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Environmental Restoration Program

REMEDIAL INVESTIGATION/FEASIBILITY STUDY OPERABLE UNIT 2, MAIN HILL FIELD SAMPLING PLAN

MOUND PLANT
MIAMISBURG, OHIO

March 30, 1994

FINAL

(Revision 1)

Department of Energy
Albuquerque Field Office

Environmental Restoration Program
EG&G Mound Applied Technologies

ENVIRONMENTAL RESTORATION PROGRAM

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
OPERABLE UNIT 2, MAIN HILL
FIELD SAMPLING PLAN

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DEPARTMENT OF ENERGY

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EG&G MOUND APPLIED TECHNOLOGIES

FINAL

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LIST OF ACRONYMS

AA	atomic absorption
ASTM	American Society for Testing Materials
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CGI	combustible gas indicator
CLP	(EPA) Contract Laboratory Program
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration (Program)
FFA	Federal Facility Agreement
FIDLER	field instrument for the detection of low-energy radiation
FS	Feasibility Study
FSP	Field Sampling Plan
GC	gas chromatograph
ICP	inductively coupled plasma
IT	International Technology
MS	mass spectrometry
MSL	mean sea level
NAS	National Academy of Science
NPDES	National Pollutant Discharge Elimination System
OVA	organic vapor analyzer
PCB	polychlorinated biphenyl
PID	photoionization detector
PM-10	particulates less than 10 microns
PUF	polyurethane foam
QAPP	Quality Assurance Project Plan
RI	remedial investigation
SCS	Soil Conservation Service
SIM	selective ion monitoring
SM/PP	Special Metallurgical/Plutonium Processing
SOP	Standard Operating Procedure
SOW	Statement of Work
SRDS	storm water retention and discharge system
TAL	Target Analyte List
TCE	trichloroethane
TCL	Target Compound List
TDS	total dissolved solids
TOC	total organic carbon
TSP	total suspended particulates
TSS	total suspended solids
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

1. INTRODUCTION

1.1. MAIN HILL REMEDIAL INVESTIGATION, OPERABLE UNIT 2

The purpose of this Field Sampling Plan (FSP) is to provide the information necessary to perform field investigations for remedial investigations and feasibility study (RI/FS) at all locations covered by Operable Unit 2 (OU-2), the Main Hill Work Plan for Mound Plant. This plan follows the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA)/Superfund guidance for conducting RI/FSs (EPA 1988c).

The Main Hill OU-2 RI addresses geology, hydrogeology, soils, surface water, and sediments. This investigation provides information that is required by the Mound Plant Environmental Restoration (ER) Program (specifically to comply with the Federal Facilities Agreement [FFA]) (EPA 1990). The field sampling has two major objectives: to describe the physical and chemical nature of the media; and to define the extent of contaminants (if any) within the media. The investigation methods are described fully in the following sections, including background information, figures showing locations of interest, and sampling activities that will be performed.

The Main Hill Work Plan provides information concerning past investigations performed at Mound Plant, objectives of this investigation, data requirements, and the sampling approaches. In addition, the Main Hill Work Plan provides information applicable to Mound Plant as a whole, including background information, potential contaminants, interaction with other operable units, and plant history. This FSP contains a brief discussion of investigation background information and sampling objectives as well as more detailed discussions of sample locations and frequencies, sample designations, sampling equipment and procedures, and sample handling and analysis.

2. GENERAL FIELD PROCEDURES

The types of work covered in this FSP are quite varied (Table II.1). Sample media include groundwater, sediment, soil, and surface water. Some of these media require special field procedures that are described in their specific sections of this FSP.

2.1. IDENTIFYING AND SURVEYING SAMPLING LOCATIONS

Before or during sampling at any of the locations covered in OU-2, the locations described herein will be identified and staked in the field. The stakes will be labeled with the sample identification information and located by a licensed surveyor. After the locations have been identified, they will be inspected by members of the Mound Plant engineering department, and a digging/excavation permit will be issued by them. Off-plant locations of intrusive work will be cleared with local utility companies and the landowners. If a location is too close to a utility line, the location will be adjusted slightly, under the direction of a Mound Plant engineer or local utility officials. After this permit is issued and the locations are cleared with the utility company, work may proceed in the area in question. Under no circumstances will a location be moved without the approval of Mound Plant engineers or local utility officials. If sample locations are adjusted, they will be re-staked and located by a surveyor after the sample has been collected. The vertical positions of permanent locations (e.g., monitoring wells) will be located to ± 0.01 ft and horizontally to ± 0.1 ft. Non-permanent locations (e.g., soil sample locations) will be located both horizontally and vertically to 0.1 ft. Horizontal locations will be reported using the Ohio State Plane Coordinate System.

2.2. SAMPLING EQUIPMENT AND PROCEDURES

Sampling equipment and procedures to be used during this RI/FS will be according to the requirements of the Mound Plant ER Program Standard Operating Procedures (SOPs). ER Program SOPs applicable to this field investigation are listed in Table II.2 and provided in Appendix A of the OU-9 Site-wide Investigation Quality Assurance Project Plan (QAPP). SOPs applicable to the OU-2 Field Sampling Plan only are provided in Appendix A of this document. A separately bound copy of all applicable SOPs will be provided to all field personnel and will be followed by all members of the field team. Equipment and procedures will be discussed in the following pertinent sections.

2.3. DECONTAMINATION OF PERSONNEL AND EQUIPMENT

Personnel and equipment will be decontaminated during the RI/FS sampling to prevent cross-contamination of samples and locations, to protect field personnel, and to prevent the spread of

Table II.1. Type of Work Covered in OU-2 Field Sampling Plan Activities

OU-2 FSP Activity	Objective of Activity
Geophysical Investigation	Measurements to determine bedrock topography, thickness of filled areas and presence of buried utilities
Subsurface Utility Investigation	Confirm locations by field verification and surveying locations and to determine integrity of subsurface utilities
Soil Gas Reconnaissance	Investigations to delineate the vertical and horizontal extent of contamination resulting from volatile organic compounds in the vadose zone as groundwater
Characterization of Hillside Seeps and Foundation Drains	Investigations that include all groundwater originating in or passing through OU-2 to assess subsurface transport of contaminants
Evaluation of Existing Monitoring Wells	Evaluation of existing monitoring well system for potential use in the OU-2 RI/FS
Installation of New Monitoring Well Clusters	Installation of seven monitoring well clusters to define groundwater flow and quality
Groundwater Flow Investigation	Collection of groundwater data to determine the direction, rate of flow, and contaminant concentrations within the sedimentary units to determine likely pathways of contaminant migration
Soil Sampling	Investigation to define the nature and extent of contamination; analyses of chemical parameters to confirm the presence or absence of contamination in suspected areas of concern.
Surface Water and Sediment Investigations	Investigations to define nature and extent of contaminant presence along drainage ways and to assess surface and subsurface transport of contaminants
Source Specific Investigation (Monitoring Well 0034)	Three phase investigation to determine the nature and extent of free oil product in the subsurface

Table II.2. RI/FS Standard Operating Procedures

	Effective Date	Revision Number	Purpose
Section 1 - General			
1.1 General Instructions for Field Personnel	March 1992	2	To provide field personnel with instructions regarding activities to be performed before, during, and after field investigations.
1.3 Sample Control and Documentation	March 1992	1	To define the steps necessary for sample control and identification, data recording, and chain-of-custody documentation.
1.4 Sample Containers and Preservation	March 1993	4	To provide guidance in the selection and preservation of suitable containers for samples, container cleaning, required sample volumes, sample collection, times, and the recommended holding preservation techniques for water, wastes, sediments, sludges, and soil samples.
1.5 Guide to the Handling, packaging, and Shipping of Samples	January 1993	2	To provide a general guide for packaging and shipping samples of environmental and hazardous materials to the laboratory. In addition, instructions are provided to select the correct category for packaging and shipping samples of unknown contents.
1.6 General Equipment Decontamination	March 1992	2	To describe methods for the decontamination of field equipment potentially contaminated during sample collection.
1.7 Sampling for Removable Alpha Contamination	June 1992	1	To describe a method of verifying that equipment leaving a controlled area that contains radioactive materials meets unrestricted release criteria for removable contamination. This equipment may include tools, vehicles, and miscellaneous items brought into contact with radioactive materials.
1.8 Personnel Decontamination - Level D Protection	March 1992	1	To describe the equipment and procedures required for the decontamination of persons who have performed field activities in Level D protective clothing.
1.9 Personnel Decontamination - Level C Protection	March 1992	1	To describe the equipment and procedures required for the decontamination of persons who have performed field activities in Level C protective clothing.
1.10 Personnel Decontamination - Level B Protection	January 1991	0	To describe the equipment and procedures required for the decontamination of persons who have performed field activities in Level B protective clothing.
1.15 Guide to Waste Management	February 1993	2	To provide a general guide for the management of investigation-derived materials at the Mount Plant.

Table II.2. (Continued)

	Effective Date	Revision Number	Purpose
Section 2 - Water Sampling			
2.1 Presample Purging of Wells	March 1992	1	To identify well purging procedures for evacuation of stagnant water from the well bore and its replacement by groundwater in sufficient quantities so that a water sample representative of the formation of completion can be collected.
2.2 Field Measurements on Ground and Surface Water Samples	March 1992	2	To obtain reliable and accurate measurements of the field chemistry of water quality samples.
2.3 Sampling Monitoring Wells with a Bladder Pump	March 1992	3	To use a bladder pump to obtain representative groundwater samples at shallow depths that are beyond the capabilities of a peristatic pump.
2.4 Sampling Monitoring Wells with a Bucket-Type Bailer	June 1991	1	To obtain a representative groundwater sample at depths beyond the range (or capability) of suction lift pumps when bailer volatile air stripping is of concern, well-casing diameters are too narrow to accept submersible pumps or other difficult conditions are present.
2.5 Sampling Monitoring Wells with a Submersible Pump	January 1991	0	To obtain a representative sample of the groundwater at depths beyond the capabilities of peristatic pumps when bailing and bladder pumps are ineffective.
2.6 Sampling Monitoring Wells with a Peristatic Pump	June 1991	1	To obtain a representative groundwater sample from a shallow well (less than 26 feet deep).
2.7 Sampling Commercial/Municipal/ Domestic Wells	June 1991	1	To define guidelines for field personnel to follow in sampling commercial, municipal, and domestic wells.
2.8 Sampling for Volatile Organics	January 1991	0	To outline procedures for collecting a representative groundwater sample and transporting it from its original environment to the laboratory for analysis of trace volatile organics.
2.9 Surface Water Sampling	June 1991	1	To define guidelines followed by field personnel in sampling surface water bodies and documenting all aspects of surface water sample collection.
2.10 Stream Flow Measurements Using Flumes, Velocity-Cross Sectional Area, and Direct Volume	March 1992	0	To define guidelines that will be followed by field personnel for measuring surface water flow rates in ditches, creeks, and springs using flumes, velocity cross sectional area method, and the bucket and stopwatch method.
2.11 Stream Flow Measurements Using Weirs	March 1992	0	To define guidelines that will be followed by field personnel for measuring surface water flow rates in rivers, creeks, springs, and ditches using weirs.

Table II.2. (Continued)

	Effective Date	Revision Number	Purpose
Section 3 - Hydraulic Testing			
3.1 Water Level Measurement	March 1992	1	To determine the depth-to-water in an open borehole, cased borehole, monitoring well, or potentiometer.
3.3 Operational Check of Pressure Transducers Used in Measuring Water Levels in Wells	September 1992	1	To describe procedures for conducting office and field checks of pressure transducers.
Section 4 - Drilling and Logging			
4.1 Soil Boring	March 1992	2	To ensure acceptable, consistent soil-boring procedures are used to prevent communication of subsurface contaminants in vadose zone soils or landfill materials with underlying groundwater.
4.1.1 Methods to Control Communications of Subsurface Contaminants with Groundwater	December 1992	2	To insure that acceptable, consistent soil-boring procedures are used to prevent communication of subsurface contaminants in vadose zone soils or landfill materials with underlying groundwater.
4.2 Rock Boring	March 1992	1	To ensure acceptable, consistent rock boring procedures for all pertinent aspects of hazardous waste investigations.
4.3 Monitoring Well Installation	March 1992	1	To ensure acceptable, consistent monitoring well installation.
4.4 Monitoring Well Development	March 1992	1	To remove foreign materials that may have been introduced into the groundwater, well annulus, or well screen during well installation and to facilitate hydraulic communication between the screened formation and the monitoring well.
4.7 Piezometer Installation	December 1992	2	To ensure acceptable, consistent piezometer installation.
4.8 Piezometer Development	December 1992	2	To remove foreign materials that may have been introduced into the groundwater, well annulus, or well screen during well installation and to facilitate hydraulic communication between the screened formation and the piezometer.
Section 5 - Soil Sampling			
5.1 Soil and rock Borehole Logging and Sampling	March 1992	1	To describe the physical nature of consolidated or unconsolidated subsurface earthen materials encountered during auger, rotary, or other drilling or trenching activities and collect samples of the earthen materials for further evaluation.
5.2 Soil Sampling with a Spade and Scoop	March 1992	3	To describe a method for collecting a soil sample less than 4 feet below the land surface.
5.3 Subsurface Solid Sampling with Hand Auger and Thin-Wall Sampler	March 1992	2	To define a method of collecting subsurface solid samples with a hand auger and thin-wall tube sampler.

Table II.2. (Continued)

	Effective Date	Revision Number	Purpose
5.4 General Soil Gas Sampling and Field Chemical Analysis	January 1991	0	To define a method that ensures acceptable, consistent soil gas sampling and on-plant analysis with a gas chromatograph for volatile organic contaminants.
5.8 Soil Sampling with a Stainless Steel Surface Soil Sampler	October 1991	1	To define procedures for collecting surface soil samples to determine the chemical and physical soil properties.
5.9 Sediment Sampling Procedures for Streams, Rivers, and Ponds	March 1992	0	To describe the methods for collecting deposited sediment samples in streams, rivers, and ponds.
Section 6 - Health and Safety			
6.1 Health and Safety Monitoring of Combustible Gas Levels	March 1992	1	To describe the equipment and proper method for monitoring combustible gas levels in order to determine when an explosion hazard exists in the work environment.
6.2 Health and Safety Monitoring of Organic Vapors with a Photoionization Detector	March 1992	1	To describe the equipment and proper method for environmental monitoring of toxic gases and vapors using a portable photoionization detector (PID).
6.3 Health and Safety Monitoring of Organic Vapors with a Flame Ionization Detector	March 1993	2	To describe the equipment and proper method for environmental monitoring of toxic gases and vapors using a portable flame ionization detector (FID).
6.4 Total Alpha Surface Contamination Measurements	May 1992	1	To provide guidance for determining levels of total surface alpha contamination on equipment vehicles, and personnel that have been in contact with material that was potentially contaminated with alpha-emitting radionuclides.
6.7 Near Surface and Soil Sample Screening for Low-Energy Gamma Radiation Using the FIDLER	May 1992	1	To describe the procedure in which a field instrument for the detection of low-energy radiation (FIDLER) is used to monitor surfaces and soil samples for the presence of low-energy gamma radiations that accompany some alpha emissions.
6.11 Beta-Gamma Radiation-Measurements	September 1992	1	To describe the methodology for measuring beta-gamma radiation levels.
6.15 Measurement of Gamma-Ray Fields Using a Sodium Iodide (NaI) Detector	January 1991	0	To describe the procedure for making count-rate measurements of a gamma-ray field with a sodium iodide (NaI) detector.

contamination within Mound Plant and off-plant. Personnel will be decontaminated as specified in the Main Hill Investigation Health and Safety Plan before leaving the work area for breaks or at the end of the day. Equipment decontamination will be according to Mound Plant ER Program SOP 1.6, General Equipment Decontamination (Revision 2). Following these decontamination procedures will minimize the possibility of spreading contamination.

At the end of each day, the decontamination water will be collected in 55-gallon drums provided by Mound Plant. The water collected during decontamination procedures will be sampled daily and analyzed for the parameters of concern to document the presence or absence of these types of contaminants. All drummed water will be labeled showing the date filled and source of the water and will be staged for disposition by EG&G.

2.4. FIELD QUALITY CONTROL SAMPLES

Trip blanks, equipment rinsate blanks, field ambient blanks, field duplicates, matrix spike/matrix spike duplicates, and bottle lot blanks, as described below, will be collected to assess field quality control. The field sample identification plan for field quality control samples is outlined in Section 2.6.

2.4.1. Trip Blanks

Trip blanks are used to evaluate organic contamination that may be introduced into the samples during shipment. Two 40-mL vials of reagent grade ASTM Type II water (organic free deionized water) will be placed in each shipping container with samples for analysis of volatile organic compounds (VOCs). These vials will then be analyzed for VOCs according to the methods described in the OU-2 QAPP.

2.4.2. Equipment Rinsate Blanks

Rinsate blanks are used to evaluate the success of the equipment decontamination process. After decontamination, the sampling equipment is rinsed a final time with reagent grade ASTM Type II water. The rinsate is collected and analyzed for the contaminants of concern. One rinsate blank will be collected at a frequency of one per group of 10 or fewer investigative samples collected.

2.4.3. Field Ambient Blanks

Field ambient blanks are used to evaluate contamination that may be introduced to the samples from the ambient work area. They are made by placing an open sample of reagent grade ASTM Type II water in the work area, sealing the container, then shipping it with the samples collected that day. One field blank

will be collected per work area or one for every group of 10 samples per medium (whichever is greater) and analyzed for contaminants of concern specific to that area.

2.4.4. Field Duplicates

Field duplicates are prepared to evaluate total within batch measurement variability, including media heterogeneity. Duplicates will be collected for all sample types and analyzed for the contaminants of concern. These analytes will be identified in the following site-specific discussions. One field duplicate will be collected at a frequency of one per group of 10 or fewer investigative samples collected by media.

2.4.5. Bottle Lot Blanks

Bottle lot blanks are prepared to evaluate the cleanliness of analytical sample bottles. A bottle lot blank will be analyzed if there is an indication from the analytical results that a non-CLP analyte is a bottle contaminant. At least one bottle for each lot number of non-CLP analyte sample bottles will be prepared and stored in the shipping box for this purpose. This sample will only be prepared by the sample document control administrator (as defined in the QAPP). Preparation consists of filling the sample bottle with organic-free, deionized water (ASTM Type II quality) and capping it.

2.4.6. Matrix Spike/Matrix Spike Duplicate

Matrix spike and matrix spike duplicates are collected, where feasible, at sample locations with known contaminants or at locations with an unusual sample matrix (e.g., soil with high organic content). This practice will provide usable spike recovery information, giving an indication of positive or negative effects from the sample matrix. If these types of sample locations are not identified for a task, the matrix spike and matrix spike duplicate will be randomly selected in the field at the specified frequency. Matrix spike/matrix spike duplicates are prepared to evaluate the effects of the sample matrix on the laboratory analytical results. In general, matrix spike/matrix spike duplicates are collected in the same manner as field duplicates (Section 2.4.4). A matrix spike/matrix spike duplicate will be collected at a frequency of one per group of 20 or fewer investigative samples collected.

2.5. SAMPLE HANDLING AND SHIPMENT

The samples obtained from the locations included in this investigation will be handled according to Mound Plant ER Program SOPs 1.3, Sample Control and Documentation (revision 1); 1.4, Sample Containers and Preservation (revision 2); and 1.5, Guide to Handling, Packaging, and Shipping of Samples (revision 1).

These SOPs are included in Appendix A of the OU-2 QAPP. Figure 2.1 shows an example of the sample label that will be used for each sample obtained during the RI/FS and an example of the custody seals that will be fixed to each sample cooler. Figure 2.2 shows the chain-of-custody form that will be completed for each sample shipment. The samples will be containerized and preserved as appropriate for the intended analytes. Table II.3 presents the container requirements for water, soil, and sediment.

For all soil, sediment, and surface water samples from on-plant locations and both on-plant and off-plant groundwater samples, a portion of each sample (500 mL) obtained during the field investigation will be screened for radioactivity by Mound Plant soil sample screening facility (Draper 1988). This screening is performed in order to identify the nature and concentrations of radionuclides present in accordance with the U.S. Department of Transportation (DOT) and U.S. Department of Energy (DOE) Order 5400.5. On-plant screening must be performed before a sample is released from Mound Plant and is not part of the off-site laboratory analytical package. Screening results, however, will be included with the corresponding samples shipped to the analytical laboratory to provide the laboratory with information concerning the samples' radioactivity levels. The analytical laboratories will screen one out of every 10 samples (consisting of an additional 40-mL volatile organic analysis vial for water samples and an additional 120 ml wide-mouth jar for soils and sediments) for the same radiological parameters to confirm Mound Plant screening facility results.

The radioactive shipping class will be determined in accordance with DOT requirements and will depend on the radionuclides present and their concentrations, determined by the on-plant screening performed by Mound Plant. Samples with concentrations of radioactivity in excess of 2,000 piocuries/gram (PCi/g) (2 nanocuries [nCi]/g) will be shipped as radioactive samples according to DOT requirements (given in 49 CFR 172 and 173) (CFR 1989) and DOE Order 5400.5. In addition, the analytical laboratory will be notified in the unlikely event they are to receive samples with concentrations of radioactivity greater than 20,000 pCi/g (20 nCi/g).

2.6. SAMPLE IDENTIFICATION SCHEME

Samples collected at Mound Plant OU-2 are numbered using a 10-digit identification system (M2XX-AYYY-ZZZZ). This sample numbering system provides information on the area, type of OU-2 investigation, sample matrix, sample location, and the interval sampled or sample depth. Individual samples are numbered according to a unique investigation type (X), sample matrix (A), sample location (Y), and sample identifier (Z). The following illustrates the sample identification scheme:

Figure 2.1. Sample Label Example

Facility Code:
Sample ID:
Lab Code:
Sampler:
Sample Depth Interval From Datum
Beginning Depth (FT from Datum):
Ending Depth (FT from Datum):
Analysis Requested:
Comments:

Location Id:
Log Date:
Log Time:
Logger Code:

ICF KAISER ENGINEERS

_____
Date

Custody Seal

_____
Signature

KAISER ENGINEERS

Chain-of-Custody Record

Sheet _____
Date: _____

Sampler's Name: _____
Signature: _____

ICF KE Supervisor: _____
ICF KE Project No.: _____
Sampling Site ID: _____

Sample ID No.	Sample Matrix	Time Taken	Analyses										Preservatives	Bottle Type	Archive Sample Y/N	Remarks

Relinquished By: _____ Date and Time: _____ Received By: _____
Relinquished By: _____ Date and Time: _____ Received By: _____
(For Laboratory) Received By: _____ (For Laboratory) Date and Time: _____

Figure 2.2. Chain-of-Custody Record

Table II.3. Container Labeling Requirements for Samples Obtained from OU-2 Investigations

Parameter	Requirement
Water, Soil, Sediment	■ Project name and site ■ Client name, address, and phone number ■ Sampler's name, firm, and phone number ■ Sample number, date, time of collection, and matrix ■ Analyses required ■ Preservative used; if applicable ■ Analysis turn-around time requested ■ Any other descriptive or explanatory information deemed pertinent by the sampler

Field Samples:

Sample Matrix	Identification Scheme
Groundwater	M2XX-0YYY-ZZZZ
Surface Water	M2XX-1YYY-ZZZZ
Surface Soil	M2XX-2YYY-ZZZZ
Subsurface Soil	M2XX-3YYY-ZZZZ

Quality Control Samples:

Sample	Identification Scheme
Duplicate	M2XX-AYYY-1ZZZ
Trip Blank	M2XX-AYYY-2ZZZ
Sample Blank	M2XX-AYYY-3ZZZ
Equipment Blank	M2XX-AYYY-4ZZZ
Field Blank	M2XX-AYYY-5ZZZZ

Qualifiers:

M2 = Mound Plant Operable Unit 2
XX = Type of OU-2 Investigation
X1 = Soil Gas Investigation
X2 = Hillside Seep Investigation
X3 = Groundwater Investigation
X4 = Surface and Subsurface Soil Investigation
X5 = Monitoring Well 0034 Investigation

A = Sample matrix; 0=groundwater, 1=surface water, 2=surface soil, 3=subsurface soil
YYY = Sample location number
ZZZZ = Sample identifier; either sample round or sample depth.

Soil gas investigations will be numbered using the site identifier M2X1. Hillside seep investigations will be numbered using the site identifier M2X2. Groundwater investigations will be numbered using the site identifiers M2X3. Surface and subsurface soils investigations will be numbered using the site identifier M2X4, and monitoring well 0034 investigations will be numbered M2X5.

A sample matrix identifier (A) of zero (0) will be used for groundwater samples collected, while identifiers 1, 2, and 3 are reserved for surface water, soil and subsurface soil, respectively.

Quality control samples will be assigned an investigation identifier, a sample location number and a sample round number. The first number in the four-digit, sample round identifier (ZZZZ) will be used to

designate the type of control sample according to the numbering scheme listed in the previous table. Duplicate samples, trip blanks, and sample blanks will be assigned prefixes 1,2, and 3 respectively, while equipment blanks and field blanks will be identified by prefixes 4 and 5, respectively.

The following example better illustrates the sample designation scheme:

M2X2-2101-0001	Defines a surface soil sample for the hillside seep investigation.
M2X2-2101-0005	Corresponds to a five-foot-deep sample at location 101 for the hillside seep investigation
M2X2-2102-0001	Designates the next soil sample location for the hillside seep investigation.
M2X2-2102-1001	Describes a duplicate sample of 001.
M2X2-0101-0001	Defines a groundwater sample for the hillside seep investigation.
M2X2-0101-2000	Defines a trip blank for groundwater investigations at the hillside seep.

3. GEOPHYSICAL INVESTIGATION

3.1. SEISMIC REFRACTION SURVEY

3.1.1. Refraction Principles

Refraction techniques are commonly used to obtain depth to geologic horizons. In order to detect a horizon using seismic refraction, the following subsurface conditions must exist:

- the velocity of seismic layers must increase with depth;
- the layers must be of sufficient thickness to permit detection; and
- the Seismic velocities must be of sufficient contrast to permit resolution of different layers.

Refraction is extremely useful for identifying the depth to contacts between horizons with large velocity contrasts. Seismic refraction methods are particularly amenable to detection of interfaces between low-velocity, unconsolidated deposits and underlying high-velocity bedrock.

The refraction method involves the use of a source to generate the seismic waves, geophones to measure the seismic signals, and a seismograph to display the signals received by the geophones. Various devices can be used to generate the seismic wave. The use of a sledge hammer to strike the ground is usually suitable for shallow data collection, whereas explosives are more appropriate for collection of data from deep horizons.

An array of geophones, implanted into the ground surface, measures the travel times of the primary seismic waves (P-waves) to various horizontal off-set distances from the source. The seismograph is used to record and graphically display the seismic signal received at the geophones. Plotting the first seismic arrivals at each geophone allows interpretation of the subsurface including, number of horizons, thickness of horizons, depths to interfaces, and seismic velocity of each horizon.

If a denser layer with a higher velocity, such as bedrock, exists below the unconsolidated soils, some of the seismic rays will be refracted as they enter the higher velocity layer. At the critical angle of incidence, waves will move parallel to the two interfaces in the underlying higher velocity layer, and some of the energy will refract back to the surface. Beyond a the critical distance, the refracted wave will arrive at a geophone prior to the direct wave. Thus, geophones closer to the source will provide velocity information on the overlying low-velocity layer, and geophones further away will provide velocity information for the bedrock layer.

First arrivals of seismic energy are plotted on time-distance charts (Figure 3.1). Line segments are drawn through points which fall in a straight line. The number of different line segments indicate the number of layers, and the slope of each line is inversely proportional to the seismic velocity in the corresponding layer. Break points in the plot (points where seismic velocity changes) are used in conjunction with the velocities to calculate depth to each interface.

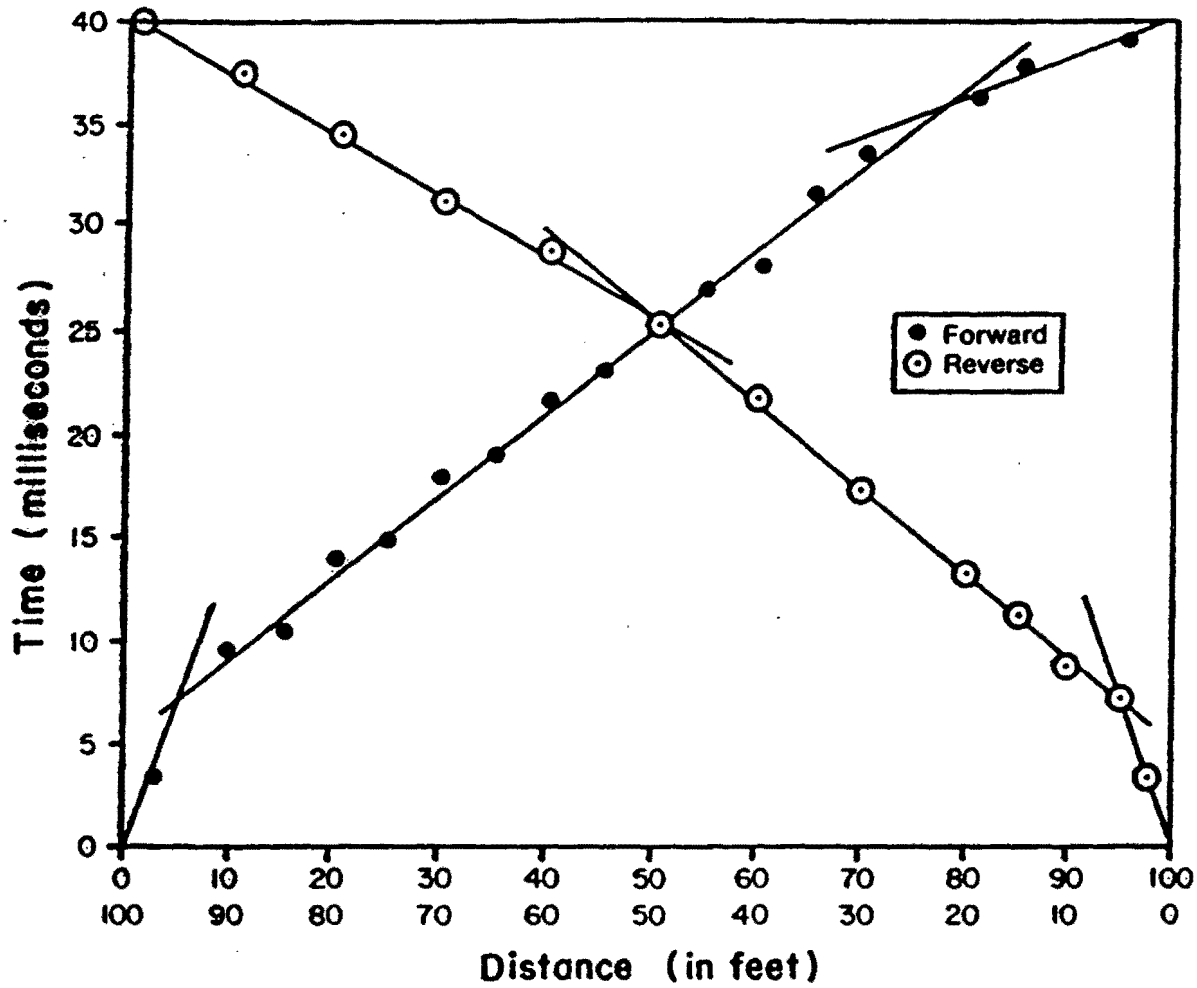
3.1.2. Site-Specific Data Collection Strategy for Seismic Survey

The seismic refraction survey of OU-2 includes the collection of 5,000 linear feet of data in nine seismic lines, whose locations are shown on Figure 3.2. The seismic refraction line lengths, locations, and orientations were selected to provide adequate subsurface coverage from the center to the flanks of the Main Hill. All data collection will be in accordance with the seismic-refraction SOP provided in Appendix A.

Prior to implementing the full scope of the field work, one of the nine seismic lines (line GL-1) will be used to pilot test the amenability of OU-2 area to the seismic refraction method. Line GL-1 will be selected following the Phase 1 site reconnaissance investigation. It will be chosen to be representative of the characteristics likely to be encountered during the investigation of all proposed lines. The data will be evaluated by the field geophysicist to determine the usefulness and appropriateness of continuing with the remaining eight lines. The field geophysicist will plot the results for line GL-1 and perform a cursory evaluation of the refraction time-distance plots which will include:

- number of identifiable layers;
- velocities of each layer;
- depths to each layer;
- lithology of each layer based on observed velocities; and
- comparison of interpreted lithology to existing borehole data.

The soil bedrock interface beneath the Main Hill at Mound Plant is expected to be anywhere from surface to approximately 10 feet below ground surface (ft-bgs). The shallow depth to bedrock beneath the Main Hill will preclude the need for a powerful seismic source. A sledge hammer and strike plate should be sufficient and will be used as the seismic source. The sledge hammer and strike plate typically have depths of penetration ranging anywhere from 30-to-50-ft-bgs, depending on the subsurface lithology. The geophone arrays will consist of 24 geophones, spaced so that a distance of approximately three to five times the expected depth to bedrock is achieved. Assuming a maximum depth of 10 ft to bedrock, geophones will be spaced from approximately 1.25 to 2.0 ft apart. This spacing may be changed at the discretion of the field geophysicist upon review of the field records. In areas where geophones can not be placed directly into the ground surface (i.e. on certain paved areas), wooden blocks, capable of



Reference: Benson, 1992

Figure 3.1.
Example Time/Distance Plot of Field Data Showing Forward and Reverse Seismic Refraction Data

holding a geophone in an upright position, will be placed on the surface at the appropriate location to anchor the geophone.

Both forward and reverse shots will be recorded for each line to allow for the interpretation of dipping strata if present. Approximately five hammer strikes will be recorded for each location and the refraction data will be summed (stacked). Stacking the data will tend to cause incoherent signal (noise) to cancel, while enhancing the coherent signal (direct and refracted waves). A 24-channel seismograph recording instrument with stacking capability will be used to collect all refraction data.

Horizontal location and elevation control points will be surveyed at approximately 30-foot intervals along each seismic line, or where undulations in topography are observed so that dipping or sloping surfaces can be taken into consideration during data reduction and interpretation.

3.2. GROUND-PENETRATING RADAR (GPR) SURVEY

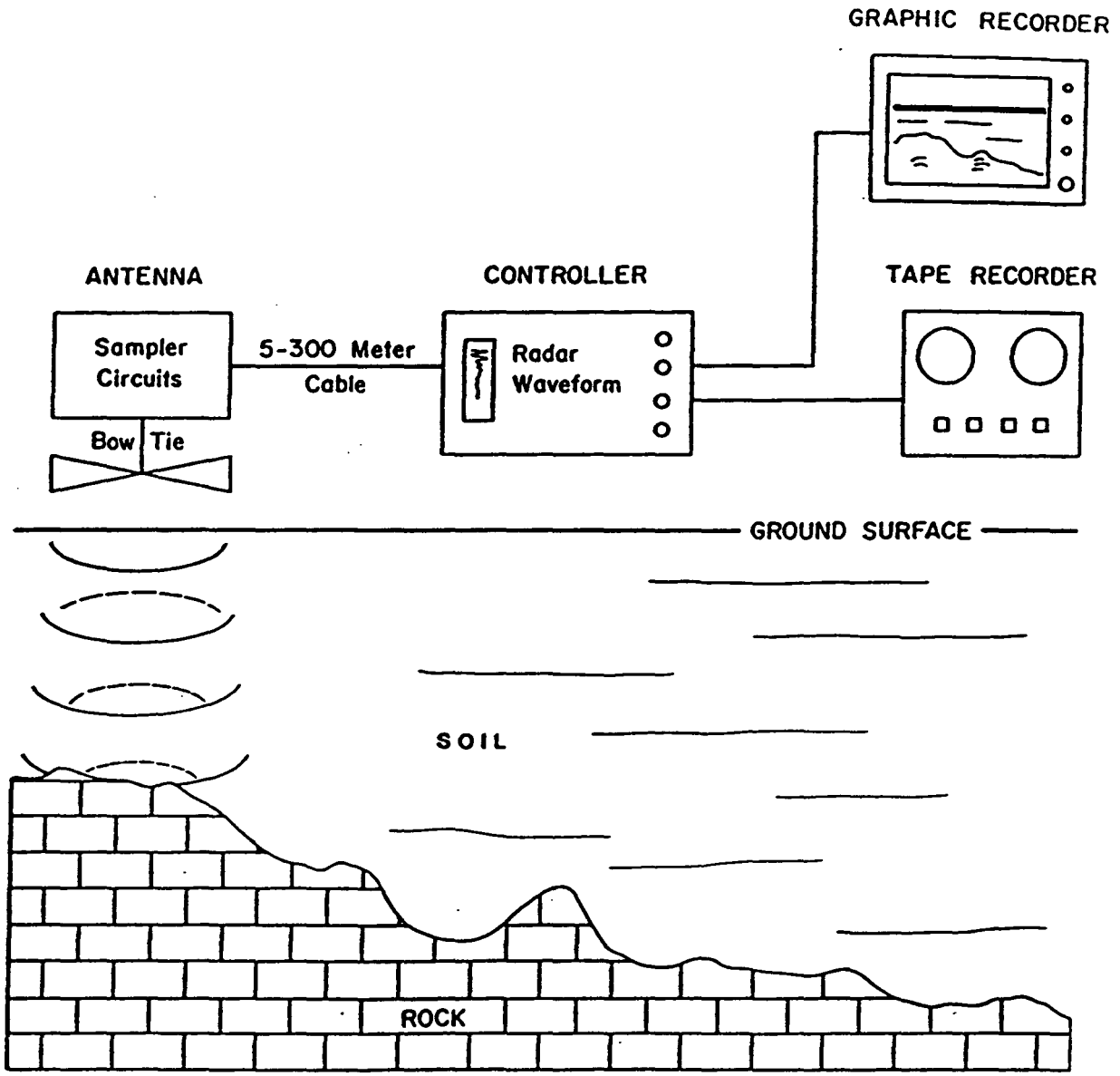
3.2.1. Ground-Penetrating Radar Principles

Ground-penetrating radar (GPR) uses high frequency radiowaves to acquire information on subsurface conditions. In order for an interface to be detected by GPR, the electrical properties of the overlying and underlying horizons must be sufficiently different.

The depth of penetration of the method is site-specific and generally varies between 3-to 30-ft-bgs (Benson, 1982). The depth of penetration is limited primarily due to wave attenuation by high conductivity subsurface materials. The best results (deepest penetrations) are typically associated with dry, sandy, or rocky areas. Poorer results are often associates with clayey or highly conductive soils.

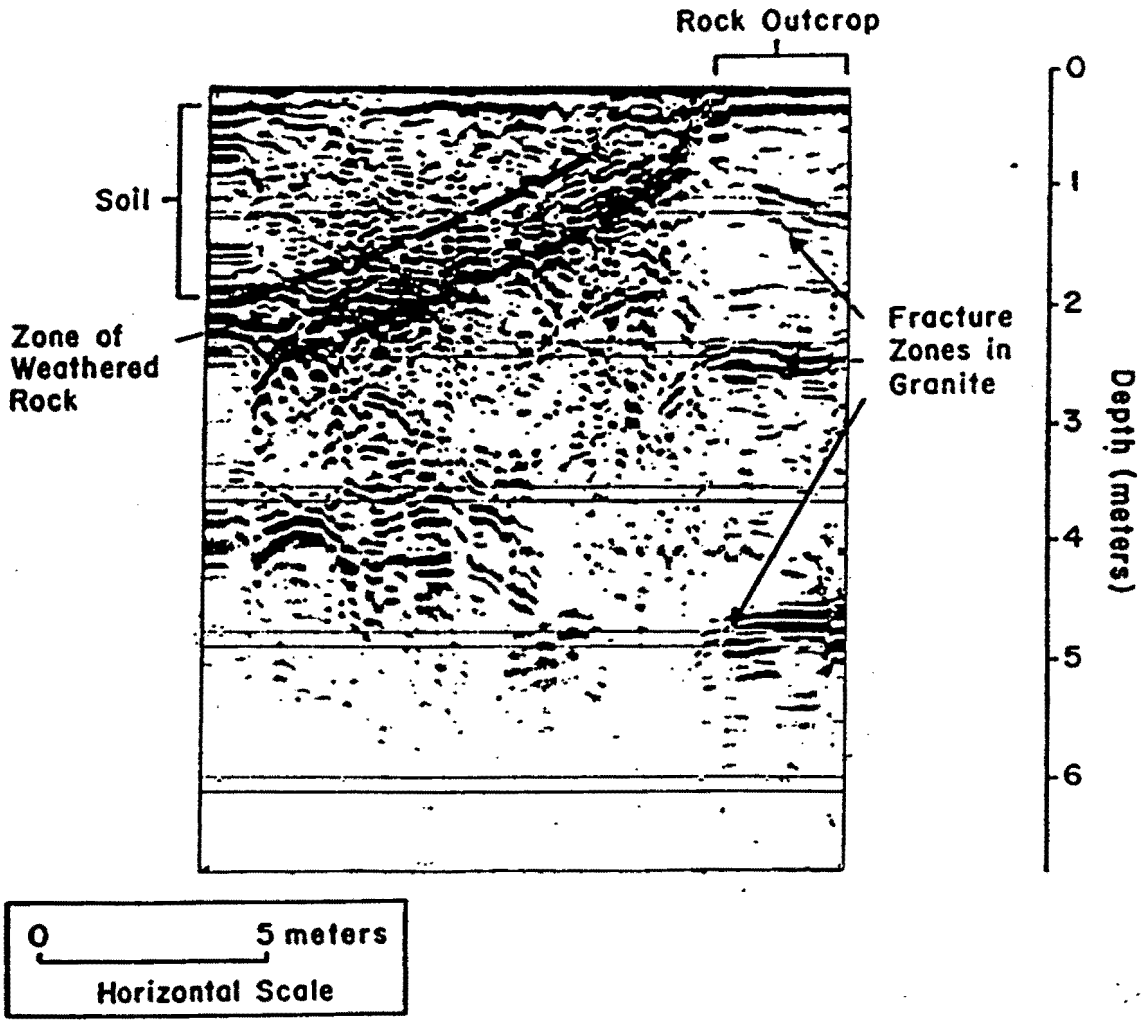
The GPR method uses a small antenna that radiates energy downward into the subsurface (Figure 3.3). As the antenna is moved slowly across the surface of the ground, energy is reflected back to a receiving antenna, where variations in the return signal are recorded and plotted. The output consists of a GPR profile of shallow subsurface condition caused by radio wave reflections from interfaces of materials having different electrical properties (Figure 3.4). The output displays the two-way travel time from the transmitter antenna to the reflecting surfaces.

The varying responses may be related to a number of subsurface conditions such as bedding, cementation, moisture, clay content, voids, fractures, intrusions, and subsurface metallic objects. The method is often used to detect buried pipes and may be useful for delineating saturated zones associated with leaking pipes.



Reference: Benson, 1992

Figure 3.3.
Cross Section Illustrating the GPR System



Reference: Benson, 1992

Figure 3.4.
Example GPR Output Profile

The depth of penetration and resolution of the GPR will vary depending on the antenna (frequency) used. Resolution is increased by increasing the frequency of the radar. High frequency antennas (500 to 900 MHz) provide resolution of subsurface conditions to a few centimeters; however, they will not penetrate the ground very far due to attenuation of the shorter wavelengths. Lower frequency antenna (80 to 125 MHz) provide greater depth of penetration but lack resolution to define features smaller than a few feet in thickness.

3.2.2. Site-Specific Data Collection Strategy for Ground-Penetrating Radar Survey

Nine GPR lines are proposed for collection within OU-2 as illustrated in Figure 3.2. The GPR line lengths, locations, and orientations were selected to provide adequate subsurface coverage from the center to the flanks of the Main Hill. All GPR data will be collected in accordance with the GPR SOP provided in Appendix A.

Prior to implementing the full scope of field work, one of the nine survey lines will be used to pilot test the amenability of the OU-2 subsurface to GPR. The data will be evaluated by the field geophysicist to determine the usefulness of the data and appropriateness of continuing with the survey of the remaining 8 lines. The field geophysicist will plot the results for test line, and perform a preliminary evaluation of the GPR data plots including

- Visibility of expected reflecting horizons and system noise
- Approximate depth to reflecting horizons
- Lithology associated with reflecting horizons (The field geophysicist will utilize available boring log information)
- Appropriateness of time window settings
- Appropriateness of antenna frequency

System adjustments will be made as appropriate at the discretion of the field geophysicist to optimize the GPR results. All potential contributors to noise (i.e. surface metal and overhead powerlines) will be noted and their location plotted on a base map.

A GPR system capable of continuous profiling will be used to perform the survey to facilitate high speed data collection. The antenna will be slowly towed by hand along each of the traverses. The depth to soil/bedrock interface beneath Mound Plant is expected to be within approximately 10 feet of the surface. The survey will be designed to optimize the signal received from the bedrock surface so that bedrock depth can be determined and its configuration mapped. The time window settings will be set to penetrate

slightly deeper than the expected top of bedrock. In order to achieve the required depth of penetration, a low frequency (80 to 125 MHz) antenna is anticipated for use, however the pilot test will include antennas of different frequencies to determine which is best for site soil conditions. A two antenna system may be employed at the discretion of the field geophysicist to optimize the benefits from recording both high and low frequencies if the results from the single antenna system are unsatisfactory.

3.3. CONE PENETROMETER TESTING (CPT)

3.3.1. Cone Penetrometer Testing Principles

Cone penetrometer testing (CPT) is an intrusive method for rapidly obtaining subsurface information without generating soil cuttings. The general methodology involves using a truck capable of thrusting a cone-shaped probe equipped with various sensing devices into the subsurface (Figure 3.5). The Standard sensing cone contains a tip resistance device and a friction sleeve. The cone tip resistance, friction, and the ratio between the two (tip resistance/friction ratio) are continuously measured and recorded on a strip chart as the probe is pushed into the ground (Figure 3.6). Depths of penetration of 50 feet or greater are typically achieved. The resistance and friction information are directly related to the physical characteristics of the material penetrated and provide information for the interpretation of soil types or lithology.

A summary of variety of CPT sensors are as follows:

- Standard CPT (cone end bearing and friction sleeve) - Measures soil resistance to mechanical penetrations, in bearing and sliding shear failure modes.

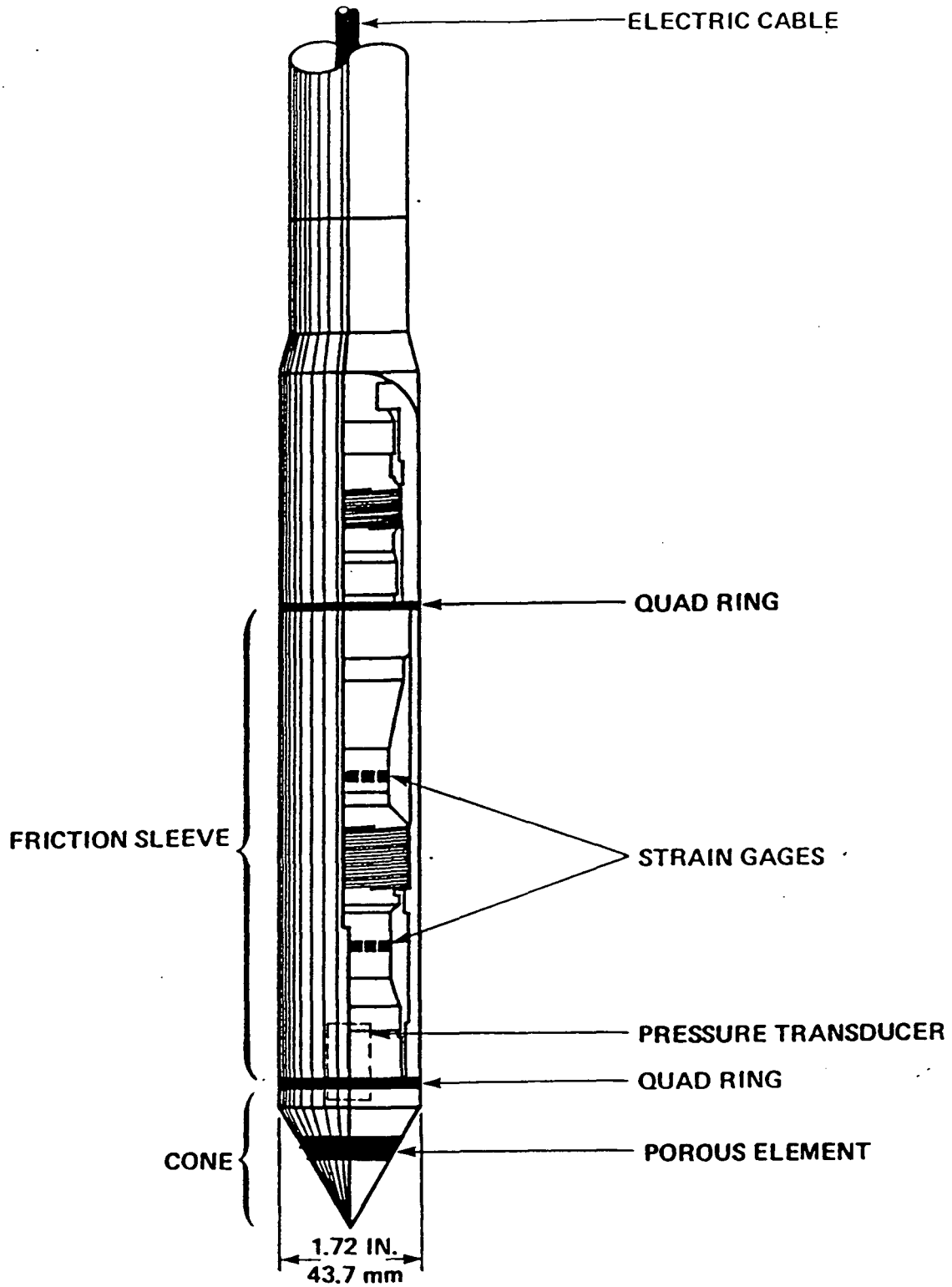
- Piezometric CPT (addition of pore pressure sensor) - Measures soil pore pressure response to mechanical penetration; can be used to obtain ambient pore pressures and an indication of permeability. Two designs are common: ported through cone tip or ported through front of sleeve. These designs give radically different measurements, especially in stiff soils.

- Resistivity CPT (addition of electrical field measurement) - Measures electrical resistance of soil around CPT instrument; responds to degree of saturation and electrolyte type.

- Thermal CPT (addition of thermistors) - Measures soil thermal response to mechanical penetration; can be used to determine ambient temperatures.

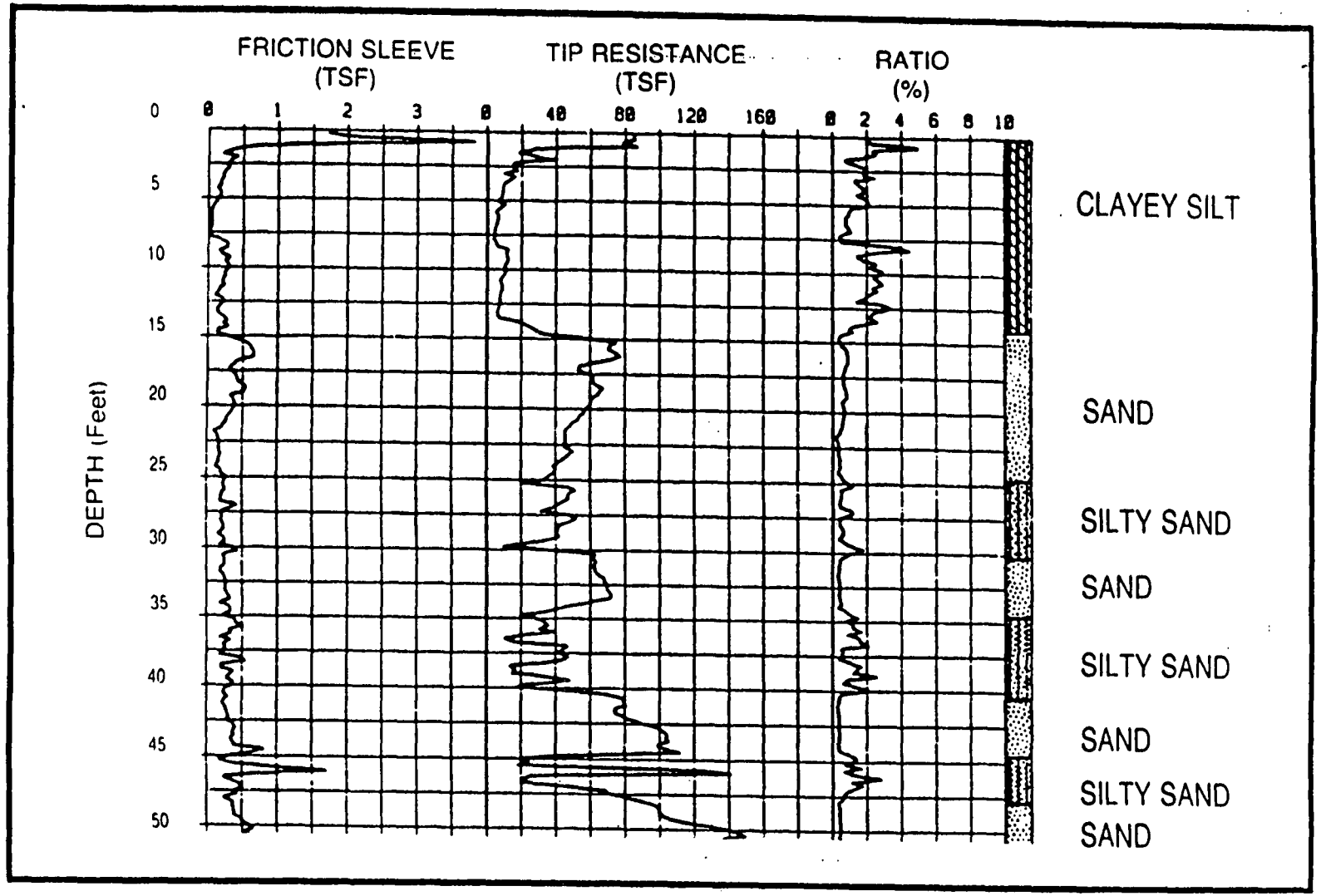
- Seismic CPT (addition of geophones) - Measures soil response to surface seismic excitation, with superior sensor-soil coupling. Down-hole and cross-hole tests may be performed.

- Nuclear CPT (addition of nuclear moisture-density-source) - Measures soil response to low level radiation, indicating in situ densities and moisture content.



Reference: ETC, undated

Figure 3.5.
Typical Cone Penetrometer Sensor



Reference: ETC, undated

Figure 3.6. Example Cone Penetrometer Field Record

- Pressuremeter CPT (addition of a pressuremeter cell) - Measures radial response of soil to radial expansion and contraction of cell.

- Fluid Sampler CPT (addition of lysimeter) - Allows acquisition of select or continuous samples of in-situ gases or liquids.

3.3.2. Site-Specific Data Collection Strategy

Twenty-six CPT data collection points (24 along refraction lines and two adjacent to proposed soil borings) are proposed within OU-2 as illustrated in Figure 3.2. All CPT data will be collected in accordance with the American Standards for Testing and Materials (ASTM) Method D3441-79 (Appendix A). The two CPT datapoints located next to soil boring will allow the CPT results to be correlated to actual site lithology.

A CPT truck capable of a 35-ton thrust capacity will be used to push the cone penetrometer into the subsurface. During testing, a record of cone tip resistance, friction, and tip resistance/friction ratio will be recorded on a strip chart and computer diskette. In addition to these measurements, a nuclear CPT sensor simultaneously will be used to collect in-situ moisture and density data. If dual standard and nuclear CPT equipment are not available, it will be acceptable to use these sensors separately by making two cone penetrometer intrusions at locations spaced approximately two feet apart.

A minimum of two additional cone penetrometer data point will be located adjacent to proposed soil boring locations, drilled during the Soil Core Sampling work described in Section 10 of this FSP. Advancement adjacent to two of the proposed soil core sampling locations will provide a calibration tool for relating CPT data directly to Site soil types.

After completing each boring, the hole made by the cone penetrometer will be tremie-grouted to the land surface with a neat cement grout to seal potential preferential avenues of surface water or contaminant migration. The SOP for sealing boreholes is provided in Appendix A.

3.4. FRACTURE-TRACE ANALYSIS

Fractures are zones of high permeability in areas of fractured aquifers or conduit systems. These fractures provide preferential flow for groundwater are likely targets for monitoring wells because they generally contain higher water yields. Fracture traces that intersect the ground surface can be identified by using aerial photography and standard USGS topographic maps. Linear features consist of tonal variation in soils, alignment of vegetative patterns, straight stream segments or valleys, surface depressions, gaps in ridges, or other linear features. Fracture traces may be related to the regional tectonic activity and tend to be oriented at a constant angle to the regional trend.

Statistical studies have shown wells located on fracture traces have a greater yield than those not on fracture traces. Fracture trace analysis is useful in determining the locations of groundwater monitoring well because groundwater flows preferentially following the most permeable pathway.

The purpose of the fracture-trace analysis is to map identifiable fractures by using aerial photographs and USGS topographic maps. This mapping will be used to determine the overall structural trends defined by the fracture trace analysis; to determine preferential flow paths and preferred flow direction of the groundwater in the bedrock flow system; to determine intersecting fracture trends for possible location of future monitoring wells; and to identify if the known or discovered seeps are located along fracture or lineament traces. Fracture traces can be confirmed by using geophysical techniques, such as seismic refraction surveys that are discussed in Section 3.1.

Procedures for determining fracture traces are the following:

- Assemble appropriate topographic maps of the area of concern and aerial and/or satellite photography. Topographic maps to be included are pre-Mound, during early operating years - 1948-1959, and post 1980.
- Map appropriate linear features that are distinguishable, avoid mapping man-made features such as power lines or fences.
- If possible, examine different sets of aerial photography (pre-Mound, early operating years - 1948-1959, and post 1980), flown in different seasons and years to confirm presence of lineaments.
- Field check and confirm orientation of traces.
- Use of geophysical methods (e.g. seismic refraction) can also confirm existance of traces.

4. SUBSURFACE UTILITY EVALUATION

A complete review and evaluation of all building, plumbing, utility, and as-built plans and drawings will be conducted to map and confirm the existing subsurface utilities. Figures 4.1 and 4.2 show the location of sanitary and storm sewers and lines under pressure, respectively, at the Main Hill Site. Confirmation of these drawings will be performed by this review and subsequent field investigation site surveys. Surveying the location will be performed using a licensed surveyor and standard surveying practices as established by the Board of Registration for Professional Engineers, Architects, and Land Surveyors for the State of Ohio. All surveyed data will be accurate to 0.1 feet for horizontal position and 0.01 feet vertical elevation.

The objectives of this evaluation and investigation are as follows:

- Produce an accurate map showing all of the locations of sewer lines, storm sewer lines and drains, pressurized lines and other subsurface utilities, sumps/tanks, and trenches where groundwater can move laterally along the trench lines.
- Confirm locations by field verification and surveying locations.
- Determine the integrity of subsurface utilities, active sumps/tanks, and if they are contributing to the groundwater in the bedrock formation.

4.1. INTEGRITY ANALYSIS OF SUBSURFACE UTILITIES

Integrity analysis of the subsurface utilities will provide information on the potential leakage or source areas that are contributing releases to the groundwater in the bedrock formation. The integrity analysis will be performed by using video cameras and hydrostatic testing procedures to determine if subsurface utilities are leaking.

4.1.1. Video Survey of Storm and Sanitary Sewers

A video camera survey will be conducted on all sanitary and sewer lines where access is available. Sewer lines that are less than 8-inch diameter may be to small for the camera survey and other testing methods will be used. The results of the video survey will be recorded on a standard VHS tape and will show areas of potential leakage or pipe failure.

If the video camera survey identifies potential areas where leakage can occur, other testing methods will be used to confirm the video camera results. These other leak detection methods will include, but are not limited to smoke testing, pressure testing, and analysis of flows (input and output volume determination).

4.1.2. Hydrostatic Leak Testing

Hydrostatic testing will be performed on sanitary and storm sewers when the results of the video camera survey indicate potential leakage or where the video camera is unable to be used because of small diameter pipe size or accessibility. Hydrostatic testing will be performed using ASTM method E 1003-84, published in August 1984.

Hydrostatic testing requires a component be completely filled with a liquid, such as water. Pressure is slowly applied to the liquid until the required time at which point the component is inspected visually or by recording pressure on a gauge. This method is useful for quality control testing and field inspection of pipeline that are expected to retain liquids. A qualified subcontractor knowledgeable in performing hydrostatic leak testing will be contracted to perform the test and will follow the ASTM method E 1003-84.

4.1.3. Pressure Line Testing

Pressure line testing will be performed on pressurized lines to determine their integrity and to evaluate if leaky pressurized lines are contributing fluids to the groundwater in the bedrock. Pressure testing of lines is typically performed by isolating a section of line to be tested from other input sources. The ends of the line are plugged and gauged as air is forced into the line at a specified psi. The materials of the line and psi rating must be known so that a proper test can be performed without causing failure of the line by the testing procedure.

Pressure testing will be performed by a qualified subcontractor knowledgeable about performing the pressure testing using the latest testing technologies.

4.1.4. Integrity Evaluation of Sumps/Tanks

A visual inspection will be performed on all sumps and tanks. Additional testing may be required based on the visual inspection and may include hydrostatic, volumetric, or pressure testing.

Where sumps and tanks have been removed from service, the results of D&D activities will be assessed to determine that the verification sampling performed meets the DQOs established for the RI.

5. SOIL GAS RECONNAISSANCE

The soil gas reconnaissance survey will be conducted in accordance with the Mound Plant ER Program SOP 5.4 "General Soil Gas Sampling and Field Chemical Analysis" and the methodology that follows. The objective of the soil gas reconnaissance is to identify sites where volatile contaminants may be present in the soil or to indicate that further investigation are not warranted.

5.1. SOIL GAS SURVEYING PRINCIPLES

Soil gas surveys are commonly used as reconnaissance tools to delineate the vertical and horizontal extent of contamination resulting from volatile organic compounds (VOCs) in the vadose zone or groundwater. The presence of VOCs in shallow soil gas indicates the observed compound may either be in the vadose zone near the probe or groundwater below the probe. Results of soil reconnaissance are useful for selecting the optimum number and location of borings and monitoring wells required for confirmation; thus, reducing the number of borings or wells required for site characterization. This advantage, coupled with the fact that this intrusive method does not generate soil cuttings that may require off-site disposal, can result in significant cost savings during site characterization activities.

The soil gas method involves pumping a small amount of soil gas from the subsurface through a hollow probe that is inserted into the ground to preselected depths, then analyzing the gas for VOCs. Selected VOCs are analyzed with fast turnaround time in a mobile laboratory equipped with a gas chromatograph (GC). Based on the field analytical results, subsequent soil gas sampling locations are selected by the person(s) directing the survey to define the extent of VOCs.

5.2. SITE SPECIFIC DATA COLLECTION STRATEGY

The objective of the OU-2 soil gas survey will be to investigate potential source areas that do not have previously collected soil gas data in close proximity. The data gathered during this survey will be used to select locations for confirmatory soil borings. Areas where previous soil gas investigations of the Main Hill have indicated the presence of VOCs will be investigated using soil borings as discussed in Section 9 of this FSP.

Three areas within OU-2 will be investigated using soil gas surveying (Figure 5.1). The soil gas investigation will be completed for one area before moving to the next area. Figure 5.1 also indicates the initial sample locations within each area.

The probes will be 3/4-inch diameter with minimum lengths of 5 feet. A van equipped with a hydraulic system capable of holding, pushing, and removing a hollow probe will be the main mechanism used for retrieving the soil gas samples. The van will also be equipped with a hydraulic hammer to pound the probe past prohibitive horizons. If it is necessary to collect samples on steep terrain to define the extent of contamination, a probe may be driven with a hand-held hammer-drill, then removed with a hydraulic jack.

The probe will be advanced into the subsurface and soil gas samples will be collected at 2.5 ft intervals from 2.5 ft-bgs to refusal. A field GC, will be used to obtain quick turnaround of soil gas results. The aboveground end of the probe will be fitted with a steel reducer and a length of polyethylene tubing leading to a vacuum pump. Gas flow will be metered by a vacuum gauge to ensure adequate flow is obtained. A minimum of 5 liters of gas will be evacuated with a vacuum pump prior to collecting the sample for analysis. After collection of the initial sample locations within an area and evaluation of the mobile laboratory analytical results, the on-site geologist will select subsequent soil gas sampling locations with the objective of defining any identified VOCs contaminant plume to within 15 feet horizontally and 2.5 feet vertically.

5.3. ANALYTICAL PARAMETERS

The soil gas survey will be limited to the VOC contaminants handled within potential source areas on the Main Hill and those detected at the seeps (Table V.1). The analytical parameters were selected based on their potential presence in the subsurface and amenability to soil gas technology. An on-site GC, equipped with electron capture detector (ECD) and flame ionization detector (FID), will be used to conduct the analyses.

Table V.1. Soil Gas Survey Sampling Summary

Locations and Depths	
Proposed Sampling Locations:	39 Initial locations are illustrated in Figure 5.1. Subsequent sampling locations will be guided by field screening results.
Proposed Sampling Depths:	First Sample at each boring collected at 2.5 ft-bgs, subsequent samples will be collected every 2.5 ft-bgs until bedrock is encountered.
Analytical Parameters	
Tetrachloroethane Trichloroethane 1,2 Cis-Dichloroethene 1,2 Trans-Dichloroethene 1,1-Dichloroethane 1,1,1-Trichloroethane Chloroform Bromodichloronethane Bromoform Toluene Freon 11 Freon 113 Total VOCs	
QC Summary	
FIELD AMBIENT BLANKS	
Number:	1 per 20 soil gas samples
Analytical Parameters:	Analytical parameter list
FIELD DUPLICATES	
Number:	1 per 20 soil gas samples
Analytical Parameters:	Analytical parameter list
Estimated Number of Samples	
The total number of samples will depend on the results of field analysis (mobile laboratory) for VOCs and the thickness of unconsolidated overburden deposits	

6. CHARACTERIZATION OF MAIN HILL SEEPS AND FOUNDATION DRAINS

The Main Hill seeps are part of the shallow or perched groundwater in the bedrock. These seeps are believed to be an expression of groundwater discharge in the indurated bedrock on or adjacent to the Main Hill and have a history of VOC and tritium contamination (DOE, 1992). The Main Hill has been the central operating portion of Mound Plant since the plant opened in 1948.

The characterization of tritium migration in the groundwater on the Main Hill and subsequent tritium migration pathways is based on data generated by the routine monitoring program and by the Mound Tritium Groundwater Assessment Program (DOE, 1989d). Eight seeps have been identified, five of which are located off Mound Plant property (Figure 6.1). Two of the identified seeps have appreciable flows (up to 5 gpm). It has been concluded that the tritium in the seeps originates from the tritium in the soil moisture below the SW Building. Low concentrations of volatile organic chemicals have also been found in the seeps on the Main Hill.

Conceptually, the Site hydrogeology can be divided into two hydrostratigraphic units: the Buried Valley Aquifer (BVA) and groundwater in the bedrock system. The seeps are believed to be associated with the perched groundwater in the bedrock. Although the seeps discharge along the hillslopes, it is possible that fractures also transmit water directly to the BVA or that hidden seepage discharges below the hillside colluvial veneer.

Groundwater flow within the bedrock system is probably along the interface between the overlying glacial tills, fill materials, and the bedrock; along fractures within the bedrock; and along the interface between limestone and shale beds. Flow paths within this system are complex and may be locally enhanced by permeable sand and gravel fills around utility trenches.

Spills and leaks from source areas on the Main Hill are assumed to have migrated to bedrock. The fractured shale and limestone of the bedrock provide a likely transport mechanism for contaminants to migrate to the seeps. Near-surface contamination most likely has been mobilized by recharge water and transmitted through the fracture system in the bedrock. Trench backfill areas associated with underground utilities and other building drains can provide permeable conduits that allow infiltration of contaminants into pipe chases and transmission lines, as well as through the soil to bedrock.

To characterize the groundwater flow in the bedrock and to the seeps, the following tasks will be completed:

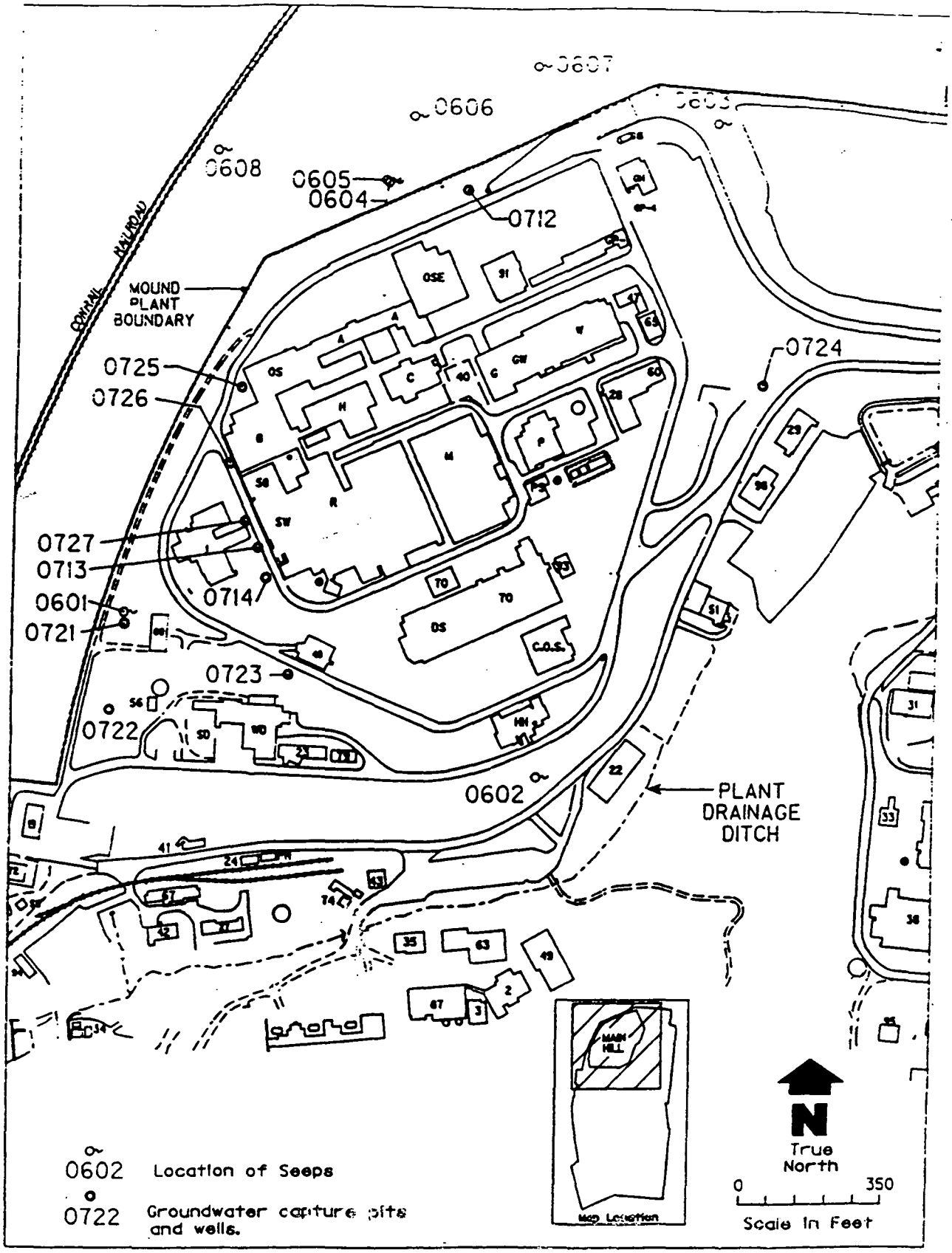


Figure 6.1. Groundwater Seeps

Reference: RI/FS OU-9 Site-wide Work Plan, May 1992

- Refine the lithologic data base of the bedrock formation.
- Determine the hydrologic properties of the bedrock formation.
- Better define the water levels of the groundwater within the bedrock.
- Locate all potential seeps during wet and dry seasons.
- Locate and map process lines, sewer lines, and foundation drains that may be contributing recharge to the hillside seeps.
- Determine the interconnection, if any, between the bedrock flow system and the BVA.
- Evaluate monitoring well network.
- Determine contributing source areas and flow paths using groundwater tracing techniques.
- Determine vertical and horizontal components of groundwater flow.

6.1. LOCATION INVESTIGATION

A location investigation will be performed to identify and locate all seeps on the Main Hill outslopes, including seeps originating from the railroad cut. Eight seeps have previously been identified; however, additional seeps may occur seasonally.

To fully characterize the shallow groundwater system, all seeps or springs need to be identified. All seeps will be located in the field and staked. Field verification of the seeps will be performed during a wet season (spring or fall) and a dry season (summer or winter). These seeps will be located before, during and after significant rainfall events to characterize possible flood overflow springs that could be paths for contaminant migration. Field verification will allow an evaluation of seasonal flow variations at the eight existing seeps and confirm the presence or absence of potential additional seeps.

All piping and building drains, sumps, and floor drains will be located by reviewing available building and utility plans. The locations will be visually field-verified where possible. The rationale for the location investigation is to fully identify potential source areas (i.e. leaky process lines, sewer lines, or floor drains) and their potential impact to soils, surface water, and groundwater (including seeps). All location information will be written in the field logbook with description of location and any identifiable features and drawings of the location with reference to physical features.

6.1.1. Infrared Aerial Photographic Survey

Color infrared (IR) aerial photography will be used to aid in characterizing surface features and conditions. Color IR photography is an effective method for defining surface vegetational and water patterns. These features are much more prominent on IR photographs when compared to conventional aerial photographs. IR photography records energy at wavelengths ranging from 0.7 to 0.9 micrometer (um). This spectral band represents reflected solar radiation, not emitted thermal energy. Advantages of IR photography are as follows:

1. Improved haze penetration, because the filter eliminates the severe atmospheric scatter that occurs in the visible and ultraviolet band. This results in a higher contrast ratio and therefore a higher spatial resolution.

2. Maximum reflectance from vegetation occurs in the photographic infrared range.

3. IR is absorbed by water, which causes the water to appear as a dark tone on IR photographs. Water and land are easily distinguished.

IR aerial photography will be utilized to assist in placement and screening for soil samples and soil gas sample locations. IR photography can assist in determining stressed vegetation and spill areas, as well as soil moisture changes during two different seasons. The location of additional seeps may also be identified by using color IR photography. The IR photographic survey will be performed by a qualified subcontractor who is knowledgeable about aerial photographic surveys and procedures. The IR photographic survey will be performed during late winter/early spring when no snow is on the ground and before vegetation and trees leaf out and during the late spring/early summer after leaves have budded to assist in determining vegetational stresses and spill areas.

6.1.2. Interview Plant Personnel

Plant personnel will be interviewed to gain insight on the location of existing process lines, sewer lines, and foundation drains that may not be represented on engineering drawings or building plans. The purpose of interviewing plant personnel is to gain a better understanding of the locations of and to document all undocumented subsurface process, sewer lines and floor drains. This information will be used in conjunction with other data sources to produce a map showing all subsurface utilities. This information also will be used to field-locate and later test of integrity of these lines for leakage and their potential connection to the groundwater discharging at the seeps along the hillside.

All interviews will be fully documented in the field logbook, recording time, date, and the name of each person interviewed. A standard list of questions will be asked each person, and the responses will be

recorded. At the completion of the interview, each person will be asked to verify their responses to the questions and to sign and date the interview sheet.

6.1.3. Site Reconnaissance

As noted previously, site field reconnaissance will be performed on the Main Hill to locate and confirm all groundwater seeps. Field reconnaissance will occur during and after periods of high precipitation. A survey also will be conducted during the dry seasons to determine which springs are perennial.

During this seep survey, temperature, specific conductance, pH, and estimated flow rates will be determined. Temperature and specific conductance will be used to characterize the groundwater as being perennial versus intermittent. Measurements of pH will provide information on the acidity of the groundwater. Measurements of pH, specific conductance, and temperature will be recorded as specified in SOP 2.2 (Appendix A).

6.1.4. Review Building Plans (Foundation Drains)

All building plans will be reviewed to determine the location and type of foundation drains. Floor drains, sumps, or other drains that could be potential source leaks also will be evaluated. All drains will be identified according to the type of drain, the source building and processes, and date and type of construction.

All process lines, sewer lines, floor drains, and associated plumbing will be field-checked and verified against the building plans for completeness and accuracy. All plans will be copied, or the information needed will be transferred to the degree of reproducibility. All field checked information will be documented in the field log books.

6.1.5. Location Survey

Seeps and subsurface utilities will be field located and staked. A professional surveyor will accurately locate the features both horizontally and vertically. The locations will tie into the existing coordinate system for Mound Plant. The surveyor will follow accepted techniques and standards. Both horizontal and vertical control will be to the third order of precision and accuracy as established according to surveying standards set by the Board of Registered Engineers, Architects, and Land Surveyors for the State of Ohio.

Building plans will be reviewed to locate process lines, sewer lines, and foundation drains. These locations will be field-checked and survey locations established for exterior manholes, sumps, or drains that tie into the subsurface utility network. The survey will be coordinated with the OU-9 RI/FS to ensure that stations are not surveyed more than once.

6.2. MONITORING CHARACTERISTICS OF FLOW

Groundwater flow patterns will be monitored to characterize the groundwater movement away from the site and suspected source areas. The characteristics of flow will include direction, velocities, dispersion, seasonal fluctuations in the water table configuration, and groundwater chemistry characteristics and variations through seasonal changes.

A portion of the shallow groundwater discharges at several small seeps along the slope of the Main Hill. Continuous monitoring of these seeps will include flow, conductivity, temperature, and pH. Refer to SOP 3.3 for procedures in setting up transducers in seeps to measure these parameters (Appendix A). In addition to these, chemical constituents will be sampled on a quarterly basis for one year.

Groundwater characterization will also include dye tracing to determine source areas and discharge points within the shallow/perched groundwater system and the impact of process lines, sewer lines, and foundation drains. Mass balance calculations will be used to determined the net inflows and outflows in the bedrock unit. Mass balance calculations will also be performed on the dye trace results if quantitative analysis can be achieved. These will be used to characterize and develop a conceptual model of the groundwater flow and contaminant transport within the bedrock.

6.2.1. Continuous Data Logging and Periodic Evaluation Schemes

Continuous logging of the seeps will be performed to determine seasonal hydrologic characteristics and evaluation of the groundwater flow within the bedrock units. Flumes with flow meters will and/or weirs will be installed on all seeps with flows large enough to monitored. This information will be stored in on-site data loggers. Refer to SOP 2.10 and 2.11 (Appendix A) for measurements of flow using flumes and weirs.

The purpose for this monitoring is to gain information on the flow hydraulics of the system in relation to the climatic changes that occur throughout the year and to discrete recharge events. This information will be used to develop a groundwater budget for the groundwater in the bedrock.

The information collected by the data loggers will be downloaded into a portable computer every two weeks. Refer to SOP 3.3 (Appendix A) for procedures on the data logger. The information gathered will

be compiled and correlated to precipitation events. Information obtained from determining inflows or outflows from process and sewer lines and foundations drains will be incorporated to assess the effects of other recharge components other than precipitation.

6.2.2. Groundwater Dye Trace Study

The hydrogeologic regime at Mound Plant consists of flow through bedrock beneath the Main Hill and SM/PP Hill and within the unconsolidated glacial deposits and alluvium associated with the BVA. The bedrock system is a complex, interbedded sequence of shale and limestone that is dominated by fracture flow. The BVA is characterized by porous flow with interbedded gravel lenses (DOE, 1992).

Monitoring wells placed in complex flow systems (i.e. fractured bedrock) may reflect regional characteristics of the groundwater flow regime, but can miss the localized flow features. Dye tracing using fluorescent dyes is an effective method for characterizing groundwater flow directions and rates within complex bedrock flow systems.

In addition to the fluorescent tracers, isotope tracers will be evaluated for their appropriateness for determining groundwater flow and hydrologic characterization. Other tracer types are carbon 14, oxygen isotopes, cations (e.g. sodium, lithium, and potassium ions), and anions (e.g. chloride, bromide, iodide, nitrate, and sulfate). In addition to using fluorescent and isotope tracers, tritium and uranium isotopes will be monitored for fluctuations during the tracing investigation to determine aquifer responses and 24-hour trends for these isotopes. Refer to Table VI.1 for a list of tracer types.

The dye tracing study will utilize existing seeps, monitoring wells, potable water supply wells, and sites along the Great Miami River. Table VI.2 lists the locations proposed for the dye tracing studies. There are 21 existing monitoring wells, three existing site groundwater potable water supply wells, four off-site private groundwater potable water supply wells, eight newly installed OU-9 groundwater monitoring wells, two existing piezometers, 25 new proposed OU-2 groundwater monitoring wells (nine cluster well locations with up to one deep, one intermediate, and one shallow well per location), six locations along the Great Miami River, 10 groundwater captive trench wells, and eight seeps along the slope of the Main Hill will be monitored during the dye tracing study. Any additional seeps discovered during the proposed field reconnaissance will be included.

Table VI.1. Survey of Groundwater Tracers

Natural Tracers		Injected Tracers					
Stable Isotopes		Radioactive		Activable		Inactive	
						Ionized Substances	Drift Material
Deuterium	^{3}H	Tritium	^{3}H	Bromine	^{35}Br	Salts: Na + Cl-	Lycopodium Spores
Oxygen-18	^{18}O	Sodium-24	^{24}Na	Indium	^{49}In	K + Cl-	Bacteria
Carbon-13	^{13}C	Chromium-51	^{51}Cr	Manganese	^{25}Mn	Li + Cl-	Viruses
Nitrogen-15	^{15}N	Cobalt-58	^{58}Co	Lanthanum	^{57}La	Na + I-	Fungi
Strontium-88	^{88}Sr	Cobalt-60	^{60}Co	Dysprosium	^{66}Dy	K + Br-	Sawdust
Sulfur-34	^{34}S	Bromine-82	^{82}Br				
Radioactive Isotopes						Fluorescent Dyes	
Tritium-3	^{3}H	Gold-198	^{198}Au			Optical Brighteners	
Carbon-32	^{14}C	Iodine-131	^{131}I			Direct Yellow 96	
Silicon-32	^{32}Si	Phosphorus-32	^{32}p			fluorescein	
Chlorine-36	^{36}Cl					Lissamine FF	
Argon-37	^{37}Ar					Rhodamine WT	
Argon-39	^{39}Ar						Physical Characteristics
Krypton-81	^{81}Kr						Water Temperature
Krypton-85	^{85}Kr						Flood Pulse

Source: Jones, 1984

Table VI.2. Dye Tracing Sampling Locations

Existing Groundwater Monitoring Wells

0020
0028
0033
0034
0035
0042
0111
0112
0113
0114
0115
0116
0117
0118
0120
0122
0137
0138
0236
0312
0315
0419

Groundwater Capture Trench Wells

0712
0713
0714
0721
0722
0723
0724
0725
0726
0727

Seeps

0601
0602
0603
0604
0605
0606
0607
0608

Existing Mound Potable Water Supply Wells

0071
0076
0271

Existing Off-Site Potable Water Supply Wells

0905
0906
0907
0912

Proposed OU-9 Monitoring Wells

0318
0322
0323
0324
0332
0335
0348
0349
0369

Existing Piezometers

P-021
P-022

Proposed OU-2 Monitoring Wells Clusters
3 wells per location
(deep, intermediate, shallow)

OU2-MW-1
OU2-MW-2
OU2-MW-3
OU2-MW-4
OU2-MW-5
OU2-MW-6
OU2-MW-7

Other Locations

Foundation Drains and Trench Fill Areas
Located During Field Reconnaissance
OU2-MW-8
OU2-MW-9

Great Miami River Locations
Approximately six locations to be
determined after site reconnaissance

The rationale for the sample locations are as follows:

- All bedrock wells (this includes existing and proposed) will be monitored because of the fractured characteristics and the connection between stratigraphic horizons and the seeps.

- The seeps will be monitored because past water quality sampling indicates a connection to source areas.

- Capture trench wells will be monitored to determine the effectiveness of the capture well system.

- Selected BVA wells that essentially surround the site will be monitored to determine the interconnection between the BVA and the groundwater in the bedrock.

- Mound Plant Site groundwater production wells and selected off-site groundwater production wells will be monitored to determine the interconnection between the groundwater in the bedrock and the BVA. Also, these wells will be monitored because they are receptor points and because they are production wells, flow directions can be induced.

- The locations along the Great Miami River are backup sampling stations in the event some or all of the other locations miss any dye migration.

The primary purpose of the groundwater dye trace are to:

- Provide data to characterize flow in the bedrock groundwater system beneath Mound Plant.

- Provide data to assess current monitoring well locations and identify optimum locations for future monitoring wells in the bedrock groundwater system

- Provide data to determine or confirm contaminant releases from SW Building, storm drains, sewers, and process lines.

- Provide data to determine the interconnection between the bedrock groundwater system and the BVA.

- Evaluate the effectiveness of the trench recovery systems.

There are several types of fluorescent dyes commonly used in groundwater tracing. Any dyes selected for use during the OU-2 RI will receive prior approval from USEPA and Ohio EPA. The dyes will be analyzed by using a scanning spectrofluorophotometer or equivalent instrument.

In addition to the fluorescent tracer dyes, isotopes as tracing agents will be considered for use in characterizing the groundwater flow in the bedrock units. Tritium levels which may indicate groundwater flow fluctuations at the seep can be identified as pulses in the groundwater flow system. Tritium

concentrations can also be viewed as the concentrations over the average value for tritium in other non-influenced areas.

Other types of tracers are ions such as bromide or chloride. Bromide is considered a superior tracer in the different types of ions used for tracing. Bromide exhibits low absorption and adsorption, is biologically stable, and is not lost by precipitation (Davis, et al., 1985). Isotopes and ion traces will be analyzed by using liquid chromatography and mass spectrometry.

Because of the complexities in determining potential groundwater movement in bedrock formations, the groundwater tracing program must be flexible in its implementation to achieve successful results. Changes may be appropriate and should be expected before and during this tracing program as the need arises or as conditions warrant. These changes may include laboratory equipment changes, changes in the field, the number of sampling events, and sampling media.

Additional tracing will be performed to determine the source areas and discharge points and potential leaks within the existing process lines, sewer lines, and foundation drains. These are all potential sources for releases to the bedrock groundwater. Additional tracing will be phased after the initial tracing study within the bedrock formation.

Because of limited data on the connection between the groundwater in the bedrock formation and the BVA, the dye tracing program will monitor wells that are sited in both hydrostratigraphic units. In addition to seeps and monitoring wells, on-site and selected off-site water supply wells will be monitored during the study.

Additional techniques will be used to determine daily fluctuations in the tritium concentrations and to determine concentrations over what is considered typical background tritium concentrations. Continuous sampling devices will be used to collect water samples for analysis.

The groundwater dye tracing study will be qualitative and semiquantitative in analyses. Decision charts are presented which summarize the qualitative and quantitative dye tracing. The charts present key steps, in sequential order, for completion of qualitative and quantitative dye tracing. Depending on the results from the seep sampling, quantitative results may be achieved (Figure 6.2 and Figure 6.3).

6.2.2.1. Proposed Dye Tracing Plan

The proposed dye tracing plan is based on current data obtained to date from previous reports and documents. Modifications to this plan are expected using information obtained from the RI Phase 1 and 2 tasks. The specific details will be submitted for USEPA/Ohio EPA approval before implementation. The proposed plan is as follows:

1. Produce an accurate groundwater elevation map using newly installed monitoring wells, existing groundwater monitoring wells, and existing on-site piezometers. This map will evaluate each hydrostratigraphic relationship, and hydrostratigraphic maps produced, illustrating the water level in the different hydrostratigraphic zones. This information will be evaluated to determine any additional data gaps and data needs associated with the installation of newly installed monitoring wells.

2. Field reconnaissance to locate and confirm the existing seeps surrounding Mound Plant. Field measurements of temperature, specific conductance, pH, and estimated flow rate will be recorded for each spring/seep. Refer to SOP 2.2 for procedures on recording water quality field parameters and SOP 2.10 (See Appendix A for SOPs). The spring survey will be conducted during a wet seasonal period (Spring or Fall) when surface infiltration and precipitation is at a maximum. Field reconnaissance will also be performed during a dry season to determine which seeps are perennial and which are wet weather seeps.

3. Place "bugs" (dye samplers consisting of activated carbon and/or cotton) in all seeps/springs, groundwater monitoring wells, site potable water supply wells, selected off-site residential potable wells, and geographically spaced locations along the Great Miami River. Refer to SOP 7.1 for procedures on placement of dye receptors.

   The sampling locations proposed are the eight seeps that have been identified along the hill side slopes of the Main Hill Site, 21 existing monitoring wells, 25 new OU-2 proposed monitoring wells (nine well clusters consisting of one deep, one intermediate, and one shallow well for seven of the well clusters and one deep and one shallow for two well clusters), 10 groundwater capture trench wells, four off-site groundwater potable water supply wells, three Mound potable water supply wells, two OU-9 installation piezometers, eight OU-9 installation monitoring wells, and six locations along the Great Miami River for a total of 83 sampling locations. Refer to Figure 6.4 for the location of the dye trace sampling points; Table VI.2 lists the sampling locations.

4. Background samples will be collected at the end of each week for a three week period (three sample rounds) to obtain three background sample sets. This will allow for the determination of the background groundwater fluorescence and to determine the dyes that can be used. The background sampling periods will be spaced to incorporate background during a dry season, wet seasons, and prior to dye injection.

5. Groundwater tracer dyes will be injected into open boreholes drilled for the dye injection, or other locations deemed appropriate such as in sanitary or storm sewer lines. Several locations will be used for dye injection purposes depending on the number of dyes that can be used and the number of traces. It is proposed that up to four different groundwater tracer dyes can be injected into four different locations or at different depths. The results of the background data will determine which and how many dyes can be used. Refer to Table VI.1 for a list of potential groundwater tracers.

   Prior to the injection of tracer dyes into the groundwater system, a slug of water is injected as a primer to lubricate the pore space or fractures the bedrock system. After the dye has been injected, another slug of water is injected as a chaser to help push the dye into the groundwater system. This procedure aids the dye during the initial injection to promote the movement of the dye. Generally, a volume of water is injected as these slugs. The amount of water to be used will be determined after analysis of the slug test results. Generally, dye injection should be during a wet period during the year (spring or fall). This will assist in the movement of dye through the system and under hydraulic conditions that are conducive for maximum groundwater movement.

6. Seep sampling locations will be monitored every hour for day zero (day of dye injection), every four hours for the first day after injection, every eight hours for day two, every 12 hours for the third day and every 24 hours from day four to day seven, and every 48 hours for the next seven sampling rounds (day 8 through day 21) then every seventh day thereafter for until the 63rd day (2 months) and then every 14th day thereafter until the completion of the dye test or re-evaluation of the test at day 175 (6 months) to determine if the test should be continued. Refer to Table VI.3 for schedule summary. Water samples will be collected at each of the seeps monitored as well as using the passive samplers (activated carbon/cotton swatches). Water samples collected at the seeps will utilize 24-hour continuous water sample collectors.

7. Capture trench wells will be monitored with the same schedule as the seeps, refer to Table VI.3 for schedule summary. Only passive samplers will be used at these locations.

8. Existing groundwater monitoring wells, OU-9 installation groundwater monitoring wells, OU-9 piezometers, and proposed OU-2 groundwater monitoring wells will be monitored once a day for the first week (day 0 to day 7), then one sample will be collected every 7th day until day 63, when the sampling schedule will be reduced to every 14 days. Only passive samplers will be used at these locations. Refer to Table VI.3 for sampling schedule for these locations.

9. Off-site production wells, on-site Mound production wells, and Great Miami River sampling stations will be monitored every 7th day until the 63rd day when the sampling schedule will be reduced to every 14th day thereafter. Refer to Table VI.3 for sampling schedule. Only passive samplers will be used at these locations.

10. The duration of the dye tracer study will be flexible. Premature cessation can jeopardize results and if no dyes are detected, other similar dyes cannot be injected. For general purposes of scheduling, assume a minimum of six months for the duration of the dye trace with the flexibility to continue the trace if results indicate the need.

Table VI.3. Dye Tracing Schedule

	Dye Injection																
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16
Seeps	X	X	X	X	X	X	X	X		X		X		X		X	
Capture Trench Wells	X	X	X	X	X	X	X	X		X		X		X		X	
Existing GW Monitoring Wells	X	X	X	X	X	X	X	X							X		
OU-9 Installation Monitoring Wells	X	X	X	X	X	X	X	X							X		
Proposed OU-2 Monitoring Wells	X	X	X	X	X	X	X	X							X		
Great Miami River Locations								X							X		
Off-Site Production Wells								X							X		
Mound On-Site Production Wells								X							X		

	Day 17	Day 18	Day 19	Day 20	Day 21	Day 28	Day 35	Day 49	Day 63	Day 77	Day 91	Day 105	Day 119	Day 133	Day 147	Day 161	Day 175*
Seeps	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X
Capture Trench Wells	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X
Existing GW Monitoring Wells					X	X	X	X	X	X	X	X	X	X	X	X	X
OU-9 Installation Monitoring Wells					X	X	X	X	X	X	X	X	X	X	X	X	X
Proposed OU-2 Monitoring Wells					X	X	X	X	X	X	X	X	X	X	X	X	X
Great Miami River Locations					X	X	X	X	X	X	X	X	X	X	X	X	X
Off-Site Production Wells					X	X	X	X	X	X	X	X	X	X	X	X	X
Mound On-Site Production Wells					X	X	X	X	X	X	X	X	X	X	X	X	X

*At the end of the 175th day, evaluate the need for additional monitoring or terminate trace with agency approval.

11. The water and passive samplers will be analyzed using a scanning spectrofluorophotometer for the presence of fluorescent dyes. Carbon samplers will be eluted to release dye out of the carbon and the solution analyzed. The cotton swatches will be viewed under a long-wave ultra-violet light source and confirmed using the spectrofluorophotometer. Refer to SOP 7.2 for procedures on eluting the charcoal packets, SOP 7.3 for procedures on analyzing cotton swatches, and SOP 7.4 for procedures on using the scanning spectrofluorophotometer and analysis of the elutriated carbon and cotton samplers (See Appendix A for SOPs).

12. Dye receptor holders will be placed in each of the groundwater monitoring wells as illustrated in Figure 6.5 and Figure 6.6. Dye receptor packets will be placed in each holder, then lowered to the screened interval based on the boring logs downhole geophysics, and video camera logging information. For wells in which the screened interval is quite large, an evaluation of the geologic boring log will be used to determine the depth to which the sample holder will be placed. Dye receptors will be placed in the seeps out of direct exposure to sunlight and attached to a weighted "gum drop" holder as illustrated in Figure 6.7 or similar means of securing the detectors.

    Sample holders for groundwater production wells are illustrated in Figure 6.8 and will be attached to the piping system of each production well used. The sampler will not effect the performance of the well. A constant flow through the sample receptor holder is required and water flowing through the holder is discharged to the ground surface. A galvanized or brass "T" and gate valve will be attached to regulate the flow through the sampler holder. Approximately 1-2 gallons per minute will be regulated through the sample holder for the duration of the dye test. A figure showing this attachment cannot be produced since each production well may be different. Until each well indicated for use as a sampling point can be visited and determination of the attachment, can a drawing be produced.

6.2.2.2. Dye Selection

Determination of the dyes that can be used cannot be evaluated until background fluorescence is determined. A background investigation will be performed prior to dye injection and will utilize both activated carbon and undyed cotton swatches in all proposed sampling locations for a three week period.

6.2.2.3. Dye Handling Procedures and Sample Collection

Extreme caution in handling the fluorescent dyes will be practiced. The personnel involved in the placement of the dye receptor holders will follow proper handling procedures. The personnel responsible for the placement of dye will also wear special elbow-length gloves before handling the dye.

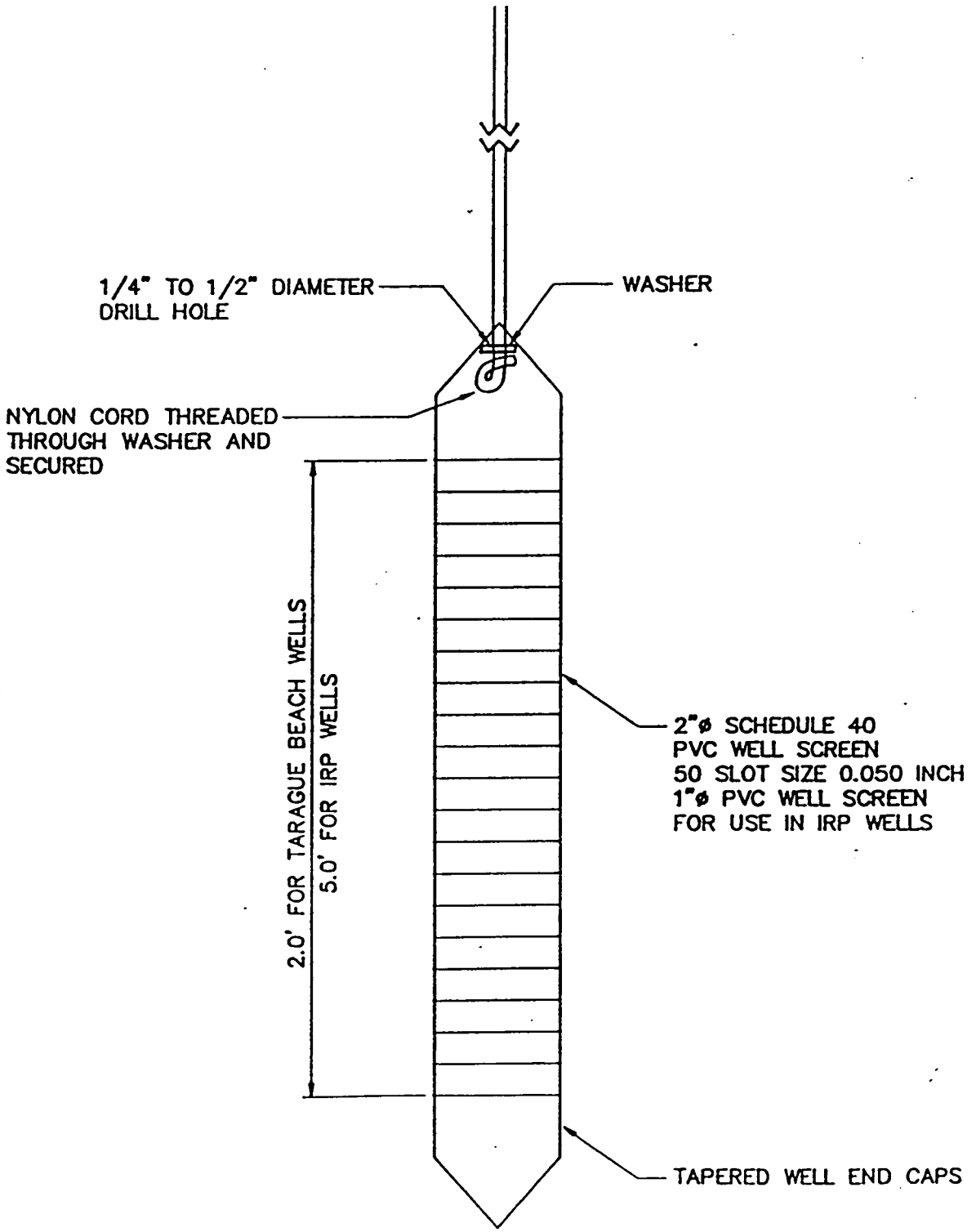


Figure 6.5. Dye Receptor Holder

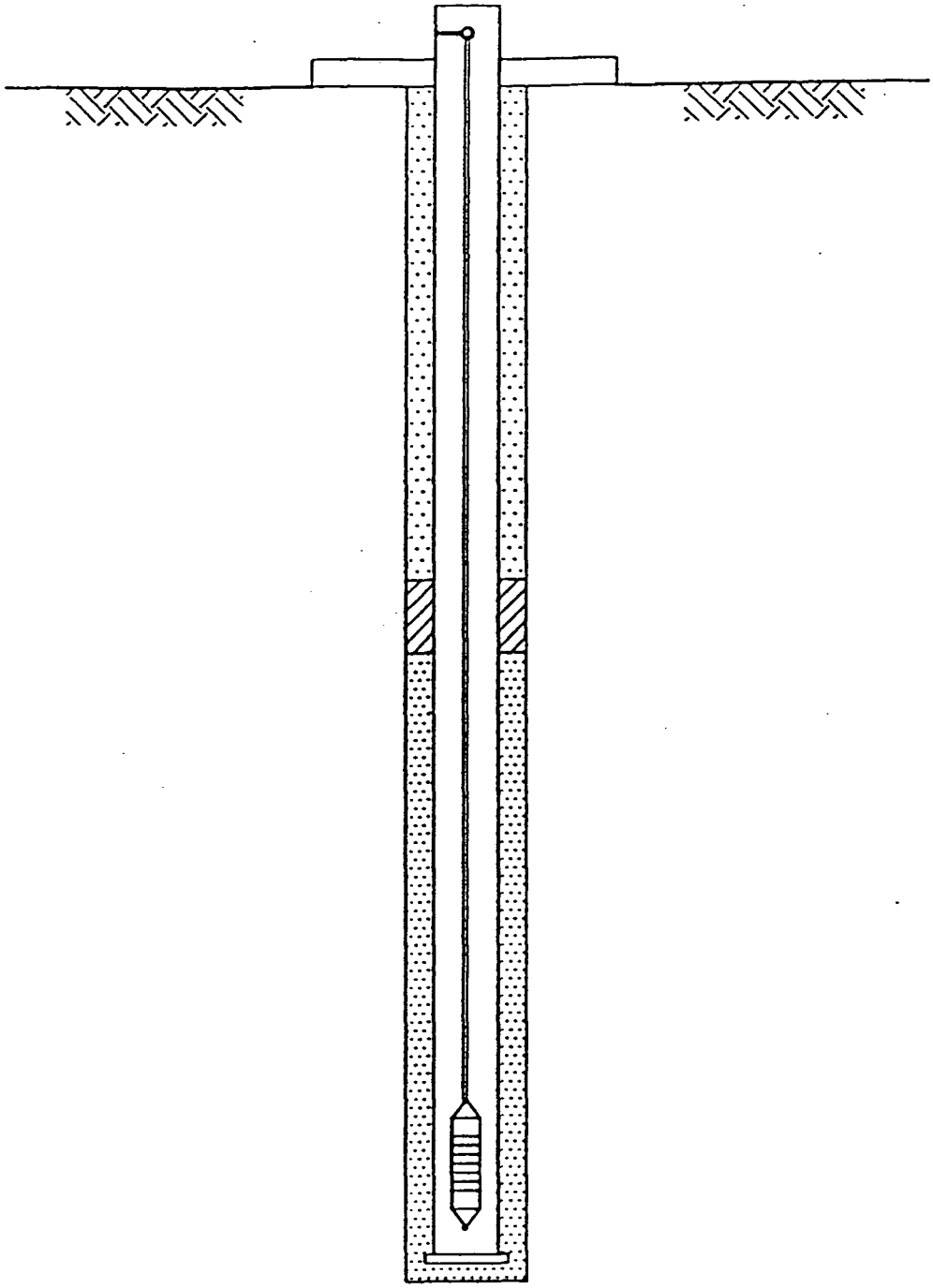


Figure 6.6. Dye Receptor Holder in Monitoring Well

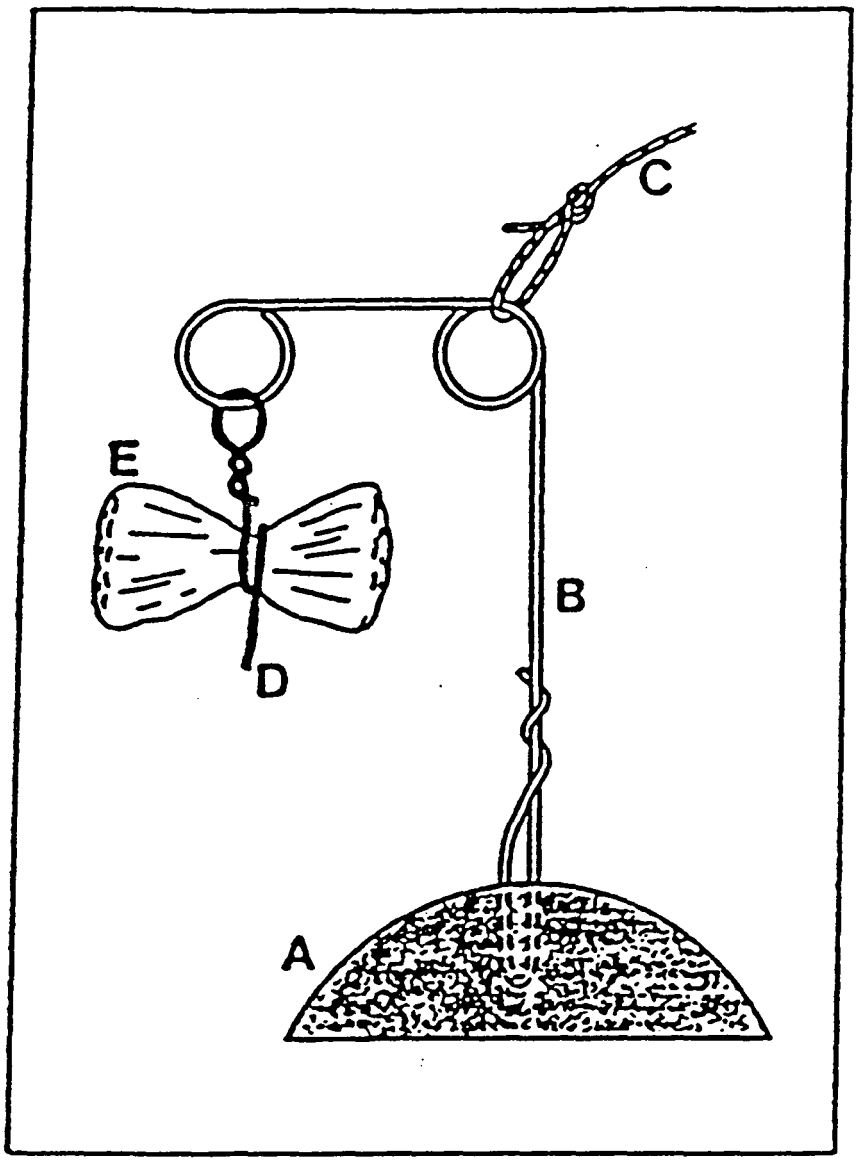


Figure 6.7. Gum Drop Holder

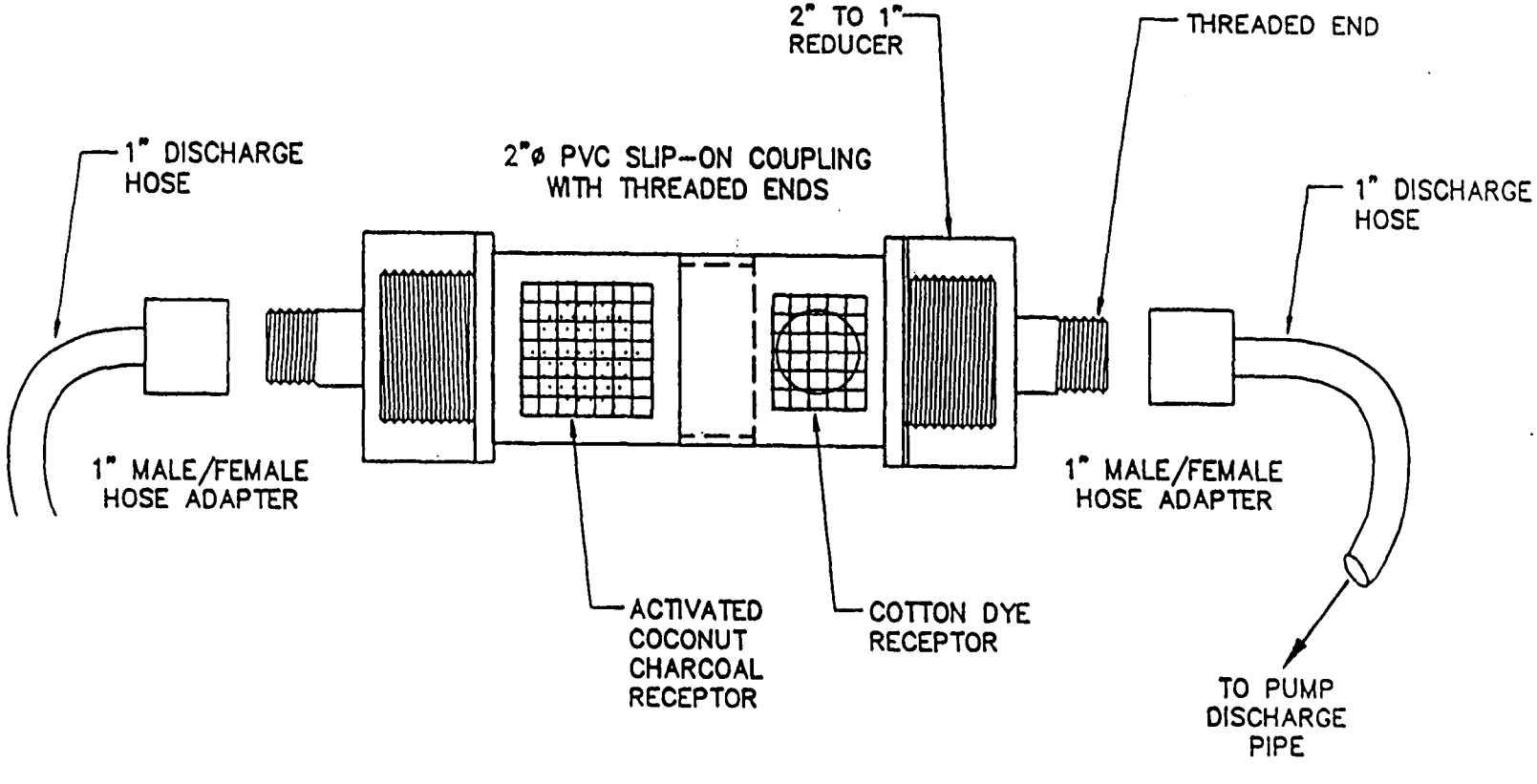


Figure 6.8. Receptor Canister for Groundwater Production Well

Passive samplers (carbon and or cotton) will be used at all sampling locations except for the seeps, in which case automatic water sampling equipment will be used to collect water samples in addition to using the passive samplers. Water samples will be collected in glass sample containers that are made to fit the continuous water collecting sampler.

After the dye(s) have been injected, the schedule of the collection of dye adsorbent packets will be followed as previously outlined. Sample collection will consist of placing the dye adsorbent packets in individual "whirl-pac" bags. The individual bags will be labeled, using a water proof marker, with the following information:

1. Sample number
2. Date of collection
3. Time of collection
4. Project number
5. Project name
6. Person(s) initials involved in the collection.

Sample collection at Mound Plant Site under the ER Program are numbered using a three-letter, 10-digit identifier (MNDXA-YYYY-ZZZZ). MND21 is the area or investigation identifier for OU-2. The identifier is 21, where the 2 represents the dye trace investigation and 1 is the identifier for a water sample. The matrix number for carbon samplers is MND22, and the matrix identifier for cotton samplers is MND23. The next portion of the identifier is YYYY, designates the specific location and the last four digits (ZZZZ) serves as sample identifier, which documents the frequency of sampling. For example, a water sample collected at seep 0603 shall be recorded as MND21-0603-0001 for the first sample collected at this location and MND21-0603-0002 for the second sample and so on. A carbon sample collected shall be recorded as MND22-0603-0001 for the first sample and MND22-0603-0002 for the second sample and so on. Cotton sample collected shall be recorded as MND23-0603-0001 for the first sample and so on.

For trip blank samples, the identifier scheme is MND21-0603-9001 for carbon samples, MND22-0603-8001 for field blanks, MND23-0603-7001 for duplicate samples, and MND21-0603-6001 for contingency samples (ran only as needed).

6.2.2.4. Laboratory Analysis

Water, eluted carbon, and cotton swatches that are used to adsorb dye at each of the proposed sampling sites will be analyzed using a Scanning Spectrofluorophotometer or similar fluorometric instrumentation. The spectrophotometer is used to determine the excitation and emission maxima of fluorescent dyes in

water solutions, eluent solutions, or on solid material (cotton swatches). The scanning spectrophotometer has the capability of distinguishing background fluorescence from tracer fluorescence in the sampling media. The scanning spectrophotometer is extremely sensitive and can distinguish several different dyes within a sample.

The advantages of using a scanning spectrofluorophotometer are to verify visual methods; facilitate tracing with multiple dyes; to reliably detect small concentrations of dyes; to reduce interference with background fluorescence; and to enhance the credibility of water tracing results. Using the spectrofluorophotometer, one can obtain hard copies illustrating the recovered dye excitation/emission spectra printout of fluorescence intensity versus wave length. Coupled with a data station and software, the data can be stored on diskettes and statistical and quantitative computations of the analysis can be performed. Refer to SOP 7.4 (Appendix A) for procedures on using the scanning spectrofluorophotometer.

A scanning spectrofluorophotometer is capable of determining both excitation and emission maxima of fluorescent substances. Synchronous scanning of excitation and emission wave lengths often yields increased selectivity and sensitivity over single emission or excitation scans.

Excitation is provided by a xenon lamp. Light from the excitation source is focused via an ellipsoidal mirror and passed through a narrow slit into the excitation monochromator. Extraneous light of unsuitable wave lengths for excitation are removed in the excitation monochromator through a series of mirrors, a diffraction grating and another narrow slit. Thus, a specific narrow wave length band of light passes into the sample which is to be analyzed. The sample is thus excited and emits light of longer wave length. The light analyzer or emission monochromator which filters out extraneous emitted wave length light in the same manner as the excitation monochromater. A specific wave length band of emitted light then passes from the analyzer monochromator through another narrow slit and strikes the photomultiplier tube. The amount of light that strikes the photomultiplier tube is measured and displayed as the relative fluorescence intensity of the sample for the chosen excitation and emission wave lengths. The chosen wave lengths can be varied continuously by scanning the monochromator(s) of choice. The range of wave lengths allowed to excite the sample and the range of wave lengths allowed to reach the photomultiplier tube on the emission side is controlled by the width of bandpass slits (Duley, 1986).

Because of the extreme sensitivity afforded by this system coupled with the ability to scan excitation wave lengths and emission wave lengths independently, it is possible to plot the excitation and/or emission spectra of a fluorescent dye or unknown sample. Unfortunately, when the excitation monochromator wave length approaches the emission wave length and the instrument is operating at it's more sensitive settings, the instrument is prone to scattered light passing through the optical system. In other words, when the emission monochromator is scanned through that specific wave length, there is an apparent

fluorescence intensity maximum at that point. This peak can be eliminated by synchronously scanning the excitation and emission monochromators at a given separation so that the maximum fluorescence excitation point for a given dye will be reached by the excitation monochromator at the same time that the maximum fluorescence emission point is reached by the emission monochromator. The use of synchronous scans improves detection limits of some dyes over methods using single excitation or emission scans and can also save analysis time as, in essence, two scans are completed in one (Duley, 1987).

6.2.2.5. Dye Selection and Quantity

Groundwater tracer dyes will be selected based on the results of the background fluorescence survey. Several types of dyes can be used, but until conclusive results of the background fluorescence evaluation is complete, only a list of possible dyes will be given. Table VI.4 lists the possible dyes and other fluorometric parameters. The names for the dyes are inconclusive because several dye manufacturers' produce the same or similar types of dyes with different names.

The quantity of dye used will be based on the results needed and the type of dyes used. Once the background survey is completed and the results analyzed, the dyes to use can be determined and then the quantity of the dyes can be determined for the site specific trace.

6.2.2.6. Dye Adsorbent Packets ("Bugs")

The type of dye(s) used will determine the adsorbent media used. Generally there are three methods for collecting samples for analysis. One is to collect water samples and analyzed with a filter fluorometer or scanning spectrofluorophotometer. The second medium is activated granular carbon, and the third is undyed cotton swatches. The carbon and cotton adsorbs the dye onto the surface of the media. Eluent of the carbon, a process which de-adsorbs the dye(s) from the carbon surface area. This elutant is then analyzed the same as the water sample. The cotton can be analyzed using a long-wave, ultra-violet light source. The dyes that adsorb onto the cotton will fluoresce under the exposure of the long-wave UV light. The cotton samples will be analyzed by the scanning spectrofluorophotometer to provide the data base and hard copies as well as any statistical or analytical data needs.

The carbon and cotton adsorption media will be placed in a nylon or fiberglass mesh screen such as used for window or door screens. The packets will be approximately 12-cm-by-15 cm and folded to form an envelope 12-cm-by-7.5 cm; the long and short edge can be sewn or stapled. If the packets are sewn, use nylon thread or monofilament fishing line. Approximately 12 grams of activated granulated charcoal (6-14 mesh size) will be placed in each packet and secured. Refer to SOP 7.5 (Appendix A) for

Table VI.4. Evaluation of Principal Water Tracers Used in North American Karst Studies

Tracer & Color	Passive Detector	Test (elutriant)[1]	Maximum Excitation & Emission nm[2]	Detectable Concentration[3]	Advantages	Disadvantages	Remarks
Fluorescein Sodium $C_{20}H_{10}Na_2O_5$ Yellow-Green Xanthene	Activated coconut charcoal 6-14 mesh	Ethyl alcohol and 5% KOH. Visual test or fluorometer & 2A-47B; 2A-12 65A filters	485 515	0.1 µg/1. Dependent on background levels. "Controls" must be us to determine background.	1) Does not require constant monitoring or any special equipment. 2) Inexpensive.	1) Dye is photochemically unstable. 2) Moderate sorption on clay. 3) pH sensitive.	This is the most popular method used in the USA. Carbon detectors first suggested by Dunn, 1957.
Rhodamine WT $C_{28}H_{31}N_2O_3Cl$ Red-Purple Xanthene	Activated coconut charcoal 6-14 mesh	Ethyl alcohol & 5% KOH or 1-Propanol + NH_4OH. Solution tested using fluorometer and 546-590 filters.	550 580	0.01 µg/1. Dependent on background levels and fluctuation.	1) Dye is photochemically stable. 2) Dye may be used in low pH waters.	1) Requires the use of a fluorometer. 2) Moderate clay sorption.	Rhodamine has been used extensively in Canada & USA. This is not a suitable method for amateurs without access to a fluorometer.
Lycopodium Spores *Lycopodium Calvitum*	Plankton netting nylon-25 micron	Spores & sediment are washed from the nets. Microscopic examination is used to identify spores.	N/A	Dependent on background levels. Several kilograms of spores are usually used.	1) Several simultaneous tests may be conducted using different colored spores. 2) No coloring of water occurs.	1) Spores may be prematurely filtered out. 2) Field collection system elaborate. 3) System is generally more expensive.	Spores have not been extensively used in North America.
Optical Brighteners Colorless normal light	Unbleached cotton	Visual examination of detectors under UV light or 7-37; 2A + 47B filters	360 435	Dependent on background levels, but generally at least 0.1 µg/1.	1) Inexpensive. 2) No coloring of water occurs.	1) Background readings may be excessively high. 2) Adsorbed onto organics.	May be used simultaneously with a green & red dye using fluorometric separation.
Direct Yellow (DY 96) Low Visibility Stilbene derivative	Unbleached cotton	Visual examination of detectors under UV light or 7-37; 2A + 47B Filters.	N/A	1.0 µg/1 on cotton, and with fluorometric analysis.	1) Little natural background. 2) Good stability and low sorption. 3) No coloring of water.	1) Moderate cost. 2) Sensitive to pH.	Has been used extensively in Kentucky.
Salt NaCl Colorless	Recording specific conductance meter or regular sampling.	Either a direct test for an increase in chloride, or a substantial increase in specific conductance.	N/A	Dependent on background levels. Several hundred kilograms may be needed for larger tests.	1) Generally considered safe for use on public water systems. 2) Useful where fluorescent background conditions exclude other methods.	1) Large quantities usually needed. 2) Background specific conductance is often high.	Salt is occasionally used by the US Geological Survey for tests dealing with public water supplies.

Source: Jones, 1984

[1]G. K. Turner Filters for Turner 111 Filter fluorometer.
[2]Dye is usually most visible in clear water, deep pools, and in bright sunlight. These figures are not exact.
[3]Very dilute dye solutions may be concentrated upon the detector over a period of time.

procedures on making sample packets. Activated charcoal has a limited useful life, so a fresh supply shall be available. Evidence indicates that activated carbon loses its adsorption ability upon exposure to the atmosphere. Therefore, carbon samplers will be made only for those sample locations for a one-week period and stored in air-tight containers or in large zip-lock bags.

The cotton containing packets will be constructed in the same way as the carbon containing packets. Undyed/unbleached surgical cotton, cotton balls, or cotton discs will be used as the adsorbent media for those dyes used that do not adsorb onto the activated carbon. The amount of cotton adsorbent to be placed in each packet will be selected considering the particular form in which the cotton is obtained, but will be a similar size as discussed above for the carbon samplers.

Transportation of dye adsorbent packets will be kept separated by media and in air tight containers or large clean zip-lock bags. The dye adsorbent packets will be kept separated from all contact with the dyes used. The person responsible for the dye injection will not handle these packets unless they are placed prior to the dye injection. If the person responsible for the dye placement also collects the adsorbent samplers, this person shall shower and put on a new clean set of clothes prior to collecting the samplers.

6.2.2.7. Adsorbent Packet Placement and Retrieval

A dye receptor holder will be dedicated to each groundwater monitoring well and piezometer used. Two packets of each adsorbent media will be placed in each holder at each location. The dye receptor holder will then be lowered into each of the proposed monitoring wells. Where seeps are sampled, the adsorbent packet will be suspended from the holder and placed in the maximum flow of the spring. A special attachment will be connected to production wells to allow a small flow of water through a sample holder. Dye adsorbent packets will be placed in a canister and attached to the discharge line of the well via minor alterations to the line. These alterations consist of attaching a "T" valve on the discharge line at the well head and then attaching the dye sampler holder using standard garden type hose and adapters. Samplers placed in the river will utilize the gum drop sample holder and secured to the shore by a thin nylon cord to ensure that in the event of heavy rains and potential flooding, the sampler will be secured.

Upon retrieval, the dye adsorbent packets will be removed from the receptor holder and placed in individual whirl-pac plastic sampling bags. These plastic bags will be labelled and placed in an ice chest for transportation to the laboratory.

6.2.2.8. Procedure for Testing Activated Carbon Adsorbent

In the laboratory, the dye adsorbent packets will be removed from the plastic whirl-pac bag and rinsed with a jet of tap water for approximately several minutes to remove clay, dirt, and debris that could alter or mask the analytical results.

Depending on the types of dyes to be used will determine the type of eluent solution to be used for releasing fluorescent dyes from the carbon.

After the carbon has been washed, the screen packet will be cut at one end and the carbon placed in a 100 ml plastic translucent disposable cup with a lid. Approximately 30 ml of the eluent will be poured over the carbon. The solution should be 1/8 to 1/4-inch above the carbon, and no more solution than needed should be added as this could dilute the sample. The eluent and carbon should set for one hour ±10 minutes for qualitative and semi-quantitative analysis, using a scanning spectrofluorophotometer. After elution, a 4-ml sample is drawn from the sample container using a pipet and placed in a cuvette. The cuvette then will be placed in the cell holder in the scanning spectrofluorophotometer. The scanning spectrofluorophotometer will provide the analyst with a print out of the synchronous scanning excitation and emission wave length spectra with its intensity. The results of the analyses will be saved on a diskette for later statistical or other computational analysis or comparisons.

The results of carbon analysis shall be compared with standard solutions and their spectra analysis when concentrations are low or for confirmation.

6.2.2.9. Procedure for Testing Cotton Detector Samplers

The dye adsorbent packet containing the cotton swatches will be removed from their plastic sample bag, washed with a jet of tap water. The cotton samplers will be washed for approximately several minutes to remove clay, dirt, and debris from the cotton swatches.

The cotton will be visually analyzed using a long-wave ultra-violet light source. The cotton samples will also be tested analytically using the scanning spectrofluorophotometer for obtaining hard copy print outs and establishing a data base for future computational analysis.

The cotton samples will be compared with standards of known concentrations established prior to sample collection and analysis. These standard samples will be used to confirm the presence of dye adsorbed onto the cotton.

6.2.3. Quality Control

6.2.3.1. Samples for QA/QC

In addition to the samples collected as mentioned in Section 6.2.2.1, the following additional samples and testing will be performed for QA/QC purposes:

- Trip Blanks: Blank dye detectors packets containing activated carbon and/or blank packets containing undyed cotton swatches will be rinsed with tap water and placed in a "whirl pac" or ziplock plastic collection bag and placed in the field collection cooler each day samples are collected. Trip blank samples will be run with the set of samples collected during that day's sample collection.

- Field Blanks: Blank dye detectors packets containing activated carbon and blank packets containing undyed cotton swatches will be collected at two randomly selected locations during each sampling day. The blank dye adsorbent packets will be rinsed with previously tested distilled water, packed in individual "whirl pac" sample bags and labelled as field blanks with the sampling location. The blank bags will then be handled identically to the sample bags containing the other detector packets.

- Duplicate Samples: A second dye detector containing activated carbon and/or detector packets containing cotton swatches will be installed at 5% of the monitoring locations. All detector packets will be retrieved, placed in "whirl pac" or ziplock sample bags, labeled and placed in ice coolers. Dye detector packets will always be replaced at all of the sampling locations.

6.2.3.2. Instrument Setup and Calibration

1. The scanning spectrofluorophotometer will be set up and tested according to the manufacturers instructions.

2. Standard concentrations of the dyes which are injected will be prepared. These standard dye concentrations will be prepared in a laboratory separate from the dye analysis laboratory or in separate rooms within the same building. The standard solutions will be stored in amber glass containers and in a dark place when not in use.

3. Standard dye solution concentrations for each of the dyes used will range in concentrations from 0.01 ug/l, 1 ug/l, 10 ug/l, and 100 ug/l. Carbon samplers will be soaked in these standard solutions for one-hour and then prepared using the procedure outlined above for elution. Cotton samplers will be placed in standard dye solutions for one hour, pressed to remove excess water/dye, allowed to air dry and analyzed. These standard solutions will be performed at the beginning of each sampling round that analysis is being conducted. In addition to the dye standards, distilled water will be ran, eluant solution analyzed, and tap water that may be used in the analytical process.

6.2.3.3. Dye and Dye Detector Handling Procedures

1. Dye will be stored and dye standard solutions mixed at locations separate from the analysis laboratory. Personnel handling and mixing the dye will wear protective disposable clothing and latex gloves. Never-the-less, personnel responsible for making and collecting the dye detector packets will not be involved in handling or mixing of the dye for injection or standard concentration analysis.

2. The vehicle used for the transporting of the dye and dye solutions for injection will not be used during the dye detector packet placement or retrieval.

3. Detector samples collected will be placed in their individual whirl-pac or ziplock bags, labelled, and placed in a ice cooler for transportation. These samples should not be exposed to sunlight, because some dyes will photodecay. If sample collector is also to handle dye, the dye receptors will be placed prior to the handling and injection of dye. Dye will be placed in sealed containers and stored and kept out of the sunlight and not in the same vehicle or room as the dye adsorbent packets. The dyes will be placed in opaque, non-breakable containers for storage.

6.2.3.4. Chain of Custody

Chain of custody forms will be filled out by the person collecting the samples. This chain of custody form is necessary in regulatory compliance and potential litigation. This ensures the samples are secure at all times and a written log is maintained that identifies each person having access to the samples. Refer to SOP 1.3 (Appendix A) for Chain of Custody procedures.

7. EVALUATION OF EXISTING MONITORING WELLS

All existing monitoring wells within the OU-2 will be evaluated for potential use in the RI/FS. This evaluation will be coordinated with the OU-9 monitoring well evaluation activities and the site-wide well abandonment plan that is currently under preparation. The following will be included in the evaluation:

- construction (casing material, length of screen, stratigraphic intervals screened, gravel pack length, and grouting materials);
- compliance with EPA's TEGD specifications; and to ASTM standards (ASTM D-50920-90) ASTM Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers; and
- condition (internal and external) of the well.

Each existing boring log and well construction diagram will be examined for compliance with accepted standards (TEGD and ASTM). If a particular well meets these standards, a field inspection will be conducted to evaluate:

- integrity of surface casing/condition of well locks;
- integrity of surface protection (concrete pad);
- total depth of the well vs. total depth recorded on the well log; and
- verify well alignment and plumbness.

After the evaluation, those wells that do not pass the field inspection may be rehabilitated through replacement of the protective surface casing, locks and concrete pad, and redevelopment to remove sediment that may have accumulated in the base of the well. The decision to rehabilitate a particular well will be based upon the value of the well to the OU-2 and OU-9 RI/FS, its intended use (i.e. water level monitoring, dye tracing sampling point, monitoring analytical sampling), and the amount of reconditioning required. Sampling of existing wells following evaluation and reconditioning as appropriate is discussed in the sections of this FSP corresponding to the intended use of the data.

Wells that do not comply with acceptable standards and that will not be rehabitated to meet these standards will be abandoned according to the methods described in "ER Program, OU-9, Well Decommissioning and Abandonment Program Plan," and consistent with the State of Ohio's Water Well Standards. SOP 4.9 contains the ER Program, OU-9, Well Decommissioning and Abandonment Program Plan. OEPA and USEPA concurrence will be obtained before any wells are abandoned.

7.1. CONDUCT GEOPHYSICAL LOGGING AND VIDEO INSPECTION WHERE APPROPRIATE

Where information is incomplete about the construction of the existing monitoring wells, selected geophysical and downhole video logging shall be performed to provide information on the depth and length of screen intervals and geological formations screened. The suite of downhole geophysical survey logging will be preceded by the downhole video camera survey.

7.1.1. Downhole Video Camera Survey

The downhole video camera survey will be used in wells where information regarding the depth of the well screen is unknown. The downhole video camera survey will provide data regarding the condition of the borehole casing and screened depth. The borehole video survey will also provide information to the depth of the water table.

The downhole video camera survey will be performed according to the procedures outlined in SOP 8.1 (Appendix A). The downhole video camera will be decontaminated according to the procedures in SOP 1.6 (Appendix A). The camera will be washed with a detergent and rinsed with a Reagent II grade water. If necessary the cable will be decontaminated as it is removed from the well. The cable will be scrubbed and rinsed as specified.

7.1.2. Borehole Geophysics

Borehole geophysics used for this well evaluation will be the natural gamma and the neutron logging. These two logs can be used through monitoring well casing to provide gross determinations of the lithology where data of this nature is lacking or requires additional detail.

7.1.2.1 Natural Gamma and Neutron Borehole Geophysical Evaluation

Natural gamma radiation measurements are widely used borehole geophysical measurements to indicate changes in lithology. These measurements are made throughout the borehole, beginning at the ground surface. Gamma rays from naturally occurring radioactive isotopes pass through the detector, creating a flash of light. The frequency of flashes indicates the level of naturally occurring radioactive isotopes associated with clay minerals. Clay/shale-rich strata are more radioactive than other strata, and therefore natural gamma radiation is used to indicate the presence of the lithology of the bedrock, determine shale layers that occur within the bedrock formation, and measurements will be used to estimate the bulk density and porosity of the formation. Porosity calculations will be used to determine hydrogeologic

characteristic, and to estimate permeabilities and flow rate characteristics. Refer to SOP 8.2 for procedures (Appendix A).

Neutron logs are made with a source of neutrons in the probe and detectors that provide a record of the neutron interactions that occur in the vicinity of the borehole. Most neutron interactions are related to the quantity of hydrogen present, which, in groundwater environments, is largely a function of the water content of the rocks penetrated by the borehole. Neutron logs are used in water resource investigations because they can be used to determine porosity for a considerable range of borehole conditions and rock types.

The neutron log will provide a digital record of the neutron capture by the rock and the contained groundwater. The log is sensitive to moisture content in the unsaturated zone and is a measure of porosity in the saturated zone. Refer to SOP 8.3 for procedures (Appendix A).

Interpretation of the geophysical logs will be compared with logging performed on newly drilled boreholes and that are correlated with lithology. Small field equipment will be decontaminated at the investigation site. The decontamination procedures for small field sampling equipment is included in SOP 1.6 (Appendix A).

8. INSTALLATION OF NEW MONITORING WELL CLUSTERS

Nine monitoring well clusters, each cluster consisting of two or three wells, will be installed to define groundwater flow and quality. Five of the monitoring well clusters will be installed on the Main Hill, two clusters will be installed north of the Main Hill and two clusters will be installed within the Tributary Valley. A discussion of the objectives for monitoring well installations is provided in the OU-2 Work Plan. The locations of the monitoring wells (OU2-MW1 through OU2-MW9) are illustrated in Figure 8.1. The current monitoring well numbering system (i.e. OU2-MW1) will be consistent with the standard Mound Plant ER Program four-digit code (i.e. 0034). The selected ER program numbers will be assigned prior to performing the field work.

The tasks presented in the remainder of this section will be performed in accordance with the appropriate Mound Plant ER Program SOPs (Appendix A). In the event the SOPs contradict with ASTM Standard D-50920-90, the ASTM standard will be followed.

8.1. BOREHOLE DRILLING

An air rotary drilling rig with continuous coring capability will be used to advance the borings into the subsurface for all bedrock monitoring well installations. The air rotary rig will be equipped with a 10-inch diameter drill bit. Wells in unconsolidated overburden deposits will be installed using hollow-stem auger (HSA) geotechnical rig. The geotechnical rig will use a 10-inch outside diameter HSA to advance the borings.

The locations of the proposed monitoring well installations may be changed slightly by the field geologist based on access or presence of subsurface utilities. Table VIII.1 summarizes the estimated boring depths and proposed lithologic targets for screening of shallow (S), intermediate (I), and deep (D) intervals.

Borehole drilling and Monitoring well installation will be in accordance with the following Mound Plant ER Program SOPs (Appendix A) and in conformance with ASTM Standard D-50920-90:

- 1.15 Guide To Waste Management
- 4.1 Soil Borings
- 4.1.1 Addendum to SOP 4.1 Methods to Control Communication of Subsurface Contaminants Within and Between Saturated Zones During Drilling and Well Installation
- 4.2 Rock Boring
- 5.1 Soil and Rock Borehole Logging and Sampling

TABLE VIII.1. Proposed Monitoring Well Completion Summary

Well Number	Estimated Surface Elevation (ft-msl)	Estimated Maximum Drilling Depth (ft)	Estimated Elevation at Total Depth (ft-msl)	Target for Screening
OU2-MW1S	875	60	815	Bedrock (Perched)
OU2-MW1I	875	75	800	Bedrock (Water Table)
OU2-MW1D	875	100	775	Bedrock (Deep)
OU2-MW2S	875	60	815	Bedrock (Perched)
OU2-MW2I	875	75	800	Bedrock (Water Table)
OU2-MW2D	875	100	775	Bedrock (Deep)
OU2-MW3S	875	60	815	Bedrock (Perched)
OU2-MW3I	875	75	800	Bedrock (Water Table)
OU2-MW3D	875	100	775	Bedrock (Deep)
OU2-MW4S	867	60	815	Bedrock (Perched)
OU2-MW4I	867	75	800	Bedrock (Water Table)
OU2-MW4D	867	100	775	Bedrock (Deep)
OU2-MW5S	845	60	815	Bedrock (Perched)
OU2-MW5I	845	75	800	Bedrock (Water Table)
OU2-MW5D	845	100	775	Bedrock (Deep)
OU2-MW6S	778	88	690	Outwash (Water Table)
OU2-MW6I	778	98	680	Weathered Bedrock or Deep Outwash
OU2-MW6D	778	118	660	Bedrock (Deep)
OU2-MW7S	743	53	690	Outwash (Water Table)
OU2-MW7I	743	63	680	Weathered Bedrock or Deep Outwash
OU2-MW7D	743	83	660	Bedrock (Deep)
OU2-MW8S	709	40	669	Outwash (Water Table)
OU2-MW8D	709	130	579	Bedrock (Deep)
OU2-MW9S	709	40	669	Outwash (Water Table)
OU2-MW9D	709	130	579	Bedrock (Deep)

Note: Suffix D designates the deep well, I the intermediate depth well, and S the shallow well at all three well clusters.

8.1.1. Main Hill Borings

Five monitoring well clusters (OU2-MW1 through OU2-MW5) will be installed on the Main Hill at the locations illustrated in Figure 8.1. Three wells will be installed into bedrock at each cluster location. Table VIII.1 summarizes the proposed targets for the shallow (S), intermediate (I), and deep (D) monitoring wells at each cluster location.

Two monitoring wells (OU2-MW8 and MW9) will be installed just north of the Main Hill at locations to be determined after a review of the potentiometric data from OU-9 wells. These wells will be used to investigate the interconnection between the bedrock and the BVA north of the hill. Table VIII.1 summarizes the proposed targets for the wells at each cluster location.

In all cases, the boring for the deep monitoring well will be drilled first. The boring will be advanced through the unconsolidated section and approximately one foot into bedrock. A 10-inch steel, temporary surface casing will be set to seal off the unconsolidated section. A coring device will then be used to collect oriented core samples continuously through the weathered zone and into competent bedrock. The boring diameter will then be increased through the cored zone by air-rotary to the top of (or slightly into) competent bedrock, at which point coring will resume. It may be necessary to advance the temporary 10-inch casing through the weathered bedrock zone to keep the hole from caving. Continuous oriented core will be collected in the competent bedrock zone to a depth of approximately 815 ft-msl. A complete suite of geophysical tools (see Section 8.3) will be used to log the open borehole from total depth up to the base of the steel casing. Gamma ray logging and neutron logging will continue to surface as these are capable of obtaining readings through the casing. After logging of this interval is completed, an 8-inch steel casing will be installed from the surface to total depth. The temporary 10-inch casing will be removed and the 8-inch casing will be cemented in place. Continuous oriented coring and air-rotary methods will be used to advance the boring through the water table surface to an elevation of approximately 750 ft-msl (estimated 100 ft-bgs). The open portion of the borehole will be logged with the suite of geophysical tools. All relevant new data will be fully evaluated before finalizing the monitoring well locations, well depths, and casing depths.

8.1.2. Buried Valley Borings

Two monitoring well clusters (OU2-MW6 and OU2-MW7) will be installed within the saturated portion of the Buried Valley at the locations illustrated in Figure 8.1. Two wells of each cluster will be installed into bedrock, and one well will be installed into the unconsolidated deposits (Table VIII.1).

In all cases, the boring for the deep monitoring well will be advanced first. The boring will be advanced through the unconsolidated section and approximately one foot into bedrock. A temporary surface casing will be set to seal off the unconsolidated section. The boring for the deep monitoring will be advanced through the weathered bedrock zone (if present) and into the competent bedrock zone using a continuous coring device (oriented core) and air rotary drilling methods. If necessary, the surface casing will be advanced to keep the weathered zone from caving. Continuous coring and air rotary will be used to advance the deep boring into competent bedrock to an elevation of approximately 660 ft-msl.

The open borehole for the deep well will be logged with a suite of geophysical tools as discussed in Section 8.3 of this FSP.

The boring for the shallow monitoring wells will be installed with a hollow-stem auger rig. Continuous split spoon samples will be collected within the unconsolidated deposits from surface to the top of bedrock. An organic vapor meter (OVM) will be used to field screen the split spoon samples for VOCs.

8.1.3. Dust Control and Waste Handling

Air rotary drilling methods tend to inject a significant amount of dust into the air. Adding water to either the borehole or cuttings as they exit the borehole will reduce the amount of dust released. Water will not be injected into the borehole for dust control. A diverter pipe will be installed inside of the 10-inch surface casing to collected the cuttings as they are forced up the borehole by air. A fine mist of clean water will be injected into the diverter pipe at the surface to moisten the cuttings and prevent them from becoming airborne. The diverter pipe will lead to a collection tank, where the water will be separated from the cuttings.

All drill cuttings (both rock and overburden cuttings) and fluids will be collected and contained within 55 gallon drums. The drums will be staged near the borehole and appropriately managed as discussed in Mound Plant ER Program SOP 1.15.

8.2. WELL INSTALLATION

The monitoring wells will be installed with a minimum borehole diameter of 8 inches. All wells will be completed with 4-inch diameter schedule 40 PVC well screens and risers where metals or radionuclides are included as contaminants of concern and stainless steel screens and risers when organic compounds are the contaminant of concern. If field screening results indicate elevated concentrations of VOCs in areas of suspected metals or radionuclides contamination, stainless steel screens and risers may be substituted for PVC. It is anticipated that wells completed in bedrock will require short screens (two to

five feet in length) to screen discrete hydrologic zones. A five or ten foot well screen is anticipated for wells completed in unconsolidated deposits. The screen slot size will be selected appropriate to the grain size fo the formation screened. In all cases, the well will be set to monitor a specific water bearing zone. If conditions are such that these screen sizes are not appropriate, the field manager will consult with the project manager prior to constructing the well.

A sized quartz sand filter-pack will be placed in the annulus between the well casing and the borehole wall from the bottom of the borehole to at least 2 ft above the top of the well screen. The filter-pack will be placed using water slurry through a tremie pipe to prevent bridging of the sand within the borehole annulus. During placement, the depth to the top of the filter-pack will be periodically gauged using a weighted measuring tape. A 6 to 12 inch fine sand blotter will be placed above the filter pack. A 2-ft to 3-ft interval of bentonite slurry will be emplaced on top of the filter-pack using a side discharge tremie pipe. Bentonite pellets may also be used at the discretion of the field geologist in wells that are less than 50 feet deep. A second fine sand blotter will be placed above the bentonite seal. The remaining borehole annulus will be filled to the ground surfacing using a cement/bentonite grout mixture if above the water table, or a bentonite grout if below the water table, placed with a side discharge tremie pipe filling from the bentonite seal upward.

Centralizers will be used to ensure the uniform and complete annular filing by granular backfill, seal, and grout materials. Centralizers will be placed at a minimum of every 50 feet for stainless steel wells, and every 25 feet for PVC wells. All water added to the boring during well construction will be from a clean off-site source. A sample will be collected from each tank of water used and submitted for analysis to ensure its integrity. The Mound Plant ER Program SOP for monitoring well installation (SOP 4.3) is included in Appendix A.

At the completion of the well construction, a minimum of three times the total volume of water introduced and lost to the borehole during drilling, well installation/construction shall be removed during well development. This is to remove any liquids introduced during well construction activities that may prohibit the collection of representative groundwater samples.

8.2.1. Main Hill Monitoring Wells

The screened interval of the deep monitoring well will be based on the results of the geophysical logging and observations of the cored bedrock. The objective will be to screen zones which have the greatest potential for contaminant transport (i.e. high transmissivity fractured zones). It is anticipated that the interface between the limestone and the shale layers will have the highest potential for transmitting potential contaminants because of the potential dissolution of the limestone as groundwater migrates

through the formation. The limestone layers are relatively thin and therefore, short screen lengths (two to five feet) are anticipated for use.

The results of the coring and borehole geophysical investigation for the deep monitoring well at each cluster will be used to determine the location of the screened interval for the shallow and intermediate monitoring wells. Figure 8.2 provides a construction diagram for wells completed within bedrock.

An intermediate monitoring well will be set to screen the water table. This well will also be cased to an elevation of approximately 815 ft-msl, unless the water table is encountered above this elevation. The shallow well will be set to screen perched water. If perched water is identified, a screen will be set an elevation of 820 ft-msl (seeps elevation). Although dry at the time of installation, seasonal variations or recharge events may cause water to periodically enter these wells. If more than one perched zone is encountered, the need to screen these zones with additional monitoring wells will be evaluated by the field geologist and project manager prior to installation. Short screen lengths (two to five ft) are anticipated for use in the shallow and intermediate wells; however, interpretation of subsurface conditions will ultimately control the screen length used.

8.2.2. Buried Valley Monitoring Wells

The screened interval of the deep monitoring well will be based on the results of the geophysical logging and observations of the cored bedrock. A construction diagram for wells completed in bedrock is provided in Figure 8.2. The objective will be to screen zones which have the greatest potential for contaminant transport. It is anticipated that the thin limestone layers that are interbedded with the shale will have the highest potential for transmitting potential contaminants. Short screen lengths covering the zones of high transmissivity (5 feet or less) are anticipated for use.

The results of the coring and borehole geophysical investigation for the deep monitoring well at each cluster will be used to determine the location of the screened interval for the intermediate monitoring wells. The intermediate monitoring well will be set to screen weathered bedrock (if present). A construction diagram for a monitoring well completed in weathered bedrock is provided in Figure 8.3. If weathered bedrock is not present, the intermediate well will be set directly above bedrock within the unconsolidated sediments. Short screen lengths (5 feet or less) are anticipated for use in the intermediate wells. The screen length will depend upon the thickness of the weathered bedrock (if present), or the saturated thickness of the unconsolidated deposits if weathered bedrock is not present.

The shallow monitoring well will be set to screen the water table within the Buried Valley. A construction diagram for wells completed in unconsolidated deposits is provided in Figure 8.4.

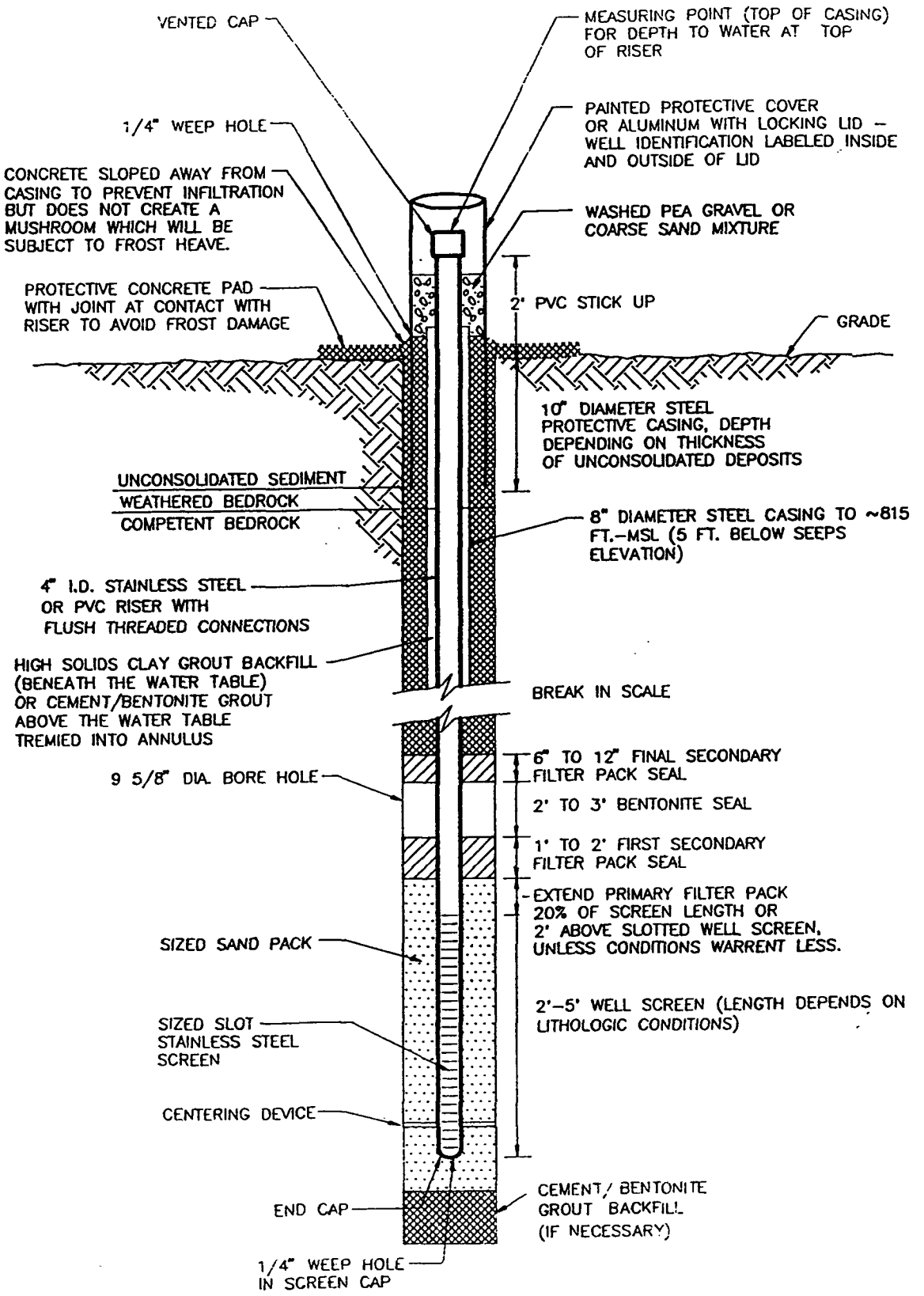


Figure 8.2. Construction Diagram for Monitoring Well Completed in Competent Bedrock

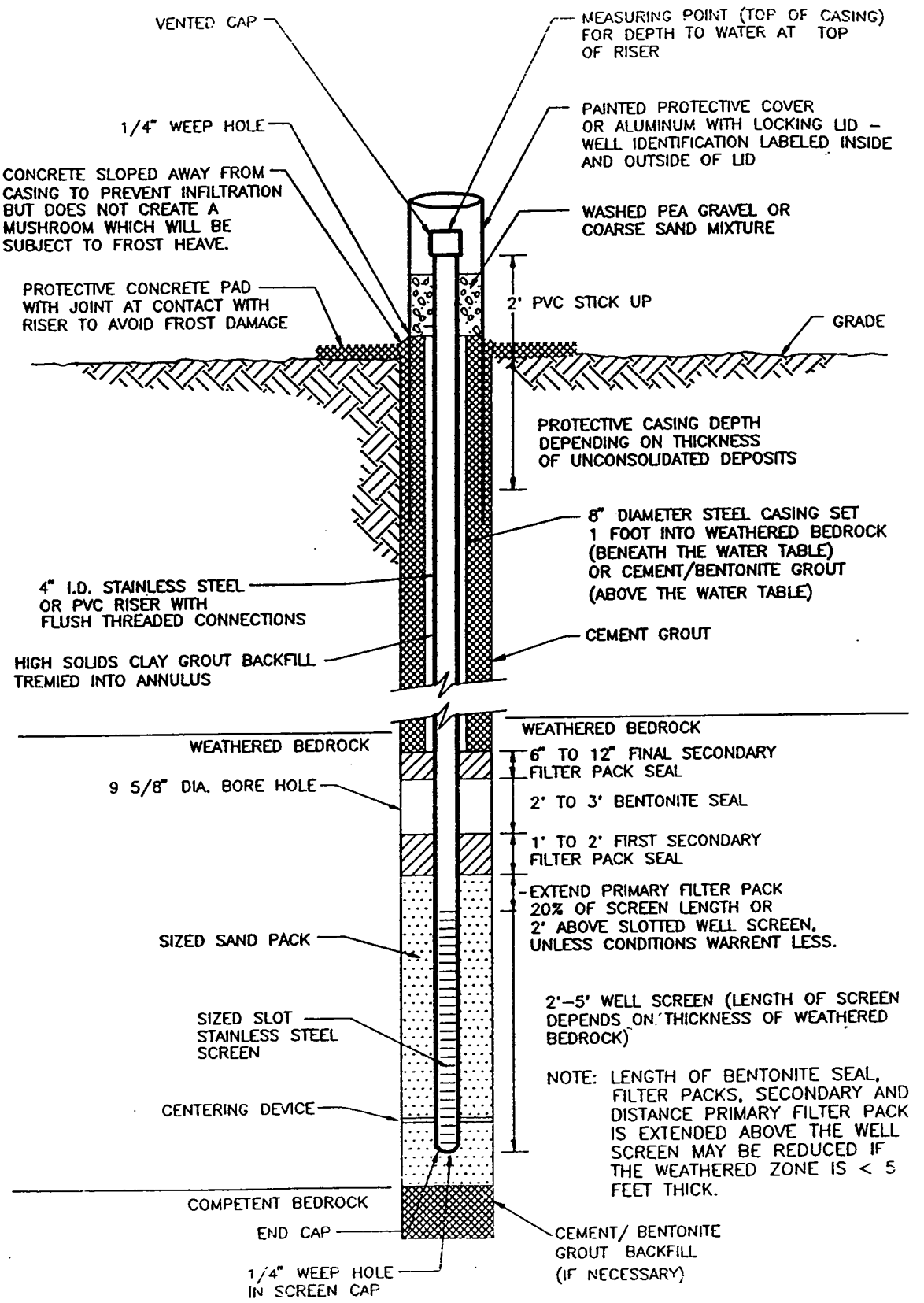


FIGURE2

Figure 8.3. Construction Diagram for Monitoring Well Completed in Weathered Bedrock

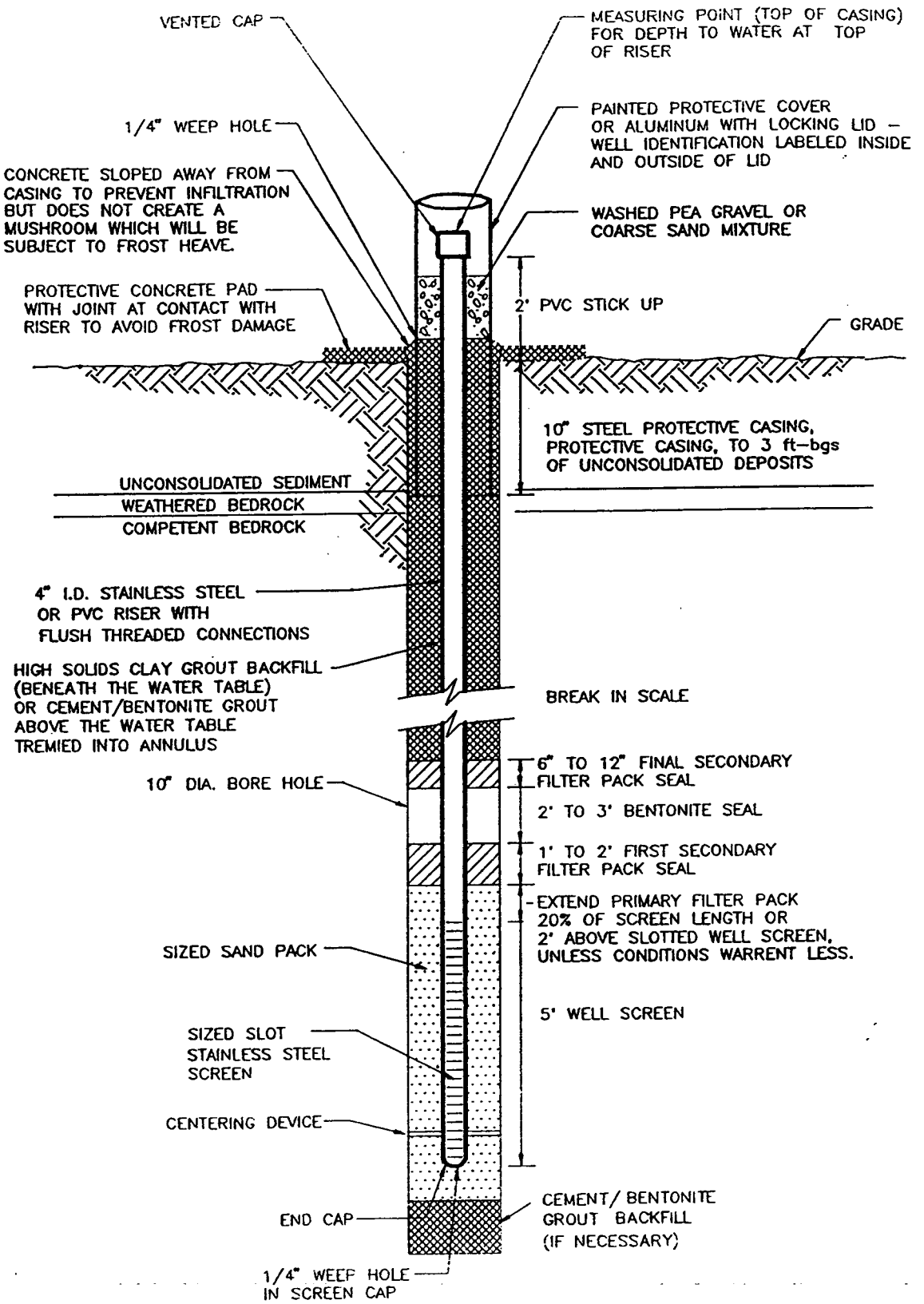


Figure 8.4. Construction Diagram for Monitoring Well Completed in Unconsolidated Deposits

8.3. DOWNHOLE GEOPHYSICAL LOGGING

At the completion of drilling, each borehole will be inspected and investigated using a suite of geophysical techniques. The geophysical survey will be conducted to gain a better understanding of the geology, lithology, and porosity or fracture permeability of the bedrock formation and to determine the depth to water. The downhole geophysics survey will be coordinated with the OU-9 downhole geophysical surveying to determine which methods are appropriate prior to making final determinations on the methods to use.

Downhole geophysical logging will be performed on the nine proposed well clusters (each location will have a well a shallow screened interval, a deep well screen and some will have an intermediate screened interval. The downhole geophysical measurements that may be made at each borehole are:

- Temperature: Temperature measurements are used to determine geothermal gradient changes within the fluid filled borehole, which would be expected to increase with depth. Temperature measurements will be made continuously below the water table. The measurements will be evaluated both for changes with respect to depth as well as for temperature differential changes between depths. Differential changes are measurements within the borehole below the water surface and these measurements can be correlated with the caliper log and well log information in determining bedding plane openings or fractures within the bedrock units. Groundwater movement is inferred from differential temperature measurements. Refer to SOP 8.2 for procedures (Appendix A).

- Borehole Flowmeter: Borehole flowmeter is used to determine potential flow velocities within the fluid filled borehole. This can be accomplished using an impeller type or a heat pulse type flowmeter. This will provide data on discrete flow zones within the borehole.

- Fluid Conductivity: Fluid conductivity is used to indicate changes in fluid chemistry of the formation water. The fluid resistivity is used to correlate with temperature to determine changes in fluid flow. Fluid resistivity measurements provide data related to the concentration of dissolved solids in the formation water. Fluid conductivity measurements will be used in the interpretation of other electrical logs used. Refer to SOP 8.2 for procedures (Appendix A).

- Natural Gamma: Natural gamma radiation measurements are widely used borehole geophysical measurements to indicate changes in lithology. These measurements are made throughout the borehole, beginning at the ground surface. Gamma rays from naturally occurring radioactive isotopes pass through the detector, creating a flash of light. The frequency of flashes indicates the level of naturally occurring radioactive isotopes associated with clay minerals. Clay/shale-rich strata are more radioactive than other strata, and therefore natural gamma radiation is used to indicate the presence of the lithology of the bedrock, determine shale layers that occur within the bedrock formation, and measurements will be used to estimate the bulk density and porosity of the formation. Porosity calculations will be used to determine hydrogeologic

characteristic, and to estimate permeabilities and flow rate characteristics. Refer to SOP 8.3 for procedures (Appendix A).

- Neutron: Neutron logs are made with a source of neutrons in the probe and detectors that provide a record of the neutron interactions that occur in the vicinity of the borehole. Most neutron interactions are related to the quantity of hydrogen present, which, in groundwater environments, is largely a function of the water content of the rocks penetrated by the borehole. Neutron logs are used in water resource investigations because they can be used to determine porosity for a considerable range of borehole conditions and rock types.

  The neutron log will provide a digital record of the neutron capture by the rock and the contained groundwater. The log is sensitive to moisture content in the unsaturated zone and is a measure of porosity in the saturated zone. Refer to SOP 8.4 for procedures (Appendix A).

- Resistivity/Resistance: Resistivity/resistance measure the changes in potential resistivity/resistance of the formation. Formation resistivity/resistance are quantitative rock analysis and when used in conjunction with the gamma log and spontaneous potential log, lithologic determinations can be made. This technique uses a single point, 16-inch normal, 64-inch normal and wet/dry resistance sonde. The single point resistance measurements are used for obtaining information regarding lithology.

  The 16-inch and 64-inch normal-resistivity logs are most useful in determining water quality. When calibrated with temperature and fluid resistivity, the measurements obtained from the formation resistivity can be converted to porosity. These measurements will also be correlated with the natural gamma measurements to determine lithology. Refer to SOP 8.5 for procedures (Appendix A).

- Spontaneous Potential: The spontaneous potential is a measurement used to provide information on the lithology and the salinity of the formation water. Spontaneous potential measurements record the potential or voltage that develops at the contact between shale/clay layers, and saline water in the borehole. The log is a relative electrical measurement of the natural potential between the surface ground and the borehole fluid. The primary sources of spontaneous potentials are the electrochemical and electrokinetic (streaming potentials). The streaming potentials are the electrochemical effects of migration of ions from concentrated to more dilute solutions, and are most effected by clay, decreases negative mobility. Electrokinetic effects are the result of water moving through the borehole.

  Spontaneous potential measurements will be used to determine lithology, in conjunction with the other electrical logs and the natural gamma measurements. Spontaneous measurements correlated with differential temperature and fluid resistivity measurements will be used to determine flow zones within the bedrock. Refer to SOP 8.6 for procedures (Appendix A).

  Acoustic/Sonic: The acoustic or sonic measurements are a record of the travel time of an acoustic wave from the transmitting probe. Acoustic logs are useful to identify lithology and measure porosity. The sonic measurements will be used in conjunction with the natural gamma measurements and borehole logging information to estimate lithology, porosity, and to indicate fracture or cavernous zones. Refer to SOP 8.7 for procedures (Appendix A).

- Caliper: A caliper will be used to measure the change in the borehole size, which will indicate rock hardness, cementation, and lithology. Caliper measurements will be made throughout the borehole (i.e. from the ground surface to depth) and used to correct other geophysical measurements. This technique will be used in determining borehole size consistency, and will be correlated with the acoustic and gamma measurements in determining lithology. Refer to SOP 8.8 for procedures (Appendix A).

Any method requiring water in the borehole will be reserved for logging below the water table. No water will be added to the boreholes or wells for logging purposes.

8.4. DOWNHOLE VIDEO SURVEYING

The downhole video camera survey will be conducted at the conclusion of the drilling of each proposed borehole. This downhole video camera survey will provide data regarding the condition of the borehole, correlate the geology and lithology of the borehole cuttings or lithologic samples taken, and determine the physical characteristics of the borehole not limited to color, appearance of fractures and bedding planes, formation seeps and the depth to the water table. The downhole video camera will use both a frontal view down the borehole and an axial view of the sidewalls of the borehole as the camera is lowered down through the boring. In addition to evaluation of the geology and assisting in the correlation of the downhole geophysics, the camera video will also be used to locate screened interval locations in all newly installed monitoring wells.

The downhole video survey will be performed before the downhole geophysical survey. The survey will begin at the ground surface and extend to the completed depth of the borehole and the survey will continue as the camera is raised to the surface. The procedures that will be followed are contained in SOP 8.7. The downhole video camera will be decontaminated according to SOP 1.6 (See Appendix A for SOPs).

8.5. WELL DEVELOPMENT

A minimum of 48 hours after grouting is completed, the wells will be developed according to Mound Plant ER Program SOP 4.8. Wells completed in bedrock will be developed using a combination of surging and pumping. Wells completed in the unconsolidated deposits will be pumped or bailed. Well development will continue until five times the standing water volume in the well (volume of water within the screen, casing, and saturated annulus) has been removed according to SOP 4.8. The well will be developed until the well is free of sediment. Development will continue until turbidity is less than 5 nephelometer turbidity units and three consecutive measurements of pH, conductivity, and temperature have stabilized to within ten percent variance. Water removed from the well will be containerized and taken to a central location

at Mound Plant and placed into a 4,000 gallon holding tank and handled according to the procedures specified in SOP 4.8.

8.6. AQUIFER TESTING

Slug testing will be performed on all new OU-2 wells installed in the bedrock. The slug test provides an advantage over pumping tests in that it does not require the disposal of large quantities of water. Slug testing is performed in lower hydraulic conductivity environments such as bedrock formations where aquifer pump testing is not conducive. The purpose of the slug tests will be to provide hydraulic conductivity values for the bedrock flow system. All five of the well clusters on the Main Hill (15 wells) will be tested. At the two cluster wells installed within the Tributary Valley, only the bedrock wells (four total) will be tested.

A falling head and rising head slug test will be performed by using a stainless steel slug and recording the rise and fall of the water levels. The stainless steel slug will be decontaminated prior to use. Pressure transducers and data loggers will be used to the record the recovery head readings. The slug testing will be performed according to ASTM method D 4044-91 published August 1991. Refer to the ASTM method D 4044-91 for performing slug test procedures (rising head slug testing) and ASTM D 4043-91 Standard Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques.

8.7. WELL PURGING

Well purging prior to sampling will be in accordance with Mound Plant ER Program SOP 2.1. Deep monitoring wells will be purged with a bladder pump. Shallow monitoring wells will be purged with a bladder pump or bailer. Well purging will continue until three consecutive readings indicate that temperature, pH, eH, and conductivity measurements have stabilized to within 10% variance, or until a maximum 10 well volumes have been removed if field parameters have not stabilized.

Purge water will be placed in a 55-gallon drum and appropriately disposed of after receipt and review of the groundwater analytical results.

8.8. WELL SAMPLING

After each well is completed, groundwater samples will be collected and analyzed from the new monitoring wells once per quarter for a full year. Existing wells within OU-2, and the seeps will also be sampled during the same time frame as the new wells on a quarterly basis. A summary of the

groundwater sampling locations, analytical parameters, QC, sample frequency and total number of samples is provided in Table VIII.2. Sampling the new wells will be coordinated with the OU-9 and OU-5 groundwater sampling events to ensure that a particular well is not sampled more than one time.

A helium-3 (He-3) molecule is formed as a degradation product of the natural decay of tritium. This is a stable isotope of helium and should be conserved in the environment. Since tritium decays to He-3 at a constant rate, the ratio of He-3 to tritium in the environment should be an indicator of the time that has elapsed since the tritium was released to the environment. Thus, if the ratio can be evaluated, it should indicated whether releases of tritium are current, on-going releases or if and when they occurred at some point in the past. Similarly, the ratio of the naturally occurring Helium-4 isotope to the He-3 isotope that occurs as a result of the decay of tritium could put an age on a tritium release. The feasibility of assessing these ratios and using the results to determine the age of tritium releases will be assessed. If a method of analysis can be found to accurately, and economically measure these ratios, it may be used in assessing the age of releases, and travel velocities of tritium in the groundwater.

Groundwater samples will be collected with a bailer in accordance with the Mound Plant ER Program SOP 2.4 "Sampling Monitoring Wells With A Bucket Type Bailer".

Preservation and container requirements for the groundwater samples are provided in QAPP. Each sample will be logged onto a chain of custody form immediately after collection in accordance with Mound Plant SOP 1.3, "Sample Control and Documentation" (Appendix A). A custody seal will be placed on each sample container and the samples will immediately be placed in a cooler containing ice or ice packs.

Enough ice or ice packs will be used to ensure that the cooler temperature does not exceed 4 degrees celsius during shipping. Samples will be shipped the same day of collection by an overnight express courier. Packaging and shipment will be in accordance with the ER Program SOP 1.5, "Guide to Handling Packaging, and Shipping Samples" (Appendix A).

8.9. FIELD QC SAMPLES

Field QC samples will include field duplicates, trip blanks, equipment blanks, and matrix spike/matrix spike duplicate samples. Each tie a group of bottles is prepared for use in the field, one of each type container used for sampling VOCs in the field will serve as a trip blank. Each of these blanks will be filled with deionized water transported to the site, and handled in the same fashion as the other sample bottles. The blanks will subsequently be sent to the laboratory for analyses. An equipment blank (i.e., rinsate blank) will be prepared for non-dedicated sampling equipment to ensure that the equipment has been

Table VIII.2. Groundwater Sampling Summary

Existing Monitoring Wells	OU-9 Monitoring Wells	OU-2 Monitoring Wells	Trenches/Pits	Seeps	Foundation Drains
0113 (Bedrock) 0114 (Bedrock) 0117 (Bedrock) 0120 (Bedrock)	0323 (Bedrock) 0324 (Bedrock) 0335 (Bedrock) 0348 (Bedrock) 0349 (Bedrock)	OU2-MW1S (Bedrock-Perched) OU2-MW1I (Bedrock-Water Table) OU2-MW1D (Bedrock-Deep) OU2-MW2S (Bedrock-Perched) OU2-MW2I (Bedrock-Water Table) OU-MW2D (Bedrock-Deep) OU2-MW3S (Bedrock-Perched) OU2-MW3I (Bedrock-Water Table) OU2-MW3D (Bedrock-Deep) OU2-MW4S (Bedrock-Perched) OU2-MW4I (Bedrock-Water Table) OU2-MW4D (Bedrock-Deep) OU2-MW5S (Bedrock-Perched) OU2-MW5I (Bedrock-Water Table) OU2-MW5D (Bedrock-Deep) OU2-MW6S (Unconsolidated Deposits) OU2-MW6I (Bedrock-Water Table) OU2-MW6D (Bedrock-Deep) OU2-MW7S (Unconsolidated Deposits) OU2-MW7I (Bedrock-Water Table) OU2-MW7D (Bedrock-Deep) OU2-MW8S (Outwash-Water Table) OU2-MW8D (Bedrock-Deep) OU2-MW9S (Outwash-Water Table) OU2-MW9D (Bedrock-Deep)	0712 (Bedrock) 0713 (Bedrock) 0721 (Bedrock) 0724 (Bedrock) 0725 (Bedrock) 0726 (Bedrock) 0727 (Bedrock)	0601 (Bedrock-Perched) 0602 (Bedrock-Perched) 0603 (Bedrock-Perched) 0604 (Bedrock-Perched) 0605 (Bedrock-Perched) 0606 (Bedrock-Perched) 0607 (Bedrock-Perched) 0608 (Bedrock-Perched)	To Be Determined
	OU-9 Background Wells				
	0331 (Bedrock) 0335 (Bedrock)				

Table VIII.2. (Continued)

Analytical Parameter List	Field Parameter List
VOCs	Temperature
SVOCs	pH
TAL inorganics	Specific conductivity
Bismuth	Dissolved oxygen
Fluoride	Redox Potential
UASTHMA -listed explosives	Water level
TCL pesticides/PCB's	
Isotopic uranium	
Isotopic plutonium (238,239/240)	
Isotopic thorium (234/235,238)	
Actinium-227	
Strontium-90	
Tritium	
Gamma spectrometry	
Nitrate/nitrite	
Sulfate*	
Chloride*	
Total organic carbon*	
Nitrite	
Nutrients (TKN,TP)*	
Total dissolved solids*	
Total suspended solids*	
Alkalinity*	
TAL inoranics (dissolved)	
Radium-226	
Americium-241	

Table VIII.2. (Continued)

QC SAMPLE SUMMARY	
TRIP BLANKS	
Number:	1 per cooler containing VOC Samples
Analytical Parameters:	VOCs
EQUIPMENT RINSATE BLANKS	
Number:	1 per 10 geochemical samples
Analytical Parameters:	Analytical parameter list
FIELD AMBIENT BLANKS	
Number:	1 per 20 geochemical samples
Analytical Parameters:	VOCs
FIELD DUPLICATES	
Number:	1 per 10 geochemical samples
Analytical Parameters:	Analytical parameter list
MATRIX SPIKE/MATRIX SPIKE DUPLICATES	
Number:	1 per 20 geochemical samples
Analytical Parameters:	Analytical parameter list

Estimated Number of Samples (Not Including Foundation Drains)

Total Locations	Groundwater Samples	QC Samples	Total Samples
51	204 (4 per quarter for one year)	94	298

NOTES

CLP - Contract Laboratory Program
PCB - polychlorinated biphenyl
SOW - statement of work
SVOCs - semi-volatile oranic compounds
TAL - target analyte list
TKN - total Kjeldahl nitrogen
TCL - target compound list
TP - total phosphorus
USATHMA - U.S. Army Toxic and Hazardous Materials Agency
VOCs - volatile organic compounds
* - indicates analysis will be conducted on 20 percent of the samples

effectively cleaned. The device will be filled or rinsed with ASTM Type II reagent grade water, and the water will then be transferred to a sample bottle and sent to the laboratory for analysis. Samples collected for matrix spikes and matrix spike duplicates will be explicitly labeled by the field team. The matrix spike/matrix spike duplicate samples will be triple the normal volume for VOCs and double the volume for semivolatile organic compounds and pesticides/PCBs. Quality assurance/quality control sampling procedures will follow the Main Hill Quality Assurance Project Plan.

9. GROUNDWATER FLOW INVESTIGATION

Groundwater flow investigation will involve the collection of groundwater data to determine the direction, rate of flow, and contaminant concentrations within the bedrock units and the BVA. This information will be used to determine the most likely pathways of contamination migration.

Water level measurements will be collected and testing of hydraulic properties (i.e. slug testing and tracer testing) will be conducted. Water level measurements will be used to construct groundwater contour maps of the different hydrostratigraphic units and to develop analytical calculations of flow directions and rates. This data will be used in developing site specific conceptual model of groundwater flow and contaminant transport and to generate a site water balance.

9.1. COLLECTION AND COMPILATION OF GROUNDWATER ELEVATION DATA

Groundwater elevation data will be collected to evaluate groundwater flow directions. All boring, monitoring well logs, and potable water supply well logs will be reviewed. Groundwater level data generated in previous investigations erroneously used all available monitoring wells to generate groundwater contour maps. The correct procedure is to map each hydrostratigraphic unit separately to fully characterize the groundwater contours and general flow directions.

Previously obtained water levels will be reviewed and contoured based on the discussion above. In addition, groundwater level data are proposed for monthly monitoring to determine seasonal trends. Atmospheric conditions including temperature and daily rainfall amounts will be collected daily at the site to further characterize the hydrogeology. This information will be used in the overall water budget calculation for the site.

Groundwater level elevations will be calculated from measured water levels taken from all available groundwater monitoring wells within the OU-2 Site boundary. Water levels will be measured to the nearest 0.01-foot using an electric water-level measuring device.

Continuous groundwater monitoring of selected wells using pressure transducers and electronic data recorders will be conducted to provide real time information on the response of the water levels within the bedrock formation and the BVA to precipitation events and changes in barometric pressure. The location and number of wells that will be continuously monitored will be determined after the installation of the OU-2 monitoring wells and an initial evaluation of flow direction.

Water levels will be measured using an electronic water level meter like the Solinist Model 101 water level indicator meter or equivalent. Refer to SOP 3.1 for procedures. Pressure transducers and continuous recorders will be used to monitor long-term variations in the groundwater surface. A pressure transducer is attached the transducer cable and lowered into the monitoring well to the desired depth and that can accommodate the psi rating of the transducer. Procedures for operational checks of the pressure transducer is located in SOP 3.3 (see Appendix A for SOPs).

9.2. GROUNDWATER DYE TRACE STUDY

The dye tracing study will utilize existing seeps, monitoring wells, potable water supply wells, and sites along the Great Miami River as discussed in Section 6.2.2. Table VI.2 lists the locations proposed for the dye tracing studies. There are 21 existing monitoring wells, three existing site groundwater potable water supply wells, four off-site private groundwater potable water supply wells, eight newly installed OU-9 groundwater monitoring wells, two existing piezometers, 25 new proposed OU-2 groundwater monitoring wells (nine cluster well locations with up to one deep, one intermediate, and one shallow well per location), six locations along the Great Miami River, and eight seeps along the outslope of the Main Hill will be monitored during the dye tracing study. Any additional seeps discovered during the proposed field reconnaissance will be included.

The primary purpose of the groundwater dye trace are to:

- provide data to characterize flow in the bedrock groundwater system beneath Mound Plant;
- provide data to assess current monitoring well locations and identify optimum locations for future monitoring wells in the bedrock groundwater system;
- provide data to determine or confirm contaminant releases from SW Building, storm drains, sewers, and process lines;
- provide data to determine the interconnection between the bedrock groundwater system and the BVA; and
- evaluate the effectiveness of the trench recovery systems.

Refer to Section 6 Characterization of Hillside Seeps and Foundation Drains for further information on the groundwater dye trace study and pertinent information concerning dyes and procedures.

10. SOIL SAMPLING

10.1. SOIL SAMPLING OBJECTIVES

Soil sampling, both at the surface and from the subsurface, will be an important element in the remedial investigation of OU-2. These samples will be collected for laboratory analysis of chemical parameters to confirm the presence or absence of contamination in suspected areas of concern, to define the nature and extent of contamination, and in support of the risk assessment. The results of random sampling will be used to provide an indication of potential contaminants in areas where contamination is unknown or unsuspected. Samples will also be submitted to a laboratory to test geotechnical parameters. This data will be used primarily in support of the feasibility study.

10.2. SOIL SAMPLING LOCATIONS AND TESTING PARAMETERS

The methods for documenting sample locations are provided in Section 2.1, while methods for collecting QA/QC samples are provided in Section 2.4.

10.2.1. Random Sampling Scheme

Soil samples will be collected from the land surface (0 to 6-inch depth) to support the OU-2 risk assessment of accidental dermal contact, ingestion, and inhalation during the present use scenario. To address the present use scenario, surface samples will not be obtained under paved areas and buildings during the first phase of sampling. To characterize risks associated with future remedial activities, construction and use, random surface and subsurface samples will be collected under paved areas and buildings in the second phase. The data will also be used to provide an indication of the potential contamination in areas where contamination is not suspected. The samples will be collected from 100 sites to be selected at random. The random sample locations will be selected by dividing the site into a 20 by 20 foot grid and selecting for collection the first 100 sampling grid coordinates drawn from a random number table that fall within current and likely-to-remain-open, unpaved areas. The sampling locations will be randomly selected after project Phase 1 has been completed, and all buried and underground utilities identified. Random samples selected using the random number table that fall on the sampling grid at a location within 20 feet of directed samples will be reselected to avoid redundancy. The random samples will be assessed for radiological, explosive, organic (except for VOCs), and inorganic parameters (Table X.1).

Table X.1. Soil Sampling Summary

Locations and Depths	
Proposed Sampling Locations: 132 initial locations are illustrated in Figure 10.1.	
Analytical Parameter List	
Analytical Parameter List	Geotechnical Parameters *
VOCs**+ SVOCs** TAL inorganics Bismuth Fluoride USATHMA -listed explosives ** TCL pesticides/PCB's** Actinium-227 Americium-241 Isotopic plutonium (238,239/240) Isotopic thorium (229, 230 234/235,238) Isotopic uranium Radium-226 Strontium-90 Tritium Protactinium-231 Gamma spectrometry Nitrate/nitrite Sulfate Chloride Total organic carbon**	Grain size distribution and Hydrometer Bulk Density Permeability Moisture Content

Table X.1. (Continued)

QC SAMPLE SUMMARY	
TRIP BLANKS	
Number:	1 per cooler containing VOC Samples
Analytical Parameters:	VOCs
EQUIPMENT RINSATE BLANKS	
Number:	1 per 10 geochemical samples
Analytical Parameters:	Analytical parameter list
FIELD AMBIENT BLANKS	
Number:	1 per 20 geochemical samples
Analytical Parameters:	VOCs
FIELD DUPLICATES	
Number:	1 per 10 geochemical samples
Analytical Parameters:	Analytical parameter list
MATRIX SPIKE/MATRIX SPIKE DUPLICATES	
Number:	1 per 20 geochemical samples
Analytical Parameters:	Analytical parameter list
Estimated Number of Samples	
132 initial locations (32 radiological, 23 organics, and 77 for organics, inorganics and radiologicals.) Locations and numbers subject to change based on results of prior phases.	

NOTES

CLP -	Contract Laboratory Program
PCB -	polychlorinated biphenyl
SOW -	statement of work
SVOCs -	semi-volatile oranic compounds
TAL -	target analyte list
TKN -	total Kjeldahl nitrogen
TCL -	target compound list
TP -	total phosphorus
USATHMA -	U.S. Army Toxic and Hazardous Materials Agency
VOCs -	volatile organic compounds
* -	indicates analysis will be conducted on 20 percent of the samples
** -	indicates parameters to be analyzed for samples specified for organic analysis.
+ -	VOCs will not be analyzed for random samples collected from the surface (0 to 6 inches).

10.2.2. Directed Sampling Scheme

Soil samples will be collected from test holes in areas where past screening investigations have indicated that contaminants are likely to be present. The purpose of this sampling program is to confirm the presence or absence of contamination and to identify the contaminants of concern. In areas where no previous studies or screening investigations have been conducted, but a potential source of contamination has been identified, additional screening activities and focused sampling will be conducted to confirm the absence or identify the presence of contamination in these areas.

The locations of proposed initial sampling test holes and the proposed analytical parameters are shown on Figure 10.1 and Table X.1. The initial locations were established based on previous field screening activities (i.e., Soil Gas Survey, and Radiological Site Survey) and previously identified potential source areas. The locations proposed are tentative and may be adjusted based on the assessment of bedrock topography and subsurface cultural features. If contaminants are detected in the initial soil cores, additional sampling will be proposed to more clearly define the extent of the contamination. The location of the test holes for further delineation of extent will be based on the preliminary findings.

After completion of the sample collection, all test holes will be abandoned by filling from bottom to surface with a neat cement/bentonite grout (4 lbs of commercial bentonite and approximately 7.5 gallons of potable water to every 94 lb. bag of portland cement). Where the bottom of the hole is clearly visible from the land surface (maximum depth approximately 5 feet), grout may be gravity placed. Where test hole depths exceed 5 feet or the bottom can not be seen, grout should be placed under pressure through a tremie pipe, filling the hole from the bottom up.

Should soil samples collected as part of the random and direct sampling schemes indicate contamination is present in an identifiable area, additional sampling will be conducted to determine the nature and extent of that contamination. This subsequent phase of the investigation will address both paved and unpaved areas, as needed.

10.3. SOIL SAMPLING EQUIPMENT AND PROCEDURES

10.3.1. Directed Sampling

Where site access is not restricted, soil sampling will be accomplished by advancing hollow stem drilling augers with a powered drilling rig. Soil sampling will be conducted continuously from the land surface to a depth of 5 feet into the bedrock surface or until auger refusal. Sampling will be conducted as specified in SOPs 4.1 - Soil Boring and 5.1 - Soil and Rock Borehole Logging and Sampling (Appendix A).

Samples for laboratory analysis of chemical parameters will be collected from near the land surface (12 to 18 inch depth), the bedrock surface, the total depth and at 5-ft intervals in between. Samples will be collected for laboratory analysis of geotechnical parameters from 20% of the test holes, and will be taken from the land surface (0 to 6-inch depth), the bedrock surface, the total depth, and at any significant change in lithology.

Where a soil test hole location is not accessible to a drilling rig, samples will be collected to the bedrock surface with hand sampling tools. A soil core piston sampler (Solinst,model 412 or similar) will be the preferred sampling tool. This sampling tool is capable of retrieving relatively undisturbed, 2-inch-diameter by 5-foot-long samples, from depths of up to 30 feet. The tool consist of disposable 2-inch-diameter thin walled aluminum tubes, a retractable drive point, and a drive head. It is driven in 5-foot increments using a jackhammer and retrieved with a winch supported from a tripod or scaffold. The specific sampling procedures using this tool are provided as SOP 5.3.1 in Appendix A. Where an adequate sample can not be attained using the soil core piston sampler hand augers will be used to retrieve the samples as prescribed in SOP 5.3 (Appendix A).

10.3.2. Random Sampling

Samples for the Random sampling scheme will be collected from the land surface using a spade and scoop, SOP 5.2 (Appendix A). Samples will be taken from the upper 6-inches of the soil horizon with all surficial vegetation removed. All soils will be described in the field by a soil scientist or geologist as specified in SOP 5.1 (Appendix A).

11. SURFACE WATER AND SEDIMENT INVESTIGATIONS

11.1. SAMPLING SCHEME

Surface water samples will be collected from the hillside seeps and from the building foundation drains during four calendar quarters as part if the OU-2 RI. Sediment samples will be collected in these areas in coordination with the OU-9 field investigation. The OU-2 RI will also examine sediments and soils in the area around lined and unlined surface drainage structures. The initial phase of the drainage way investigation will be conducted as a reconnaissance survey to locate areas where surface water may pond and areas of lined trenches where breaks or cracks may allow plant drainage water to infiltrate to the subsurface. Following the reconnaissance survey, the soils in potential infiltration areas will be sampled to determine if contamination is present in the soils. Random sampling will also be conducted along the unlined plant drainage ways to determine if contaminants are present in the drainage way sediments.

11.2. MAIN HILL SEEPS AND FOUNDATION DRAINS

Surface water samples will be collected from each identified Main Hill seep and building foundation drain during each calendar quarter for one year. Additional off-site seeps found along the railroad cut will be monitored as well. Samples will be collected with a clean decontaminated stainless steel ladle and transferred immediately to the appropriate sample container. The samples will be analyzed for radiological, organic, inorganic, and explosive parameters. Section 2.4. identifies the QA/QC sample requirements. Additional samples will be obtained for assessment of field parameters, which will consist of temperature, pH, specific conductance, redox potential, and dissolved oxygen.

An estimation of flow rate will be made at each sampling site during sample collection. At those active seeps where flows are significant, weirs will be established to quantify flow. At seeps where flows are diffuse or for any other reason establishment of a weir is not practical, flow volume will be estimated by evaluating the total flow from an area where flows have coalesced and apportioning the flow to the contributing seeps.

11.3. DRAINAGE WAY SEDIMENT SAMPLING

11.3.1. Systematic Random Sampling

A systematic random sampling scheme will be used to investigate the possibility of contaminants being present in the drainage way areas not associated with ponded water. Initially 30 samples will be collected from the surface sediments (0 to 6-inch depth) within the drainage way; if significant contamination is

found, additional samples will be collected to define the extent of the contamination. The sampling interval will be selected by dividing the total length (measured in feet along the channel bottom) of the unlined drainage system in OU-2, as identified during the Site reconnaissance investigation, by 30, which is the total number of samples to be collected. Beginning at the upgradient end of the drainage way, grade stakes will be set along the drainage way at the determined sampling interval. Sampling will alternate from the bottom of the ditch at the first grade stake, to the left side of the channel (looking downstream) just below the suspected high water line, perpendicular to the second grade stake, to the right side of the channel just below the suspected high water line at the third grade stake. The fourth sampling location will return to the bottom of the channel. If any discharge channel reach is less than 90 feet in total length, that reach will be sampled by dividing the total length by four and collecting two samples from the channel bottom, one from the upstream end and one from the downstream end, and one sample from both the left and right side of the channel margin.

11.3.2. Directed Sampling

Surface sediment samples will be collected in areas where surface water is known to pond following storm events. Three samples will be collected from each area; one from just below the suspected high water mark on the uphill or influent side of the ponded area, one from the bottom of the ponded area, and one from just below the expected high water mark on the downhill or discharge side of the ponded area. The samples will be collected with clean decontaminated scoops or trowels as specified in SOP 5.2, (Appendix A). Analysis of the samples will include all radiological, organic, inorganic and explosive parameters as identified in Table II.1. All sample locations will be documented as specified in Section 2.1, and QA/QC samples will be collected as specified in Section 2.4.

12. SOURCE SPECIFIC INVESTIGATION (Monitoring Well 0034)

Monitoring Well 0034 is located on the southeast edge of the Main Hill at the base of the slope (See Figure 8.1). A detailed background description of the monitoring well 0034 area, and specific investigation objectives is provided in the OU-2 Work Plan. Well 0034 is reported to have received a one-time discharge of waste oil or fuel oil. A personal communication with plant personnel indicates that up to several feet of free-phase petroleum hydrocarbons (free-product) may be floating on top of groundwater in the well. The investigation of this well will be broken into two tasks. Task 1 will include the identification of the free-product in Monitoring Well 0034 and the installation of two additional monitoring wells. Task 2 will include the delineation of the extent of contamination and removal of free product. This well is approximately 20 ft deep and is completed in bedrock (Figure 12.1)

12.1. TASK 1: FREE PRODUCT IDENTIFICATION

The Task 1 investigation will identify the type of free-product present, provide an initial assessment of the extent of free-product, and determine if MW 0034 is the potential source of free-product in the subsurface.

The initial field activity of this task will involve soil sample collection and laboratory analysis of the unconsolidated deposits overlying bedrock. Two test borings will be advanced using a hollow stem auger drill rig near MW 0034, one test boring will be advanced at a location 5 feet up-slope from MW 0034 and the second will be located 5 feet down-slope of MW 0034. Continuous split-spoon sampling will be conducted from the surface to the top of bedrock. Upon retrieval, samples will be field screened with an HNu and logged. A sample from each 2 foot interval will be submitted for TPH analysis.

After completion of the test boring, an air rotary drilling rig will be used to advance the boring into bedrock. The unconsolidated sediments will be cased prior to drilling into bedrock to avoid potential cross-contamination between the two zones. A 2-inch stainless steel monitoring well will be completed in accordance with the appropriate Mound Plant ER Program SOPs (Appendix A). The well screen will be set to straddle the water table to allow free-floating product (if present) to enter the well. The well screen will be 10 feet in length and have 0.010 slot openings.

The monitoring wells will be developed in accordance with Mound Plant ER Program SOP 4.8. The wells will be allowed to stabilize for two weeks after installation to allow free-product to accumulate (if present). If free-product is present in either of the two additional monitoring wells, a sample will be collected and submitted for a petroleum fingerprint analysis. If free-product is not present, a groundwater sample will be collected and analyzed for TPH. A sample of the free-product will also be collected from MW 0034 for

GEOLOGIC LOG	MOUND PLANT	Project Manager Al Gleason	PAGE: 1 of 1

Drilling Company	Raymond Int.	Borehole/Well Id	0034
Drilling Method	Auger	STATE PLANE COORDINATES	
Drilling Fluid	Unk	North (ft)	598082.49
Date Started	5/26/76	East (ft)	1496257.79
Date Completed	5/26/76	Ground Surface Elev. (ft)	818.10
Logged By	Dames and Moore	Top of Casing Elev. (ft)	818.71
Checked By	Tom Tharp	Total Depth (ft)	20.0
Comments:	Dames and Moore Well # 34-1.		

Depth	Sample T	Sample A	Sample ID	Well Materials	Well Con	Lith	USCS or Rock Type	Lithologic Description
0				SEAL: Bentonite.			FL	Fill.
5								
10				CASING: PVC, 3".			TI	Gray till.
				BACKFILL: Earth.				
							SH	Weathered shale.
				SEAL: Bentonite.				
15								
				SCREEN: Steel, 3". FILTER PACK: Gravel.			SH	Unweathered shale. Total Depth = 20.0 feet.
20								

GROUNDWATER

DEPTH	HOUR	DATE
16.46	14:10	09/20/90

Reference: Operable Unit 9, Site-Scoping Report: Volume 2 - Geologic Log and Well Information Report, May 1992

WESTON

Figure 12.1. Boring Log and Well Construction Diagram for Monitoring Well 0034

fingerprinting analysis. Groundwater and free-product levels will be measured and recorded in each of the three wells prior to sampling.

All fluids and drill cuttings recovered from the well will be placed in an appropriately labeled 55-gallon drum. Sample of fluid and drill cuttings will be collected for radiological screening and analyzed at the Mound Plant Laboratory. The results of the screening and analytical results will be used to establish proper disposal protocol.

12.2. TASK 2: DELINEATION OF EXTENT

If it is determined that MW 0034 is the only well to contain free-product from Task 1 sampling, MW 0034 will be hand bailed until it is determined that all recoverable free-product has been removed. After the removal of free-product, MW 0034 will be properly abandoned in accordance with appropriate Mound Plant ER Program SOPs (Appendix A) since the OU-9 RI/FS Site-wide Work Plan indicates that this well does not meet the standards set forth in USEPA's Technical Enforcement Guidance Document (TEGD). The two additional wells will remain as monitoring wells.

If analysis indicates that a significant volume of free product exists in the subsurface, additional test borings and monitoring wells will be installed, using methods as discussed in Task 1, to further evaluate the extent of the free product in soil and within the groundwater table. The location and number of these monitoring wells will be selected after an evaluation of the Task 1 data, which are expected to provide insight into the actual thickness and volume of groundwater floating on the water table. The screen position for these wells would straddle the water table to allow floating product to enter the wells. The number and location of Task 2 wells will be selected by DOE, USEPA, and Ohio EPA based on the Task 1 findings.

The extent of free product contamination will be delineated and the most appropriate method of removal/treatment will be determined. If it is determined that MW 0034 will not be utilized as part of the free product removal, MW 0034 will be abandoned according to Mound Plant ER Program protocol. If MW 0034 will be utilized as part of the free product removal, upon determination that clean up has been completed, MW 0034 will be abandoned according to Mound Plant ER Program protocol. The additional monitoring wells will remain in place as supplemental monitoring wells for the Main Hill.

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APPENDIX A

STANDARD OPERATING PROCEDURES

NOTE: The actual SOPs identified in Sections 1 through 6 can be found in Appendix A of the OU-9 QAPP.

MOUND PLANT ER PROGRAM

LIST OF STANDARD OPERATING PROCEDURES

SECTION 1 - GENERAL

1.1 General Instructions for Field Personnel
1.2 General Surface Geophysics
1.3 Sample Control and Documentation
1.4 Sample Containers and Preservation
1.5 Guide to the Handling, Packaging, and Shipping of Samples
1.6 General Equipment Decontamination
1.7 Sampling for Removable Alpha Contamination
1.8 Personnel Decontamination - Level D Protection
1.9 Personnel Decontamination - Level C Protection
1.10 Personnel Decontamination - Level B Protection
1.12 Air Particulate Sampling with a Real-Time Aerosol Monitor
1.15 Guide to Waste Management

SECTION 2 - WATER SAMPLING

2.1 Presample Purging of Wells
2.2 Field Measurements on Ground and Surface Water Samples
2.3 Sampling Monitoring Wells with a Bladder Pump
2.4 Sampling Monitoring Wells with a Bucket-Type Bailer
2.5 Sampling Monitoring Wells with a Submersible Pump
2.6 Sampling Monitoring Wells with a Peristatic Pump
2.7 Sampling commercial/Municipal/Domestic Wells
2.8 Sampling for Volatile Organics
2.9 Surface Water Sampling
2.10 Stream Flow Measurements Using Flumes, Velocity Cross Sectional Area, and Direct Volume
2.11 Stream Flow Measurements Using Weirs

SECTION 3 - HYDRAULIC TESTING

3.1 Water Level Measurement
3.3 Operational Check of Pressure Transducers Used in Measuring Water Levels in Wells

SECTION 4 - DRILLING AND LOGGING

4.1 Soil Boring
4.1.1 Methods to Control Communication of Subsurface Contaminants Within and Between Saturated Zones During Drilling and Well Installation
4.2 Rock Boring
4.3 Monitoring Well Installation
4.4 Monitoring Well Development
4.6 Test Pit Logging and Sampling
4.7 Piezometer Installation
4.8 Piezometer Development

SECTION 5 - SOIL SAMPLING

5.1 Soil and Rock Borehole Logging and Sampling
5.2 Soil Sampling with a Spade and Scoop

5.3 Subsurface Solid Sampling with Hand Auger and Thin-Wall Sampler
5.4 General Soil Gas Sampling and Field Chemcial Analysis
5.8 Soil Sampling with a Stainless Steel Surface Soil Sampler
5.9 Sediment Sampling Procedures for Streams, Rivers, and Ponds

SECTION 6 - HEALTH AND SAFETY

6.1 Health and Safety Monitoring of Combustible Gas Levels
6.2 Health and Safety Monitoring of Organic Vapors with a Photoionization Detector
6.3 Health and Safety Monitoring of Organic Vapors with a Flame Ionization Detector
6.4 Total Alpha Surface Contamination Measurements
6.7 Near Surface and Soil Sample Screening for Low-Energy Gamma Radiation Using the FIDLER
6.11 Beta-Gamma Radiation Measurements
6.15 Measurement of Gamma-Ray Field Using A Sodium Iodide (No. I) Detector
6.16 Heat Stress Monitoring

OU-2 FIELD SAMPLING PLAN

LIST OF STANDARD OPERATING PROCEDURES

SECTION 7 - DYE TRACING

7.1 Placement of Dye Receptor (Samples) Holders
7.2 Elution of Activated Carbon Samplers
7.3 Procedure for Analyzing Cotton Samplers
7.4 Procedures for Analyzing Samples Using the RF-50004 Scanning Spectrofluorophotometer
7.5 Procedure for Preparing Dye Sample Packets
7.6 Procedure for Preparing Fluorescent Dye Standards

SECTION 8 - DOWNHOLE GEOPHYSICS

8.1 Downhole Video Camera Survey
8.2 Downhole Geophysics - Temperature/Fluid Resistivity
8.3 Downhole Geophysics - Natural Gamma
8.4 Downhole Geophysics - Neutron
8.5 Downhole Geophysics - Electric
8.6 Self-Potential
8.7 Downhole Geophysics - Sonic
8.8 Downhole Geophysics - Caliper

SECTION 9 - SURFACE GEOPHYSICS

9.1 Seismic Refraction Surveys
9.2 Ground Penetrating Radar (GPR)

STANDARD OPERATING PROCEDURE 7.1

PLACEMENT OF DYE RECEPTOR (SAMPLER) HOLDERS

1. PURPOSE

The purpose of this SOP is to define guidelines followed by field personnel in placement and retrieval of dye receptor holders and samplers.

2. DISCUSSION

The placement of dye receptor holders is critical to the overall objectives of the dye tracing study. This requires care in the placement and to avoid cross contamination between sampling sites.

The preferred method for sample placement is dependent on the sampling point (i.e. seep, monitoring well, or potable water supply well). Seep sampling locations will use a weighted "gum drop" sampler as shown on attached Figure 6.7. Some alteration may be required depending on the site conditions at the time of sample placement. Samplers placed in monitoring wells will use a 1-2 foot PVC 50-slot screen with the carbon and cotton samplers placed within the screen interval. A brass or copper wire strand will be used to hold the samplers in place. The sample container placement is illustrated in Figure 6.5. Samplers placed at potable water supply wells will use a sample container similar to the illustration in Figure 6.8.

3. PROCEDURES

3.1 ASSOCIATED PROCEDURES

Before every operation, review of the SOP's 1.1-1.10 is necessary. These SOP's contain information on the performance of field activities. They should be consulted for specific information about equipment and supplies; sample collection, preservation, packaging, and shipping; decontamination procedures; and documentation requirements. Procedures directly associated with this SOP are listed below.

SOP No.	SOP Title
1.1	General Instructions for Field Personnel
1.3	Sample Control and Documentation
1.4	Sample Containers and Preservation
1.5	Guide to Handling, Packaging, and Shipping of Samples

3.2. PREPARATION

3.2.1. Office

A. Review the FSAP or WP and SOP's listed in Section 3.1.

B. Coordinate schedules/actions with the installation staff.

C. Obtain appropriate permission for property access as required.

D. Assemble the equipment and supplies needed for this SOP task.

E. Notify the analytical laboratory of sample types, the number of samples, and the approximate arrival time.

F. Contact the carrier that will transport samples to obtain information on regulations and specifications.

3.2.2. Documentation

A. Obtain field logbook from the QA officer.

B. Obtain a sufficient number of dye receptor "Bug Sheets" to record site monitoring stations, date of placement and collection and time of day and sample media.

C. Consult Program data administrator for a current list of information management codes, location ID's, and sample numbers used in the completion of data forms.

3.2.3. Field Procedures

A. Locate sampling site

B. Don personal protective equipment necessary before handling samplers and sample holders. Disposable gloves must be worn prior to placing and handling samplers. This is to avoid cross contamination of the samples between sample location.

C. At all sampling sites, two sets of sample packets will be placed and replaced during every sampling event. This is for QA/QC purposes and in the event of laboratory accidents, a second set will be available for analysis.

3.2.3.1. Seep and River Sample Placement and Collection

A. Attach carbon and/or cotton sampler to wire strand as illustrated in Figure 6.7.

B. Place sampler attachment in the area of the seep with the maximum flow rate. Also, try to place the sampler out of direct exposure to sunlight.

C. Make sure carbon/cotton sampler is completely submerged. If the "gum drop" sample holder device is not appropriate, modification can be made by bending the wire strand. Sample holders placed in the river will need a security cord attached to the holder and secured by a stake to prevent accidental lose of samplers because of high water.

D. Replace samplers according to FSAP by removing the "gum drop" sampler holder from the seep or river and replacing the carbon/cotton samplers. Each sampler will be placed in it's own individual sampling bag and labelled. Refer to SOP's in Section 3.1. Place samples and holder back in the seep.

3.2.3.2. Monitoring Well Sample Placement and Collection

A. Attach carbon and/or cotton sampler to a # 9 or similar gauge brass or copper strand.

B. Bend the wire strand so that the sample packets are placed at equivalent distances apart within the sample screen holder.

C. Slide the wire strand and sample packets into the 50-slot PVC sample screen and cap (Figure 6.5).

D. The PVC sample container is attached by a polypropylene rope and rope clamps. One end of the sampling cap will have a hole for the rope to fit through.

E. The sample tube is lowered down into the monitoring well to the sampling depth required. The sample container is secured by tying off the rope to an "eye" bolt or similar attachment at the top of the monitoring well (Figure 5.6).

F. The well is secured.

G. During the next sampling round, the well is unlocked, the rope pulled up with the sample container and the rope is placed on plastic sheeting placed around the monitoring well.

H. One end of the cap is removed and the wire strand with the sample packets can be removed and replaced.

3.2.3.3. Potable Water Supply Well Sample Placement and Collection

A. Sample packets are placed in the sample container illustrated on Figure 6.8. One end of the sample container is removed and the sample packets placed within and the container end replaced.

B. The sample container is attached to a garden type hose with one end connected to a faucet or connected to the discharge line at the well head with a galvanized tee and gate valve.

C. The gate valve is turned on to allow approximately one to two gallons of water per minute flow through the sample container.

D. The discharge end of the hose is placed and allowed to discharge to the ground. If this is not acceptable.

E. Collection of the samplers require the valve to be turned off first. Then the samplers can be collected and replaced by removing one end of the sample container.

3.3. POST-OPERATION

3.3.1. Field

A. Ensure all equipment is accounted for and samples are properly labelled and ready for shipment.

B. Ensure all disposable items and personal protective equipment used is picked up and properly disposed off or stored in field vehicle.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

3.3.3. Office

A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

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5. ATTACHMENTS

5.1. Equipment and Supplies Checklist

5.2. Dye Trace Sample Placement and Collection Log Sheet Samples

STANDARD OPERATING PROCEDURE 7.2

ELUTION OF ACTIVATED CARBON SAMPLERS

1. PURPOSE

The purpose of this SOP is to define guidelines followed by laboratory personnel in preparing the activated carbon samplers for analyses.

2. DISCUSSION

Elution of the activated carbon samplers is critical to the objectives for analytical analysis in the dye trace study. This requires care in the laboratory procedures to avoid cross contamination between samples.

The samples will be eluted with a solution of 5% NH4OH (aqueous ammonia hydroxide) in 70% isopropyl alcohol (standard rubbing alcohol) referred to as the Aley Solution. Other elution solutions that can be used are the Smart Solution, consisting of a 5:2:3 mixture of 1-propanol, concentrated NH4OH, and distilled water or a solution of 5% KOH (potassium hydroxide) in 70 % isopropyl alcohol or 5% KOH in ethanol (known as the MODNR Solution). The Aley solution is preferred when two or more dyes are anticipated to be eluted out of the carbon. The Smart solution is preferred for Rhodamine WT dyes, but the fumes created by the ammonia hydroxide are of concern. The MODNR solution is preferred for fluorescein and the fumes produced are not of great concern.

3. PROCEDURES

3.1. ASSOCIATED PROCEDURES

Because this is a laboratory procedure, review all Materials Safety Data Sheets for all chemicals and dyes that are used in the laboratory. All laboratory personal shall wear a white laboratory apron and gloves when mixing eluent solutions and dye standards.

3.2. PREPARATION

3.2.1. Office

A. Coordinate schedules/actions with the field and laboratory staff.

3.2.2. Documentation

A. Obtain field logbook from the laboratory QA officer.

B. Obtain a sufficient number of the Record of Dye Test log sheets to record the results of the analyses. This information will also be recorded in the laboratory logbook. Record date and time of collection from the chain of custody report and sample media.

C. Consult Program data administrator for a current list of information management codes, location ID's, and sample numbers used in the completion of data forms and laboratory logbook.

3.2.3. Laboratory Procedures

A. Laboratory personnel shall thoroughly wash hands prior to handling samples or mixing eluent solutions or dye standards.

B. Prepare a solution of 5% NH4OH (aqueous ammonia hydroxide) in 70% isopropyl alcohol by mixing 5ml of aqueous ammonia hydroxide with 95ml of isopropyl alcohol. The volume of eluent can be increased by increasing the proportion to the volume needed.

If other eluent solutions are desired, contact the Dye Trace Project Director for approval and procedures for preparing solutions. The Dye Trace Project Director will make the determination in changing eluent solutions.

C. Eluent solutions shall be stored in amber glass containers.

D. Prior to eluting carbon samples, arrange samples in numerical order. This will assist in documentation and management of the run files.

E. Place 8 ounce specimen cups on lab table. Take one sample packet and mark on the specimen cup all information on the sample bag. Record this information in the laboratory logbook.

F. Remove charcoal packet from sample bag and rinse carbon with approved filtered and/or purified water that does not contain chlorine or other organics. The packets will be rinsed for several minutes to remove clay and silt that can accumulate in the carbon.

G. Cut the screen packet and place carbon granules in the marked specimen cup. Only one sample will be prepared at a time. Pre-marking specimen cups is not desired because of potential errors that may occur with transferring carbon to the sample cup.

H. Pour approximately 30 ml of eluent in the specimen cup, covering the carbon sample by approximately 1/8 to 1/4 inch. Do not pour any more solution than necessary, since the more eluent used, the more dilution the eluent (eluent and dye) will result.

I. Cover the specimen cup with the lid and allow sample to elution for 1 hour (+/- 10 minutes).

J. The eluant is now ready to be analyzed. Refer to SOP 7.4 for procedures on analyzing the samples.

3.3. POST-OPERATION

3.3.1. Field

A. Ensure all equipment is accounted for and samples are properly labelled and ready for shipment.

B. Ensure all disposable items and personal protective equipment used is picked up and properly disposed off or stored in field vehicle.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

3.3.3. Office

A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

Alexander, E. Calvin, Jr. and James F. Quinlin, 1992 (2nd Edition). Practical Tracing Of Groundwater With Emphasis On Karst Terranes. Short Course Manual presented on the occasion of the Annual Meeting of the Geological Society of America. October 24, 1992, Cincinnati, Ohio.

5. APPENDIX

5.1. Equipment and Supplies Checklist

5.2. Dye Trace Sample Placement and Collection Log Sheet

ATTACHMENT A

EQUIPMENT AND SUPPLIES CHECKLIST

_____ Overshoes

_____ Work gloves (2 pairs)

_____ Acid (10% HCL) bottle

_____ Clipboard case

_____ Strapping tape

_____ Pin hammer

_____ Tape measure (tenths)

_____ Protractor

_____ Hat

_____ First aid kit

_____ Sun screen

_____ Thermoluminescent dosimeter (TLD)

_____ Safety shoes/boots

_____ Ziplock bags

_____ Preprinted labels

_____ Distilled (organic-free) water

_____ Methanol (Nanograde)

_____ Freight forms

_____ Telephone directories

_____ Chain-of-custody forms

_____ Hard hat

_____ Pieces of wood (2 inches x 2 inches x 8 inches) to indicate core loss intervals

ATTACHMENT A , continued

EQUIPMENT AND SUPPLIES CHECKLIST

_____ Stamped, addressed envelopes (large and regular sizes)

_____ Phone and gas credit cards

_____ Calculator

_____ Pens, pencils, and permanent markers

_____ Package cord

_____ Flagging

_____ Hand lens

_____ Tool box

_____ Rain suit

_____ Camera

_____ Ear plugs

_____ Stopwatch

_____ Cold-weather gear

_____ Alpha meter

_____ Safety glasses

_____ Kitchen screen (determine lithology)

_____ Ice chest

_____ Bound logbook

_____ Data collection forms

ATTACHMENT B

BUG SHEET– Sites Monitored for Dyes

TEST _____ RUN BY _____ DATE _____

JAR #	AY73 Fluor.	Rhod. WT	OB	DY 96	Site Code	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
	Charcoal		Cotton								

erence: Alexander and Quinlin, 1992

RECORD OF DYE TEST

Input Point (Name of test) _____ Date _____ Time _____

Tracer _____ Amount _____ Investigator _____

Precipitation Before or During Test _____

Detectors placed at	Date, Number of days since dye input, and results												
	Date												
	Number of Days												

Legend:

-	Negative Result	B	Background
+	Positive	B+	Fluorescence Significantly above background
++	Very Positive	NR	Not Recovered (because of high water or other reason)
+++	Spectacularly, Gloriously Positive	L	Bug Lost or Stolen
/	Bugs not changed	G	New or Extra Gumdrop
Installed			

Remarks: _____

_____

_____

_____

Interpretation: _____

_____

Reference: Alexander and Quinlin, 1992

STANDARD OPERATING PROCEDURE 7.3

PROCEDURE FOR ANALYZING COTTON SAMPLERS

1. PURPOSE

The purpose of this SOP is to define guidelines followed by laboratory personnel in preparing and analyzing cotton samplers.

2. DISCUSSION

Proper analysis of cotton samplers is critical to the objectives of the dye trace study. This requires care in the laboratory procedures to avoid cross contamination between samples.

The cotton samples will be viewed under an long-wave ultra-violet light source and the results verified by running the samples in the RF-5000U Scanning Spectrofluorophotometer or similar instrument or method. The visual analysis is strictly subjective and qualitative. The visual analysis can be verified by viewing standard samples of various known concentrations to categorize the viewed results as being strongly positive, moderately positive, weakly positive, or negative for dye adsorption.

3. PROCEDURES

3.1. ASSOCIATED PROCEDURES

Care will be taken to ensure samples are not cross contaminated. Disposable gloves and laboratory apron will be worn to protect the laboratory analyst from possible dye adsorption of clothes or cross contaminating cotton samples.

3.2 PREPARATION

3.2.1. Office

A. Coordinate schedules/actions with the field and laboratory staff.

3.2.2. Documentation

A. Obtain copy of field logbook from the laboratory QA officer.

B. Obtain sufficient number of Record of Dye Test Log forms to record the results of the analysis. This information will also be recorded in the laboratory logbook. Record date and time of collection from the chain of custody form or field logbook and sample media.

C. Consult Program Data Administrator for a current list of information management codes, laboratory ID's, and sample numbers used in the completion of the data forms and laboratory logbook.

3.2.3. Laboratory Procedures

A. Laboratory personnel shall thoroughly wash hands with a non-phosphate laboratory grade detergent (i.e. alconox or liquinox) prior to handling samples. Lab personnel will wear laboratory apron and disposable gloves during the handling and analysis procedures.

B. Arrange samples to be analyzed in numerical order. This will assist in the data management and recording.

C. Record sample number on log sheet and laboratory logbook.

D. Take cotton sampler out of sample collection bag and rinse cotton sampler with filtered and/or purified water to remove clay and silt from cotton.

E. If possible, allow the cotton samples to air dry under a covered hood or decanter. This is not necessary, but is less messy than working with wet samples. Wet samples (drippy wet) will not be allowed in the Scanning Spectrofluorophotometer. Damp samples may be placed in the sample compartment of the spectrofluorophotometer and analyzed.

F. Place cotton sampler in ultra-violet viewing cabinet and turn on long-wave ultra-violet light. This is strictly qualitative analysis and the laboratory analyst should have practical experience in this procedure. For qualitative analysis, the following degree of positiveness of fluorescence is used:

1. Strongly positive: Cotton swatch is entirely white; the color is brilliantly white or brightened throughout the sample.

2. Moderately positive: Cotton sampler is entirely white or brightened; the color is not brilliantly white.

3. Weakly positive: Cotton sampler is brightened, but less than 75% of the cotton is whitened.

4. Negative for optical brighteners: Optical brighteners are either not detectable or they are absent.

G. Record the results in the laboratory logbook and on the Record of Dye Test Log Sheet.

H. Confirm the results by running the samples in the RF-5000U Scanning Spectrofluorophotometer. Refer to SOP 7.4 for procedures on using the spectrofluorophotometer.

3.3. POST-OPERATION

3.3.1. Field

A. Ensure all equipment is accounted for and samples are properly labelled and ready for shipment.

B. Ensure all disposable items and personal protective equipment used is picked up and properly disposed off or stored in field vehicle.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

3.3.3. Office

A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

Alexander, E. Calvin, Jr. and James F. Quinlin, 1992 (2nd Edition). Practical Tracing Of Groundwater With Emphasis On Karst Terranes. Short Course Manual presented on the occasion of the Annual Meeting of the Geological Society of America. October 24, 1992, Cincinnati, Ohio.

Barner, Wendell L., 1988. Investigation of the Geology and Hydrology of Stone County, Missouri to Determine the Extent of Groundwater Contamination. Unpublished Thesis.

5. APPENDIX

5.1. Equipment and Supplies Checklist

5.2. Dye Trace Sample Placement and Collection Log Sheet

STANDARD OPERATING PROCEDURE 7.4
PROCEDURES FOR ANALYZING SAMPLES USING
THE RF-5000U SCANNING SPECTROFLUOROPHOTOMETER

1. PURPOSE

The purpose of this SOP is to define guidelines followed by laboratory personnel in analyzing sampler using the RF-5000U Scanning Spectrofluorophotometer.

2. DISCUSSION

Analysis of carbon and cotton samplers is critical to the objective of the dye trace study. This requires care in the laboratory procedures to avoid cross contamination between samples and proper equipment procedures.

3. PROCEDURES

3.1. ASSOCIATED PROCEDURES

Care will be taken to ensure samples are not cross contaminated. Disposable gloves and laboratory apron will be worn to protect the laboratory analyst from possible dye adsorption of clothes or cross contaminating cotton samples.

3.2. PREPARATION

3.2.1. Office

A. Coordinate schedules/actions with the field and laboratory staff.

3.2.2. Documentation

A. Obtain copy of field logbook from the laboratory QA officer.

B. Obtain sufficient number of Record of Dye Test Log forms to record the results of the analysis. This information will also be recorded in the laboratory logbook. Record date and time of collection from the chain of custody form or field logbook and sample media.

C. Consult Program Data Administrator for a current list of information management codes, laboratory ID's, and sample numbers used in the completion of the data forms and laboratory logbook.

3.2.3. Laboratory Procedures

A. Personnel involved in the direct analysis of the samples using the RF-5000U Scanning Spectrofluorophotometer will be required to attend a course on using the analytical equipment by the manufacturer or representative distributer.

B. After completion of the course/training session, the personnel will be given a training course by the Dye Trace Project Manager on the specific procedures required for the site specific needs.

3.3. POST-OPERATION

3.3.1. Laboratory

A. Ensure all equipment is accounted for and samples are properly labelled and stored.

B. Ensure all disposable items and personal protective equipment is used properly disposed of.

C. The laboratory facilities will be cleaned after each day's work.

D. Analytical equipment will be maintained and checked according to manufacturers' specifications.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

D. Record maintenance procedures of analytical equipment in laboratory log book.

3.3.3. Office

A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

None

5. APPENDIX

5.1. Equipment and Supplies Checklist

5.2. Dye Trace Sample Placement and Collection Log Sheet

ATTACHMENT A

EQUIPMENT AND SUPPLIES CHECKLIST

_____ Overshoes

_____ Work gloves (2 pairs)

_____ Acid (10% HCL) bottle

_____ Clipboard case

_____ Strapping tape

_____ Pin hammer

_____ Tape measure (tenths)

_____ Protractor

_____ Hat

_____ First aid kit

_____ Sun screen

_____ Thermoluminescent dosimeter (TLD)

_____ Safety shoes/boots

_____ Ziplock bags

_____ Preprinted labels

_____ Distilled (organic-free) water

_____ Methanol (Nanograde)

_____ Freight forms

_____ Telephone directories

_____ Chain-of-custody forms

_____ Hard hat

_____ Pieces of wood (2 inches x 2 inches x 8 inches) to indicate core loss intervals

ATTACHMENT A , continued

EQUIPMENT AND SUPPLIES CHECKLIST

_____ Stamped, addressed envelopes (large and regular sizes)

_____ Phone and gas credit cards

_____ Calculator

_____ Pens, pencils, and permanent markers

_____ Package cord

_____ Flagging

_____ Hand lens

_____ Tool box

_____ Rain suit

_____ Camera

_____ Ear plugs

_____ Stopwatch

_____ Cold-weather gear

_____ Alpha meter

_____ Safety glasses

_____ Kitchen screen (determine lithology)

_____ Ice chest

_____ Bound logbook

_____ Data collection forms

ATTACHMENT B

BUG SHEET-- Sites Monitored for Dyes

TEST _____ RUN BY _____ DATE _____

J A R #	AY73 Fluor.	Rhod. WT	OB	DY 96	Site Code	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
	Charcoal		Cotton								

ence: Alexander and Quinlin, 1992

RECORD OF DYE TEST

Input Point (Name of test) _____ Date _____ Time _____

Tracer _____ Amount _____ Investigator _____

Precipitation Before or During Test _____

Detectors placed at	Date, Number of days since dye input, and results												
	Date												
	Number of Days												

Legend:

-	Negative Result	B	Background
+	Positive	B^+	Fluorescence Significantly above background
++	Very Positive	NR	Not Recovered (because of high water or other reason)
+++	Spectacularly, Gloriously Positive	L	Bug Lost or Stolen
/	Bugs not changed	G	New or Extra Gumdrop
Installed			

Remarks: _____

_____

_____

_____

Interpretation: _____

_____

Reference: Alexander and Quinlin, 1992

STANDARD OPERATING PROCEDURE 7.5

PROCEDURE FOR PREPARING DYE SAMPLE PACKETS

1. PURPOSE

The purpose of this SOP is to define guidelines followed by laboratory personnel in preparing dye sampler packets for the dye tracing study.

2. DISCUSSION

Preparation of carbon and cotton samplers is critical to the objective of the dye trace study. This requires care in the laboratory procedures to avoid cross contamination between samples and to ensure proper quality control measures.

3. PROCEDURES

3.1. ASSOCIATED PROCEDURES

Care will be taken to ensure samples are not cross contaminated. Disposable gloves and laboratory apron will be worn to protect the laboratory analyst from possible cross contaminating dye samplers.

3.2. PREPARATION

3.2.1. Office

A. Coordinate schedules/actions with the field and laboratory staff.

3.2.2. Documentation

A. Document in the laboratory logbook the data, time, and the number and type of dye samplers prepared.

B. Dye samplers will be made only a few days in advance of the field work.

3.2.3. Laboratory Procedures

A. The carbon and cotton adsorption media will be placed in a nylon or fiberglass mesh screen such as used for window or door screens. The packets will be approximately 12 cm by 15 cm and folded to form an envelope 12 cm by 7.5 cm; the long and short edge can be sewn or stapled (See Attached Figure A). Another method is illustrated in the attached Figure B. Stainless steel, brass or copper wire should be used for the frame material. If staples are used they must be stainless steel or other suitable material that will not rust or leach alloys into the groundwater. If the packets are sewn, use nylon thread or one pound rating monofilament fishing line.

B. Approximately 12 grams or two heaping teaspoons of activated granulated charcoal (6-14 mesh size) will be placed in each packet and secured. Activated charcoal has a limited useful life, so a fresh supply shall be available. Evidence indicates that activated carbon loses its adsorption ability upon exposure to the atmosphere. Therefore, carbon samplers will be made one week in advance of the sample collection and stored in air-tight containers or large zip-lock bags.

C. The cotton containing packets will be constructed in the same way as the carbon containing packets. Undyed/unbleached surgical cotton, cotton balls, or cotton discs will be used as the adsorbent media for those dyes used that do not adsorb onto the activated carbon. The amount of cotton adsorbent to be placed in each packet will be selected considering the particular form in which the cotton is obtained, but will be a similar size as discussed above for the carbon samplers.

D. Cotton samples will be viewed under an long-wave ultra-violet light before cotton samples are prepared to ensure the quality control of the samples.

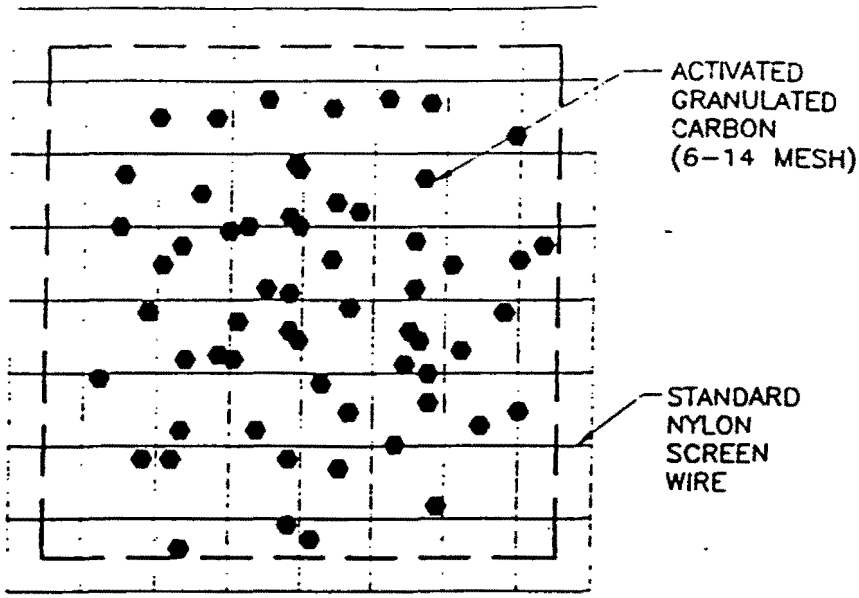
E. Activated carbon will be obtained by the same manufacturer or supply house throughout the duration of the tracing study to ensure quality control. If supplies are discontinued or are back ordered, other sources will be found and this will be documented in the laboratory logbook and a memorandum prepared and sent to EG&G.

3.3. POST-OPERATION

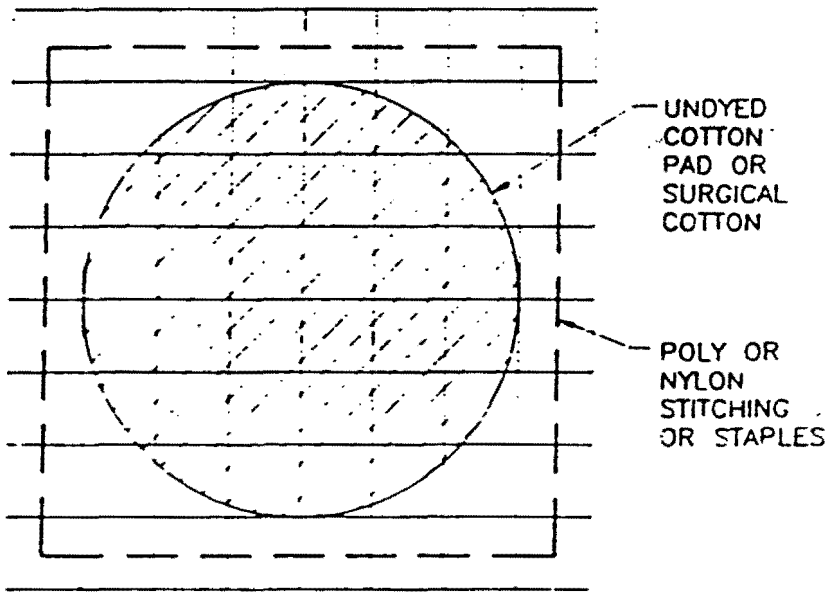
3.3.1. Laboratory

A. Ensure all equipment is accounted for and samples are properly labelled and stored.

Figure A



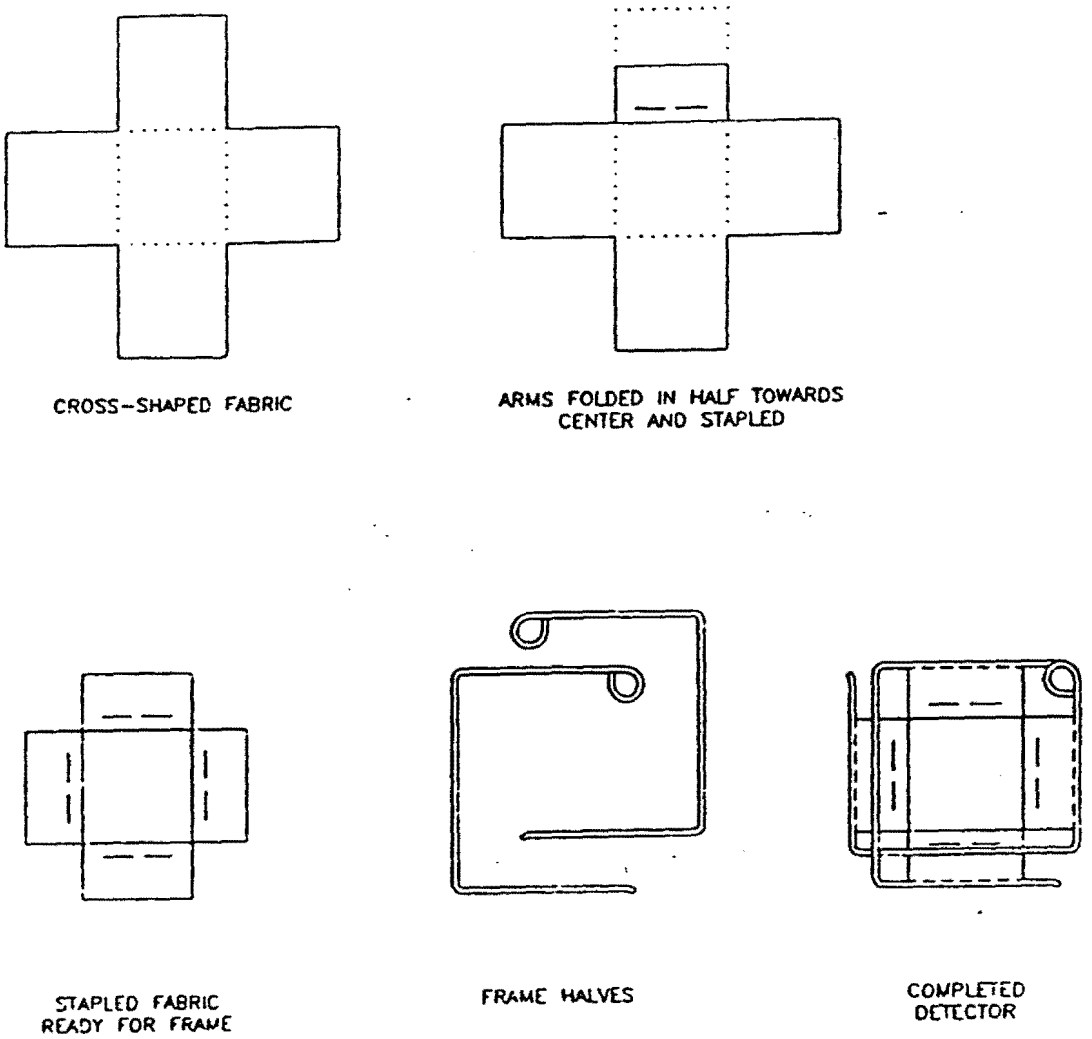
ACTIVATED COCONUT CHARCOAL SAMPLER



COTTON DYE SAMPLER

FACKET

Figure B



PROCEDURE FOR THE CONSTRUCTION OF PASSIVE DYE DETECTORS FROM COTTON FABRIC. (FROM BYRD, 1981)

FABRIC

B. Ensure all disposable items and personal protective equipment used is properly disposed of.

C. The laboratory facilities will be cleaned after the day's work.

D. Analytical equipment will be maintained and checked according to manufacturers' specifications.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

3.3.3. Office

A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

None

5. APPENDIX

None

STANDARD OPERATING PROCEDURE 7.6.

PROCEDURE FOR PREPARING FLUORESCENT DYE STANDARDS

1. PURPOSE

The purpose of this SOP is to define guidelines followed by laboratory personnel in preparing fluorescent dye standards for the dye tracing study.

2. DISCUSSION

Preparation of fluorescent dye standards is critical to the objective of the dye trace study. This requires care in the laboratory procedures to avoid cross contamination between samples and to ensure proper quality control measures. The dye standards are used to confirm instrument performance and to verify the presence of fluorescent dyes from carbon or cotton samples. The dye standards prepared are not used for instrument calibration (using the Shimadzu RF-5000U Scanning Sprectrofluorophotometer).

3. PROCEDURES

3.1. ASSOCIATED PROCEDURES

Care will be taken to ensure samples are not cross contaminated. Disposable gloves and laboratory apron will be worn to protect the laboratory analyst from possible cross contamination.

3.2. PREPARATION

3.2.1. Office

A. Coordinate schedules/actions with the field and laboratory staff.

3.2.2. Documentation

A. Document in the laboratory logbook the data and time and the number and type of dye standards prepared.

B. Dye standards will be made prior to the dye injection.

C. Dye standards prepared will be run prior to the sample round collected.

3.2.3. Laboratory Procedures

Dye standards will be prepared as follows:

A. Rhodamine WT dye standard concentrations will be prepared according to the TABLE 1. Rhodamine WT is a 20% solution and requires a three step dilution process to arrive at a 100 ug/l solution. This third dilution is referred to as the "working solution" (Mull, et al., 1987) and the remaining dye concentrations can be prepared using this working solution.

TABLE 1

THREE-STEP SERIAL DILUTION FOR PREPARATION OF RHODAMINE WT DYE STANDARDS

(Adapted from Mull, et al., 1987)

	Initial Concentration (micrograms per liter)	Specific Gravity (grams per cubic Centimeter)	Volume of Dye (milli-liter)	Volume of Diluent (milli-liter)	New Concentration (micrograms per liter)
First Dilution	200,000,000	1.190	20	2,068	2,280,000
Second Dilution	2,280,000	1.002	20	3,000	15,100
Third Dilution	15,100	1.000	20	3,000	100

B. Standard solutions will be prepared for each dye used in the water tracing program and maintained at the laboratory for calibration comparison using the scanning spectrofluorophotometer and to verify results.

C. Dye standard solutions for powdered dyes will be prepared based on per weight basis of the dye. Powdered dyes are not always pure and information on these dyes are subject to manufacturers' willingness to provide this information. Because dyes like fluorescein come from a variety of manufactures and under different names for trade secret purposes, the exact quantity of "dye" in the mixture is not always available or accurate. Therefore, some dyes are used strictly for qualitative purposes and not quantitative analysis. For dye concentration preparation for powdered dyes, 1 gram of powdered dye in 1000 ml of water equals 1 mg/l of dye, assuming a

dye concentration of the powder form is 100% pure. If percentages of actual dye concentration is available, then the ratio can be calculated.

D. Once the working solution is prepared (100ug/l) other standard solutions can be prepared from this solution. Table 2 illustrates other dye concentrations that can be produced from the working solution (only with Rhodamine WT dye or Pontacyl pink and acid yellow 7 powdered dyes). Figure A (attached) illustrates the procedure for preparing standard dye dilutions.

3.3. POST-OPERATION

3.3.1. Laboratory

A. Ensure all equipment is accounted for and samples are properly labelled and stored.

B. Ensure all disposable items and personal protective equipment is used properly disposed of.

C. The laboratory facilities will be cleaned after the each day's work.

D. Analytical equipment will be maintained and checked according to manufacturers' specifications.

3.3.2. Documentation

A. Record cleanup procedures and any uncompleted work in the logbook.

B. Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.

C. Review data collection forms for completeness.

3.3.3. Office

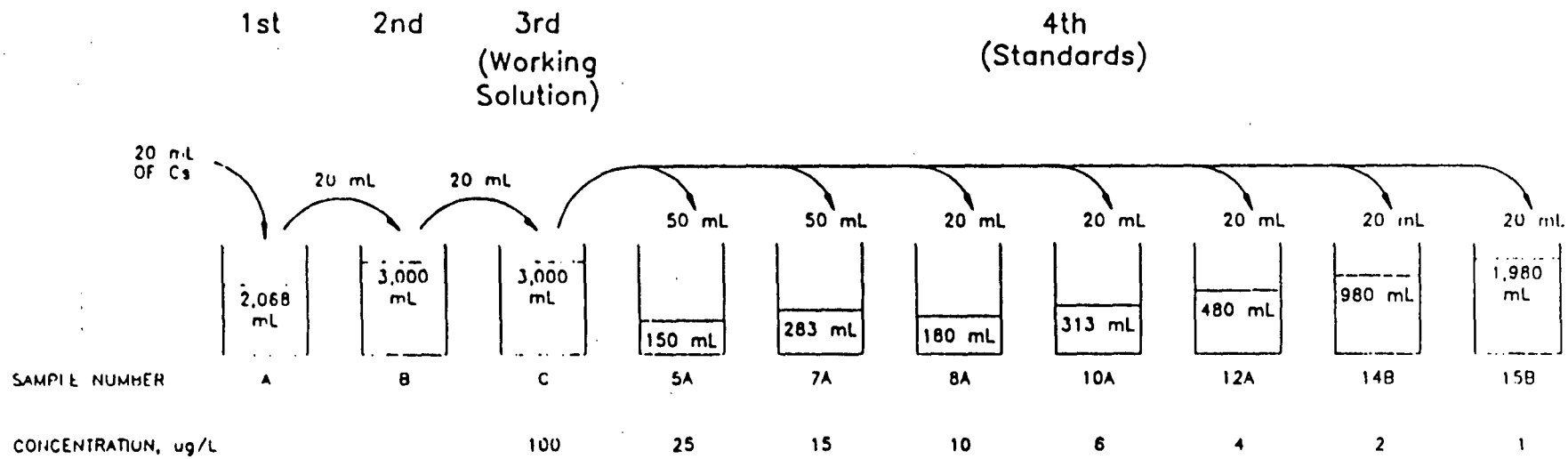
A. Deliver original forms and logbook to the site manager for technical review. Site manager will review, sign forms, and transmit to the document control officer (copies of the files) for eventual delivery to the Department of Energy.

B. Inventory equipment and supplies. Repair or replace broken or worn equipment and supplies. Return equipment and supplies to equipment manager and report incidents of malfunction or damage.

DILUTION

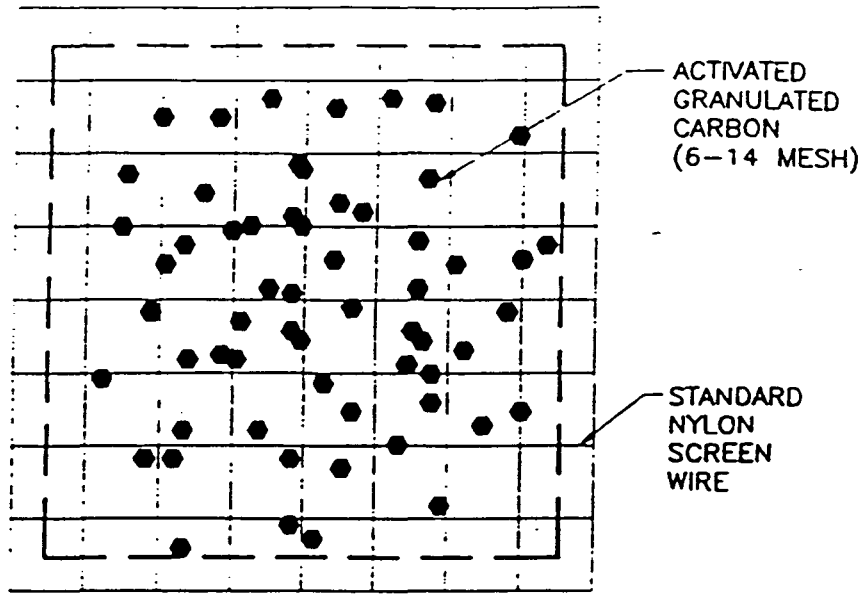
TABLE 2

DILUTIONS

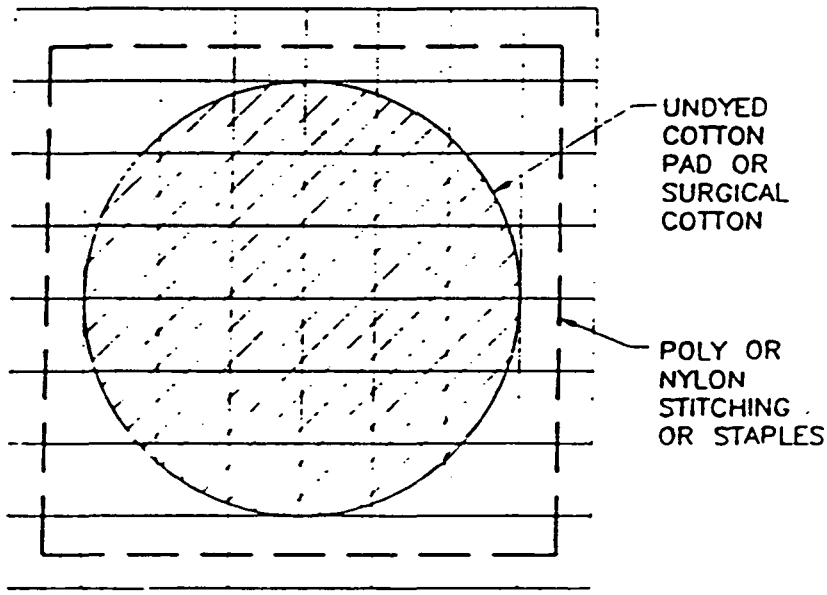


EXAMPLE USING TABLE 1 FOR PREPARING
DYE STANDARD SOLUTIONS OF RHODAMINE WT.

Figure A



ACTIVATED COCONUT CHARCOAL SAMPLER



COTTON DYE SAMPLER

JACKET

C. Contact the analytical laboratory to ensure that samples arrived safely and instructions for sample analyses are clearly understood.

4. SOURCES

None

5. APPENDIX

None

STANDARD OPERATING PROCEDURE 8.1

DOWNHOLE VIDEO CAMERA SURVEY

1. SCOPE AND APPLICATION

Borehole video logging will be performed in boreholes and monitoring wells in the area of the OU-2 investigation that include the main base at Andersen, MARBO Annex, and Harmon Annex. The borehole video logging will be performed in completed boreholes in an attempt to provide the following data:

- Formation color;
- Vugs within the limestone formations;
- Location or horizons where cavernous zones, or fractures and joints occur;
- Estimation of permeability and porosity from observing downhole video tapes;
- Location of infiltrating groundwater; and
- Correlation between downhole geophysics, borehole cuttings, and coring data.
- Final results will be presented on goring logs

2. EQUIPMENT

- Health and Safety Equipment
- Decontamination equipment, Health and Safety Plan
- 3-inch color downhole video camera,
- VHS recorder and cassettes,
- 1,000 feet of co-axial cable, and
- Decontamination equipment, and
- Log notebook and indelible ink pen.

3. PROCEDURES

1. All equipment will be decontaminated prior to mobilization to site and in accordance with procedures outlined in SOP 1.1. Read Health and Safety Plan and follow appropriate protocol.

2. Mobilize to the site and set-up equipment, calibrate to ground surface, and obtain all available borehole/well information applicable for the logging. Information may include, but not be limited to, the borehole/well name, location name, total depth, depth to water, history, and site conditions, and borehole conditions.

3. A 3-inch color camera manufactured by Laval Underground Systems or equivalent will be used. A color camera is required to evaluate formation color.

4. The axial lens is used first to view the gross features of the borehole. The logging speed should not exceed five (5) feet per minute.

5. Following the initial video logging, a second film will be made using the radial-view mirror to evaluate details of the borehole walls. The logging speed should not exceed 5 feet per minute.

   All measurements will be recorded both going into the hole and coming out of the hole.

6. All equipment will be logged, run and cleaned following site specific decontamination procedures as outlined in SOP 1.6. At a minimum, a portable spray washer and deionized water will be sprayed on the cableline and the camera immediately after logging. Depending on site conditions, intensive decontamination procedures may be required, which may include steam cleaning of the cable while it is being reeled out of the borehole and going through a line wiper decontamination assembly.

7. All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

8. Complete field notes and sign-off sheet showing personnel logging and reviewers will be provided with the final videos.

9. Copies of the videos will be made as soon as possible to avoid loss or destruction of data. If original is lost prior to reproduction, the borehole will be re-logged.

4. REFERENCES

None

STANDARD OPERATING PROCEDURE 8.2

DOWNHOLE GEOPHYSICS - TEMPERATURE/FLUID RESISTIVITY

1. SCOPE AND APPLICATION

Downhole temperature and fluid resistivity (inverse of fluid conductivity logs will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The temperature and the fluid resistivity are run to see where changes in flow are occurring. Two logs may be obtained from the temperature. One is a log of the changes in temperature throughout the logged borehole. The other log is of the differential temperature which notes rate of changes from point to point. Often the differential temperature will show changes that are not easily recognizable on a regular temperature log. Requirements are a fluid filled open hole. One can log down through the casing to the open section.

The fluid resistivity log is run in conjunction with the temperature log and is used to indicate changes in fluid resistivity which may be due to changes in fluid chemistry or temperature. The difference in this log to a fluid conductivity log is that of an inverse proportion. The fluid resistivity is commonly cross correlated to the temperature log and may detect changes in fluid flow when the temperature is the same in one flow as the other. Requirements are the same as the temperature.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.

- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the temperature and fluid resistivity measurements are:

1. Temperature and fluid resistivity probe
2. Logging cable / winch

3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

The Temperature/Fluid Resistivity combination probe will be run from the surface downward at a sufficiently slow logging speed to detect any ground water flow anomalies (8 fpm or less). The drilling fluid is sometimes disturbed by the logging process and repeat sections may not be appropriate and may not repeat, (a repeat run may be tried on the first well to check for consistency in the well). Field calibration checks with the temperature probe consists of comparing the tool response of a container of drill fluid with the response from a Yellow Springs Model YSI-33, or equivalent, portable salinity, conductivity and temperature meter. Shop calibration of this equipment consists of a water bath and precision thermometer and checking fluid resistivity over a range of salinities. Please note that the drill hole needs to stabilize without circulation as long as possible (at least 8 hours) prior to running the temperature probe for optimum results. As an optional service, these wells can be injected with cold or hot water and relogged with temperature over time. This provides a 'temperature tracer' that will highlight the significant permeable zones for subsequent testing.

Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

3.1. CLEANING, DECON AND HAZARDOUS SITES

All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

3.2. ON SITE DATA RECORDS

All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator
- Drilling contractor and address
- Client and address
- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.
- For the full waveform sonic the transmitter to receiver spacing may be noted.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected Instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized. Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably

greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 25 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

Bob Crowder, Colog, Inc. 1992
17303 W. Colfax
Suite 265
Golden, Colorado 80401

STANDARD OPERATING PROCEDURE 8.3

DOWNHOLE GEOPHYSICS - NATURAL GAMMA

1. SCOPE AND APPLICATION

Downhole natural gamma logs will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The natural gamma or gamma log is one of the most widely used of borehole geophysical logs and is most often used to indicate changes in lithology, by measuring changes in natural gamma radiation. The gamma log may be logged in fluid or air and is attenuated somewhat in casing.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.
- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the natural gamma measurements are:

1. Natural gamma probe
2. Logging cable / winch
3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

The natural gamma logging probe will be lowered to the bottom of the well and logged upwards at a constant logging speed. After the natural gamma has been logged upward for about 100' (comparison log), the log will be stopped, and the probe returned to the bottom of the well and then logged to the surface. Pre- and post- calibration field standards (and shop calibration) consisting of a gamma sleeve will be used with this equipment. Logging speed is limited to a maximum speed of 25 feet per minute with the optimum speed at about 20 feet per minute.

Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

3.1. CLEANING, DECON AND HAZARDOUS SITES

All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

3.2. ON SITE DATA RECORDS

All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator

- Drilling contractor and address
- Client and address
- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.
- For the full waveform sonic the transmitter to
- receiver spacing may be noted.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected Instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized. Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 25 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

Bob Crowder, Colog, Inc. 1992
17303 W. Colfax
Suite 265
Golden, Colorado 80401

STANDARD OPERATING PROCEDURE 8.4

DOWNHOLE GEOPHYSICS - NEUTRON

1. SCOPE AND APPLICATION

Downhole neutron logs will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The neutron log is one of the most widely used of borehole geophysical logs and is most often used in groundwater resource evaluations because they can be used to determine porosity for a considerable range of borehole conditions and rock types.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.
- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the neutron measurements are:

1. Neutron probe
2. Logging cable / winch
3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

The neutron logging probe will be lowered to the bottom of the well and logged upwards at a constant logging speed. After the neutron has been logged upward for about 25' (comparison log), the log will be stopped, and the probe returned to the bottom of the well and then logged to the surface. Pre- and post- calibration field standards (and shop calibration) consisting of a neutron sleeve will be used with this equipment. Logging speed is limited to a maximum speed of 25 feet per minute with the optimum speed at about 20 feet per minute.

Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

3.1. CLEANING, DECON AND HAZARDOUS SITES

All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

3.2. ON SITE DATA RECORDS

All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator

- Drilling contractor and address
- Client and address
- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.
- For the full waveform sonic the transmitter to
- receiver spacing may be noted.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected Instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized. Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 25 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

Bob Crowder, Colog, Inc. 1992
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STANDARD OPERATING PROCEDURE 8.5

DOWNHOLE GEOPHYSICS - ELECTRIC

1. SCOPE AND APPLICATION

Downhole electric logs (spontaneous potential (SP), resistance, and resistivity) will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The electric logs which include the SP, resistance, 16" and 64" normal resistivities measure the changes in potential, resistance and resistivity of the formations and are used with the gamma log for lithologic determination. The resistivity measurements can be used for quantitative rock analysis. Requirements are a fluid filled open hole.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.
- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the electric log measurements are:

1. Electric logging probe
2. Logging cable / winch
3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

The SP, 16" and 64" Normal Resistivity and Induced Polarization combination probe will be lowered to the bottom of the well and logged upwards at a constant logging speed. After this probe has been logged upward for about 100' (comparison log), the log will be stopped, and the probe returned to the bottom of the well and then logged to the casing (or fluid-level). Pre- and post- calibration field standards (and shop calibration) consisting of resistor arrays and a millivolt SP source will be used with this equipment. Logging speed within the data acquisition restrictions does not affect the quality of the data from this probe since all electrical measurements are nearly instantaneous. This probe will probably be logged at 25 to 30 fpm and can only be obtained in the fluid filled open hole portion of the borings.

Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

3.1 CLEANING, DECON AND HAZARDOUS SITES

All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

3.2 ON SITE DATA RECORDS

All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator

- Drilling contractor and address
- Client and address
- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected Instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized. Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 25 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

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STANDARD OPERATING PROCEDURE 8.6

SELF-POTENTIAL

1. SCOPE AND APPLICATION

The majority of self-potential (SP) surveys conducted for engineering or environmental applications involve studies of: groundwater movement related to leakage of dams, canals, reservoir floors, and other containment structures; the location of voids, sinkholes, tunnels, faults, archeological remains, and other ysubsurface features that affect groundwater flow patters; the delineation of flow in the vicinity of landslides, wells, drainage structures and springs; and regional groundwater flow.

The self-potential method will be utilized to assess the location of subsurface voids. The voids of interest are expected to be located within the shallow subsurface limestone or weathered limestone.

1.1. SUMMARY OF SELF-POTENTIAL METHOD

The self-potential (SP) method is a passive geophysical method that involves the measurement of naturally occurring electric field within the earth. The fields can be produced by a variety of different subsurface sources generally associated with subsurface flows of fluid, heat or ions. The electrical current produced by these sources give rise to an electrical potential that can be measured on the ground surface.

SP surveys are performed by measuring the potential difference between a stationary "base" electrode and "measuring" electrode. The measuring electrode is moved to various measurement points along a traverse or grid pattern. A variety of different base and measuring electrode configurations can be used. The end result of an SP survey is a set of potential difference profiles (data obtained from traverses) or a contour map of equipotentials (data obtained from a grid system). The target or feature of interest is represented as an anomaly in the data. Estimates of depth can be made from the characteristics of SP anomalies. Computer programs based on analytical modeling techniques can be used to calculate self-potentials generated by subsurface sources.

SP anomaly amplitudes encountered in engineering and environmental studies are lower than those encountered in mineral or geothermal exploration. Therefore, extreme care in the acquisition and reduction of field data, and recognition of characteristic fields associated with artificial and natural noise sources, are critical to the success of SP investigations.

2. EQUIPMENT

Unlike other geophysical equipment, complete SP equipment sets are not readily available from commercial sources and must be assembled by the user. The equipment required to obtain SP measurements include: at least three porous pot electrodes, connecting wire (up to several thousand feet), a reel to hold the wire, a portable container of electrolyte solution, a measuring meter (standard multimeter), and a tool for digging electrode holes.

Non-polarizing electrodes are essential for SP measurements. Metal stakes used as electrodes create electrochemical action at the ground contacts which generate spurious potentials of the same size as those being measured. Furthermore, these contact potentials are quite erratic in different ground and at different times so it would not be possible to make a fixed correction to the data. Porous pot electrodes consist of a metal immersed in a saturated solution of its own salt (such as copper immersed in copper-sulfate solution) contained in a porous pot which allows the solution to leak slowly and make contact with the ground. These are the type that should be used for SP measurements.

3. PROCEDURES

Prior to performing the SP study, detailed work plan will be written. The grid system (or traverses), measurement interval and electrode configuration should be determined in the work plan. site logistics (brush clearing, scheduling, etc.) will be planned prior to the field investigation.

A measurement should be obtained between the base and measuring electrodes, in a bath of electrolyte solution, before installation of the base electrode (drift/polarization error measurement for fixed base configuration). This should also be performed at the end of each survey or field day after removal of the base electrode (base station location). During the survey, an auxiliary electrode should be carried in a bath of electrolyte solution and a measurement between the auxiliary and measuring electrodes should be obtained periodically (approximately every 15 minutes). Electrodes should be kept out of the sun and as much as possible at the same temperature. All of these readings will be documented in a field note book.

Base and measuring electrodes must be installed (dug in) deep enough to penetrate dry (or rain saturated) surface soils so as to encounter vadose soil moisture and to minimize surface temperature variations. In compact soils, this depth is only a few inches, however, loose, dry or rocky soils may require one foot or more. A tight contact between the electrode and soil must be achieved.

Information for each SP survey should be recorded prior to collecting data. Standardized data sheets should be used to enter original field notes and data obtained for each sounding. The following information will be recorded for each SP survey.

- Project, task, site, and location identification,
- Company or client organization,
- Date and time,
- Weather, site conditions and temperatures,
- Name and signature of each member of the field crew,
- Number of electrodes used in survey and configuration of electrode array used for study (e.g., fixed-base or gradient configuration, etc.),
- Measurement interval and/or grid size,
- Measurement number, location and/or coordinates of measurement location on grid system,
- All drift/polarization error measurement (in millivolts),
- Actual data for each measurement location (in millivolts), and
- Data for each survey should be recorded in a single field notebook, if possible.

During the survey, the same field procedures will be employed for each SP measurement. The general procedures for a given SP survey are listed below.

1. At the beginning of each survey take a reading between the base and measuring electrode in a bath of electrolyte fluid. Record this measurement and time of the measurement in a field notebook.

2. Properly install the base electrode at the selected location. Properly install the measuring electrode at the first measurement station. Record the measurement in a field notebook.

3. Proceed along the traverse or grid system at the pre-determined measurement intervals properly installing the measuring electrode at each measurement station. Record each measurement in a field notebook.

4. Take a measurement between the measuring between the measuring electrode and auxiliary electrode (in a bath of electrolyte fluid) approximately every fifteen minutes during the survey. Record the measurement and time of the measurement in a field notebook.

5. AT the end of each survey take a reading between the base and measuring electrode in a bath of electrolyte fluid. Record this measurement and time of the measurement in a field notebook.

4. PRECAUTIONS

None

5. REFERENCES

None

6. ATTACHMENTS

None

STANDARD OPERATING PROCEDURE 8.7

DOWNHOLE GEOPHYSICS - SONIC

1. SCOPE AND APPLICATION

Downhole sonic logs will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The full waveform sonic (FWS) measures sound properties through the rocks. Fws sonic logs can be used for fracture identification, lithologic determination, waveform analysis, and rock property analysis such as porosity, permeability, and competency. Comparison of the sonic log to other logs such as the gamma and the electric logs may show changes not indicated on the other logs. Requirements are a fluid filled open hole and a formation travel time above 5000 feet per second. Cement bond logs may be logged in casing.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.
- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the sonic log measurements are:

1. Sonic logging probe
2. Logging cable / winch
3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

The next logging probe used will be the Full Waveform Sonic probe. This probe allows for the digitized full waveforms from two receivers (probably 36" and 48") to be recorded along with an automatic Delta T (interval travel time) and amplitude. Delta T and amplitude are plotted on the field prints. Typical logging speed is 10 to 12 fpm, (when collecting data at 0.2 foot intervals and 5 to 6 fpm at 0.1 foot intervals). Determination of the sonic logging speed is also dependent upon hole conditions. Field verifications consist of checking out full waveform response by either: 1) logging into steel or pvc surface casing and checking the probe delta T to known travel times, (55-60 microseconds for steel and 140-155 microseconds for cemented pvc), or 2) look for waveform responses using a bar between the transmitter and receivers as a functionality check. This log can only be obtained in the fluid filled portion of the wellbore. As with most logs, a repeat section at the bottom of the well will be recorded and compared, prior to changing to the next probe.

Depending upon the type of data being extracted, it may be desirable to relog the sonic with a second logging probe at different transmitter/receiver spacings, (e.g. 18" and 30" versus 36" and 48"). This allows two additional checks to be made for the shear wave picks and increases confidence in the accuracy of the data.

Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

3.1. CLEANING, DECON AND HAZARDOUS SITES

All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

3.2. ON SITE DATA RECORDS

The sonic data will be picked automatically on-site while logging with the 'first zero crossing after user defined threshold' algorithm. This data will be repicked post-acquisition with the other algorithm's listed above.

All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator
- Drilling contractor and address
- Client and address
- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.
- For the full waveform sonic the transmitter to receiver spacing may be noted.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized. Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably

greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 25 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

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STANDARD OPERATING PROCEDURE 8.8

DOWNHOLE GEOPHYSICS - CALIPER

1. SCOPE AND APPLICATION

Downhole caliper logs will be collected on site wells and borings as specified in the work plan to aid in site characterization.

The caliper log shows changes in borehole size and may be utilized as an indicator of rock hardness, cementation, lithology, and to avoid misinterpretations on other logs due to changes in hole size rather than chemical or physical changes in the rock. The caliper may be logged in fluid, air, open or cased holes.

The following information as a minimum will be provided on this project:

- Hard copy printouts of all the logs annotated with date and time of the logging run, type of logs, reporting instrumentation, manufacturer, model, serial number, operator signature, site, borehole designation, instrument settings, depths logged, recorder scale.
- Digital copies of all the logs on 3-1/2 or 5-1/4 high-density floppy diskettes, also annotated with site, borehole designation, type of logging runs, dates of runs, diskette numbers and date of format, etc.

2. EQUIPMENT

The logging equipment to obtain the caliper log measurements are:

1. Caliper logging probe
2. Logging cable / winch
3. Generator
4. Logging Instrument and data recorder
5. Field notebook
6. Calibration Sheets
7. Printer
8. Field Computer

All well logs, with the exception of the borehole video digitally will be corrected on a personal computer. Real time waterfall displays of the logs will occur on a monitor with a hard copy made simultaneously on a printer.

3. PROCEDURES AND METHODOLOGY

1. Initial field activities will be to mobilize to the site and set-up equipment, pre-calibrate, obtain all available well information, applicable to the logging job. Information may include the Well name, TD, samples, history, and site conditions, etc. on the well(s).

2. Repeat sections are one of the best means for checking the functioning of instrumentation and data quality. The comparison log will be run on the first 25 feet of the log run. A log run will then be started over again and logged for the entire length of the applicable section of the hole, (to casing, fluid level, surface, or TD if logging down). This process will provide approximately 25' repeat section which will then be compared prior to changing probes.

3. The three arm caliper log will be run in the borehole. If the hole is shown to be unstable one may want to run the caliper log last, as sometimes the pressure from the caliper arms, may further unstabilize the hole. If the hole has been staying open during previous logging runs, the slight pressure of the caliper arms is not likely to make a difference. The caliper will be run now instead of last, (if possible), as the remaining probes use different uphole electronics or systems. The length of the arms will adjusted to give maximum sensitivity for the hole size being logged. Calibration rings of known size and closest to that wellbore will be used for field calibration for the caliper measurement. Caliper calibrations will be run before and after the logging run. A 25 foot comparison run will also be logged.

4. Generally a 0.1 ft or 0.2 ft. digital recording interval is used depending on the degree resolution needed. If logging for basic information, such as general lithology then a 0.5 foot interval may be used, and have the advantage of being able to log some of the logs faster.

5. All equipment will be logged, run and cleaned following site specific decon procedures. As a minimum, a portable spray washer with fresh water will be sprayed on the cableline and the probes immediately after logging. Depending on the specific site conditions, intensive decon procedures may be required, which may include steam cleaning of the cable while it is coming out of the hole and going through a line wiper decon assembly.

6. All records, QA/QC documentation, field calibrations, and data will be reviewed and completed. Review should be double checked by a client representative.

7. Complete field prints and a copy of the raw digital data will be made and delivered prior to leaving the site. Ensuring at least two different sets of recoverable data in case one set is lost or destroyed.

8. A Sign-off sheet showing the logging engineer, processing engineer, and everyone reviewing the data will be provided with the final logs.

4. QA/QC LOGGING OPERATION DESCRIPTIONS AND PROCEDURES

4.1. DOCUMENTATION AND TRACEABILITY

Initial uphole recorded data will be processed; if processed data is also provided, any algorithms used will also be provided. Regardless of the purpose of the logs, acquisition procedures, repair, and calibration information will be documented for future reference. Probes will be numbered to simplify identification of associated documentation. Documentation of all field problems with any components of the logging system, including probes, cable, and uphole electronics will be done. This will include the steps taken to solve any problems and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check probe response may aid in the identification of field problems. Probes will be re-calibrated in a physical model after repairs are made.

Field logging engineers will fill out a **Logging Report** in the field as they are conducting the logging operations. Logging reports supply necessary information for Log Headings (Headers) and are attached to the top of every log. The Log Report and the resultant log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information about the log should be included on the final log heading. Header information is saved on computer hard disk. If information is not available or applicable, it should be noted. header. Space for the following items are found on the logging report.

- Owner of well and address
- Location of well
- Date
- Logging contractor and address
- Logging operator
- Drilling contractor and address
- Client and address

- Witness and address
- Elevation of top casing and distance above ground level
- Drilling history
- Casing description
- Description of log depth datum
- Elevation of log depth datum
- Description of probe reference point
- Drilling method
- Type of drilling fluid
- Resistivity and temperature of mud filtrate and cake
- Depth of origin of mud samples
- Fluid level
- Time since last mud circulation
- Bottom hole temperature
- Model and manufacturer of tool
- Logging company tool number
- Date and type of last calibration
- Times of field standardization
- Top and bottom of logged interval
- Logging speed and direction
- Vertical depth error after logging, and
- Time constant or digital sampling interval, or both.

Daily log forms will be filled out by field engineers. This record includes the logging history: which logs were run when? and to what depth?, as well as an accounting of the engineers' time to the closest 15 minute interval.

Processing Reports are filled out during data reduction and processing. All of the raw field data will be recorded in the original raw data format. The raw data is recorded without probe offsets or filtering.

The processing record documents the steps that were performed to the raw data to generate the final data and includes the raw file names, any intermediate file names, and the final data file names.

The success of processing records is demonstrated by the ability of someone not associated with the project to be able to duplicate the processing steps through to the final data and to end up with the same product.

Copies of selected Instrument check/calibration records will be maintained on site and will be attached with the report.

4.2. CALIBRATION AND STANDARDIZATION

When geophysical logs are to be used for any type of quantitative or qualitative analysis or to measure changes in a ground water system with time, they need to be properly calibrated and standardized.

Calibration and standardization also are needed to reference the accuracy, comparability, equipment, time frames, and various units of logs to known values and each other. Since some types of calibration and standardization can be expensive, the level and type of calibration should be related to project objectives.

For purposes of this document, calibration is considered to be the process of correlating a logging system response to known values. Logging responses are referenced to known values in various properties, (electrical, physical, chemical, nuclear, electromagnetic, etc.). Calibration is carried out before going to the field to log to make sure that the equipment is functional. Calibrations, such as rings for caliper probes or resistors for resistivity systems, may be used in the field or the laboratory. A calibration may also be done in the field, before and/or after logging.

Standardization is the process of correlating a calibrated logging system response to a standard reference unit or point. Most logs are standardized during calibration. The purpose of calibration and standardization is to reference the logs to known values and to show the repeatability and consistency of the logs.

Because of the variability in most rocks, more values are needed if core analyses from a borehole are used for calibration. Boreholes that have been carefully cored, and the cores that have been analyzed quantitatively, may also be used to calibrate logging probes. To reduce depth errors, core recovery in calibration holes should approach 100% for the intervals used for calibration, and log response should be used to select samples for laboratory analysis. Cores to be used for log calibration should only be analyzed from depth intervals where log response is relatively uniform for a depth interval considerably greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts should not be used because of the possibility of adjacent bed effects.

The logging system response should be checked regularly using field standards and the values placed on the log. On going checks and calibrations of probes provide the basis for correcting for changes in output with time due to system drift, which may be caused by temperature or other factors. Standardization should include at least two values: for example, 2 caliper rings, of different sizes. These values need to be in the same range as the field data being recorded.

4.3. OPERATION CHECKS

The logging engineer will calibrate and test all equipment prior to mobilization and, if possible, in the field to verify correct operation of the logging system.

As applicable, all logs will have a 100 foot comparison section to check the repeatability of each log.

All calibrations will be recorded.

A logging report as noted in the form section of the QA/QC document, will be filled in to document the project.

There is often a difference in the standardization frequency between logs that are used for quantitative application and those that are used for qualitative application. The field engineer will use the same rigorous procedures for all logs on this project regardless of the initial intended use. This will assure that the logs will still be suitable if a quantitative application is required later.

5. REFERENCES

Bob Crowder, Colog, Inc. 1992
17303 W. Colfax
Suite 265
Golden, Colorado 80401

STANDARD OPERATING PROCEDURE 9.1

SEISMIC REFRACTION SURVEYS

1. SCOPE AND APPLICATION

All seismic refraction investigations will be conducted by a qualified geophysicist.

Seismic refraction techniques are used to determine vertical and horizontal dimensions of subsurface materials. Seismic waves generated at a source travel at differing velocities in various types of subsurface materials and are refracted (according to Snell's law) at the interface between differing materials. Therefore, the travel time of the waves from the source to a receiver is a function of the characteristics of the subsurface materials. Generally for hazardous waste investigations the compressional (P) wave, which arrives first, is used for the analysis. It is easy to distinguish from the other elastic waves that arrive later. A plot of the distance from the source to a geophone vs. time are then constructed. From these plots the depths and thicknesses of the various layers may be calculated.

Application and Limitations: The method may be used to define the characteristics of natural materials in the subsurface and to locate burial pits and trenches. However the use of seismic refraction requires that the compressional wave travel at increasing velocities with depth. In other words, the transmission velocities for subsurface materials must increase with depth. This usually means that the density and hardness of the materials must increase with depth. If the transmission velocity decreases the compressional wave will be refracted away from the detector. This is due to the "blind zone" effect produced by a materials with lower transmission velocities (interbed) lying below one of higher velocity.

2. EQUIPMENT

To conduct a survey a seismic source (e.g sledge hammer and plate or explosive device), low-hertz geophones (receivers), and seismograph (24-channel signal enhancement) are required.

3. METHODOLOGY AND PROCEDURES

1. All seismic refraction profiles should be recorded using continuous reversed profiling. Shot points should be located, and shots recorded, at or offset from both ends of every profile (end shots). For refraction profiles longer than 100 meters (330 feet) forward and reverse shot points should be located, and shots recorded, between the ends of the profile (mid-shots). The distance intervals for these shot points should be appropriate to each specific investigation, but with the exception of offset shots, in no case should these intervals be greater than 50 meters (160 feet).

The actual profile lengths, geophone spacings and shot separations, and the supporting rationale, should be documented in an appropriate site characterization report.

2. Where necessary, seismic refraction data should be filtered or enhanced to remove false signals (noise) and enhance the true seismic response; however, such filtering or enhancement should not significantly degrade the true signal. The types of filters used should be documented in an appropriate site characterization report.

3. Seismic refraction data should be modeled using the Generalized Reciprocal Method (GRM). The intercept-time method (ITM), the delay-time method (DTM), or other equivalent technique should be acceptable alternatives under the following conditions: 1) documented evidence shows that the strata under investigation are not highly irregular and possess dips of less than 10 degrees; 2) The ITM or DTM models are part of an initial study, and will be used to plan additional detailed seismic surveys.

4. When explosives are deemed necessary for use as an energy source for refraction surveys, all handling of explosives should be performed by a blaster with the appropriate license.

   Seismic refraction surveys at hazardous waste sites are typically limited in depth to less than 50 meters. At these shallow depths and adequate seismic signal (shot) can usually be generated by using a sledge hammer, weight drop, or seismic gun. For penetration significantly below this depth however or in environments that are less then ideal, explosive charges are usually required.

5. The locations of seismic refraction profiles should be surveyed and located. These locations should be presented in all appropriate work plans and site characterization reports. The surveying techniques and precision of the same should be appropriate to the data requirements and to the purpose of the data.

6. When subsurface lithologic and hydrologic data are available, the seismic refraction models should be correlated with the subsurface information. The results of this correlation should be included in an appropriate site characterization report.

7. Seismic data should be stored digitally so that post processing of the data can be applied. If possible first arrivals should be picked using software that allows for digitally picking the break on a CRT. Hard copy records should always be reviewed and compared to the digital picking process.

8. The data should be presented showing seismic cross sections which indicate layers, velocity change, and interpreted lithology and structures.

9. General.

Information obtained during an refraction survey should be presented according to a standard data format, using standardized data sheets with original field entries. As a minimum, this should include the following information:

- Project, task, site, and location identification;
- Company or organization;
- Date (and time, if applicable);
- Operator's name and signature;
- Method/technique identification;
- Instrument make, model, serial number, and calibration date/frequency (if applicable);
- Geophone type and configuration;
- Line or site grid location(s);
- Weather and site conditions and temperatures;
- Relevant calibration and QC data;
- Number of traces and length of record in seconds;
- Sampling interval;
- Type and frequency of filters applied to data;
- Notes of features and seismic noise (cars, powerlines, wind, etc.) which may affect the data.

STANDARD OPERATING PROCEDURE 9.2

GROUND PENETRATING RADAR (GPR)

1. SCOPE AND APPLICATION

GPR surveys will provide subsurface information and aid in site characterization and detection of subsurface targets such as tanks, trenches, pipes, and buried drums. All GPR investigations will be conducted by a qualified geophysicist.

GPR is typically useful in detecting three classes of subsurface anomalies - metallic objects, layers/areas/objects of differing electrical properties, and disruptions in the layering of the subsurface materials. Buried metallic objects, such as pipes, barrels, bomb casings, and underground storage tanks, typically show prominent hyperbolic signatures due to the high contrast in electrical conductivity between metals and soil materials. Buried materials of differing electrical properties, such as concrete or brick walls, or water or air-filled PVC pipes, can also be detected. In some cases, contamination in the soils or floating on the water table can be directly detected using GPR. For example, free petroleum product strongly attenuates the radar signal and can often be detected floating on the water table. GPR is also useful for delineating disruptions in the natural soil layering, due to excavations, disposal trenches, or voids.

2. EQUIPMENT

Geophysical Survey Systems, Incorporated's (GSSI) SIR System 8 and/or 10 or equivalent ground-penetrating radar systems will be used for the GPR survey. Both GSSI systems utilize impulse radar technology to sense and record continuous, high resolution profiles or subsurface materials.

The primary variable in GPR instruments is the antenna configuration. Antennas are currently available in both monostotic (one-piece) and bistatic (two-piece) configurations and are generally designed to detect radar signals ranging from about 60 to 1000 Mhz. No one antenna configuration is suitable for all cases, even at the same site. The survey crew will carry multiple antennas to the site for the survey so that an optimal configuration will be available.

3. METHODOLOGY AND PROCEDURES

1. GPR measurements will be collected over target areas defined by the work plan and anomalous areas detected by the EM measurements. Data will be collected continuously along profiles.

2. GSSI systems employ an electronic marking device that records a mark on direct field graphic records or within digital radar files. Generally, double marks or clicks are made at the beginning and end of the survey lines and single clicks are recorded as the antenna passes over predetermined distance intervals. Following acquisition of data in the field the data will be downloaded from digital tape to magneto-optical storage media for subsequent processing and analysis in the office.

3. The calculation of the depth of exploration for a particular GPR configuration may be accomplished by knowing the dielectric constant of the earth materials or the depth to a particular reflector that is clearly visible on the radar record. In addition, the depth may be calculated through identification and graphical measurement of hyperbolic signatures or through the development wide angle refraction and reflection (WARR) data.

4. After an optimal GPR survey configuration has been decided upon, the unit is activated and the antenna is towed along one of the prearranged grid lines. An electronic mark is placed on the data at the beginning and end of each survey line, and every 10 or 20 feet along the line, so that the position of the data and anomalies on each radar line is readily apparent. The locations of surface metal, utilities, walkways, etc., are noted on the log during the survey.

5. All radar traces and interpreted data sets should be accompanied by quality control data that indicate the level of quality of the data. Periodic replicate measurements should be made so that measurement precision may be established. Time and/or depth calibrations should be performed on a daily bases.

   A calibration that yields significant changes in instrument parameters or travel time may indicate the need for repetition of data or increased density of travel time calibrations in the area of interest. Graphical data should be reviewed during the field activities to determine the data quality is adequate, and whether the survey results appear to be consistent with conceptual models.

6. Although much of the data obtained in GPR surveys are automatically recorded by the instrumentation, additional information to unambiguously identify and to interpret each trace should be recorded in the field logbook. At a minimum, the field logbook should contain the following information:

   - Project name, number and location
   - Company or organization

- Date and time of day
- Operator's name
- Line and trace designation (also recorded directly on the signal recording medium)
- Equipment serial numbers
- Antenna frequency
- Direction and speed of antenna movement
- Weather and temperature
- Site map coordinates at the beginning and end of the trace
- Other pertinent notes, remarks or comments
- Electromagnetic velocity in the subsurface medium at the nearest calibration point.

4. REFERENCES

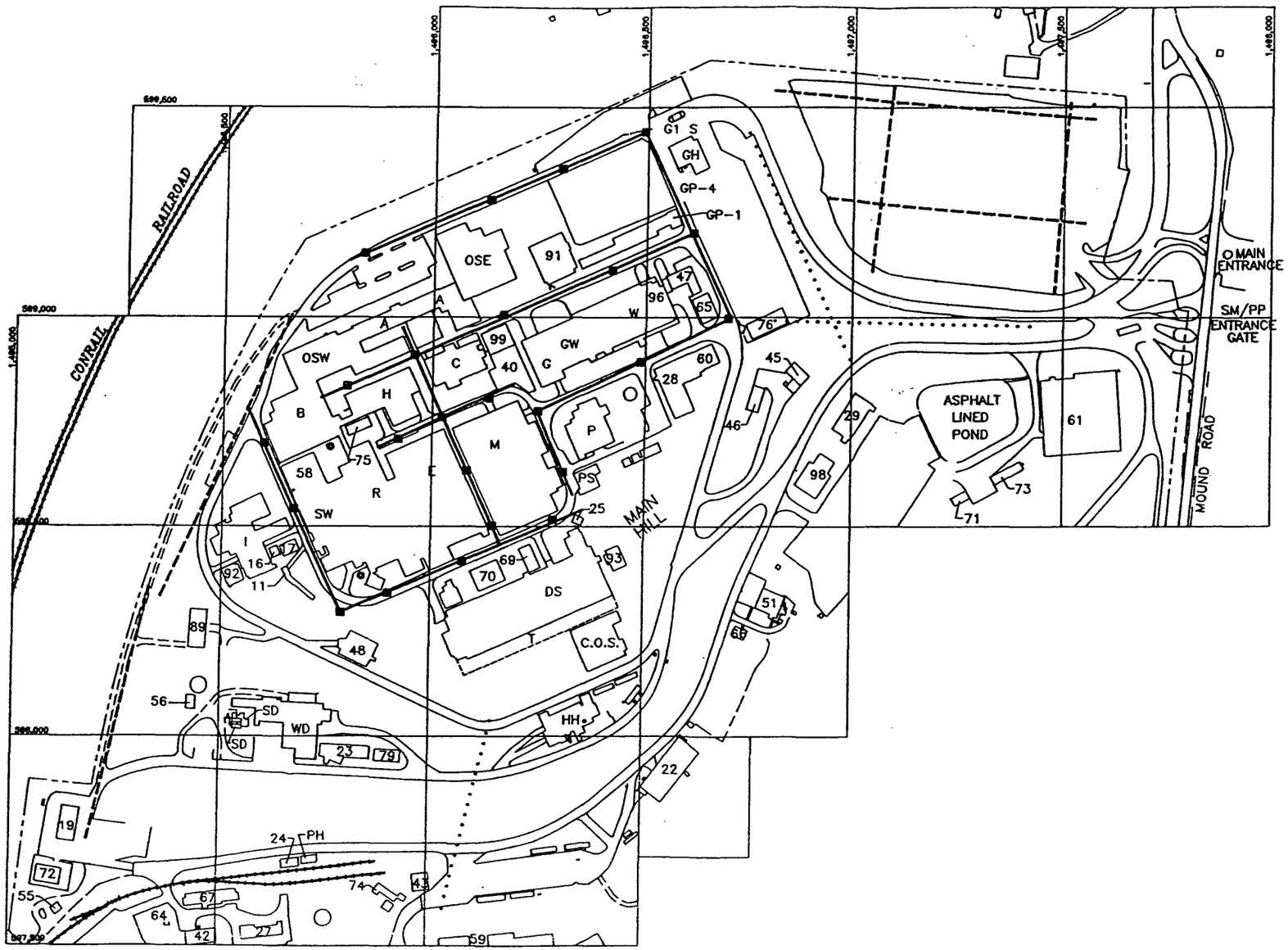
Benson, Richard., Robert A. Claccum and Michael R. Noel, 1983, Geophysical Techniques for Sensing Buried Wastes and Waste Migration, Technos, Inc., Miami FL, Contract No. 68-03-3050, US EPA Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Bowders, J.J., Jr., R.M. Koerner and A.E. Lord, Jr., 1982, Buried Container Detection Using Ground Penetrating Radar, Journal of Hazardous Materials, 7, 1-17.

Costello, Robert L., 1980, Identification and Description Geophysical Techniques, Report No. DRXTH-TE-CR-80084, US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD; Defense Technical Information System Number ADA 123939.

Geophysical Survey Systems, Inc., 1980, Instrument Literature for the SIR-8-System.

OYO Corporation, 1987, Operation Manual, Model 2441 Georadar-I.



N

0 75 150 300
Scale in Feet

NOTES:

1. THE ELECTRONIC BASE MAP DATA FILE WAS OBTAINED BY ICK KAISER ENGINEERS, CINCINNATI, OHIO, FROM ROY F. WESTON, INC., ALBUQUERQUE, NEW MEXICO, WHO OBTAINED IT FROM WOOLPERT CONSULTANTS, INC., DAYTON, OHIO. THE DATA WERE PHOTOGRAMMETRICALLY COMPILED FROM AERIAL PHOTOGRAPHY DATED 12/08/85.

2. WESTON CONVERTED MOUND PLANT COORDINATES TO OHIO STATE PLANE COORDINATES USING AN ALGORITHM PROVIDED BY OAK RIDGE NATIONAL LABORATORY, GRAND JUNCTION PROJECT OFFICE.

3. LOCATION OF PROPOSED TRANSECT AND POTENTIAL TRANSECTS DEPENDING UPON SITE CONDITIONS WERE DIGITIZED FROM RI/FS OU-9 WORK PLAN, MAY 1992, FIG. 6.28.

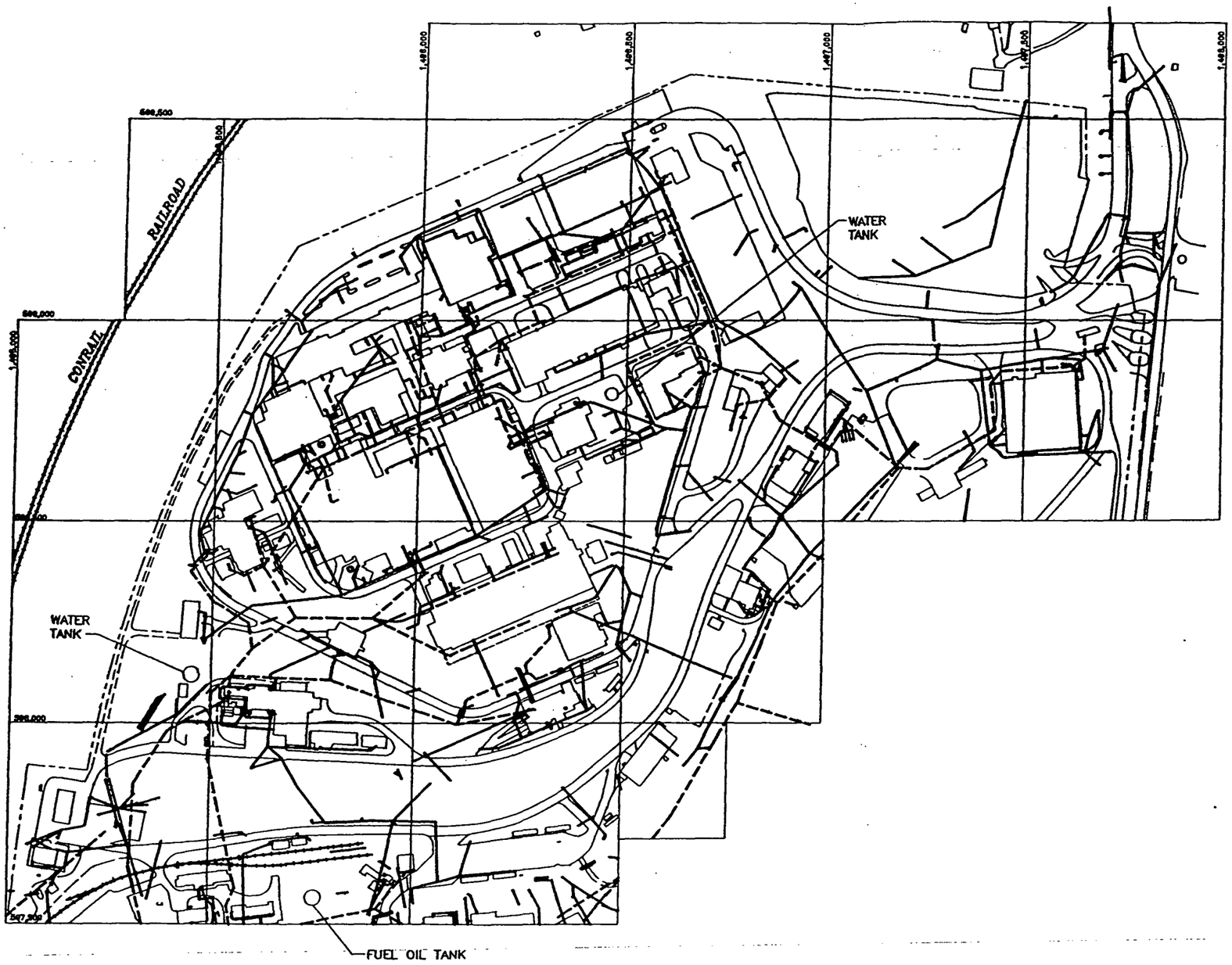
LEGEND:

- 53 STRUCTURES
- PAVED ROADWAY
- UNPAVED ROADWAY
- RAILROAD
- MOUND PLANT BOUNDARY
- SMOKESTACK
- STORAGE TANK
- OU-9 POTENTIAL REFRACTION LINES DEPENDING UPON SITE CONDITIONS
- OU-9 PROPOSED REFRACTION LINES
- OU-2 PROPOSED SEISMIC REFRACTION AND GPR LINES
- OU-2 PROPOSED CONE PENETROMETER LOCATIONS (APPROXIMATE)

Figure 3.2.

Location of Seismic Refraction and GPR Traverses and Cone Penetrometer Data Collection Points

SEISMIC



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0 75 150 300
Scale in Feet

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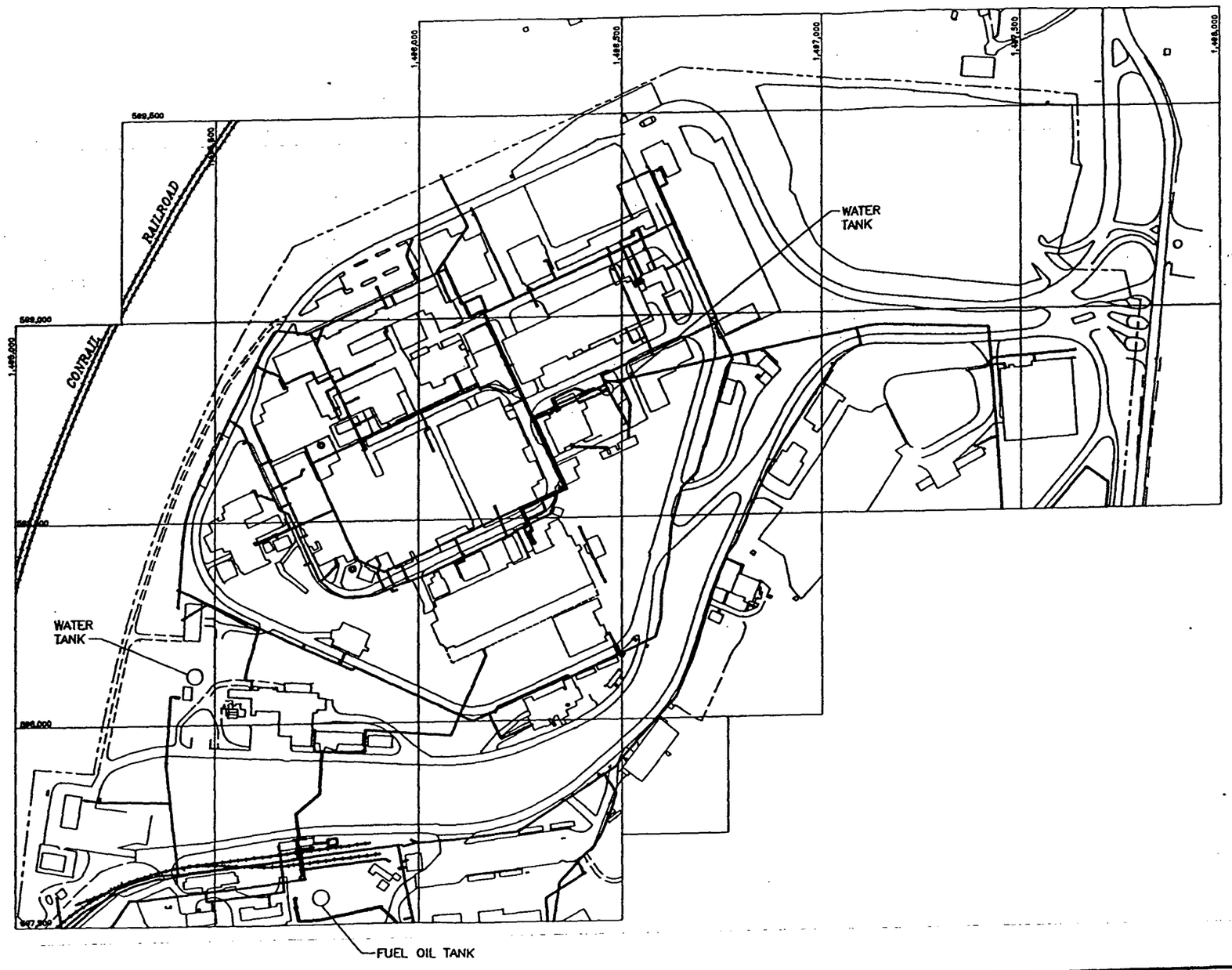
2. WESTON CONVERTED MOUND PLANT COORDINATES TO OHIO STATE PLANE COORDINATES USING AN ALGORITHM PROVIDED BY OAK RIDGE NATIONAL LABORATORY, GRAND JUNCTION PROJECT OFFICE.

LEGEND:

- 53 STRUCTURES
- PAVED ROADWAY
- UNPAVED ROADWAY
- RAILROAD
- MOUND PLANT BOUNDARY
- SMOKESTACK
- STORAGE TANK
- STORM SEWER
- SANITARY SEWER

Figure 4.1. Sanitary and Storm Sewers



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0 75 150 300
Scale in Feet

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LEGEND:

- 53 STRUCTURES
- PAVED ROADWAY
- UNPAVED ROADWAY
- RAILROAD
- MOUND PLANT BOUNDARY
- SMOKESTACK
- STORAGE TANK
- PRESSURIZED WATER LINES

Figure 4.2. Surface Tanks and Pressurized Lines

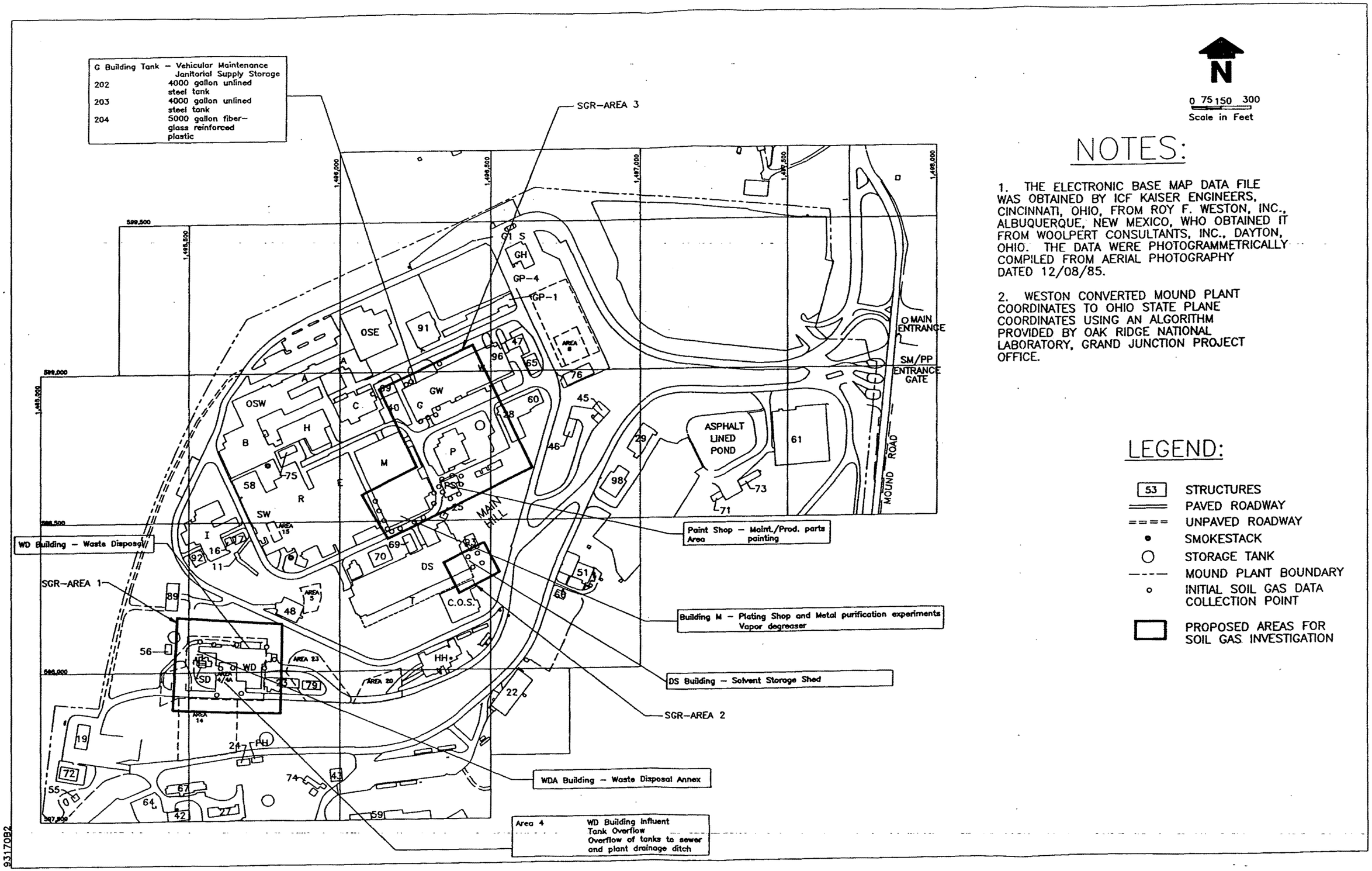


Figure 5.1. Locations of Areas for Soil Gas Reconnaissance

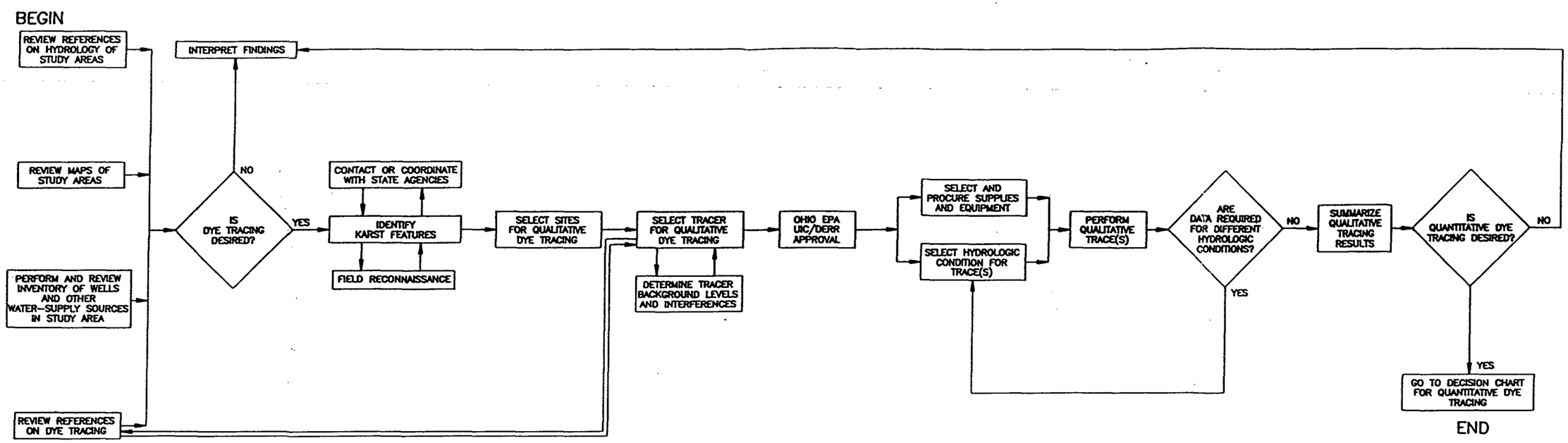
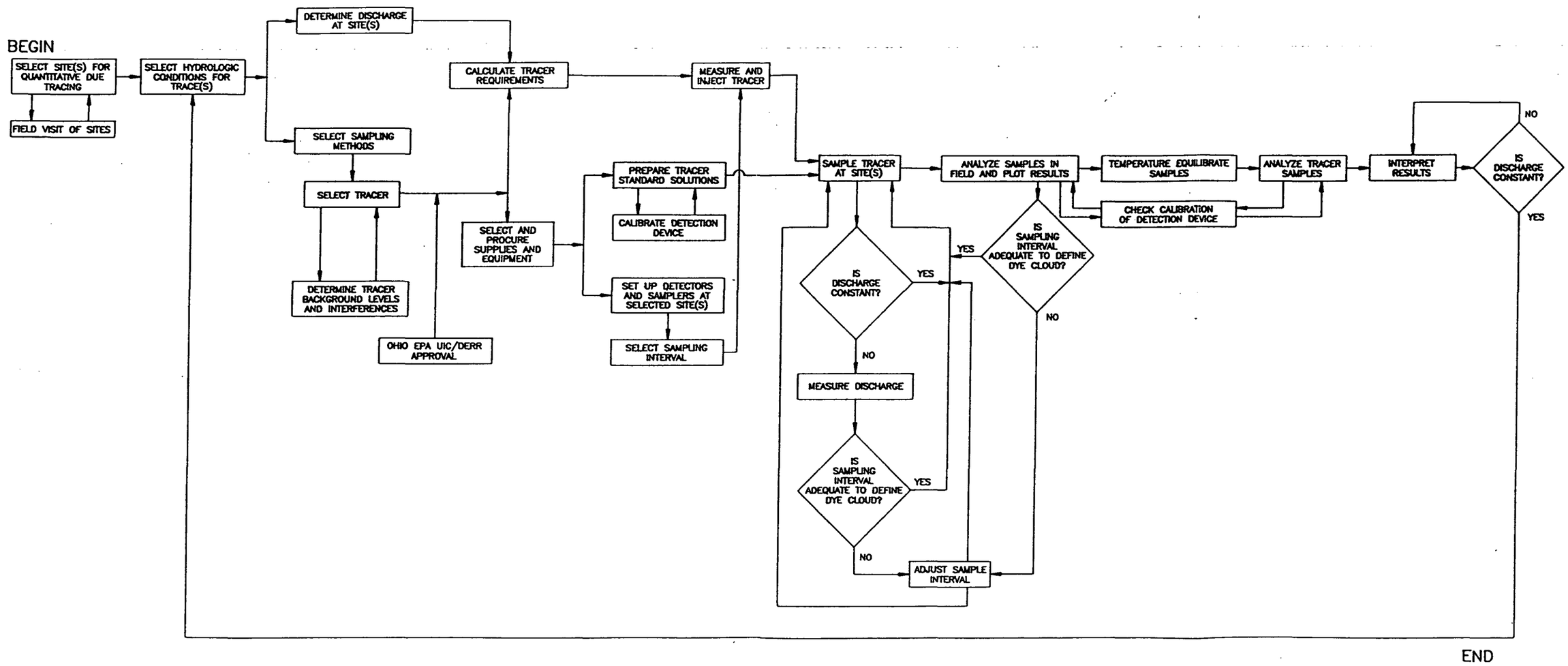


Figure 6.2. Decision Charts for Qualitative Dye Tracing

DYE-2



DYE-1

Figure 6.3. Decision Charts for Quantitative Dye Tracing

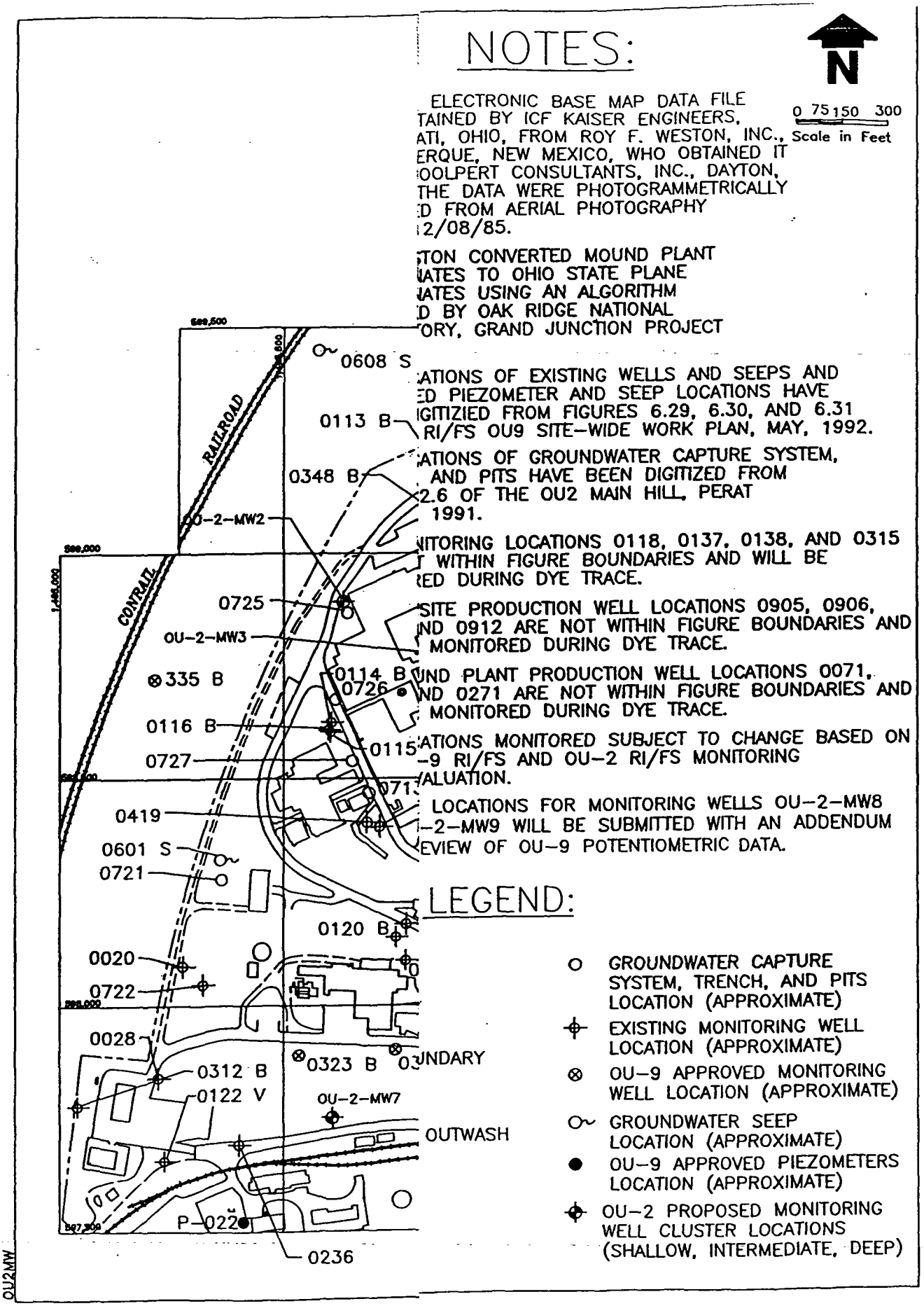
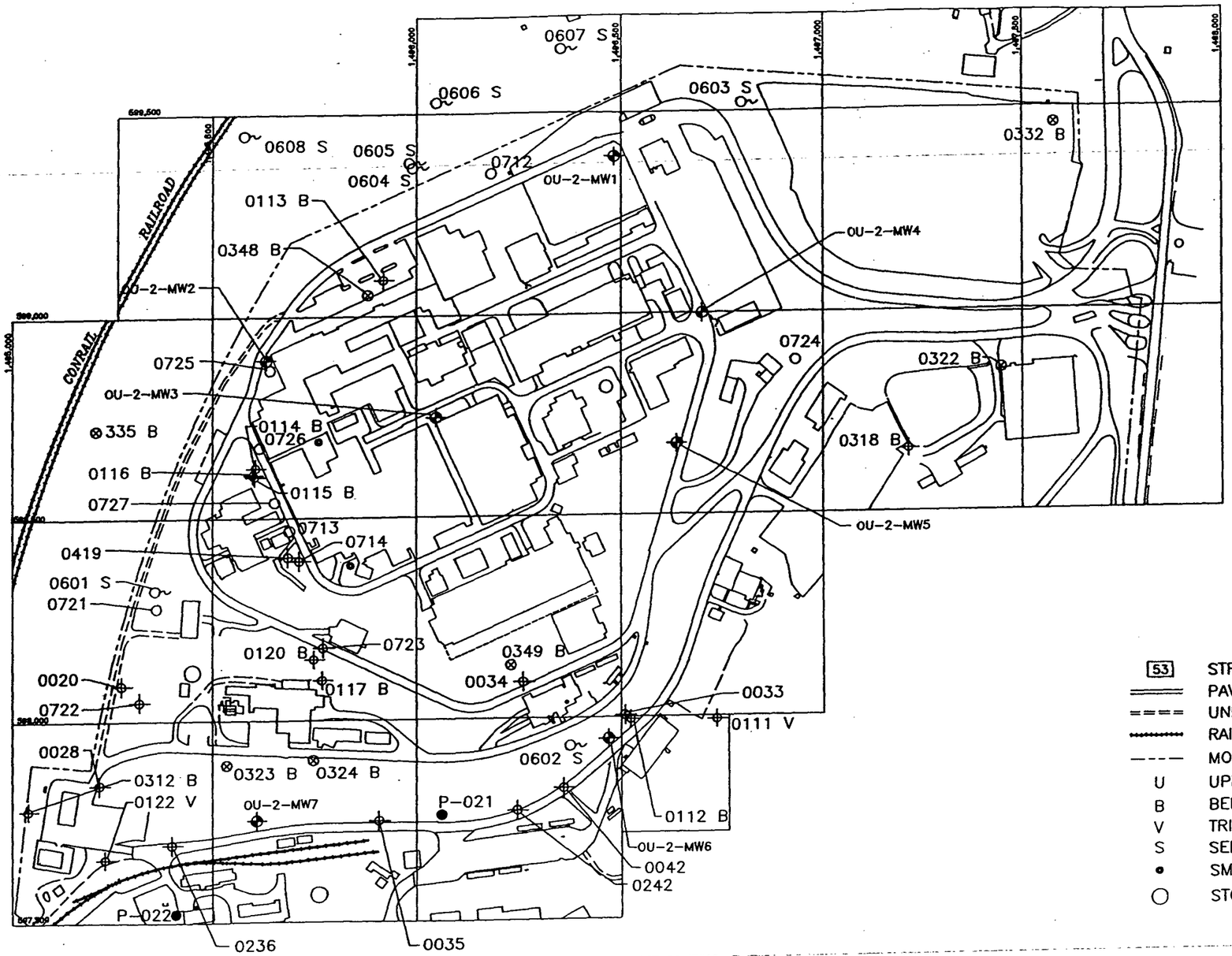


Figure 6.4. Dye Tracing Sampling Locations



NOTES:

N

0 75 150 300
Scale in Feet

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2. WESTON CONVERTED MOUND PLANT COORDINATES TO OHIO STATE PLANE COORDINATES USING AN ALGORITHM PROVIDED BY OAK RIDGE NATIONAL LABORATORY, GRAND JUNCTION PROJECT OFFICE.

3. LOCATIONS OF EXISTING WELLS AND SEEPS AND APPROVED PIEZOMETER AND SEEP LOCATIONS HAVE BEEN DIGITIZIED FROM FIGURES 6.29, 6.30, AND 6.31 OF THE RI/FS OU9 SITE-WIDE WORK PLAN, MAY, 1992.

4. LOCATIONS OF GROUNDWATER CAPTURE SYSTEM, TRENCH, AND PITS HAVE BEEN DIGITIZED FROM FIGURE 2.6 OF THE OU2 MAIN HILL, PERAT AUGUST, 1991.

5. MONITORING LOCATIONS 0118, 0137, 0138, AND 0315 ARE NOT WITHIN FIGURE BOUNDARIES AND WILL BE MONITORED DURING DYE TRACE.

6. OFFSITE PRODUCTION WELL LOCATIONS 0905, 0906, 0907, AND 0912 ARE NOT WITHIN FIGURE BOUNDARIES AND WILL BE MONITORED DURING DYE TRACE.

7. MOUND PLANT PRODUCTION WELL LOCATIONS 0071, 0076, AND 0271 ARE NOT WITHIN FIGURE BOUNDARIES AND WILL BE MONITORED DURING DYE TRACE.

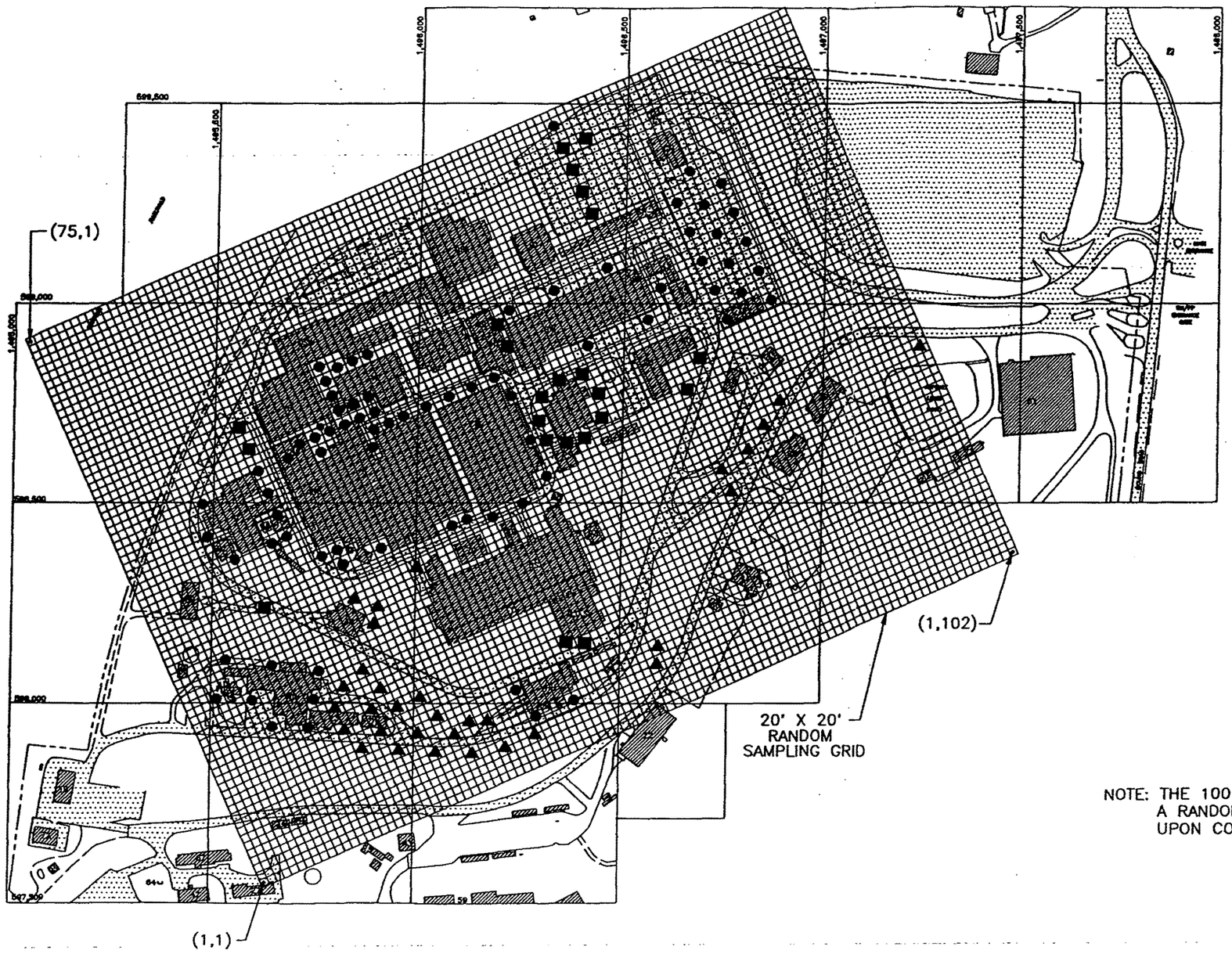
8. LOCATIONS MONITORED SUBJECT TO CHANGE BASED ON THE OU-9 RI/FS AND OU-2 RI/FS MONITORING WELL EVALUATION.

9. THE LOCATIONS FOR MONITORING WELLS OU-2-MW8 AND OU-2-MW9 WILL BE SUBMITTED WITH AN ADDENDUM UPON REVIEW OF OU-9 POTENTIOMETRIC DATA.

LEGEND:

- [53] STRUCTURES
- PAVED ROADWAY
- UNPAVED ROADWAY
- RAILROAD
- MOUND PLANT BOUNDARY
- U UPPER OUTWASH
- B BEDROCK
- V TRIBUTARY VALLEY OUTWASH
- S SEEP SAMPLE
- SMOKESTACK
- STORAGE TANK
- GROUNDWATER CAPTURE SYSTEM, TRENCH, AND PITS LOCATION (APPROXIMATE)
- EXISTING MONITORING WELL LOCATION (APPROXIMATE)
- OU-9 APPROVED MONITORING WELL LOCATION (APPROXIMATE)
- GROUNDWATER SEEP LOCATION (APPROXIMATE)
- OU-9 APPROVED PIEZOMETERS LOCATION (APPROXIMATE)
- OU-2 PROPOSED MONITORING WELL CLUSTER LOCATIONS (SHALLOW, INTERMEDIATE, DEEP)

Figure 8.1. Location of Existing and Proposed Monitoring Wells



N

0 75 150 300
Scale in Feet

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2. WESTON CONVERTED MOUND PLANT COORDINATES TO OHIO STATE PLANE COORDINATES USING AN ALGORITHM PROVIDED BY OAK RIDGE NATIONAL LABORATORY, GRAND JUNCTION PROJECT OFFICE.

LEGEND:

- [53] STRUCTURES
- PAVED ROADWAY
- UNPAVED ROADWAY
- MOUND PLANT BOUNDARY
- SMOKESTACK
- STORAGE TANK
- DIRECT RADIOLOGICAL, INORGANIC AND ORGANIC PARAMETERS
- DIRECT ORGANIC PARAMETERS
- DIRECT RADIOLOGICAL PARAMETERS
- (75,1) (ROW 75, COLUMN 1)

NOTE: THE 100 RANDOM SAMPLES WILL BE SELECTED WITH THE AID OF A RANDOM NUMBER TABLE FROM THE 75 ROWS AND 102 COLUMNS UPON COMPLETION OF THE PHASE 1 ACTIVITIES.

93170B1

Figure 10.1 Proposed Initial Soil Boring Locations