monitor wells are constructed of two-inch- or four-inch-diameter polyvinyl chloride (PVC) or stainless steel, as most sampling devices can easily accommodate these diameters. For wells used to extract groundwater (e.g., recovery wells), well diameters may need to be larger (e.g., six inches or greater) to accommodate submersible pumps.

The Site Remediation Program does not ordinarily allow use of permanent monitor wells with a diameter of less than two inches unless they are used for the sole purpose of obtaining water-level measurements (i.e., piezometers). The use of piezometers to collect groundwater samples may be approved by the Site Remediation Program provided they meet the monitor well construction requirements.

In all cases where wells are installed in oversize boreholes, the borehole diameter must be a minimum of four inches larger than the well casing diameter. For example, a borehole must be at least eight-inches in diameter if a four-inch well casing will be installed.

A.6.1.4.2 Well Construction Materials

Overburden monitor wells should be constructed with either PVC or stainless steel casing and screen. In general, PVC is acceptable for most applications. However, where free product is present and it is likely to cause failure of the well, use of PVC may not be appropriate since PVC can degrade in free product causing the well to collapse or the screen to fail. In this case, stainless steel should be used. However, stainless steel should not be used in highly corrosive waters since metals may leach from the stainless steel causing the detection of false positives in water samples analyzed for metals. In such waters, PVC should be used. Other construction materials (e.g., PTFE) must be approved by the SRP case/site manager or geologist prior to use.

Bedrock wells are typically constructed using carbon steel casing with the intake of the well being an open hole in the bedrock. In cases where the bedrock is friable, well casing and screen may be installed in the borehole of a bedrock well. Either PVC or stainless steel well casing and screen may be appropriate for installation in bedrock, depending on the type of contaminants present (see paragraph above). In this case, installation of an outer casing (double-cased well) may not be necessary, particularly where there is a thin overburden formation and the bedrock is shallow and instead, a single-cased well that is consistent with the Monitor Well Requirements for Unconsolidated Aquifiers may be appropriate. However, the driller must submit a deviation request to the Bureau of Water Allocation that is consistent with N.J.A.C. 7:9D-2.8(a). If the borehole diameter is 6-inches, then the casing and screen diameter should be 2-inches.

A.6.1.4.3. Screen Length

The maximum length of well screen (or open borehole in bedrock wells) for monitor wells is 25 feet. The purpose of this limitation is to minimize the potential to cross-contaminate uncontaminated aquifers. In most cases, screen length should be minimized (e.g., 5 to 10 feet of screen) if sufficient well yield is available to allow sampling of the well. In cases where low-flow sampling is intended in newly installed monitor wells, the wells should be installed with no more than five feet of screen (see Section 6.9.2.2, *Low-Flow Purging and Sampling*).

In cases where a well will be used for groundwater recovery, injection, air sparging, soil vapor extraction or aquifer testing, construction of the well with more than 25 feet of screen or open borehole may be acceptable. However, approval must be obtained from the SRP case/site manager or geologist prior to installing such wells.

A.6.1.4.4 Screen Slot Size and Filter Pack Materials

Filter pack material should be clean silica sand which is sized according to the texture of the borehole materials from sieve analysis data. The uniformity coefficient of the filter pack materials should not exceed 2.5. The screen slot size should be selected to retain at least 90% of the filter pack material. No more than five feet of filter pack should be placed above the well screen. The top of the filter pack may be graded from coarser to finer (going upward) to minimize penetration of the overlying grout.

A.6.1.4.5 Grouting Materials

The annular space in wells must be sealed to prevent the borehole from acting as a conduit for vertical migration of contamination. Acceptable grouting materials are provided in N.J.A.C. 7:9D-2.9 and the required procedures for sealing the annular space of wells is specified in N.J.A.C. 7:9D-2.10. All grouting materials should be installed as slurry using a side-discharge tremie pipe in order to prevent invasion of the grout into the filter pack. Examples of material include Portland cement, high-grade bentonite and Portland cement/high-grade bentonite mixtures. *The installation of a bentonite seal above the filter pack using bentonite pellets is not permitted*. Proposals for their use must be submitted as a deviation request to BWA, pursuant to N.J.A.C. 7:9D-2.8(a).

A.6.1.4.6 Well Depth

Pursuant to the Technical Requirements for Site Remediation, groundwater contamination must be delineated both horizontally and vertically (see N.J.A.C. 7:26E-4.4(h)3i). This may require installation of wells in clusters at various depths (see also Multi-screened Wells below). The well clusters not only provide information on water quality with respect to depth but also provide information with respect to horizontal and vertical hydraulic gradients in the aquifers which is required to properly characterize contaminant fate and transport.

Special considerations may be necessary for the construction of deep wells compared to shallow wells. For example, deep wells installed with 2-inch-diameter PVC casing and screen may require the use of Schedule 80 (wall thickness 0.218 inches), rather than Schedule 40 (wall thickness 0.154 inches), PVC since it is more rigid.

A.6.1.4.7 Multi-Screened Wells

Where groundwater contamination is found to be present at depth, the use of multi-screened or multiple-level wells may provide information on the vertical extent of contamination. The installation of such wells must be performed as prescribed by the manufacturer and must first be approved by the Department, pursuant to N.J.A.C. 7:9D-2.8. Examples of such wells include the Waterloo Multilevel Groundwater Monitoring System® and the FLUTe® method. (This should not be construed to represent an official Department endorsement of these methods; this discussion is for informational purposes only.) Seals installed between well intake zones should be at least two feet thick.

In most cases, installation of well pairs (e.g., shallow and deep) and well clusters (e.g., shallow, intermediate and deep) may be more appropriate than installation of multi-screened wells since they use conventional well installation technology. No packers are used to separate sample ports; packers can fail or not seal properly.

Likewise, well clusters, where wells are installed in separate boreholes, may be more appropriate than well nests in which multiple wells share the same borehole. Grout is less likely to invade well intakes (screens) if the wells are installed in separate boreholes. Regardless of which method is

used (i.e., well clusters versus well nests and mulit-screened wells), care must be taken to assure that any confining unit between aquifer zones is not breached without providing adequate protection of underlying/overlying aquifers (e.g., installing double casing and grout, etc.).

Disadvantages of multiple-level devices are: 1) it is difficult, if not impossible, to repair the device if clogging occurs, 2) it is difficult to prevent and/or evaluate sealant and packer leakage, 3) there is a potential for the sampling ports to be labeled or identified incorrectly, and 4) these installations are more expensive than single-level monitoring wells.

The FLUTe™ (Flexible Liner Underground Technologies, Ltd., see URL below) system involves the use of a flexible liner that can be used to temporarily seal a boring in unconsolidated sediments or bedrock wells. The liners can also be used to sample borings and wells at specific depths through dedicated tubing within the liners. In addition, vapor samples can be obtained in the unsaturated (vadose) zone. The liners can be installed in both vertical and horizontal wells.

The liner can also be coated with a material (e.g., hydrocarbon-detecting paste) that reacts with NAPL. The liner then can be installed through the interior of a cone penetrometer rod. Water is added to the inside of the liner causing the liner to dilate in the hole but not in the CPT rods, which are then removed. After the reaction with the NAPL occurs, the liner is removed from the hole and the NAPL stains and their depths are observed and recorded.

Use of the FLUTe™ method (http://www.flut.com/systems.htm) and multi-screened wells requires specific approval from the SRP case/site manager or geologist and from BWA. Specific approval for installing bedrock wells with more than 25 feet of open borehole must be obtained from both SRP and BWA. For boreholes left open for more than 48 hours, or that are deeper than 50 feet, a well drilling permit must be obtained from BWA; a well record and well abandonment report must also be provided to BWA.

A.6.1.4.8 Pre-Packed Well Screens

Pre-packed PVC well screens are manufactured with filter pack materials (silica sand) inside them or they can be filled with sand in the field. They may also have bentonite seals or a foam bridge, which seals the well and prevents water from above from entering the screen. They have been developed for use with direct-push samplers (see above). The purpose of the pre-packed screen is to reduce the turbidity of the water samples collected using the direct-push method. The pre-packed well screen is placed inside of the direct-push rods. Upon reaching the targeted sample depth, the rods are retrieved leaving the screen in the ground. The seal expands to allow collection of water from a discrete depth. The screens are typically 3/4, 1 1/4 or 2 inches in diameter and 2.5 to 5 feet long. As with any direct-push sampling method, care must be taken to assure that confining units are not breached and contaminants are not permitted to migrate downward into formerly uncontaminated portions of the aquifer.

A.6.1.4.9 Horizontal Wells

Horizontal wells must be installed by a New Jersey-licensed well driller who must obtain a well permit from BWA. All proposals for installation of horizontal wells must first be approved by the Department. Installation of horizontal wells may include well screens longer than 25 feet provided that appropriate justification is submitted to the Department. All proposals for installation of horizontal wells must include the purpose of the well (e.g., monitor well or recovery well), type of well (e.g., blind or continuous), depths of the well/screened intervals, proposed construction diagram, the method used to install and centralize the well casing and screen, the grouting procedures and the specific sampling method(s) that will be used.

A.6.1.4.10 Wells Used to Investigate LNAPL and DNAPL

Any well installed to detect floating product, or light, non-aqueous-phase liquid (LNAPL), must be screened across the water table. Any overburden well installed in either LNAPL or dense, non-aqueous-phase liquid (DNAPL) should be constructed of stainless steel if the NAPL has the potential to cause failure of a PVC well.

Wells installed to detect DNAPL must be constructed so that DNAPL can enter the well screen. N.J.A.C. 7:9D-2.4(c)1 states that the screened interval or the filter pack shall not extend across the interface of a confining layer and an aquifer. However, a well screened down to the top of a confining unit will not necessarily detect DNAPL present on the confining unit if the thickness of the DNAPL is not sufficient enough for it to enter the screen. Most well screens are not slotted down to the bottom of the screen; the lowest slot may be two or three inches above the bottom of the well. In addition, the bottom well cap also raises the well slots from the bottom of the well. For these reasons, the bottom one to two feet of the screen may extend into the confining unit in order to create a sump for the DNAPL to accumulate in, provided that specific approval is first obtained from the Site Remediation Program and the Bureau of Water Allocation for constructing wells in this manner, pursuant to N.J.A.C. 7:9D-2.8. Care must be taken to prevent the well from completely penetrating the confining unit.

Wells installed in bedrock must meet the construction requirements provided in this Appendix and in N.J.A.C. 7:9D-2.4. These requirements include drilling the borehole used to case off the overburden a minimum of 10 feet into competent bedrock. However, if DNAPL and/or dissolved contamination is suspected or likely to be present in the weathered bedrock, the ten-foot casing requirement will hide the DNAPL from detection. In this case, an overburden well (with casing and screen) should be installed in the weathered bedrock and an outer steel casing installed ten feet into bedrock would not be required. Likewise, if the weathered bedrock is found to be contaminated, a well may need to be installed within the upper 10 feet of competent bedrock. If the well will be constructed with an open hole in the bedrock, an outer steel casing should be installed in the top two feet of competent bedrock to case off the overburden and weathered bedrock aquifers. If casing and screen will be installed in the bedrock aquifer, then installation of the outer steel casing may not be required. In any event, specific approval must first be obtained from the BWA for constructing wells in these situations, pursuant to N.J.A.C. 7:9D-2.8.

A.6.1.4.11 Lysimeters

Contamination moving from the surface toward the water table passes through the vadose zone. Because the soil water in the vadose zone is under tension, it cannot flow into a well under gravity. If soil water needs to be sampled, it must be collected with a suction lysimeter.

A suction lysimeter is a porous cup located on the end of a hollow tube (Fetter, 1993). The tube can be PVC or stainless steel. The porous cup can be ceramic, nylon, Teflon^{Ò} or stainless steel. A suction is applied to the hollow tube and held for a period of time. The flow of soil moisture to the porous cup can be slow, and it may be necessary to hold the vacuum overnight to supply a sufficient volume of water for chemical analysis.

Suction lysimeters are considered to be Category 5 wells, pursuant to N.J.A.C. 7:9D-2.1(a)5, and must be installed and decommissioned accordingly, pursuant to N.J.A.C.7:9D-2.6 and N.J.A.C. 7:9D-3, respectively.

A.6.1.5 Miscellaneous Well Construction Considerations

A.6.1.5.1 Well Development

In accordance with N.J.A.C. 7:9D-2.11(b) all well development or redevelopment work shall be performed by a licensed well driller of the proper class. The objective of a monitor well is to provide a representative sample of water as it exists in the formation. Therefore, well development must restore the area adjacent to the well to its indigenous condition by correcting damage done to the formation during the drilling process. Monitor well development is required to: remove drilling fluid residues remaining in the borehole or surrounding aquifer; remove imported drilling water lost to the aquifer during the drilling procedure; restore the hydraulic properties of the formation immediately surrounding the monitor well, and; sort the filter pack material to allow ground water to freely flow to the monitor well.

There are three primary factors that influence the development of a monitor well: 1) the type of geologic material the well is installed in, 2) the design and completion of the well, and 3) the type of drilling method employed to install the well (EPA, 1991). Any of these factors can affect the success of, and the level of effort needed during, well development.

Acceptable well development methods include: bailing, overpumping, mechanical surging, air-lift surging, and water jetting. The best methods involve surging water flow back and forth through the well screen to sort the filter pack materials (see Figure 6.9) (Driscoll, 1986). Pumping alone will tend to cause particles moving toward the well to “bridge” together or form blockages that restrict subsequent particulate movement. The best methods include bailing, pumping/overpumping/backwashing, and surging with a surge block or a combination of these methods. Following the use of these methods, the wells must be pumped to remove the fines from the wells. The use of chemicals (e.g., detergents, chlorine, acids, or other chemicals) to increase or restore the yield of monitor wells is not acceptable. However, their use in recovery and/or injection wells may be acceptable with prior approval from the Department.

Air-lift methods may be used to effectively develop wells installed in permeable formations. However, they may introduce air into the aquifer surrounding the monitor well, and this air has the potential for altering groundwater quality, particularly for volatile organics. For these reasons, air-lift methods should not be performed within a well screen unless the double-pipe method is used. Whenever an air compressor is used, an air filter should be used to filter out any entrained oil.

Overpumping involves pumping a well at a rate that substantially exceeds the rate that the formation can deliver water. This rate is usually much higher than the rate that will be induced during subsequent purging and sampling of the well. This higher rate causes rapid and effective migration of particulates toward the pumping well. However, overpumping alone does not effectively develop monitor wells since a surging action is needed to properly sort the filter pack and permit removal of particulates from the borehole. Where there is no backflow-prevention valve installed, the pump can be alternately started and stopped. This allows the column of water that is initially picked up by the pump to be alternately dropped and raised up in a surging action (backwashing). Also, overpumping of a monitor well during development may draw groundwater to the monitor well from considerable distances and draw groundwater of quality not representative of the immediate vicinity of the monitor well, especially in anisotropic and/or bedrock aquifers.

Well yields determined during the development of monitor wells and the well development method(s) used should be recorded on all well logs, well records and as-built construction diagrams. The well yields should be taken into consideration when designing a sampling program. Well development should not be performed until the day after (i.e., a minimum of eight hours

after) the well has been installed. This will allow time for the cement grout to set prior to well development.

A.6.1.5.2 Maintenance of Wells

Over time wells may become silted up. This may be the result of poor well design (e.g., inappropriate filter pack materials or screen slot size) or cases where wells are installed in fine-grained sediments (e.g., silt). When this occurs, part of the well screen can no longer yield a sufficient volume of water for sampling and/or it may prevent water from the most contaminated zone from entering the well. This requires that the well be redeveloped. Acceptable well development methods are discussed above (see Well Development).

Wells may become damaged due to weather conditions, accidents or vandalism. A well maintenance program should be developed to assure that wells are properly maintained so that samples can be collected that are representative of aquifer conditions and to prevent contaminants at the ground surface from seeping into wells and contaminating groundwater. Periodic inspections should be performed to assure that caps are present and locked, concrete collars are not cracked or broken and that flush-mounted well boxes remain water tight (i.e., lid and gasket are present).

A.6.1.5.3 Well Decommissioning Requirements

All Category 3 monitor wells must be sealed upon abandonment using the methods specified at N.J.A.C. 7:9D-3.1 (general requirement for decommissioning all wells). A Well Abandonment Report must be submitted to BWA within 90 days of decommissioning a Category 3 well. All Category 5 wells and geotechnical borings must be sealed in accordance with N.J.A.C. 7:9D-3.4. Borings 25 feet or less in depth may be decommissioned by back-filling with cuttings, pursuant to N.J.A.C. 7:9D-3.4(b). All borings 25 feet or greater in depth must be decommissioned using an approved sealing material in accordance with N.J.A.C. 7:9D-3.1.

However, the Site Remediation Program also requires that where NAPL is present or is likely to be present and/or confining layers are or may be present, the borehole must be sealed with an acceptable grout (see N.J.A.C. 7:9D-3.1 for acceptable grouting materials). Where the boreholes are 25 feet or less in depth, and no NAPL is present and/or no confining layers have been breached, then the boreholes may be back-filled with native materials.

Upon sealing a monitor well or permitted boring, the New Jersey-licensed well driller of the proper class must submit a Well Abandonment Report to the Bureau of Water Allocation within 90 days of decommissioning the well pursuant to N.J.A.C. 7:9D-3.1(l).

A.6.1.5.4 Flush Mount Wells

In some circumstances (e.g., operating service station), it may be impractical to install wells with casing above the surface. In such situations, flush mounted wells may be installed. Flush mounted wells must be installed with road boxes specifically manufactured for wells. The road box must be of the type with bolt-down lids, waterproof and able to withstand vehicular traffic. The lid must be clearly labeled as a monitor well. The road box must be firmly anchored to, or embedded in, a concrete surface seal. The concrete seal must be sloped away from the box, providing drainage for water and easy vehicular traffic. The road box shall extend slightly above the surface (1-2 inches) to prevent pooling of water on the bolt-down lid.

By the nature of their design, flush-mounted well boxes cannot be locked from the outside. As such, flush-mounted well boxes must be completed with a lockable cap on the inner casing. This cap must be water-tight. No vent hole shall be drilled in the cap or casing. In addition, flush-

mounted well boxes must be large enough to allow adequate room to install and remove the lock and cap from the inner casing. There must also be adequate room to secure the flush-mounted box lid with the inner cap locked in place (See Figure 6.11).

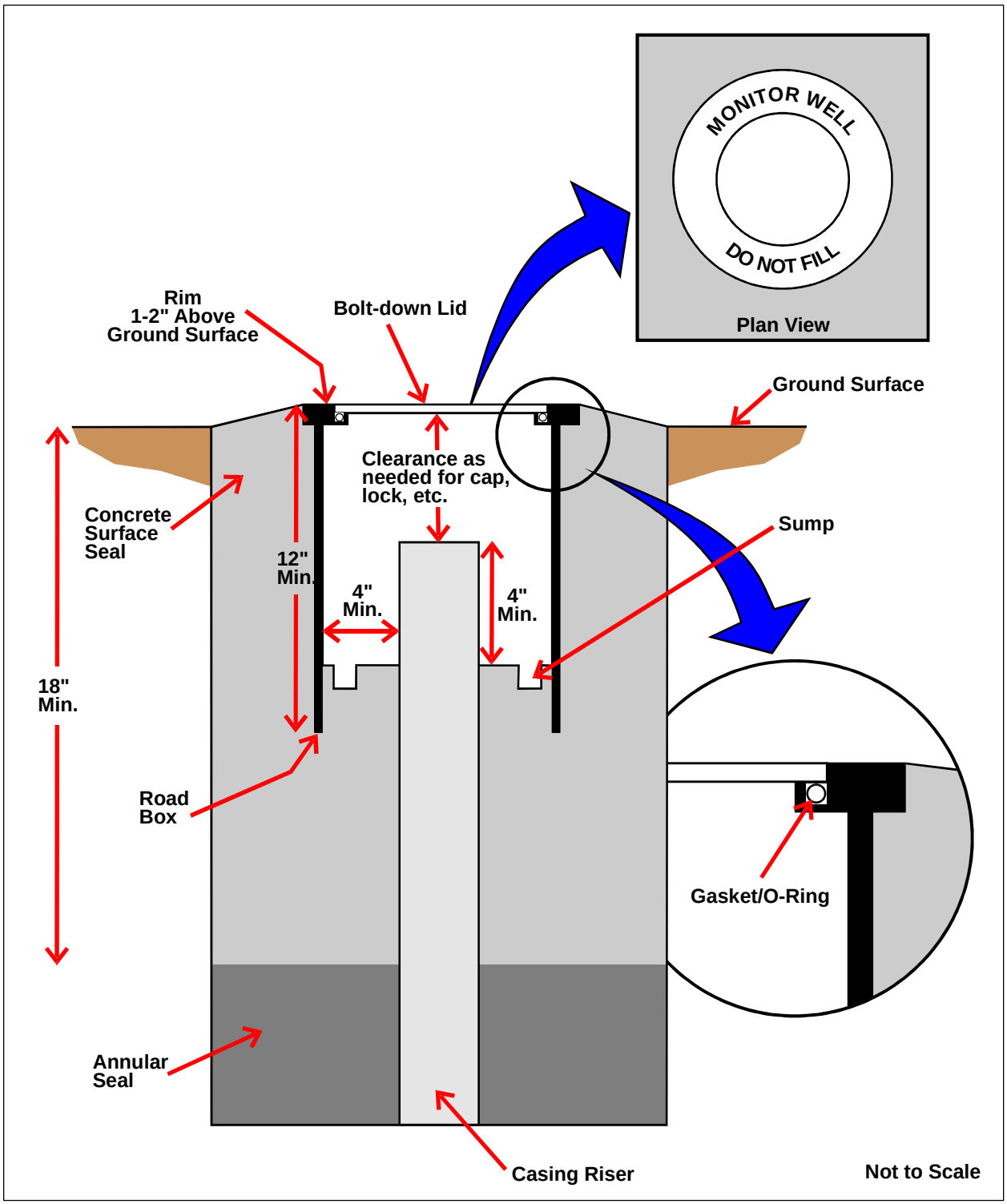


Figure 6.11 Typical Flush-Mount Completion. Illustration by M. Romanell.

Some wells may also be installed in below-grade vaults (e.g., recovery/extraction wells). The vaults must be watertight. Large vaults, whose maintenance would require someone to enter them, may be confined spaces and they would have to be entered with the appropriate precautions.

After installation of a well, a reference point must be marked on the top of the inner casing (with an indelible marker or by notching the top of the casing) for future water-level measurements. The well must be labeled with the owner's well number and Department's well permit number.

A.6.1.5.5 Subsurface and Overhead Utilities

It is the responsibility of the well driller to assure that well drilling activities do not encounter any subsurface or overhead utilities to avoid both disruption to utility services and for health and safety considerations. The driller must comply with all applicable OSHA requirements, pursuant to 29 CFR 1910, during well drilling operations and obtain utility markouts prior to starting drilling activities. At least three business days prior to commencing drilling activities, the driller should call 1-800-272-1000 or, from out of state, 1-908-232-1232. Well drillers should also be participating in a Medical Surveillance Program (MSP) and wear appropriate personal protective equipment.

Appendix 6.2
NJDEP Monitor Well Specifications for Bedrock, Unconsolidated and Confined Aquifers

A.6.2.1 Monitoring Well Requirements For Bedrock Formation (See Figure 6.12)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. The use of glues or solvents is prohibited in the installation of well screens, riser pipes and well casings.
3. The locking cap must be made of steel.
4. A New Jersey-licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be established on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
5. Wells should be developed to a turbid-free discharge.

Notice is Hereby Given of the Following:

The Department does not review well locations or depths to ascertain the presence of, or the potential for, damage to any pipeline, cable, or other structures.

The permittee (applicant) is solely responsible for the safety and adequacy of the design and construction of monitoring well(s) required by the Department.

The permittee (applicant) is solely responsible for any harm or damage to person or property which results from the construction or maintenance of any well; this provision is not intended to relieve third parties of any liabilities or responsibilities which are legally theirs.

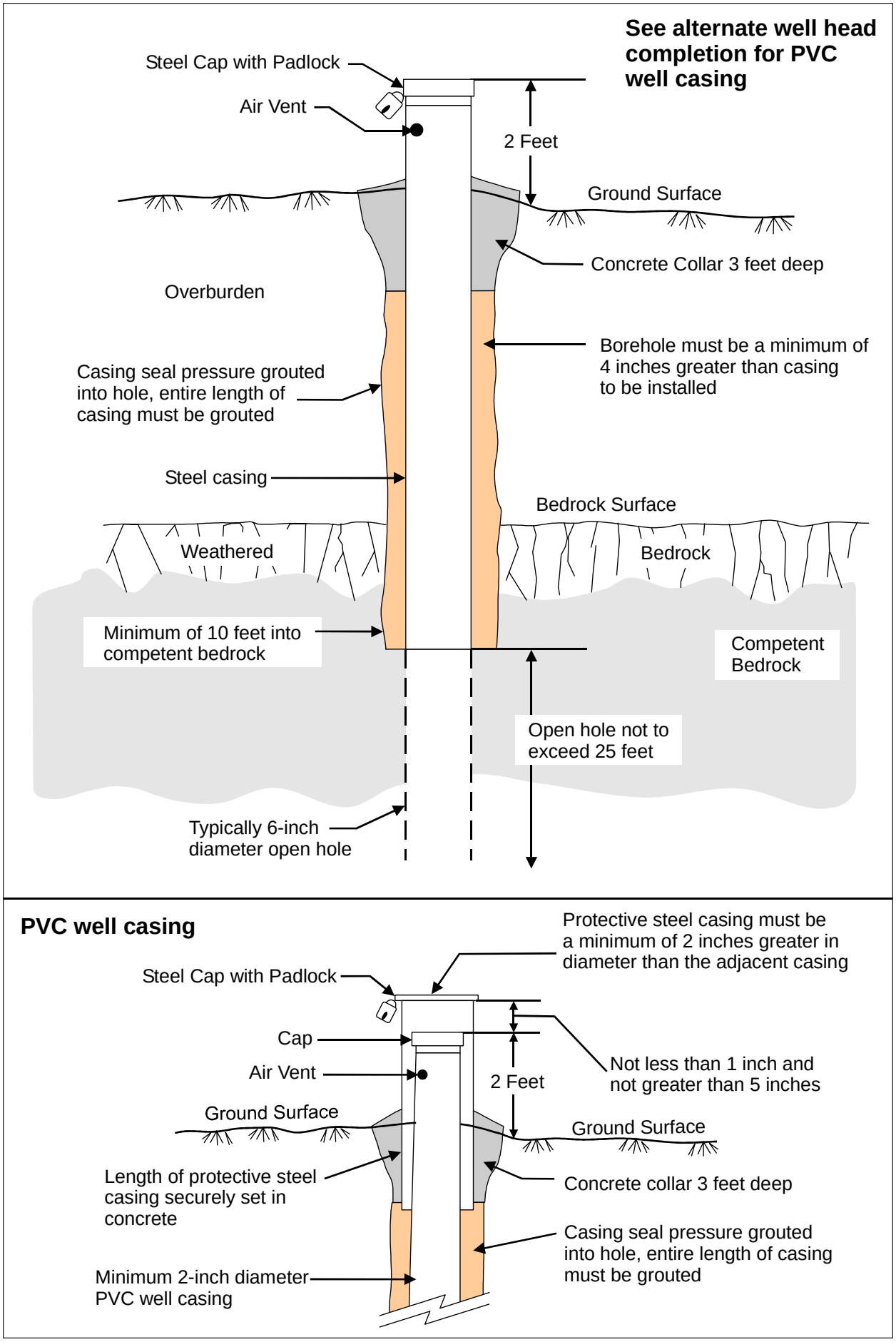


Figure 6.12 Bedrock Formation Well

A.6.2.2 Monitor Well Requirements For Unconsolidated Aquifers (See Figure 6.13)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. Minimum screen and riser pipe inner diameter is 2 inches.
3. The use of glues or solvents is prohibited in the installation of well screens, riser pipes and well casing.
4. In order to prevent any induced interconnection between the overburden/weathered bedrock and competent bedrock, the well screen shall not extend across the aforementioned interface.
5. Wells must have a filter pack installed.
6. When grouting the annular space directly above a filter pack, the grout should be discharged horizontally from the tremie pipe.
7. The locking cap must be made of steel.
8. A New Jersey-licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be extablished on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
9. Wells should be developed to a turbid-free discharge.

Notice is Hereby Given of the Following:

The Department does not review well locations or depths to ascertain the presence of, or the potential for, damage to any pipeline, cable, or other structures.

The permittee (applicant) is solely responsible for the safety and adequacy of the design and construction of monitoring well(s) required by the Department.

The permittee (applicant) is solely responsible for any harm or damage to person or property which results from the construction or maintenance of any well; this provision is not intended to relieve third parties of any liabilities or responsibilities which are legally theirs.

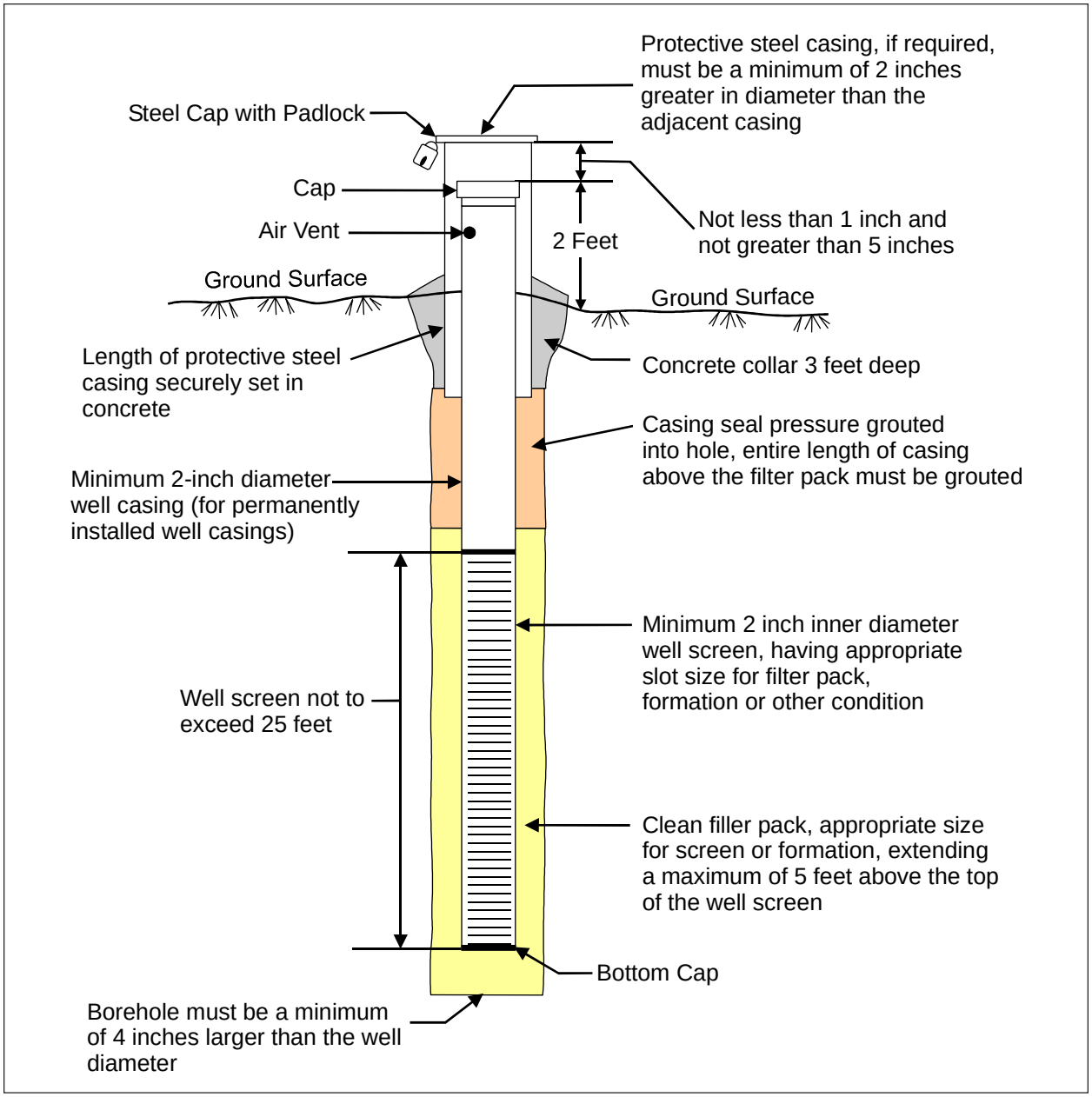


Figure 6.13 Unconsolidated Aquifer Well

A.6.2.3 Monitor Well Requirements For Confined Unconsolidated Aquifers (See Figure 6.14)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. Minimum screen and riser pipe inner diameter is 2 inches.
3. The use of glue or solvents is prohibited in the installation of well screens, riser pipes and well casing.
4. In order to prevent any induced interconnection between the overburden/weathered bedrock and competent bedrock, the well screen shall not extend across the aforementioned interface.
5. Wells must have a filter pack installed.
6. When grouting the annular space directly above a filter pack, the grout should be discharged horizontially from the tremie pipe.
7. The locking cap must be made of steel.
8. A New Jersey licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be established on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
9. Wells should be developed to a turbid-free discharge.

Notice is Hereby Given of the Following:

The Department does not review well locations or depths to ascertain the presence of, or the potential for, damage to any pipeline, cable, or other structures.

The permittee (applicant) is solely responsible for the safety and adequacy of the design and construction of monitoring well(s) required by the Department.

The permittee (applicant) is solely responsible for any harm or damage to person or property which results from the construction or maintenance of any well; this provision is not intended to relieve third parties of any liabilities or responsibilities which are legally theirs.

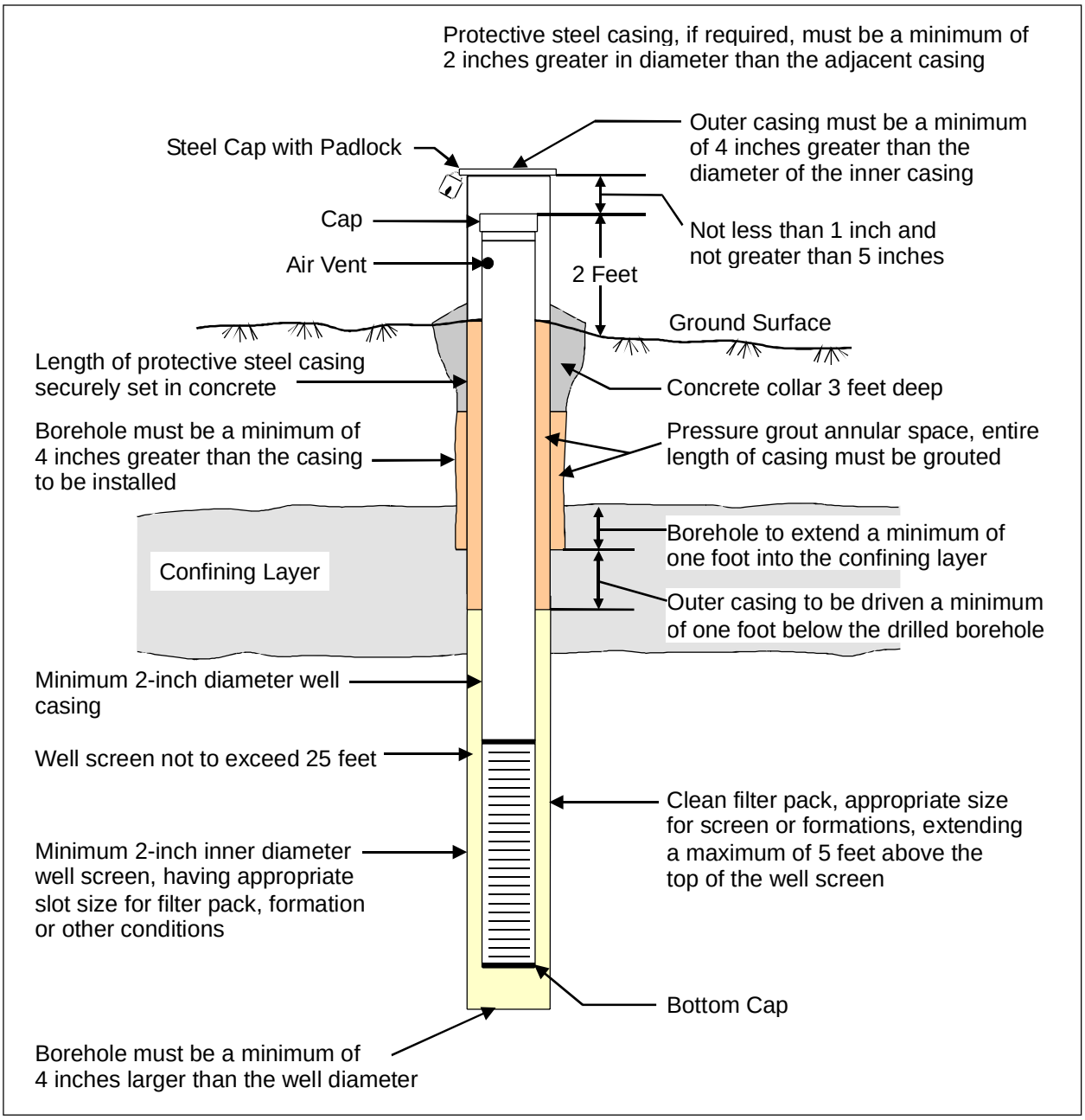


Figure 6.14 Confined Unconsolidated Aquifer Well

Return to TOC

Chapter 6
References

Abdul, Abdul, S., Sheila F. Kia, and Thomas L. Gibson, *Limitations of Monitoring Wells for the Detection and Quantification of Petroleum Products in Soils and Aquifers, Ground Water Monitoring Review*, Vol. IX, No. 2, p. 90-99, Spring 1989.

Acker, W.L. III, *Basic Procedures for Soil Sampling and Core Drilling*, Acker Drill Company, Scranton, PA, 1974.

American Society for Testing and Materials, *Standards Related to Environmental Site Characterization, Sponsored by ASTM Committee D-18 on Soil and Rock*, ASTM, West Conshohocken, Pennsylvania, 1997.

American Society for Testing and Materials, *Standard Practice for Diamond Core Drilling for Site Investigation, D 2113-83*, ASTM, West Conshohocken, Pennsylvania, 1987.

American Society for Testing and Materials, *Standard Practice for Using the Disposable En Core Sampler for Sampling and Storing soil for Volatile Organic Analysis, D 6418-99*, ASTM West Conshohocken, Pennsylvania, 1999.

American Society for Testing and Materials, *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*, E 1527-00, 2000.

American Society for Testing and Materials, *Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds, D 4547-98*, ASTM West Conshohocken, Pennsylvania, 1998.

American Society for Testing and Materials, *ASTM Standards on Ground Water and Vadose Zone Investigations, sponsored by ASTM Committee D-18 on Soil and Rock, second edition*, ASTM West Conshohocken, Pennsylvania, 1994.

American Society for Testing and Materials, *Test Method for Sieve Analysis of Fine and Coarse Aggregates*, ASTM C136-92.

American Society for Testing and Materials, *Test Method for Particle-Size Analysis of Soils*, ASTM D422-63.

American Society for Testing and Materials, *Practice for Soil Investigation and Sampling by Auger Borings*, ASTM D1452-80, 1996.

American Society for Testing and Materials, *Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D1586-84, 1992.

American Society for Testing and Materials, *Classification of Soils for Engineering Purposes (Unified Soil Classification System)*, ASTM D2487-93.

American Society for Testing and Materials, *Practice for Description and Identification of Soils (Visual-Manual Procedure)*, ASTM D2488-93.

American Society for Testing and Materials, *Standard Guide for Sampling Waste Piles*, D6009-96. 1996.

American Society for Testing and Materials, *Guide for Soil Sampling from the Vadose Zone*, ASTM D4700-91.

American Society for Testing and Materials, *Guide for Field Logging of Subsurface Explorations of Soil and Rock*, ASTM D5434.

American Society for Testing and Materials, *Test Method for Particle-Size Analysis of Soils*, ASTM D422-63.

American Society for Testing and Materials, *Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh-Water Invertebrates*, ASTM E-1706-00, 2000.

American Society for Testing and Materials, *Standard Guide for Documenting a Ground Water Sampling Event*, ASTM D6089-97e1.

Anderson, G., *Coring and Core Analysis Handbook*, PennWell Books, Tulsa, OK, 1975.

Applegate, Joseph L., Fitton, Douglas M., *Rapid Site Assessment Applied to the Florida Department of Environmental Protection's Dry Cleaning Solvent Cleanup Program*, Conference Proceedings, HazWaste World Superfund XVIII., Vol. 2, December 1997.

Bailey, Dr. Renata, *Improving Sampling Techniques for the Analysis of Lead in Ground Water: Determining Optimal Filtration Conditions*, State of New Jersey, Department of Environmental Protection, Division of Science, Research and Technology, Final Report 2002.

Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske, *Practical Guide for Ground-Water Sampling*, Illinois State Water Survey, ISWS Contract Report 314, 1985.

Barcelona, Gibb and Miller, *A Guide to the Selection of Materials for Monitoring Well Construction and Ground Water Sampling*, Champaign, Il., US Government Printing Office, August 1983.

Barcelona, M.J., J.A. Helfrich, E.E. Garskey, and J.P. Gibb, *A Laboratory Evaluation of Ground Water Sampling Mechanisms*, in Ground Water Monitoring Review, Spring, Vol. 4, No. 2, pp. 32-41. 1984.

Barcelona, M.J., J.A. Helfrich, E. E. Garske, and J.P. Gibb, *Field Verification of Sampling Methods and Materials Selection for Ground Water Contamination Studies*, Presented at: Symposium for Ground Water Contamination Studies and Their Standardization, ASTM, Cocoa Beach, Fla., Feb. 1986.

Barth, D.S. and B.J. Mason, *Soil Sampling Quality Assurance and the Importance of an Exploratory Study*, ACS Symposium Series 267, Environmental Sampling for Hazardous Waste, ACS Publications, American Chemical Society, Wash. D.C., 1984.

BP Corporation North America and USEPA Region 4 and Region 5., *Monitoring Well Comparison Study: An Evaluation of Direct-Push versus Conventional Monitor Wells*, May, 2002.

Brady, N. and R. Weil, *The Nature and Property of Soils*, 12th ed., Prentice Hall.

Burmister, D.M., *Suggested Methods of Tests for Identification of Soils*, 1950.

Burton Jr., G. S. and P. F. Landrum, *New Standard Guide for Collection, Storage, Characterization and Manipulation of Sediments for Toxicological Testing, Draft 5*, Wright State University, Dayton, Ohio, December 1989.

California State University, Sacramento School of Engineering, *Water Treatment Plant Operation – A Field Study Training Program*, Sacramento, California, pp. 485-488, 1983.

Christensen, Thomas H., Bjerg, Poul L., Kjeldsen, P., *Natural Attenuation: A Feasible Approach to Remediation of Ground Water Pollution at Landfills?*, Ground Water Monitoring Review, Winter, 2000.

Church, Peter E., and Granato, Gregory E., *Bias in Ground Water Data Caused by Well-Bore Flow in Long-Screen Wells*" Ground Water, Vol.34, No.2, pp. 262-273, 1996.

Cohen, Robert M., Bryda, Anthony P., Shaw, Scott T., Spalding, Charles P., *Evaluation of Visual Methods to Detect NAPL in Soil and Water*, Ground Water Monitoring Review, Fall, 1992.

deVera, Emil R., Bart P. Simmons, Robert D. Stephens and David L. Storm, *Samplers and Sampling Procedures for Hazardous Waste Streams*, Cincinnati, USEPA Municipal Environmental Research Lab EPA-600/2-80-018, 1980.

Dragun, J., R.Gambino and W. Kuhn, *Coloration Changes of Geologic Media After Addition of Gasoline, Diesel Fuel, and Ethylbenzene*, The Journal of Soil Contamination, Vol. 5, No. 1, pp. 1 - 8, 1996

Dragun, J., *The Fate of Hazardous Materials in Soil, What Every Geologist and Hydrogeologist Should Know,* Part 1, HMC, March/April 1988

Driscoll, F.G., *Ground Water and Wells*, Second Edition, H.M. Smyth Company Inc., St. Paul, Minnesota, 1986

Elton, E.L. and E. Fendley, *Installing the Perfect Monitoring Well:Identifying, Quantifying, and Mitigating Interferences from Monitoring Well Installation Techniques*, Presented at: Symposium for Ground Water Contamination Studies and Their Standardization, ASTM Cocoa Beach, Fla., February 1986.

Environmental Research Laboratory, Robert S. Kerr, *Practical Guide for Ground Water Sampling*, Ada. OK, US Government Printing Office, EPA-600/2-85/104, 1985.

Fetter, C.W., Jr., *Contaminant Hydrogeology*, 1993

Fink, Michael J., Boyajian, Ralph T., *Decontamination Procedures for Ground Water Sampling Equipment*, Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, May 1989.

Folk, R.L., *Petrology of Sedimentary Rocks*, Hemphill Publishing Company, 1974.

Foster, M., Stefanov, J, Bauder, T., Shinn, J., and Wilson, R., *Piezometer Installation Using a Cone Penetrometer* Ground Water Monitoring Review Fall, 1995.

Franson, MaryAnn H., Managing Ed., *Standard Methods for the Examination of Water and Wastewater 16th Edition*, Port City Press, Baltimore, Md., 1985.

Franson, Mary Ann H., Managing Ed., *Standard Methods for the Examination of Water and Wastewater 20th Edition*, American Public Health Association, Washington, D.C., 1998.

Gallant, R.F., J.W. King, P.L. Levins, J.F. Piecewicz, *Characterization of Sorbent Resins for Use in Environmental Sampling*, Research Triangle Park, N.C., US Government Printing Office, EPA-600/7-78-054, 1978

Gerlach, Robert W., Dobb, David E., Raab, Gregory A., and Mocerino, John M., *Gy Sampling Theory in Environmental Studies. 1. Assessing Soil Splitting Protocols*, Journal of Chemometrics, Vol. 16, pp. 321-328, 2002.

Gibbs, J., Brown, Allan G., Turner, Kenneth S., MacLeod, Cecilia L., Jelinski, James C., Koehnlein, Susan A., *Effects of Small-Scale Vertical Variations in Well-Screen Inflow Rates and Concentrations of Organic Compounds on the Collection of Representative Ground-Water Quality Samples*, Ground Water, Vol. 31, No.2, March-April, 1993.

Gibb, J.P., and M.J. Barcelona, *The Development of Effective Ground Water Sampling Protocols*, Presented at: Symposium of Field Methods for Ground Water Contamination Studies and Their Standardization, ASTM, Cocoa Beach, Fla., Feb. 1986.

Gibs, J., and Imbrigiotta,Thomas E., *Well Purging Criteria for Sampling Purgeable Organic Compounds*, Ground Water Vol.28, No. 1, pp 68-78, 1990.

Gibs, J., Imbrigiotta, Thomas E., Ficken, James H., Pankow, James F., Rosen, Michael E., *Effects of Sample Isolation and Handling on the Recovery of Purgeable Organic Compounds*, Ground Water Monitoring Review, Spring, 1994.

Gillham, R.W., M.J.L. Robin, J.F. Baker, and J.A. Cherry, *Ground Water Monitoring and Sample Bias*, American Petroleum Institute, APR Publication 4367, p 206, 1983.

Hacket, Glen, *Drilling and Constructing Monitoring Wells with Hollow-Stem Augers, Part 2 Monitoring Well Installation*, Ground Water Monitoring Review, pages 60 - 68, 1988

Hart, Barbara F., Tomlinson, Rodger B., and Chaseling, J., *Using the Stabilization Plateau to Estimate Optimum Well Purge Volume*, Ground Water Monitoring Review, Summer, 2000.

Hewitt, A.D.. *Enhanced Preservation of Volatile Organic Compounds in Soil with Sodium Bisulfate*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 95-26, 1995.

Hewitt, Alan D., Jenkins, Thomas F., Grant, Clarance L., *Collection, Handling and Storage: Keys to Improved Data Quality for Volatile Organic Compounds in Soil*, American Environmental Laboratory, February 1995.

Hewitt, Alan D., Lukash, Nicole J.E., *Obtaining and Transferring Soils for In-Vial Analysis of Volatile Organic Compounds*. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 96-5, 1996.

Hewitt, Alan D., *Chemical Preservation of Volatile Organic Compounds in Soil*, Environmental Science and Technology, Vol. 31, No. 1, 1997

Hewitt, Alan D., *Dynamic Study of Common Well Screen Materials*, Ground Water Monitoring Review, Winter, 1994.

Hewitt, Alan D., *Storage and Preservation of Soil Samples for Volatile Organic Compound Analysis*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 99-5, 1999.

Hewitt, A. D., Myers, K. F., *Sampling and On-Site Analytical Methods for Volatiles in Soil and Groundwater-A Field Guidance Manual*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 99-16, 1999.

Hewitt, Alan D., *Frozen Storage of Soil Samples for VOC Analysis*, Environmental Testing and Analysis, Vol. 8, No. 5, 1999.

Hewitt, Alan D., *Methods of Preparing Soil Samples for Headspace Analysis of Volatile Organic Compounds: Emphasis on Salting Out*, Proceedings of the Waste Testing and Quality Assurance Symposium, pp. 323-329, 1996.

Hewitt, Alan D., Jenkins, Thomas F., Grant, Clarance L., *Collection Handling and Storage: Keys to Improved data quality for Volatile Organic Compounds in Soil*, American Environmental Laboratory, February, 1995.

Hyman, Jennifer A., McLaughlin, Dennis G., *Multi-Level Sampling for Naphthalene In a Shallow, Sandy Aquifer*, Ground Water Management, Proceedings of the Fifth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods. 1991.

Hutchins, Stephen R., Acree, Steven D., *Ground Water Sampling Bias Observed In Shallow, Conventional Wells*, Ground Water Monitoring Review, Winter, 2000.

Hutzler, Neil J., *Processes Controlling the Transport and Fate of VOCs in Soil*, National Symposium on Measuring and Interpreting VOCs in Soils: State of the Art and Research Needs, Las Vegas, Nevada, January 12-14, 1993.

Hutchins, Stephen R., Acree, Steven D., *Ground Water Sampling Bias Observed In Shallow, Conventional Wells*, Ground Water Monitoring Review, Winter, 2000.

Imbrigiotta, Thomas E., Gibs, J., Fusillo, T.V., Kish, George R., Hochreiter, Joseph J., *Field Evaluation of Seven Sampling Devices for Purgeable Organic Compounds in Ground Water*, Ground-Water Contamination: Field Methods, ASTM STP 963, A.G. Collins and A. J. Johnson, Eds., American Society for Testing and Materials, Philadelphia, PA 1998.

Jones, J.L. and L.M. Roberts, *The Relative Merits of Monitoring and Domestic Wells for Ground Water Quality Investigations*, Ground Water Monitoring and Remediation, Vol. XIX, No. 3, pp. 139-144, Summer 1999.

Jury, W.A., Russo, D., Streile, G., Sesham, E.A., *Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface*. Water resources Research, Vol. 26, No. 1 pp.13-20, 1990.

Kaplan, E., Banerjee, S., Ronen, D., Magaritz,M., Machlin, A., Sosnow,M., Koglin, E., *Multilayer Sampling in the Water-Table Region of a Sandy Aquifer*, Ground Water, Vol. 29, No.2, 1991.

Kearl, P.M., N.E. Korte and T.A. Cronk, *Suggested Modifications to Ground Water Sampling Procedures Based on the Observations from the Colloidal Borescope*, Ground Water Monitoring Review, Vol. XII, No. 2, pp. 155-160, Spring 1992.

Kerri, Kenneth D., Proj. Dir., *Operation of Wastewater Treatment Plants, Sacramento, Ca*., California State University, 1983.

Kerri, Kenneth D., Proj. Dir., *Industrial Waste Treatment, Sacramento, Ca*., California State University, 1987.

Kerri, Kenneth D., Proj. Dir., *Pretreatment Facility Inspection, Sacramento, Ca*., California State University, 1988.

Lapham, W.W., F.D. Wilde, and M.T. Koterba, *Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells, and Supporting Documentation*, U.S.G.S. Water-Resources Investigations Report 96-4233, 1997.

Liikala, Terry L., Olsen, Khris B., Teel, Steven S., Lanigan, David C., *Volatile Organic Compunds: Comparison of Two Sample Collection and Preservation Methods*, Environmental Science and Technology, Vol. 30, No. 12, 1996.

Mackiewicz, Michael C., *A Simple 11 Step Procedure to Document the Accuracy, Precision and Significance of Measurements by Field Instrumentation*, Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, Ground Water Management, 1990.

Marinelli, Fred, and Deanna S. Durnford, *LNAPL Thickness in Monitoring Wells Considering Hysteresis and Entrapment*, *Ground Water*, Vol. 34, No. 3, p. 405-414, 1996.

McAllister, P.M., Chiang, C.Y., *A Practical Approach to Evaluating Natural Attenuation of Contaminants in Ground Water*, Ground Water Monitoring Review, Spring, 1994

McCall, W., Stover,S., Enos, C., Fuhrmann,G., *Field Comparison of Direct Push Prepacked Screen Wells to Paired HAS 2" PVC Wells*, Conference Proceedings, HazWaste World Superfund XVIII, December, 1997.

McGinnis Services, *Engineered Technical Approach for the Installation & Sampling of the SVE/AS Well Project, Routes 532 & 72*, Woodland Private Study Group Site, 1998.

Millson, M., Eller, P.M., Ashley, K., *Evaluation of Wipe Sampling Materials for Lead In Surface Dust*, Journal of American Industrial Hygiene,Vol. 55, No.4 p.339-1994.

Minnesota Pollution Control Agency, Water Quality Division, *Sampling Procedures for Ground Water Monitoring Wells*, 1997.

Montgomery, John H., Welkom, Linda M., *Groundwater Chemicals Desk Reference*, Lewis Publishers, Chelsea, Michigan, 1990.

Morrison, Robert D, *Ground Water Monitoring Technology: Procedures, Equipment, and Applications*, Prairie DuSac, Wis., TIMCO Mfg., Inc., 1983.

Neilson, David M. and Gillian L. Yeates, *Comparison of Sampling Mechanisms Available for Small-Diameter Ground Water Monitoring Wells*, Ground Water Monitoring Review vs.Vol. 4, No. 2 pp. 83-99, Spring, 1984.

Newell, Charles J., Lee, Robert S. Spexet, AnnMarie H., *No-Purge Ground Water Sampling: An Approach for Long-Term Monitoring*, American Petroleum Institute, October, 2000.

Newell, Charles J., Steven D. Acree, Randall R. Ross, and Scott G. Huling, *Light Nonaqueous Phase Liquids*, EPA Ground Water Issue, 1995.

NJDEP, *Alternative Ground Water Sampling Techniques Guide*, July, 1994.

New Jersey Department of Environmental Protection and Energy, *Field Sampling Procedures Manual*, pp. 134-135, May, 1992.

New Jersey Department of Environmental Protection, *Field Procedures Manual for Water Data Acquisition*, Division of Water Resources, 1987.

New Jersey Department of Environmental Protection, *New Jersey Safe Drinking Water Act, N.J.A.C. 7:10-1.3.* Division of Water Resources.

New Jersey Department of Environmental Protection, *The Technical Requirements for Site Remediation*, N.J.A.C. 7:26E *et seq*.

New Jersey Register, Proposed New Rules: *N.J.A.C. 7:9D*, Monday, August 7, 2000.

Nyer, E.K., and Gearhart, M.J., *Plumes Don't Move*, Ground Water Monitoring Review,Winter, 1997.

Oneacre, John., and Figueras, Debbie., *Ground Water Variability at Sanitary Landfills Causes and Solutions, Proceedings of Uncertainty*, Geotechnical Engineering Division/ASCE,1996.

Parker, Louise V., *The Effects of Ground Water Sampling Devices on Water Quality: A Literature Review*, Ground Water Monitoring Review, Vol. 14, No. 2, pp. 130-141, 1994.

Parker, L.V. and T.A. Ranney, *Sampling Trace-Level Organics with Polymeric Tubings: Part 1. Static Studies*, Ground Water Monitoring and Remediation, Vol. 17, No. 4, pp. 115-124, 1997.

Parker, L.V. and T.A. Ranney, *Decontaminating Groundwater Sampling Devices*, Special Report 97-25, CRREL, 1997.

Parker, L.V. and T.A. Ranney, *Decontaminating Materials Used in Groundwater Sampling Devices*, Special Report 97-24, CRREL, 1997.

Parker, L.V. and T.A. Ranney, *Sampling Trace-Level Organics with Polymeric Tubings: Part 2. Dynamic Studies*, Ground Water Monitoring and Remediation, Vol. 18, No.1, pp. 148-155, 1998.

Parker, L.V. and T.A. Ranney**,** *Decontaminating Materials used in Ground Water Sampling Devices: Organic Contaminants*, Ground Water Monitoring and Remediation, Vol. 19, No. 1, pp. 56-68, 2000.

Parker, L.V. and T.A. Ranney. *Decontaminating Materials Used in Ground Water Sampling Devices: Organic Contaminants*. *Ground Water Monitoring Review.* pp. 56-68, 2000.

Paul, Cynthia J., and Puls, Robert W., *Impact of Turbidity on TCE and Degradation Products in Ground Water*, Ground Water Monitoring Review, Winter, 1997.

Pettijohn, F.J., *Sedimentary Rocks*, Harper & Row, 1975.

Public Service Electric and Gas Company, *Generic Remedial Investigation Work Plan*, Rock Coring - Standard Operating Procedure 310, November, 1997.

Public Service Electric and Gas Company, *Phase III Remedial Investigation Report for the Former Paterson Gas Plant, Paterson, NJ*, Woodward-Clyde Consultants.

Puls, Robert W., and Barcelona, Michael J., *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, USEPA Report, EPA/540/S-95/504, April, 1996.

Puls, Robert W., Eychaner, James H., *Sampling of Ground Water for Inorganics – Pumping Rate, Filtration, and Oxidation Effects*, Ground Water Management Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, 1990.

Puls, R.W. and Powell, *Acquisition of Representative Ground Water Quality Samples for Metals*, Summer 1992 Ground Water Monitoring Review, Vol. XII, No. 3, pp. 167-176, 1997.

Radcliffe, M.J., B.W. Rehm, C.S. Peters, T.R. Stolzenburg, and S.D. Johannsen, *Sample Handling: The Impact of Filtering Ground Water Samples*, Proceedings of the Fourth Annual Hazardous Materials Management Conference, Atlantic City, NJ, June 1986.

Rajagopal, R., Williams, L. R., *Economics of Sample Compositing as a Screening Tool*, Ground Water Quality Monitoring, Vol. 9, No. 1, 1989.

Ranney, T.A. and L.V. Parker, *Comparison of Fiberglass and Other Polymeric Well Casings: Part III. Sorption and Leaching of Trace-Level Metals*, Ground Water Monitoring and Remediation, Vol. 18, No. 3, pp. 127-133, 1998.

Ranney, T.A. and L.V. Parker, *Comparison of Fiberglass and Other Polymeric Well Casings: Part II. Sorption and Leaching of Trace-Level Organics*, Ground Water Monitoring and Remediation, Vol. 18, No. 2, pp. 107-112, 1998.

Ricker, Michael J., *Determining Volatiles in Soils: A New Sampling Procedure*, Environmental Testing and Analysis, Vol. 8, No. 4, 1999.

Robbins, Gary A., Martin-Hayden, James M., *Mass Balance Evaluation of Monitoring Well Purging* Journal of Contaminant Hydrology, Vol. 8, pp. 203-224, 1991

Robbins, Gary A., Henebry, Brent J., Cummins, Timothy M., Goad, Christopher R., Gilbert, Edward J., *Occurrence of MTBE in Heating Oil and Diesel Fuel in Connecticut*, Ground Water Monitoring Review, Fall, 2000.

Robin, M.J.L., and Gillham, R.W., *Field Evaluation of Well Purging Procedures*, Ground Water Monitoring Review, Fall, 1987.

Rose, S., and Long, A., *Monitoring Dissolved Oxygen in Ground Water: Some Basic Considerations*, Ground Water Monitoring Review, Winter, 1998.

Ryan, Robert G., and Dhir, V.K., *The Effect of Interfacial Tension on Hydrocarbon Entrapment and Mobilization Near a Dynamic Water Table*, Journal of Soil Contamination, Vol. 5, No.1 pp.9-34. 1996.

Saar, R.A., *Filtration of Ground Water Samples: A Review of Industry Practice*, Ground Water Monitoring Review, pp. 56-62, 1997.

Scalf, Marion R. et. seq., *Manual of Ground Water Sampling Procedures*, USEPA and National Well Water Association, Worthington, OH, pp. 92-93, 1981.

Schumacher, Brian A., Ward, Steven, E., Q*uantitation Reference Compounds and VOC Recoveries from Soils by Purge and Trap GC/MS*., Environmental Science and Technology, Vol. 31, No. 8, 1997.

Schumacher, B.A., Shines, K.C., Burton, J.V., Papp. M.L., *A Comparison of Soil Sample Homogenization Techniques*, Hazardous Waste Measurements, Chapter 4. Lewis Publishers, Michigan, 1991.

Seanor, A.M. and L.K Brannaka, *Influence of Sampling Techniques on Organic Water Quality Analysis*, Presented at: Management of Uncontrolled Hazardous Waste Sites Conference, Washington, DC., Oct., 1984.

Siegrist, Robert L., *Measurement Error Potential and Control When Quantifying Volatile Hydrocarbon Concentrations in Soils*, Hydrocarbon Contaminated Soils, Vol. I, Lewis Publishers, pp. 205-215, 1991.

Siegrist, Robert L., Jenssen, Petter D., *Evaluation of Sampling Method Effects on Volatile Organic Compound Measurements in Contaminated Soils*, Environmental Science and Technology, Vol. 24, No. 9, 1990.

Sorini, Susan S., Schabron, John F., Rovani, Joseph F., Evaluation of VOC Loss From Soil Samples Contaminated Soil Sediment and Water, April/May, 2002.

Steila, D. and T. Pond, *The Geography of Soils, Formation, Distribution and Management*, 2nd edition, Rowman & Littlefield Publishers, Inc., 1989.

Stevenson, T.J., *Design of a Quality Assurance Program for the Assessment of Ground Water Contamination*, Presented at: NWWA Conference on Ground Water Management, Orlando, Fla., October, 1984.

Stone, William J., *Low Flow Ground Water Sampling-Is It a Cure-All?*, Ground Water Monitoring Review Spring, 1997.

Storch Engineers, *Standard PCB Transformer Sampling Procedures*, in SOP, 1986.

Tai, Doreen Y., Turner, Kenneth S., and Garcia, Lisa A., *The Use of a Standpipe To Evaluate Ground Water Samplers*, Ground Water Monitoring Review, Winter, 1991.

Testa, Stephen M., and Michael T. Paczkowski, *Volume Determination and Recoverability of Free Hydrocarbon*, *Ground Water Monitoring Review*, Vol. IX, No. 1, p. 120-128, Winter 1989, and errata sheet, Vol. IX, No. 2, p. 190 Spring 1989.

Testa, Stephen M., and Winegardner, Duane L., *Restoration of Contaminated Aquifers*, Lewis Publishers, New York, New York, 1991.

Thomas, J.M., J.R. Skalski, L.L. Eberhardt, and M.A. Simmins, *Field Sampling for Monitoring, Migration and Defining the Areal Extent of Chemical Contamination*, Presented at: Management of Uncontrolled Hazardous Waste Sites Conference, Washington, DC., Oct. 1984.

Triplett, Laura D., Burford, P., Sielaff, B., Clark, R.C., *Sampling Procedures for Ground Water Monitoring Wells*, State of Minnesota, Minnesota Pollution Control Agency, 1997.

United States Department of Interior, *Ground Water Manual, A Water Resources Technical Publication*, Bureau of Reclamation, Chapters 16 and 17, 1985.

United States Environmental Protection Agency, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, Office of Research and Development, EPA/600/4-89/034, Washington, D.C., March, 1991.

USEPA, *Field Analytical and Site Characterization Technologies Summary of Application*s EPA-542-R-97-011, November, 1997.

USEPA, *Characterization of Hazardous Waste Sites: A Methods Manual Vol. II Available Sampling Methods*, EPA-600/4-83-040 Environmental Monitoring and Support Laboratory Las Vegas, NV, 1983.

USEPA, *Handbook for Sampling and Sample Preservation of Water and Wastewater*, EPA-600/4-82-029 Environmental Monitoring and Support Laboratory, Cincinnati OH, 1982.

USEPA, *Field and Laboratory Methods for Macroinvertebrate and Habitat Assessment of Low Gradient Non-Tidal Streams*, Mid-Atlantic Coastal Streams Workgroup, Environmental Services Division, Region 3, Wheeling, WV 26003, 23 pp.,1997.

USEPA, Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling, *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition, EPA 841-B-99-002, USEPA Office of Water, Washington, DC, 1999.

USEPA, *Methods for Measuring The Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates*, Second Edition. EPA/600/R-99/064, USEPA Office of Research and Development and Office of Water, Washinton, DC, 2000.

USEPA, *Ground Water Monitoring Guidance for Owners and Operators of Interim Status Facilities*, EPA-SW-963, Office of Solid Waste and Emergency Response Washington, DC, 1983.

USEPA, *Handbook for Sampling and Sample Preservation of Water and Wastewater*, Cincinnati, OH, 1982.

USEPA, *Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*, Office of Water Engineering and Analysis Division, April, 1995.

USEPA, *Suggested Operating Procedures for Aquifer Pumping Tests*, EPA/540/S-93/503, Office of Research and Development, Washington, DC, 1993.

USEPA, *Immunoassay Guidelines for Planning Environmental Projects*, USEPA Quality Assurance Unit Staff, Office of Environmental Measurement and Evaluation, October, 1996.

USEPA, *Light Non-Aqueous Liquids*, EPA/540/S-95/500, Office of Solid Waste and Emergency Response, 1995.

USEPA, *Non-Aqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling and Remediation*, EPA/540/S-95/503, Office of Solid Waste and Emergency Response, 1995.

USEPA, *Suggested Operation Procedures for Aquifer Pumping Tests*, EPA/540/s-93/503, Office of Solid Waste and Emergency Response, February, 1993.

USEPA, *Standard Operating Procedure for Elemental Analysis Using the X-Met 920 Field X-Ray Fluorescence Analyzer*, Office of Environmental Measurement and Evaluation, November, 1996.

USEPA, *Soil Sampling and Analysis for Volatile Organic Compounds*, EPA/540/4-91/001, Office of Solid Waste and Emergency Response, 1991.

USEPA, *Lead in Drinking Water-Should You Be Concerned?*, Office of Water, February 1987.

USEPA, *NPDES Compliance Inspection Manual*, Washington, D.C., 1984.

USEPA, *NPDES Compliance Sampling Manual*, Washington, D.C., 1977.

USEPA, *Contract Lab Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*, Document OLMO4.1. 1998.

USEPA, *Rapid Bioassesment Protocols for Use In Streams and Rivers*, 1989.

USEPA, *Test Methods for Evaluating Solid Waste Physical/Chemical*, SW-846 Final Update3 to the 3rd Edition, 1996.

USEPA, *Standard Operating Procedures, Model 5400 GeoprobeÔ Operation*, SOP 2050, 1996.

USEPA, *Clarification Memorandum from Elizabeth Cotsworth to Regions I-X Regarding Use of SW-846 Methods*, Office of Solid Waste, 1998.

USEPA, *Contract Lab Program Statement of Work for Organic Analysis, Multi-Media, Multi-Concentration*, Document OLMO4.2A Corrections/Modifications/Clarifications. 2000.

USGS, *Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water Quality Samples and Related* Data, U.S. Geological Survey Report 95-399. 1995.

USGS, *Field Guide for Collecting Samples For Analysis of Volatile Organic Compounds In Stream Water for the National Water Quality Assessment Program*, U.S. Geological Survey Report 97-0401, 1997.

USGS, *Field Guide for Collecting and Processing Stream-Water Samples for the National Water-Quality Assessment Program*, U.S. Geological Survey Report 94-455, 1994.

University of Arizona, College of Agriculture, *Field Manual for Water Quality Sampling*, March, 1995.

Urban, Michael J., Smith, James S., Schultz, Elizabeth.K., Dickenson, Randall K., *Volatile Organic Analysis for a Soil, Sediment or Waste Sample*, Fifth Annual Waste Testing and Quality Assurance Symposium, July 24-28, Washington, D.C.,pp. II-87 to II-101, 1989.

United State Geological Society, *Field Guide for Collecting Samples for Analysis of Volatile Organic Compounds in Stream Water for the National Water-Quality Assessment Program*, US Geological Survey Report 97-401, 1997.

USGS, *Ground-Water Data – Collection Protocols and Procedures for the National Water-Quality Assessment Program: Selection, Installation, and Documentation of Wells, and Collection of Related Data*, U.S. Geological Survey, Report 95-398, 1995.

USGS, *Guidelines for Collecting and Processing Samples of Stream Bed Sediment For Analysis of Trace Elements and Organic Contaminants for the National Water Quality Assessment Program*, US Geological Survey Report 94-458, 1994.

USGS, *Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, August, 1998.

USGS, *U.S. Geological Survey Protocol for the Collection and Processing of Surface Water Samples for the Subsequent Determination of Inorganic Constituents in Filtered Water*, USGS Report 94-539, 1994.

USGS, *Quality-Control Design for Surface-Water Sampling in the National Water-Quality Assessment Program*, US Geological Survey Report 97-223, 1997.

USGS, *Use of an Ultra-Clean Sampling Technique with Inductively Coupled Plasma-Mass Spectrometry to Determine Trace-Element Concentrations in Water from The Kirkwood-Cohansey Aquifer System, Coastal Plain, New Jersey*, US Geological Survey Report 96-142, 1996.

Vroblesky, Don A., Borchers, James W., Campbell, Ted R., Kinsey, W., *Investigation of Polyethylene Passive Diffusion samplers for Sampling Volatile Organic Compounds in Ground Water at Davis Global Communications, Sacramento, California, August 1998 to February 1999*, U.S. Air Force Center for Environmental Excellence, 2000

Vroblesky, Don A. Hyde, Thomas W., *Diffusion Samplers as an Inexpensive Approach to Monitoring VOC's in Ground Water*, Ground Water Monitoring Review, Summer, 1997.

Vroblesky, Don A., *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells*, Part 1 and Part 2., USGS Reports 01-4060 and 01-4061, 2001.

Vroblesky, Don A., Petkewich, Matthew D., *Diffusion Sampler Testing at Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, November 1999 to May, 2000*

Vroblesky, Don A. and Peters, Brian C., *Diffusion Sampler Testing At Naval Air Station North Island, San Diego County, California, November 1999 to January 2000*, USGS Water Resources Investigation, Columbia, South Carolina, 2000

Wells, R.B., *Cores, Cores, Cores*, National Drillers Buyers Guide, pp. 47, August ,1991.

West, Olivia R., Siegrist, Robert L., Mitchell, Toby J., Jenkins, Rodger A., *Measurement Error and Spatial Variability Effects on Characterization of Volatile Organics in the Subsurface*, Environmental Science and Technology, Vol. 29, No. 3, 1995.

Wickramanayake, Godage B., Gavaskar, Arun R., Kelley, Mark E., Nehring, Karl W., *Risk, Regulatory, and Monitoring Considerations Remediation of Chlorinated and Recalcitrant Compounds*, The Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 2000.

Wilson, Neal, *Soil Water and Ground Water Sampling*, Chapter 3, Lewis Publishers, 1995

Wisconsin Department of Natural Resources, *Ground Water Sampling Desk Reference*, Report PUBL-DG-037 96, September, 1996.

Wisconsin Department of Natural Resources, *Ground Water Sampling Field Manual*, Report PUBL-DG-038 96, September, 1996.

29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response: Interim Final Rule*, Occupational Safety and Health Administration.

USGS Links of Interest

Return to TOC

http://water.usgs.gov/owq/FieldManual/
USGS National Field Manual for the Collection of Water-Quality Data

http://toxics.usgs.gov/pubs/FS-075-01/#4
USGS information on packer application

http://water.usgs.gov/nrp/proj.bib/paillet.html
USGS National Research Program: *Borehole Geophysics as Applied to Geohydrology*

http://ca.water.usgs.gov/pnsp/pest.rep/voc.html
USGS Open-File Report 97-401. A *Field Guide for Collecting Samplers for Analysis of VolatileOrganic Compounds in Stream Water for the National Water-Quality Assessment Program.*

http://water.usgs.gov/pubs/wri/wri004252/
USGS Water-Resources Investigations Report 00-4252. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation and Reporting.*

http://water.usgs.gov/admin/memo/QW/qw97.03.html
USGS Memorandum on proper cleaning of churn splitters when trace metal analysis is required.

http://water.usgs.gov/owq/FieldManual/mastererrata.html#Chapter4
USGS Field Manual Errata on how to repair churn splitter leakage at the spigot.

http://toxics.usgs.gov/pubs/FS-075-01/#4
USGS National Research Program: *Characterizing Ground-Water Chemistry and Hydraulic Properties of Fractured-Rock Aquifers Using the Multifunction Bedrock-Aquifer Transportable Testing Tool (BAT^3)*

http://energy.usgs.gov/factsheets/Core/crc.html
USGS Core Center Research: *Sample and Data Rescue at the Core Research Center*

http://geology.cr.usgs.gov/crc/
USGS Core Center Research: *About the Core Research Center*

http://water.usgs.gov/owq/pubs/wri/wri964233/wri964233.pdf
USGS Water Resoures Investigation Report 96-4233: *Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells and Supporting Documentation.*

USEPA Links of Interest

http://www.epa.gov/superfund/programs/dfa/dirtech.htm
USEPA Direct Push Information Web Page

http://epa.gov/swerust1/pubs/esa-ch5.pdf
USEPA Chapter 5 "Direct Push Technologies" *From: Expedited Site Assessment Tools For Underground Storage Tank Sites: A Guide for Regulator, EPA 510-B-97-001* – Released by the Office of Underground Storage Tanks.

http://www.epa.gov/etv/index.html
USEPA ETV Home Page

Other URLs of Interest

Return to TOC

Soil Science

http://www.astm.org/DATABASE.CART/PAGES/D2113.htm
ASTM Document Summary: D-2113-99, *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.*

http://www.astm.org/DATABASE.CART/PAGES/D2487.htm
ASTM Document Summary: D-2487-00, *Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)*

http://www.astm.org/DATABASE.CART/PAGES/D5079.htm
ASTM Document Summary: D-5079-02, *Standard Practices for Preserving and Transporting Rock Core Samples.*

http://www.astm.org/DATABASE.CART/PAGES/D6032.htm
ASTM Document Summary: D-6032-02, *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core.*

http://www.fact-index.com/g/gr/grain_size.html
Wikipedia Fact Index: *Grain Size*

http://scholar.lib.vt.edu/theses/available/etd-32398-73623/unrestricted/appendixB.pdf
Unified Soil Classification Chart*: Relationship between Swell Index and Attenberg Limits*

http://www.dlwc.nsw.gov.au/care/soil/soil_pubs/soil_tests/pdfs/usc.pdf
Soil Survey Standard Test Method, Unified Soil Classification System: *Field Method*

http://www.itc.nl/~rossiter/Docs/FM5-410/FM5-410_Ch5.pdf

Soil Classification

http://www.brookes.ac.uk/geology/8320/sst-text.html
Oxford Brookes University, *Geology: Textures in Terrigenous Clastic Rocks*

http://www.seafriends.org.nz/enviro/soil/rocktbl.htm#soil%20properties
Classification of Common Rocks, Soil and More

http://csmres.jmu.edu/geollab/Fichter/SedRx/sedclass.html
James Madison University Geology Lab: *A Basic Sedimentary Rock Classification*

http://www.eos.ubc.ca/courses/eosc221/sed/sili/siligsize.html
University of British Columbia, *Siliciclastics: Grain Size*

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10931
US Dept. of Labor, Occupational Safety and Health Admin., Regulation (Standards - 29 CFR), *Soil Classification - 1926 Subpart P, Appendix A.*

http://www.hawaiiasphalt.com/HAPI/modules/06_design_factors/usc.htm
Hawaii Asphalt Paving Industry's Table depicting the *Unified Soil Classification System*

http://web.stclair.k12.il.us/splashd/soiltype.htm
Soil Type Decision Tree

http://www.civil.columbia.edu/%7Eling/burmister/burmister.html
Biography of Donald Burmister

Sediments

http://www.epa.gov/ost/cs/
USEPA Water Science: *Contaminated Sediments*

http://www.epa.gov/OST/pc/csnews/
USEPA Water Science: *Contaminated Sediments Newsletters (Archived)*

http://el.erdc.usace.army.mil/dots/
US Army Corps of Engineers: *Dredging Operations Technical Support Program*

http://www.epa.gov/glnpo/sediments.html
USEPA, *Great Lakes Contaminated Sediments Programs*

http://www.nap.edu/books/0309054931/html/
National Academy of Science, Contaminated Sediments in Ports and Waterways*: Cleanup Strategies and Technologies*

http://www.sednet.org/
European Sediment Research Network

http://www.smwg.org/
Sediment Management Work Group: *Home Page*

http://www.rtdf.org/
Remediation Technologies Development Forum: *Home Page*

Manufacturers/Vendors of Environmental Sampling Equipment

http://geoprobe.com
Geoprobe Home Page

http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm
ARTS Manufacturing Home Page

http://www.generaloceanics.com/
General Oceanics Home Page

http://www.aquaticresearch.com/
Aquatic Research Instruments Home Page

http://www.fultzpumps.com/
Fultz Pumps Home Page

http://www.wildco.com/
Wildlife Supply Company Home Page

http://www.geotechenv.com/
Geotech Home Page

http://www.bennettsamplepump.com/
Bennett Sample Pumps Home Page

http://www.qedenv.com/
QED Environmental Systems

http://www.isco.com/
ISCO

http://eonpro.com/
EON Home Page

http://www.caslab.com/
Columbia

http://www.flut.com/
FLUTe Home Page

http://prosoniccorp.com/
Prosonic Corp. Home Page

http://www.solinst.com/
Solinst Home Page

General

http://www.state.nj.us/dep/srp/regs/techrule/index.html
NJDEP "Tech Rules" N.J.A.C. 7:26E *Technical Requirements for Site Remediation*

http://www.animatedsoftware.com/pumpglos/pumpglos.htm
The Internet Glossary of Pumps (Animated)

www.pca.state.mn.us/water/groundwater/wqsampling.html

http://www.frtr.gov/

http://www.dnr.wi.gov/org/water/dwg/gw/pubs/field.pdf

http://www.dnr.wi.gov/org/water/dwg/gw/pubs/desk_a.pdf

http://www.dnr.wi.gov/org/water/dwg/gw/pubs/desk_b.pdf

http://deq.state.wy.us/wqd/groundwater/pollution.asp

http://www.esemag.com/0596/napl.html

http://portal.environment.wa.gov.au/portal/page?_pageid=233,1&_dad=portal&_schema=PORTAL

http://www.afcee.brooks.af.mil/

http://www.ngwa.org/