R-49-6-91-19

FINAL
REMEDIAL INVESTIGATION QUALITY ASSURANCE PLAN

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN) PROGRAM

NAVAL WEAPONS INDUSTRIAL RESERVE PLANT BETHPAGE, NEW YORK

NORTHERN AND CHESAPEAKE DIVISIONS

CONTRACT N62472-90-D-1298, CTO 003

AUGUST 1991

HALLIBURTON NUS
Environmental Corporation

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Environmental Corporation

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NORTHERN AND CHESAPEAKE DIVISIONS

Submitted To:
Northern Division
Environmental Branch, Code 1423/FK
Naval Facilities Engineering Command
Building 77-L, U. S. Naval Base
Philadelphia, PA 19112-5094

Submitted By:
HALLIBURTON NUS Environmental Corporation
Park West Two - 2100 Cliff Mine Road
Pittsburgh, PA 15275-1071

Contract No. N62472-90-D-1298, CTO 003

AUGUST 1991

SUBMITTED BY:

David D. Brayack

DAVID D. BRAYACK, P.E.
PROJECT MANAGER

APPROVED FOR SUBMITTAL BY:

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PROGRAM MANAGER

technologies and services for a cleaner and safer world

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1.0 PROJECT DESCRIPTION

As requested by the U. S. Navy, HALLIBURTON NUS has prepared this Quality Assurance Project Plan (QAPP) for a Remedial Investigation/Feasibility Study (RI/FS) at the Naval Weapons Industrial Reserve Plant (NWIRP) facility, located in Bethpage, New York.

HALLIBURTON NUS has established quality assurance/quality control (QA/QC) measures and a program to ensure that these measures are applied to the collection and interpretation of all environmental quality data at the NWIRP facility. The QAPP is designed to assure that the precision, accuracy, representativeness, comparability, and completeness (the PARCC parameters) of the data are known, documented, and adequate to satisfy the data quality objectives of the study.

This plan represents the policies, organization, objectives, data-collection activities, and QA/QC activities that will be utilized to ensure that all data collected during, and reported by, this study are representative of existing conditions. Chemical analyses will be conducted by a laboratory subcontractor. The laboratory will have prior NEESA approval. QA/QC procedures for the chemical analyses will conform to or exceed the requirements of the NYSDEC Analytical Services Protocols (ASP) and will satisfy NEESA requirements for Level D QC. The Site and Data Management Plan outlines the procedures that will be followed for the inventory, control, storage, and retrieval of data collected during the performance of the RI/FS.

2.0 RI/FS SCOPE OF WORK

The Remedial Investigation (RI) will be performed to obtain representative hydrogeologic and environmental quality data capable of clearly defining conditions at the NWIRP facility. These data will be used to evaluate the nature and extent of potential contamination, and the risks associated with this contamination. Details of the RI, such as the approach, selection of drilling locations, and sample collection activities, are found in Section 4.0 of the Work Plan. Descriptions of physical features and site use history can be found in Section 2.0 of the Work Plan.

3.0 SAMPLE MATRICES, PARAMETERS, AND FREQUENCY COLLECTION

As part of the RI, environmental quality samples will be collected from the following matrices: soil, bottom sediment, solid waste, groundwater, and recharge basin water. A listing of the sample matrices, parameters, and frequency of collection is found in Table 3-1. Sampling protocols to be used in this study are provided in Section 6.0 of this QAPP. As required by NEESA, a sampling rationale is included in Section 3.0 and Section 4.0 of the Work Plan. All samples submitted for laboratory analysis (except for deep soil samples) will be analyzed for TCL volatiles, TCL base-neutral acid extractables, TAL metals and cyanide. Additional parameters are summarized in Table 3-1.

4.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

HALLIBURTON NUS will be responsible for the overall management of the project, including the field inspection and conduct of all drilling and sampling activities. The identification and qualifications of primary HALLIBURTON NUS personnel are presented in Section 5.1 of the Work Plan. Personnel from Navy will be actively involved in the investigation and will coordinate with personnel from HALLIBURTON NUS in a number of areas. In particular, Navy personnel will offer input regarding the coordination and implementation of the citizen participation plan.

4.1 Project Organization

The key firms and personnel involved in the RI/FS, as well as the chain-of-communication and responsibility of the project personnel, are as follows.

Northern Division
Naval Facilities Engineering Command
U. S. Naval Base, Building 77L
Philadelphia, Pennsylvania 19112
(215) 597-6280

Frank Klanchar (Code 1423)
Remedial Project Manager

HALLIBURTON NUS Environmental Corporation
Park West Two
2100 Cliff Mine Road
Pittsburgh, Pennsylvania 15275
(412) 788-1080

Art Bomberger
Program Manager

TABLE 3-1
FIELD AND QA/QC SAMPLES REMEDIAL INVESTIGATION

NWIRP
BETHPAGE, NEW YORK

Number of Samples	Number of Duplicates(a)	Number of Field Blanks(b)	Number of MS/MSD/LD(c)	Number of Rinsate Blanks(d)	Number of Trip Blanks(e)	Total Number of Samples	Analysis	Analytical Method
MATRIX - SOIL								
75	8	2	4	4	8	101	TCL Volatiles	CLP SOW
53	6	2	4	4	-	69	TCL BNA	CLP SOW
53	6	2	4	4	-	69	TAL metals	CLP SOW
53	6	2	4	4	-	69	Cyanide	CLP SOW
10	1	1	1	4	-	17	TCL Pesticides/PCBs	CLP SOW
6	1	0	0	0	-	7	pH	SW846-9045
6	1	0	0	0	-	7	TOC	MSA 29.3.5.2
6	1	0	0	0	-	7	Bulk density	MS CH.13
6	1	0	0	0	-	7	Grain size	ASTM-D422-63
6	1	0	0	0	-	7	Water leachate	ASTM-D2216-80
MATRIX - GROUNDWATER								
24	5	1	2	3	5	40	TCL Volatiles	CLP SOW
24	5	1	2	3	-	35	TCL BNA	CLP SOW
24	5	1	2	3	-	35	TAL metals - total	CLP SOW
24	5	1	2	3	-	35	TAL metals - filtered	CLP SOW
24	5	1	2	3	-	35	Cyanide	CLP SOW
3	1	1	1	1	-	7	Hardness	EPA 130.2
3	1	1	1	1	-	7	Alkalinity	EPA 310.1

TABLE 3-1
FIELD AND QA/QC SAMPLES REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
PAGE 2

Number of Samples	Number of Duplicates[a]	Number of Field Blanks[b]	Number of MS/MSD/LD[c]	Number of Rinsate Blanks[d]	Number of Trip Blanks[e]	Total Number of Samples	Analysis	Analytical Method
MATRIX - GROUNDWATER (Continued)								
3	1	1	0	1	-	6	TOC	EPA 415.1
3	1	0	0	0	-	4	TDS	EPA 160.1
3	1	0	0	0	-	4	TSS	EPA 160.2
3	1	1	0	1	-	6	BOD_5	EPA 405.1
3	1	1	0	1	-	6	COD	EPA 410.2
3	1	1	0	0	-	5	pH	
24	5	1	2	3	-	35	Hexavalent chromium	EPA 218.4
MATRIX - SEDIMENT								
6	1	1	1	1	-	10	TCL volatiles	CLP SOW
6	1	1	1	1	-	10	TCL BNA	CLP SOW
6	1	1	1	1	-	10	TAL metals	CLP SOW
6	1	1	1	1	-	10	Cyanide	CLP SOW
MATRIX - SURFACE WATER								
2	1	0	1	1	1	6	TCL volatiles	CLP SOW
2	1	0	1	1	-	5	TCL BNA	CLP SOW
2	1	0	1	1	-	5	TAL metals - total	CLP SOW
2	1	0	1	.	-	5	TAL metals-filtered	CLP SOW
2	1	0	1	1	-	5	Cyanide	CLP SOW
2	1	0	1	1	-	5	Hexavalent chromium	EPA 218.4

TABLE 3-1
FIELD AND QA/QC SAMPLES REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
PAGE 3

Number of Samples	Number of Duplicates[a]	Number of Field Blanks[b]	Number of MS/MSD/LD[c]	Number of Rinsate Blanks[d]	Number of Trip Blanks[e]	Total Number of Samples	Analysis	Analytical Method
MATRIX - SOLID WASTE								
1	1	1	1	1	-	5	TCL volatiles	CLP SOW
1	1	1	1	1	-	5	TCL BNA	CLP SOW
1	1	1	1	1	-	5	TAL metals	CLP SOW
1	1	1	1	1	-	5	TCL Pesticides/PCBs	CLP SOW
1	1	-	-	-	-	2	pH	SW846-9045
1	1	-	-	-	-	2	TOC	MSA 29.3.5.2
1	1	-	-	-	-	2	Bulk density	MSA CH.13
1	1	1	1	1	-	5	Cyanide	CLP SOW
1	1	-	-	-	-	2	Grain size	ASTM D422-63
1	1	-	-	-	-	2	Moisture content	ASTM D2216-80
1	1	1	1	1		5	Hexavalent chromium	EPA 218.4

(a) - 10%
(b) - 1/source/event; all analyses
(c) - According to CLP Users' Guide, no extra volume needed for lab duplicates. According to CLP U.G., need triple the sample volume for at least 1/20 per matrix for MS, MSD and reanalyses 1/20
(d) - 1/day, metals and organics, samples analyzed every other day
(e) - 1/cooler

EPA Methods from 40 CFR 136

David Brayack
Project Manager

Patricia Armstrong
Quality Assurance/Quality Control

Kevin Kilmartin
Field Operations Leader

Alan Margraf
Health and Safety

The Project Manager has the primary responsibility for project and technical management of this project. He is responsible for the coordination of all onsite personnel, and for providing technical assistance for all activities that are directly related to the determination of the hydrogeologic conditions and the environmental quality of the site. The review of all environmental and hydrogeologic data will be conducted by the project manager. If quality assurance problems or deficiencies requiring special action are identified, the project manager and project QA/QC advisor will identify the appropriate corrective action.

4.2 Field Organization

The HALLIBURTON NUS field investigation team will be organization according to the activity planned. For onsite sampling, the sampling team members will be selected based upon the type and extent of effort required. The team will consist of a combination of the following personnel:

- Field Operations Leader (FOL)
- Field hydrogeologist/geologist
- Quality assurance/quality control advisor
- Site health and safety specialist

The FOL will responsible for the coordination of all onsite personnel and for providing technical assistance when required. The FOL, or his or her designee will coordinate and be present during all all sampling activities and will assure the availability and maintenance of all sampling materials/equipment. The FOL will be responsible for the completion of all sampling, well construction, and chain-of-custody documentation, and will assume custody of all samples and ensure the proper handling and shipping of samples.

The FOL will also be responsible for providing technical supervision of the drilling subcontractor and for maintaining a geologic log of all borings drilled. Copies of the forms to be used in this investigation are provided as Appendix A.

The QA/QC advisor will be responsible for the adherence of all QA/QC guidelines as defined in this QAPP. Strict adherence to these procedures is critical to the collection of acceptable and representative data.

The site health and safety specialist will be responsible for assuring that all team members adhere to the site health and safety requirements. Additional responsibilities of the site health and safety specialist are as follows:

- Updating equipment or procedures based upon new information gathered during the site operation.

- Modifying the levels of protection based upon site observations.

- Determining and posting locations and routes to medical facilities, including poison control centers, and arranging for emergency transportation to medical facilities.

- Notifying local public emergency officers, including police and fire departments, of the nature or the team's operations and for posting these department's telephone numbers.

- Examining work-party members for symptoms of exposure of stress.

- Providing emergency medical care and first aid as necessary on site. The site health and safety manager also has the responsibility to stop any field operation that threatens the health or safety of the team or the surrounding populace.

4.3 Laboratory Operations

Analyses of all environmental samples will be performed by a NEESA-approved laboratory. The laboratory work will be performed on QC Level D, which requires CLP methods and CLP deliverables. These QA/QC procedures should meet or exceed NYSDEC requirements.

5.0 QUALITY ASSURANCE OBJECTIVES

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide environmental monitoring data of known and acceptable quality. Specific procedures to be used for sampling, chain-of-custody, calibration of field instruments, laboratory analysis, reporting, internal quality control, audits, preventative maintenance, and corrective actions are described in later sections of this QAP. The purpose of this section is to address the data quality objectives in terms of the (PARCC) parameters, quantitation and detection limits, field blanks, trip blanks, rinsate blanks, and bottleware cleanliness.

5.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and/or quantitative statements regarding the quality of data needed to support the RI/FS activities. The sampling rationale provided in the RI Work Plan explains the choice of sample locations and media which will supply information needed for the RI/FS. The use of CLP RAS and SAS analyses listed in Table 3-1 following current CLP SOW protocols is expected to satisfy data quality needs in accordance with NEESA, NYSDEC, and CLP requirements.

5.2 Quantitation Limits

Both aqueous and solid quantitation limits are those required as CRQL for the current CLP SOW with allowances for dilutions and dry weight conversions. These CRQL are presented in Table 5-1.

5.3 Detection Limits

Instrument detection limits (IDL) are reported quarterly under CLP protocol. The quarterly IDLs applicable at the date of analysis will be supplied in each data package. IDLs must be less than or equal to CRQLs.

5.4 PARCC Parameters

The quality of data set is measured by certain characteristics of the data, namely the PARCC parameters. Some of the parameters are expressed quantitatively, while others are expressed qualitatively. The objectives of the RI/FS and the intended use of the data define the PARCC goals.

TABLE 5-1

CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK

A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Volatile Organic Compounds	G, Teflon-lined septum Three 40-mL vials	Cool, 4°C HCl to pH<2	14 days		CLP SOW 2/88
Chloromethane				10	
Bromomethane				10	
Vinyl Chloride				10	
Chloroethane				10	
Methylene Chloride				5	
Acetone				10	
Carbon Dilsulfide				5	
1,1-Dichloroethene				5	
1,1-Dichloroethane				5	
1,2-Dichloroethene (total)				5	
Chloroform				5	
1,2-Dichloroethane				5	
2-Butanone				10	
1,1,1-Trichloroethane				5	
Carbon Tetrachloride				5	
Vinyl Acetate				10	
Bromodichloromethane				5	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Volatile Organic Compounds (Continued)	G, Teflon-lined septum Three 40-mL vials	Cool, 4°C HCl to pH < 2	14 days		CLP SOW 2/88
1,2-Dichloropropane				5	
cis-1,3-Dichloropropane				5	
Trichloroethene				5	
Dibromochloromethane				5	
1,1,2-Trichloroethane				5	
Benzene				5	
trans-1,3-Dichloropropane				5	
Bromoform				5	
4-Methyl-2-pentanone				10	
2-Hexanone				10	
Tetrachloroethene				5	
Toluene				5	
1,1,2,2-Tetrachloroethane				5	
Chlorobenzene				5	
Ethyl Benzene				5	
Styrene				5	
Xylenes (total)				5	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
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A. Groundwater and Recharge Basin Water Samples

Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds	G, Teflon-lined cap two 80–oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
Phenol				10	
bis(2-Chloroethyl)ether				10	
2-Chlorophenol				10	
1,3-Dichlorobenzene				10	
1,4-Dichlorobenzene				10	
Benzyl Alcohol				10	
1,2-Dichlorobenzene				10	
2-Methylphenol				10	
bis(2--Chloroisopropyl)ether				10	
4-Methylphenol				10	
n-Nitroso-di-n-dipropylamine				10	
Hexachloroethane				10	
Nitrobenzene				10	
Isophorone				10	
2-Nitrophenol				10	
2,4-Dimethylphenol				50	
Benzoic Acid				10	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
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BETHPAGE, NEW YORK
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds (Continued)	G, Teflon-lined cap two 80–oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
bis(2-Chloroethoxy)methane				10	
2,4-Dichlorophenol				10	
1,2,4-Trichlorobenzene				10	
Naphthalene				10	
4-Chloroaniline				10	
Hexachlorobutadiene				10	
4-Chloro-3-methylphenol (para-chloro-meta-cresol)				10	
2-Methylnaphthalene				10	
Hexachlorocyclopentadiene				10	
2,4,6-Trichlorophenol				10	
2,4,5-Trichlorophenol				50	
2-Chloronaphthalene				10	
2-Nitroaniline				50	
Dimethylphthalate				10	
Acenaphthylene				10	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds (Continued)	G, Teflon-lined cap two 80–oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
2,6-Dinitrotoluene				10	
3-Nitroaniline				50	
Acenaphthene				10	
2,4-Dinitrophenol				50	
4-Nitrophenol				50	
Dibenzofuran				10	
2,4-Dinitrotoluene				10	
Diethylphthalate				10	
4-Chlorophenyl-phenyl ether				10	
Fluorene				10	
4-Nitroaniline				50	
4,6-Dinitro-2-methylphenol				50	
n-Nitrosodiphenylamine				10	
4-Bromophenyl-phenyl ether				10	
Hexachlorobenzene				10	
Pentachlorophenol				50	
Phenanthrene				10	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds (Continued)	G, Teflon-lined cap two 80–oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
Anthracene				10	
Di-n-butylphthalate				10	
Fluoranthene				10	
Pyrene				10	
Butylbenzylphthalate				10	
3,3'-Dichlorobenzidine				20	
Benzo(a)anthracene				10	
Chyrsene				10	
bis(2-Ethylhexyl)phthalate				10	
Di-n-octylphthalate				10	
Benzo(b)fluoranthene				10	
Benzo(k)fluoranthene				10	
Benzo(a)pyrene				10	
Indeno(1,2,3-cd)pyrene				10	
Dibenz(a,h)anthracene				10	
Benzo(g,h,i)perylene				10	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TAL Metals, Cyanide	P; one 1-liter bottle total, one 1-liter bottle dissolved	HNO_3 to pH<2 Cool, 4°C	180 days from VTSR (except where noted)		CLP SOW 7/88
Aluminum				200	
Antimony				60	
Arsenic				10	
Barium				200	
Beryllium				5	
Cadmium				5	
Calcium				5,000	
Chromium				10	
Cobalt				50	
Copper				25	
Iron				100	
Lead				5	
Magnesium				5,000	
Manganese				15	
Mercury			26 days	0.2	
Nickel				40	
Potassium				5,000	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
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BETHPAGE, NEW YORK
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TAL Metals, Cyanide (Continued)	P; one 1-liter bottle total, one 1-liter bottle dissolved	HNO_3 to pH<2 Cool, 4°C	180 days from VTSR (except where noted)		CLP SOW 7/88
Selenium				5	
Silver				10	
Sodium				5,000	
Thallium				10	
Vanadium				50	
Zinc				20	
Cyanide	P; one 1-liter bottle	NAOH pH>12 0.6 g ascorbic acid Cool 4°C	12 days	10	

A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL ($\mu g/L$)	Methodology
Additional Analytes					
Chromium VI	P, G one 1-liter bottle	Cool 4°C Navy lists HN03 to pH<2 but requirements for this method do not	24 hours	NA	EPA 218.4
Hardness	P; one 1-liter bottle	HNO_3 to pH<2 Cool 4°C	180 days	10 mg/L	EPA 130.2
Alkalinity	P; one 1-liter bottle	Cool 4°C	14 days	1 mg/L	EPA 310.1
Total Organic Carbon	P; one 1-liter bottle	H_2SO_4 to pH<2 Cool 4°C	28 days	5 mg/L	EPA 415.1
Total Dissolved Solids	P; one 1-liter bottle	Cool 4°C	7 days	10 mg/L	EPA 160.1
Total Suspended Solids	P; one 1-liter bottle	Cool 4°C	7 days	4 mg/L	EPA 160.2
Biochemical Oxygen Demand, 5-day	P; one 1-liter bottle	Cool 4°C	48 hours	1 mg/L	EPA 4051.
Chemical Oxygen Demand	P; one 1-liter bottle	H_2SO_4 to pH<2 Cool 4°C	28 days	5 mg/L	EPA 410.2

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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BETHPAGE, NEW YORK
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
<u>TCL Volatile Organic Compounds</u>	G, Teflon-lined septum three 40-mL vials	Cool, 4°C	7 days from VTSR		CLP SOW 2/88
Chloromethane				10	
Bromomethane				10	
Vinyl Chloride				10	
Chloroethane				10	
Methylene Chloride				5	
Acetone				10	
Carbon Dilsulfide				5	
1,1-Dichloroethene				5	
1,1-Dichloroethane				5	
1,2-Dichloroethene (total)				5	
Chloroform				5	
1,2-Dichloroethane				5	
2-Butanone				10	
1,1,1-Trichloroethane				5	
Carbon Tetrachloride				5	
Vinyl Acetate				10	
Bromodichloromethane				5	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
REMEDIAL INVESTIGATION
NWIRP
BETHPAGE, NEW YORK
PAGE ELEVEN

B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
<u>TCL Volatile Organic Compounds Continued</u>	G, Teflon-lined septum three 40-mL vials	Cool, 4°C	7 days from VTSR		CLP SOW 2/88
1,2-Dichloropropane				5	
cis-1,3-Dichloropropane				5	
Trichloroethene				5	
Dibromochloromethane				5	
1,1,2-Trichloroethane				5	
Benzene				5	
trans-1,3-Dichloropropane				5	
Bromoform				5	
4-Methyl-2-pentanone				10	
2-Hexanone				10	
Tetrachloroethene				5	
Toluene				5	
1,1,2,2-Tetrachloroethane				5	
Chlorobenzene				5	
Ethyl Benzene				5	
Styrene				5	
Xylenes (total)				5	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds	G, Teflon-lined cap two 8–oz jars	Cool, 4°C	10 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
Phenol				330	
bis(2-Chloroethyl)ether				330	
2-Chlorophenol				330	
1,3-Dichlorobenzene				330	
1,4-Dichlorobenzene				330	
Benzyl Alcohol				330	
1,2-Dichlorobenzene				330	
2-Methylphenol				330	
bis(2--Chloroisopropyl)ether				330	
4-Methylphenol				330	
n-Nitroso-di-n-dipropylamine				330	
Hexachloroethane				330	
Nitrobenzene				330	
Isophorone				330	
2-Nitrophenol				330	
2,4-Dimethylphenol				330	
Benzoic Acid				1,600	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (μg/L)	Methodology
<u>TCL Semivolatile Compounds (Continued)</u>	G, Teflon-lined cap two 8–oz jars	Cool, 4°C	10 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
bis(2-Chloroethoxy)methane				330	
2,4-Dichlorophenol				330	
1,2,4-Trichlorobenzene				330	
Naphthalene				330	
4-Chloroaniline				330	
Hexachlorobutadiene				330	
4-Chloro-3-methylphenol (para-chloro-meta-cresol)				330	
2-Methylnaphthalene				330	
Hexachlorocyclopentadiene				330	
2,4,6-Trichlorophenol				330	
2,4,5-Trichlorophenol				1,600	
2-Chloronaphthalene				330	
2-Nitroaniline				330	
Dimethylphthalate				330	
Acenaphthylene				330	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Semivolatile Compounds (Continued)	G, Teflon-lined cap two 8–oz jars	Cool, 4°C	10 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
2,6-Dinitrotoluene				330	
3-Nitroaniline				1,600	
Acenaphthene				330	
2,4-Dinitrophenol				1,600	
4-Nitrophenol				1,600	
Dibenzofuran				330	
2,4-Dinitrotoluene				330	
Diethylphthalate				330	
4-Chlorophenyl-phenyl ether				330	
Fluorene				330	
4-Nitroaniline				1,600	
4,6-Dinitro-2-methylphenol				1,600	
n-Nitrosodiphenylamine				330	
4-Bromophenyl-phenyl ether				330	
Hexachlorobenzene				330	
Pentachlorophenol				1,600	
Phenanthrene				330	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
<u>TCL Semivolatile Compounds (Continued)</u>	G, Teflon-lined cap two 8-oz jars	Cool, 4°C	10 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
Anthracene				330	
Di-n-butylphthalate				330	
Fluoranthene				330	
Pyrene				330	
Butylbenzylphthalate				330	
3,3'-Dichlorobenzidine				660	
Benzo(a)anthracene				330	
Chyrsene				330	
bis(2-Ethylhexyl)phthalate				330	
Di-n-octylphthalate				330	
Benzo(b)fluoranthene				330	
Benzo(k)fluoranthene				330	
Benzo(a)pyrene				330	
Indeno(1,2,3-cd)pyrene				330	
Dibenz(a,h)anthracene				330	
Benzo(g,h,i)perylene				330	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (μg/L)	Methodology
TCL Inorganics	G; one 8–oz glass jar	Cool, 4°C	180 days from VTSR (except where noted)		CLP SOW 7/88
Aluminum				NA	
Antimony				NA	
Arsenic				NA	
Barium				NA	
Beryllium				NA	
Cadmium				NA	
Calcium				NA	
Chromium				NA	
Cobalt				NA	
Copper				NA	
Iron				NA	
Lead				NA	
Magnesium				NA	
Manganese				NA	
Mercury			26 days	NA	
Nickel				NA	
Potassium				NA	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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B. Soils, Solid Waste, Bottom-Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Inorganics (Continued)	G; one 8–oz glass jar	Cool, 4°C	180 days from VTSR (except where noted)		CLP SOW 7/88
Selenium				NA	
Silver				NA	
Sodium				NA	
Thallium				NA	
Vanadium				NA	
Zinc				NA	
Cyanide			12 days from VTSR	NA	
pH (except sediment)	G; one 8 oz jar	Cool 4°C	14 days		SW 846-9045
Total Organic Carbon (except sediment)		Cool 4°C	28 days	10 mg/kg	MSA 29.3.5.2
Bulk Density (except sediment)	G; one 32 oz jar	None	None		MSA Ch.13
Grain Size (except sediment)	G; one 32 oz jar	None	None	-	ASTM D422-63
Moisture Content (except sediment)	G; one 32 oz jar	None	None	-	ASTM D2216-80

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL µg/L)	Methodology
<u>TCL Pesticides/PCBs</u>	G, Teflon-lined cap two 80- oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
alpha-BBC				0.05	
beta-BHC				0.05	
delta-BHC				0.05	
gamma-BHC (lindane)				0.05	
Heptachlor				0.05	
Aldrin				0.05	
Heptachlor Epoxide				0.05	
Endosulfan I				0.05	
Dieldrin				0.10	
4,4'-DDE				0.10	
Endrin				0.10	
Endosulfan II				0.10	
4,4'-DDD				0.10	
Endosulfan Sulfate				0.10	
4,4'-DDT				0.10	
Methoxychlor				0.5	
Endrin Ketone				0.10	

TABLE 5-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
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A. Groundwater and Recharge Basin Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL µg/L)	Methodology
TCL Pesticides/PCBs Continued	G, Teflon-lined cap two 80- oz. amber jugs	Cool, 4°C	5 days from VTSR until extraction, 40 days after extraction		CLP SOW 2/88
alpha-Chlordane				0.5	
gamma-Chlordane				0.5	
Toxaphene				1.0	
Aroclor-1016				0.5	
Aroclor-1221				0.5	
Aroclor-1232				0.5	
Aroclor-1242				0.5	
Aroclor-1248				0.5	
Aroclor-1254				1.0	
Aroclor-1260				1.0	

5.4.1 Precision

Precision characterizes the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for a sample under the same or similar conditions. Precision is expressed as a range (the difference between two measurements of the same parameter) or as a relative percent difference (the range relative to the mean, expressed as a percent). Range and Relative Percent Difference (RPD) values are calculated as follows:

$$\text{Range} = \text{OR} - \text{DR}$$

$$\text{RPD} = \frac{[\text{OR} - \text{DR}]}{1/2\,(\text{OR} + \text{DR})} \times 100\%$$

where: OR = original sample result

DR = duplicate sample result

The internal laboratory control limits for precision are three times the standard deviation of a series of RPD or range values. RPD values may be calculated for both laboratory and field duplicates, and can be compared to the control limits as a QA check. Laboratory duplicates will be analyzed at the rate required by the CLP. Field duplicates will be collected for 10 percent of all samples collected.

5.4.2 Accuracy

Accuracy is the comparison between experimental and known or calculated values expressed as a percent recovery (%R). Percent recoveries are derived from analysis of standards spiked into deionized water (standard recovery) or into actual samples (matrix spike or surrogate spike recovery). Recovery is calculated as follows:

$$\%R = \frac{E}{T} \times 100\%$$

where: E = experimental result

T = true value (theoretical result)

and

$$T = \frac{(\text{sample aliq.})(\text{sample conc.}) + (\text{spike aliq.})(\text{spike conc.})}{\text{sample aliq.} + \text{spike aliq.}}$$

Control limits for accuracy are set at the mean plus or minus three times the standard deviation of a series or %R values. Organic %R values are set at the mean plus or minus two times the standard deviation.

Accuracy for aqueous and solid samples will be evaluated by use of surrogate and matrix spikes at the CLP-required incidences. CLP acceptance criteria and corrective actions apply. Out-of-criteria results will be reviewed for data applicability as a part of data validation.

5.4.3 Representativeness

All data obtained should be representative of actual conditions at the sampling location. The Work Plan is designed so that the samples taken will present an accurate representation of actual site conditions. The rationales discussed in the Work Plan and QAP are designed to ensure this. All sampling activities will conform to the protocols given in Section 6.0 of this QAP. The use of CLP analytical protocols and data deliverables will ensure that analytical results and deliverables are representative, and both consistently performed and reported.

5.4.4 Comparability

Comparability will be achieved by utilizing standardized sampling and analysis methods and data reporting format. Both analytical procedures and sample collection techniques will maximize the comparability of this new data to previous data. Additionally, consideration will be given to seasonal conditions and other environmental conditions that could influence analytical results.

5.4.5 Completeness

Completeness is a measure of the amount of valid data obtained from the measurement program, compared to the total amount collected. For relatively clean, homogeneous matrices, 100-percent completeness is expected. However, as matrix complexity and heterogenicity increase, completeness may decrease. Where analysis is precluded or where DQOs are compromised, effects on the overall investigation must be considered. Whether any particular sample is critical to the investigation will be evaluated in terms of the sample location, the parameter in question, the intended data use, and the risk associated with the error.

Critical data points may not be evaluated until all the analytical results are evaluated. If in the evaluation of results it becomes apparent that the data for a specific medium are of insufficient quality (95 percent), either with respect to the number of samples or an individual analysis, resampling of the deficient data points may be necessary.

5.5 Field Blanks

To determine whether cross-contamination of samples has occurred, field blanks will be obtained. Field blanks will be taken at the rate of one per source per sampling event, and will be analyzed for TCL VOCs, BNA, PCBs, pesticides, and TAL metals, in accordance with NEESA guidelines.

5.6 Trip Blanks

To determine whether contamination of samples or bottleware has occurred in the field, trip blanks will be used. Trip blanks consist of analyte-free water taken from the laboratory to the site, and returned. Trip blanks are taken at the rate of one per cooler of organics and will be analyzed for TCL VOAs only.

5.7 Rinsate Blanks

An equipment rinsate blank consists of the final analyte-free water rinse from equipment cleaning. Rinsate blanks are collected daily during the sampling event, and the results from every other day are analyzed for inorganic and organic contaminants. If potential contamination is observed, the remaining rinsate blanks are also analyzed.

5.8 Bottleware

NEESA requires specific bottleware cleaning procedures. If precleaned bottles are used, this must be stared in the QA Plan. Precleaned bottles will be used at the NWIRP Bethpage site; the required certification will be provided.

6.0 SAMPLING PROCEDURES

6.1 Site Background

The site background information is provided in Section 1.0 of the RI Work Plan.

6.2 Sampling Objectives

The overall objective of the RI will be to characterize the nature and extent of potential environmental contamination and associated risks to human health and the environment at the NWIRP. The data collected will also be used to evaluate potential remedial options. The specific objectives for the Bethpage plant are to identify the location and concentration of potential soil and groundwater contamination by solvents and metals at three sites identified in the Initial Assessment Study (IAS) (RGH 1986) and to determine whether these sites are the source of a trichloroethene (TCE) contaminated groundwater plume in the Bethpage area. The NWIRP, the Grumman Aerospace Corporation (Grumman), and the RUCO Polymer Corporation (RUCO) are potential sources of this contamination.

An Initial Assessment Study of NWIRP Bethpage, New York and NWIRP Calverton, New York conducted in 1986 (RGH 1986) indicated that three areas at the Bethpage Plant may pose a threat to human health or the environment. These three sites are Site 1 - Former Drum Marshaling Area (identified as Site 7 in the Initial Assessment Study, or IAS), Site 2 - Recharge Basin Area (identified as Site 8 in the IAS), and Site 3 -Salvage Storage Area (identified as Site 9 in the IAS). (These sites were renumbered to avoid confusion with the Site designations at the Calverton Plant.)

6.3 Sample Location and Frequency

Soils, sediments, surface water, groundwater, and a waste sample will be collected during the field activities. These samples will be analyzed in accordance with CLP methodology for volatile organics, semivolatile organics, PCBs, pesticides, metals, cyanide, and other engineering parameter-type analytes. A list of the analytes, analytical method, contract required quantification limits, containers, preservatives, and holding times are provided in Table 5-1.

The sampling program consists of six activities. These activities are as follows and are described below.

- Soil-Gas
- Soil Sampling
- Temporary Monitoring Well Survey
- Monitoring Well Sampling
- Surface Water/Sediment Sampling
- Waste Sampling

A concurrent, three-phase field investigation is planned at this facility. These three phases are a soil-gas survey, a soil sampling and temporary monitoring well groundwater sampling investigation, and a groundwater sampling investigation. The first phase will be a soil-gas survey to identify potential areas of soil and groundwater contamination. The soil-gas samples will be analyzed at an onsite mobile field GC laboratory. Locations for the Phase 2 activities will be selected at the areas found to have high soil-gas contaminant concentrations. The second phase will consist of a soil sampling, waste sampling (if encountered), and a temporary monitoring well groundwater sampling investigation. The soil samples will be collected at 5 feet and/or 21 feet and coincide with elevated concentrations in the soil-gas measurements. These samples will be analyzed at an offsite fixed-base laboratory. The temporary monitoring well samples will be collected approximately 5 feet into the water table and analyzed at a local laboratory using GC analysis. The temporary monitoring well groundwater survey will be used to determine the location of groundwater contamination and to place the monitoring well clusters. The third phase will consist of the installation of monitoring wells and the sampling and chemical analysis of surface soils, groundwater, sediment, and surface water. These samples will be analyzed at an offsite fixed-base laboratory. The three phases will overlap in order to avoid schedule delays. All of the samples will be analyzed for TCL (Target Compound List) volatile organics. Soil samples at the surface and up to five feet deep, groundwater (except the temporary monitoring well samples), sediments, surface water, and the waste (if found) will be analyzed for TCL semivolatile organics, TAL (Target Analyte List) metals, and cyanide. The water samples (except the temporary monitoring well samples) and waste samples will also be analyzed for hexavalent chromium. Soil samples identified as stained will be analyzed for PCBs and pesticides. In addition, select soil, sediment, and groundwater samples will be analyzed for engineering parameters.

Soil-Gas

The soil-gas survey will consist of placing soil-gas points in a uniform grid pattern in each of the three sites. A grid spacing of 150-foot centers will be used. In addition, opportunity locations will be selected in the field based on results from grid pattern soil-gas locations, as well as areas of suspected to be contaminated, (drum marshaling areas). At each location, soil-gas samples will be obtained at two depths, 5 feet and 21 feet. The 5-foot depth represents potential contamination in the soil near the source of a spill. Elevated soil-gas measurements at this depth would likely be an indication of soil contamination. The 21-foot depth represents the practical depth of this technique and the result would likely be influenced by both soil and groundwater contamination. The samples will be analyzed in the field using a field GC.

A 3-point by 4-point grid would be used at Site 1, see Figure 6-1. In addition, four opportunity sample locations would be selected in the field. A potential location of several of the opportunity locations would be near the former drum marshaling areas.

A 5-point by 5-point grid would be used at Site 2, see Figure 6-2. In addition, four opportunity sample locations would be selected in the field. A potential location of several of the opportunity locations would be near the former sludge drying beds.

A 6-point by 5-point grid would be used at Site 3, see Figure 6-3. In addition, four opportunity sample locations would be selected in the field. A potential location of several of the opportunity locations would be near the drum marshaling area.

The results of this testing are expected to provide a three dimension map of volatile organic contaminants in the soil vadose zone. These results would then be mapped for each site. Soil contamination would be expected to result in a relatively confined area of elevated soil-gas readings at the 5-foot depth, or at the 5-foot depth and the 21-foot depth. Whereas groundwater contamination would be expected to extend in the direction of the groundwater flow and result in higher readings at the 21- foot depth than at the 5-foot depth.

Based on this testing, temporary monitoring well groundwater sample locations and soil sample locations and depths would be selected. If minimal or no elevated soil-gas readings are found, then the temporary monitoring well sample points would be located primarily along the hydraulic upgradient and downgradient boundaries of the three sites. If elevated soil-gas readings are found, then 2 to 3 temporary monitoring well groundwater points would be located along the hydraulic downgradient boundary of each site; 2 to 3 temporary monitoring well groundwater points would be located along the hydraulic upgradient border of each site; and 3 to 4 temporary monitoring well groundwater points would be located in the center of the contamination at each site.

Soil Sampling

Surface and subsurface soil samples will be collected at the site. The surface sample locations will consist of points in a relatively uniform 300-foot by 300-foot grid plus field determined opportunity sample locations. Areas covered by buildings and asphalt would not be considered for the predetermined sample locations. The soil borings and soil samples during the collection of temporary monitoring well groundwater samples will be used to investigate the subsurface soil contamination.

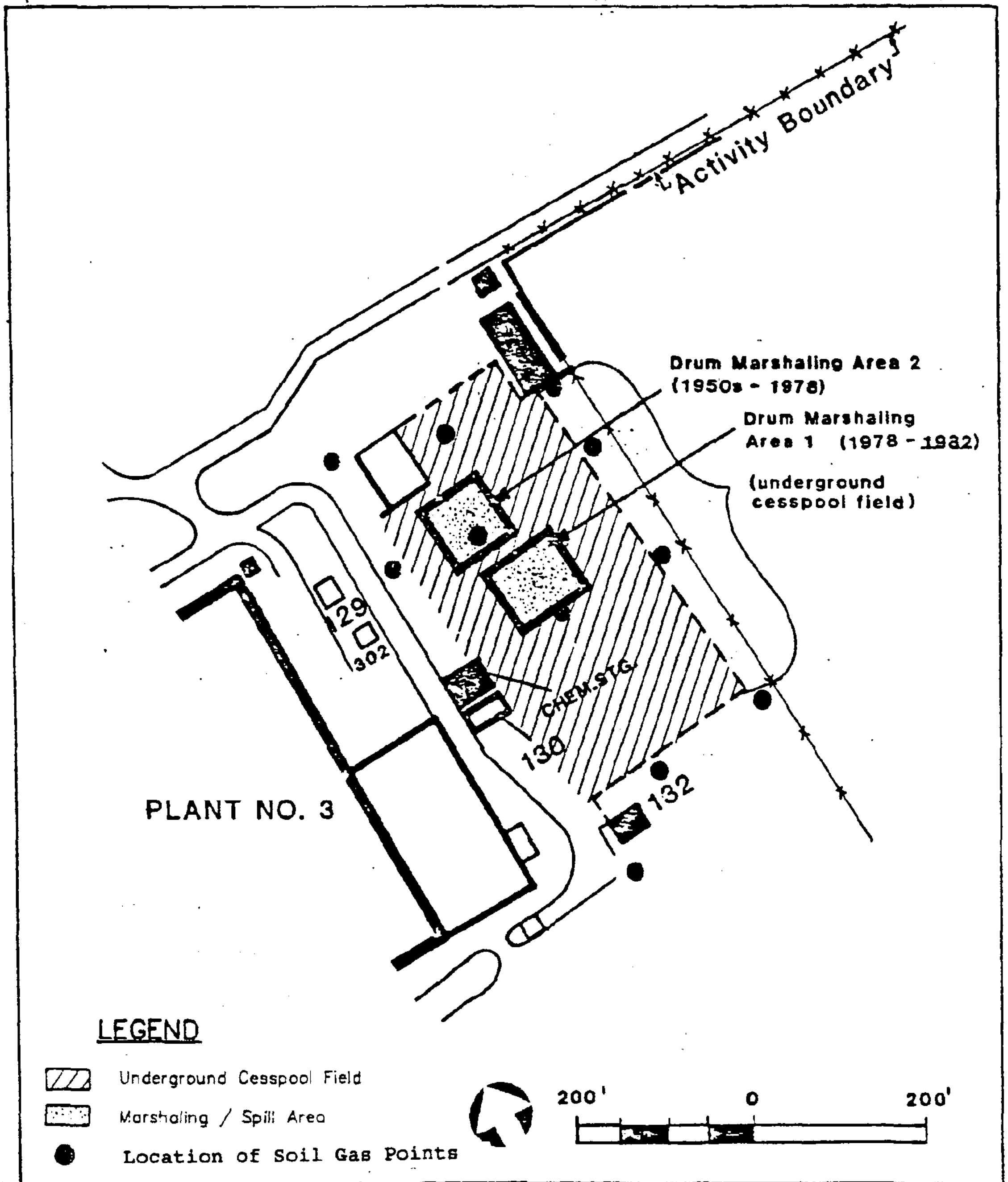

Figure 6-1

Location of Soil Gas Points
Site 1 Drum Marshaling Area
NWIRP Bethpage, NY

Remedial Investigation
Naval Weapons Industrial
Reserve Plant
Bethpage and Calverton
Long Island, New York

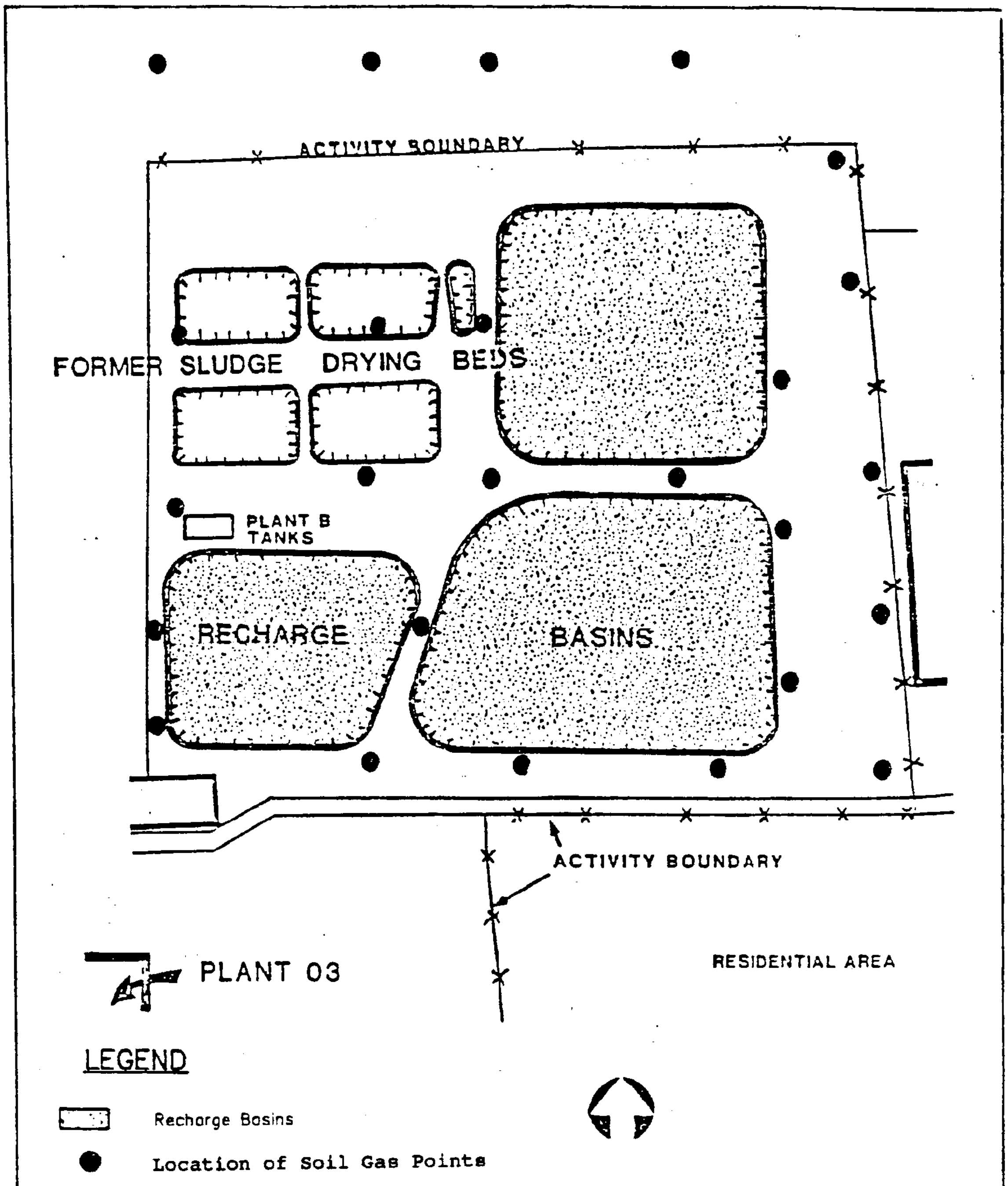

Figure 6-2

Location of Soil Gas Points
Site 2 Recharge Basins
NWIRP Bethpage, NY

Remedial Investigation
Naval Weapons Industrial
Reserve Plant
Bethpage
Long Island, New York

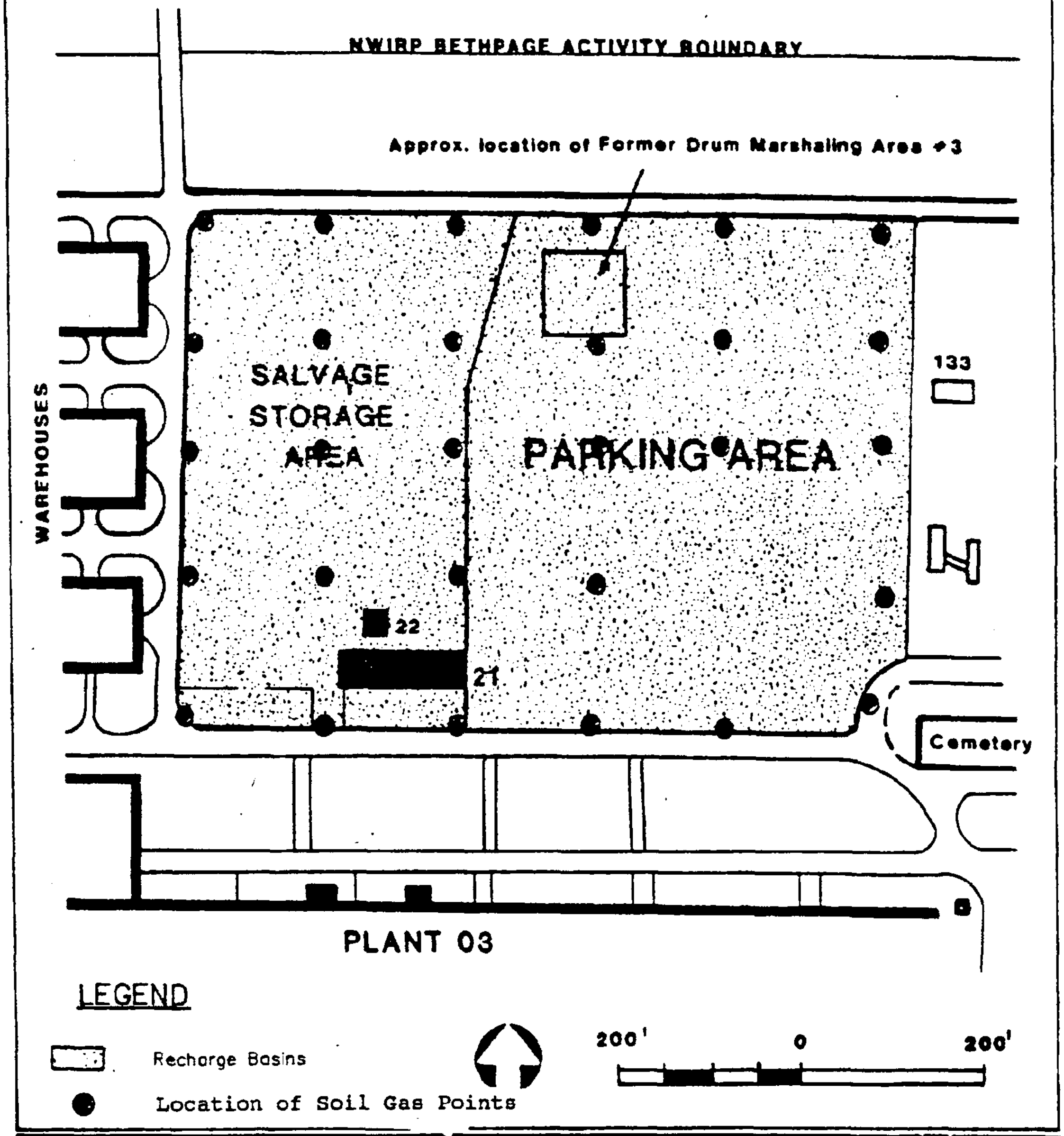

Figure 6-3

Location of Soil Gas Points
Site 3 Salvage Storage Area
NWIRP Bethpage, NY

Remedial Investigation
Naval Weapons Industrial
Reserve Plant
Bethpage and Calverton
Long Island, New York

The grid of predetermined surface soils samples is illustrated in Figure 6-4. There would be a 2-point by 3-point grid at Site 1; a 3-point by 4-point grid at Site 2; and a 2-point by 3-point grid at Site 3. The opportunity samples would be selected in the field during the field activities. Soils which appear to be stained or visually discolored would be selected. The total number of surface samples would be 29 samples. These samples would be collected at a depth of 1 to 6 inches and would be analyzed for TCL volatile and semivolatile organics, TAL metals, and cyanide. In addition, if the soil samples are observed to be stained, then the samples will be analyzed for TCL pesticides and PCBs. The results will be used to determine the nature and extent of soil contamination and to prepare a risk assessment.

The subsurface samples will be collected at a depth of 5 feet and/or 21 feet. For each location, the decision to sample is dependent on the soil-gas measurement at that location of depth. In general, if volatile organics were detected at that point, then a soil sample will also be obtained for offsite fixed-base laboratory analysis. And if volatile organics were not detected at that point, then a sample would not be obtained. However, a minimum of two soil samples will be collected at points were soil-gas measurements indicated the absence of contamination. These samples would be analyzed offsite at a fixed-base laboratory to confirm the absence of soil contamination. There will be an estimated 29 locations for the soil augering with an estimated 1.5 soil samples (for offsite analysis) at each location.

Samples will be collected with a split-spoon device. The split spoon samples will be used to collect samples for analytical testing, and to identify the depth of the groundwater table and the lithology. For analytical testing, the split spoon samples will be collected at a depth of 3 to 5 feet and/or at 19 to 21 feet. To identify the depth of the groundwater table and the lithology, the split spoon sampling would start again at about 40 to 45 feet and be conducted continuously until a suitable lithology for use of the temporary monitoring well point is encountered in the groundwater.

The location of the soil borings will be established through the results of the soil-gas survey.

All the soil samples will be analyzed for TCL volatile organics. The surface and near surface (3 to 5 feet deep) soil samples will also be analyzed for semivolatile organics, TAL metals, and cyanide. If the surface and near surface soils are observed to be stained, then they will also be analyzed for PCBs and pesticides. These results primarily will be used to determine the nature and extent of soil contamination and to prepare a risk assessment.

In addition to these chemical analyses, select samples will also be evaluated for engineering parameters. Two samples will be selected at each site (for a total of six), based on the field screening data. For each site, one sample should represent a relatively low level of contamination, and the

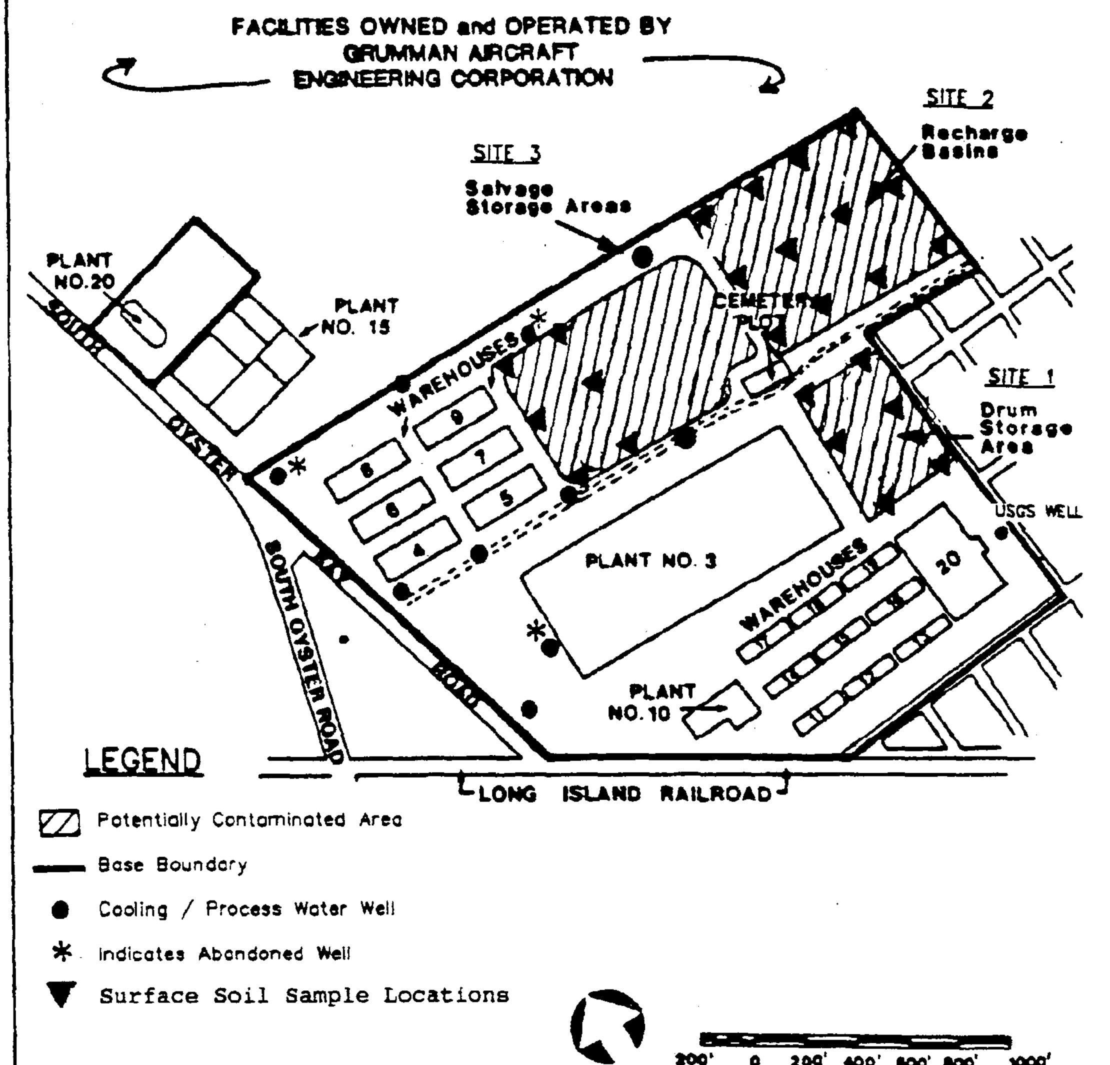

Figure 6-4

Surface Soil Sample Locations
NWIRP Bethpage, NY

Remedial Investigation
Naval Weapons Industrial
Reserve Plant
Bethpage
Long Island, New York

second sample should represent an intermediate or high level of contamination. The engineering parameters consist of:

- Total organic carbon (TOC) to evaluate the potential for groundwater contamination through an estimate of the contaminant soil/water partition coefficient,
- Bulk density, grain size, moisture content, and pH for general engineering considerations.

Temporary Monitoring Well Survey

A temporary monitoring well survey will be conducted to aid in the placement of the permanent monitoring wells. This groundwater samples will be collected using either a temporary well point or a HydroPunch. The well point consists of installing a 2 inch well screen through a hollow stem auger. The well point is purged and sampled. The HydroPunch allows for the collection of groundwater samples without the installation of permanent monitoring points. A soil auger with periodic split spoon samples is used to advance a hole to the water table. The HP is then driven or pushed to the sampling horizon. At this point, a sampling port is exposed and a groundwater sample is taken. The minimum depth at which a sample may be collected is 5 feet below the water table because 5 feet of head is required to fill the HP. The samples will be screened with a gas chromatograph (GC). All sampling equipment will be decontaminated between sampling events.

The temporary monitoring well points will be selected based on the results of the soil gas survey. As a result, the location cannot be presented at this time. Potential sample point location scenarios were presented in the discussion of the soil-gas. At present, 29 sampling points coinciding with the soil sample locations are planned for the three sites.

Monitoring Well Sampling

Monitoring wells will be installed to evaluate the impact of the three sites being investigated on the local groundwater quality and to assess the potential vertical and lateral migration of any contaminants. The potential vertical migration of the contaminants will be investigated through the construction of well clusters composed of shallow (50- to 60-foot deep), intermediate (100- to 150-foot deep), and deep (200- to 250-foot deep) monitoring wells. These will yield groundwater quality analyses from various depths and define the magnitude and direction of local vertical hydraulic gradients. The potential lateral migration of any contaminants will be investigated through the placement of wells both upgradient and downgradient from the sites. These wells will define the slope and gradient of the water table and thereby yield local directions of flow. A comparison of water quality analyses from the upgradient and downgradient wells will show the impact of each site on the local groundwater quality.

Two rounds of water-level measurements will be conducted to better define groundwater flow paths and horizontal and vertical gradients. The measurements will be conducted at each of the HALLIBURTON NUS-installed monitoring wells, the USGS well located south of Site 1, and five of the Grumman monitoring well clusters (GM-6, GM-7, GM-8, GM-12, and GM-13, see Figure 6-5).

A total of 17 monitoring wells (7 shallow, 7 intermediate, and 3 deep) will be installed at the NWIRP. An additional well cluster (one shallow and one intermediate) may be placed, if the soil-gas and temporary monitoring well surveys indicate a contaminant plume passing between the Grumman monitoring wells. The preliminary locations of these wells are illustrated in Figure 6-5. As discussed above, the results of the soil-gas and temporary monitoring well program will be used to determine the exact locations of the wells. Because of the proximity and location of the three sites, some wells between Site 1 and Site 2 and 3 will perform two functions. That is, they will serve as downgradient wells for Sites 2 and 3 and will serve as upgradient wells for Site 1. Where possible, the site process-water wells will serve as medium or deep wells. Additional discussion on the location of the monitoring wells is provided in the RI Work Plan.

The shallow and intermediate wells will be drilled with hollow stem augers. Formation samples will be collected every 5 feet with a split-spoon sampler. Every 10 feet, a sample will be collected, placed in a jar and the headspace will be analyzed using an HNU. The placement depth of the well screens will be based on the lithologic and contamination information obtained from these samples.

The drilling of the deep wells presents problems. These wells are too deep to be drilled with the required large ID hollow stem augers. The potential presence of running or heaving sands presents special geotechnical problems. In addition, the New York State Department of Environmental Conservation (NYSDEC) has informed Geraghty and Miller, Inc., working on the adjacent Grumman facility, that the use of the mud rotary technique will not be allowed through the depth interval to be screened and monitored. Therefore, HALLIBURTON NUS plans to drill the deep wells with a hybrid technique currently being employed by Geraghty and Miller at the Grumman facility. This technique calls for the wells to be drilled with the mud rotary technique until the depth to be screened is reached. At this depth, a reverse-circulation water rotary technique will be used to advance the borehole through the interval to be screened to the total depth of the well.

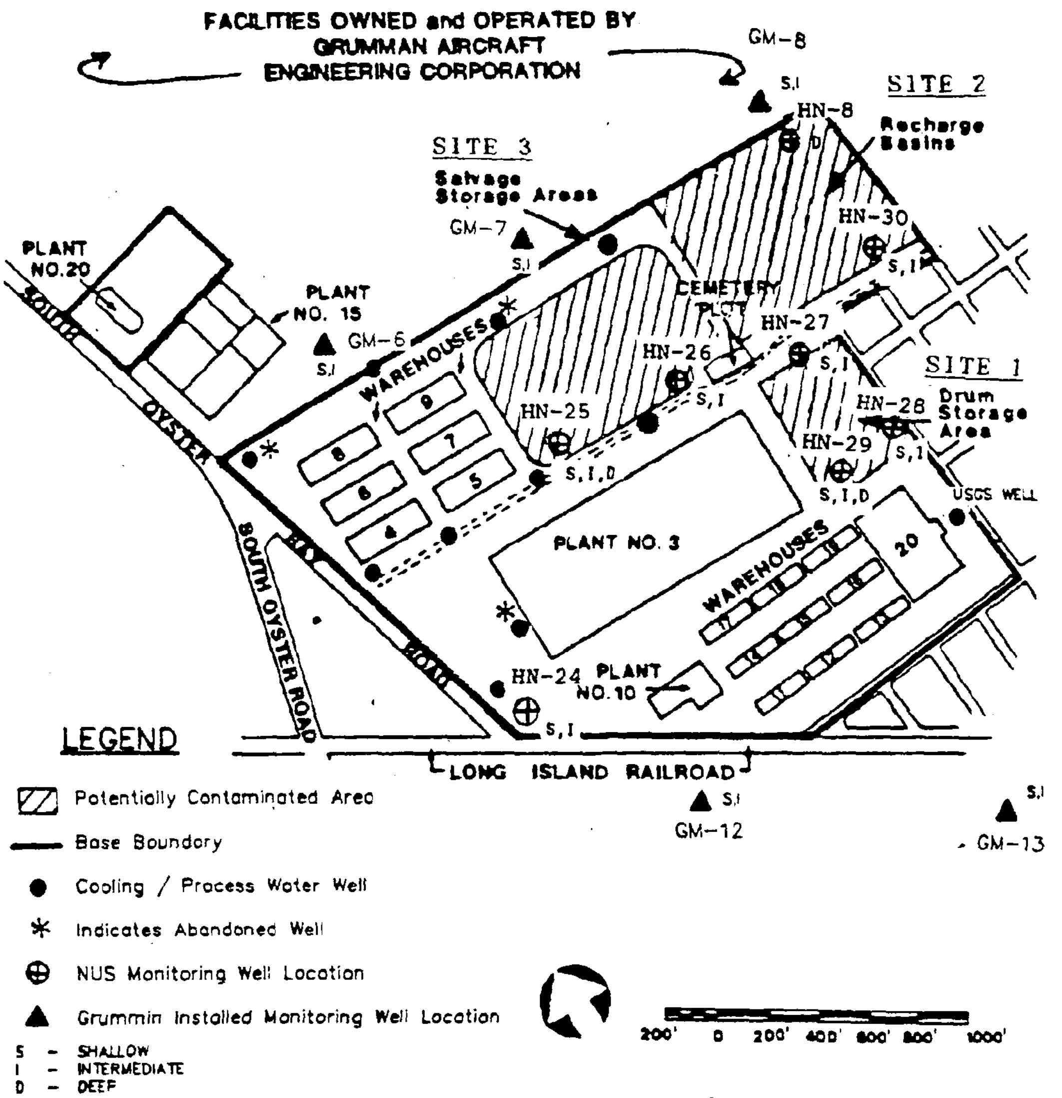

Figure 6-5

Preliminary Monitoring Well Location NWIRP Bethpage, NY

Remedial Investigation
Naval Weapons Industrial Reserve Plant
Bethpage
Long Island, New York

An obvious requirement of this hybrid drilling technique is that the interval to be screened must be identified prior to the drilling of the well. To accomplish this, pilot holes will be drilled with small ID, hollow-stem augers. Split-spoon samples will be taken every 5 feet to identify the lithologies present at that location; the screen depth for the wells will be based on the results of the headspace analysis as with the shallow and intermediate wells and the lithology encountered in the pilot hole. Upon completion, the pilot holes will be backfilled with a bentonite/cement grout and abandoned.

One round of groundwater sampling is proposed. Each new monitoring well will be sampled. The samples will be analyzed for TCL volatile and semivolatile organics and TAL metals. In addition, the samples will be analyzed for cyanide and hexavalent chromium. During the evaluation of the metal data, turbidity from the surrounding sediments often results in an over-estimation of risks associated with metal contaminants. As a result, the groundwater samples will be analyzed for total TAL metals and field-filtered TAL metals. These chemical analyses would be used to determine the nature and extent of contamination and to prepare a risk assessment.

In addition to the chemical analysis used for the nature and extent of contamination and risk assessment, select samples will also be evaluated for engineering parameters. A total of three samples will be selected from all of the monitoring wells, based on the field screening data. One sample should represent a relatively low level of contamination, one sample should represent an intermediate level of contamination, and one sample should represent a high level of contamination. The selection of these wells will be determined based on the temporary monitoring well testing program. These engineering parameters consist of:

- pH, total dissolved solids (TDS), alkalinity, and hardness to evaluate the scaling potential of the groundwater;

- Biological oxygen demand (BOD), total organic carbon (TOC), chemical oxygen demand (COD), and total suspended solids (TSS) to evaluate other contamination in the groundwater and potential treatment requirements.

Four process water wells are located around Site 3 and a USGS well is located south of Site 1. Samples will be collected of the water in these wells and analyzed for TCL volatile and semivolatile organics and total TAL metal, cyanide, and hexavalent chromium.

Surface Water/Sediment Sampling

Two samples of the surface water will be collected from one of the basins and two samples of the sediment from each of the three basins (total of six sediment samples).

One surface water sample will be collected during a precipitation event to evaluate the potential transport of sediments into the basins, and the second sample will be collected during a non-precipitation event to evaluate potential contamination in process- generated wastewaters. The samples will be analyzed for TCL volatile and semivolatile organics and TAL metals. In addition, the samples will be analyzed for cyanide and hexavalent chromium. During the evaluation of the metal data, turbidity from the surrounding sediments often results in the over estimation of risks associated with the metals. As a result, the surface-water samples will be analyzed for total TAL metals and field-filtered TAL metals. These chemical analysis would be used to confirm the reported noncontact source of this waste water.

The six sediment samples will be analyzed as the soil samples. The samples will be analyzed for TCL volatile and semivolatile organics, TAL metals, and cyanide. These results will be used to primarily determine the nature and extent of contamination and to prepare a risk assessment.

Waste Sampling

During the drilling operations in Site 2, sludge from the area of the former sludge drying beds may be encountered. One sample of this sludge will be collected to evaluate potential direct contact and groundwater contamination risks. This sample will be analyzed for TCL volatile and semivolatile organics, PCBs and pesticides, hexavalent chromium, TAL metals, and cyanide. These results primarily will be used to determine the nature and extent of contamination and to prepare a risk assessment.

6.4 Sample Designation

The following sample designations will be used.

Location - Matrix - Site - Number - QA/QC qualifiers

The location is Bethpage:	BP

The matrices are:

- Soil	S
- Groundwater	G
- Sediment	SD
- Surface water	SW
- Waste	W

The sites are 1, 2, or 3.

The numbers are matrix specific and will start with 01 for each matrix.

The QA/QC qualifiers are:

- Duplicate	D
- Matrix Spike	MS
- Matrix Spike Duplicate	MSD
- Field Blank	FB
- Rinsate Blank	RB
- Trip Blank	TB

6.5 Sample Equipment and Protocols

The sampling equipment and protocols to be used are presented in Appendix A and are HALLIBURTON NUS Standard Operating Procedures GH-1.2 through GH-1.7 and GH 2.5.

6.6 Sample handling and Analysis

Sample handling and analysis are presented in Sections 5.0, 6.0, and 7.0 of this QAP.

6.7 Equipment Decontamination

The following procedure will be used on all reusable equipment between the collection of each sample.

Drilling Augers

Steam cleaning.

Split Spoons and Other Reusable Equipment

- Remove debris with a scrub brush and tap water;
- Scrub with Alconox/DI water mixture;
- Rinse with 10% nitric acid;
- Rinse with DI water;
- Rinse/scrub with methanol;
- Rinse equipment three times with DI water and allow to air dry.

7.0 SAMPLE CUSTODY

Sample custody procedures are designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. An example of the chain-of-custody form, which will be used during this investigation, is included in Appendix B.

Samples collected during the site investigation will be the responsibility of identified persons from the time they are collected until they, or their derived data, are incorporated into the final report. Stringent chain-of-custody procedures will be followed to document sample possession.

7.1 Field Custody

- The FOL, or his or her designee, is responsible for the care and custody of the samples collected until they are delivered to the analyzing laboratory or entrusted to a carrier.

- Sample logs or other records will always be signed and dated.

- Chain-of-custody sample forms will be completed to the fullest extent possible prior to sample shipment. They will include the following information: project name, sample number, time collected, source of sample and location, description of sample location, matrix, type of sample, grab or composite designation, preservative, and name of sampler (see attached form). These forms will be filled out in a legible manner, using waterproof ink, and will be signed by the sampler. Similar information will be provided on the sample label which will be securely attached to the sample bottle. The label will also include the general analyses to be conducted. In addition, sampling forms will be used to document collection, filtration, and preparation procedures. Copies of all logs used are provided in Appendix B.

7.2 Transfer of Custody and Shipment

The following procedures will be used when transferring custody of samples:

- Samples will always be accompanied by a chain-of-custody record. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time of the chain-of-custody record. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common carrier). Upon arrival at the laboratory, internal sample custody procedures will be followed.

- Prior to shipment to the laboratory for analysis, samples will be properly packaged. Individual custody records will accompany each shipment. Shipping containers will then be sealed for shipment to the laboratory. The methods of shipment, courier name, and other pertinent information, will be entered in the remarks section of the custody record.

- All shipments will be accompanied by the chain-of-custody record identifying the contents. The original record will accompany the shipment; and a copy will be retained by the field sampler.

- Proper documentation will be maintained for shipments by common carrier.

7.3 Sample Shipment Procedures

The following procedures will be followed when shipping samples for laboratory analysis:

- Samples requiring refrigeration will be promptly chilled with ice or Blue Ice to a temperature of 4°C and will be packaged in an insulated cooler for transport to the laboratory. Ice will be sealed in containers to prevent leakage of water. Samples will not be frozen.

- Only shipping containers that meet all applicable state and Federal standards for safe shipment will be used.

- Shipping containers will be sealed with nylon strapping tape, custody seals will be signed, dated, and affixed, in a manner that will allow the receiver to quickly identify any tampering that may have occurred during transport to the laboratory.

- The field chain-of-custody document will be placed inside the shipping container in a sealed plastic envelope after the courier has signed the document.

- Shipment will be made by overnight courier. After samples have been taken, they must be sent to the laboratory within 24 hours.

7.4 Field Documentation Responsibilities

It will be the responsibility of the FOL to secure all documents produced in the field (geologist's daily logs, lithologic and sampling logs, communications) at the end of each work day.

The possession of all records will be documented; however, only the project FOL or designee may remove field data from the site for reduction and evaluation.

The data generated by the laboratory will be sent to HALLIBURTON NUS, validated, and stored by HALLIBURTON NUS until completion and acceptance of the RI and FS investigation reports. A final QC data report will be issued to the NCR at least 3 weeks before the final report is issued.

8.0 CALIBRATION PROCEDURES

Field equipment such as the portable gas chromatograph (GC), the photoionization equipment (TIP or HNU), the pH and specific conductance meters, and any geophysical equipment used during this project will be calibrated and operated in accordance with the manufacturer's instructions and manuals. A log will be kept documenting the calibration results for each field instrument. The log will include the date, standards, personnel, and results of the calibration.

Calibration procedures for laboratory equipment used in the analysis of environmental samples will be performed in accordance with CLP requirements.

9.0 ANALYTICAL PROCEDURES

Environmental samples collected during the field investigation for chemical analyses will be analyzed using the appropriate analytical procedures as outlined in Sections 3.3 and Table 3-1 of this QAPP.

The methods are referenced to the appropriate CLP, EPA, or other guidance. pH of recharge basin water and groundwater samples will be analyzed in the field at the time of sampling.

10.0 DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction, validation, and reporting are basic steps in the control and processing of field and laboratory project-generated data. Procedures for data reduction and reporting are described in the Site and Data Management Plan. Data validation procedures are described below.

Data validation consists of a stringent review of an analytical chemical data package with respect to sample receipt and handling, analytical methods, data reporting and deliverables, and document control. The quality of data generated by a laboratory is extremely important; it is an integral part of the investigation and should be clearly tied to the project goals. Data used to develop qualitative trends, for example, will not have the same data validation requirements as data used for litigation purposes.

A qualified HALLIBURTON NUS chemist will analyze the analytical data package using CLP procedures. After the data is validated, a listing of non-conformities will be generated and used to determine whether the data can be utilized for its intended purpose (assessment, enforcement, litigation). Non-conformities require data qualifiers, which are used to alert the data user to inaccurate or imprecise data. For example, if holding times are exceeded, the data reviewer must qualify all positive results as estimated and all sample quantitation limits as estimated. For situations in which there are several quality control criteria out of specification (with regard to the limits specified in the Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program), the data validator may make professional judgments and/or comments on the validity of the overall data package. In situations where the validity of an entire data package is in question, it may be necessary for the sample(s) to be re-analyzed. The reviewer will then prepare a technical memorandum presenting changes in the data, if necessary, and the rationale for making such changes.

A QC data report shall be sent to the NCR at least 3 weeks before issuance of the final report. For Level D QC, a subset of data from the CLP data packages shall be submitted. For 20 percent of the water and 20 percent of the soil samples, the subcontractor shall submit the full CLP package. The report shall indicate the duration and location of storage for all raw data, QC charts, corrective action, sample lists, COC information, notebooks, work sheets, automated data processing system output, and calibration. The net result is a data package that has been carefully reviewed for its adherence to prescribed requirements and is suitable for its intended use. Data validation thus plays a major role in determining the confidence with which key technical evaluations may be made.

The final report, which shall be reviewed by the NCR prior to its release, will include a data summary. The summary of analytical data will exclude non-detected compounds. No subtraction of blanks will be allowed. Data will be flagged if blank contamination occurs. All data flags will follow the result in the summary.

The final report will also include a QC summary section. The QC summary will discuss flagged data, laboratory blanks, matrix spikes/spike duplicates, control charts, laboratory duplicates, surrogate holding times, field blanks, trip blanks, rinsates, field duplicates, precision, accuracy, and completeness.

The laboratory data for each sample will be reported in an appendix. These data will be presented in a spreadsheet format with all trip, field, and laboratory blanks marked. The format recommended by NEESA will be used.

Field logs and forms will be included in another appendix. Another appendix will include method blank spike control charts, surrogate recoveries, matrix spike and duplicate, field, and laboratory duplicates for all spike samples.

11.0 INTERNAL QUALITY CONTROL CHECKS

Quality control samples generated by HALLIBURTON NUS will include the collection of field replicates, the preparation of field blanks, and the use of laboratory-prepared trip blanks. An approximate 10 percent replication (one per 10 samples or one per sample matrix if less than 10 samples are collected (see Table 3-1) of recharge basin water and groundwater samples will be used to monitor the laboratory performance. Waste samples will not be replicated due to the nonhomogeneous nature of the samples.

Trip blanks (VOCs only) will be shipped along with the sample bottles and will be analyzed concurrently with the collected environmental samples. Rinsates, prepared by running distilled water through the sampling equipment, will be analyzed to determine whether the sampling procedures may be biasing the data. Field blanks will be prepared at a rate of one per source per event; trip blanks at a rate of one per sample shipment. Procedures for collecting these samples are contained in the Section 6.0 of this QAPP.

There are two types of quality assurance mechanisms used to ensure the production of analytical data of known and documented quality. The internal quality control procedures for the analytical services are specified in the CLP protocol and Table 3-1. These specifications include the types of control samples required (sample spikes, surrogate spikes, controls, and blanks), the frequency of each control, the compounds to be used for sample spikes and surrogate spikes, and the quality control acceptance criteria. It will be the laboratory's responsibility to document, in each package, that both initial and on-going instrument and analytical QC criteria are met. This documentation will be included in the data packages generated by contract laboratory.

Analytical results of field-collected quality control samples will also be compared to acceptance criteria, and documentation will be performed showing that criteria have been met. Any samples in nonconformance with the QC criteria will be identified and reanalyzed by the laboratory, if possible. The following procedures will be employed for the NWIRP Bethpage samples:

- Proper storage of samples.
- Use of qualified and/or certified technicians.
- Use of calibrated equipment traceable to the CLP Protocol.
- Formal independent confirmation of all computation and reduction of laboratory data and results.
- Use of standardized test procedures.
- Inclusion of replicate samples at a frequency of one replicate per 10 samples or one per sample matrix if less than 20 samples are collected.

12.0 PERFORMANCE AND SYSTEM AUDITS

System audits will be performed on a semicontinuous basis, as appropriate, to assure that the work is being implemented in accordance with the approved project SOPs and in an overall satisfactory manner.

- The FOL will supervise and check on a daily basis that the monitoring wells are installed and developed correctly, field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and the field work is accurately and neatly documented.

- The data validator will review (on a timely basis) the data packages submitted by the laboratory. The data validator will check that the data was obtained through the approved methodology, that the appropriate level of QC effort and reporting was conducted, that holding times were met, and that the results are in conformance with the QC criteria. On the basis of these factors, the data validator will evaluate the data quality and limitations.

- The project manager will oversee the FOL and data validator, and check that management of the acquired data proceeds in an organized and expeditious manner.

- System audits for the laboratory are performed on a regular basis.

  A formal audit of the field sampling procedures will be conducted in addition to the auditing that is an inherent part of the daily project activities.

- The auditors will check that sample collection, sample handling, decontamination protocols, and instrument calibration and use are in accordance with the approved project SOPs. The auditors will also check that the field documentation logs and chain-of-custody forms are being filled out properly.

Performance audits of laboratories participating in the CLP are performed quarterly in accordance with the procedures and frequencies established by the CLP.

13.0 PREVENTATIVE MAINTENANCE

HALLIBURTON NUS has established a program for the maintenance of field equipment to ensure the availability of equipment in good working order when and where it is needed. This program consists of the following elements:

- The equipment manager keeps an inventory of the equipment in terms of items (model and serial number) quantity and condition. Each item of equipment is signed out when in use, and its operating condition and cleanliness checked upon return.

- The equipment manager conducts routine checks on the status of equipment and is responsible for the stocking of spare parts and equipment readiness.

- The equipment manager maintains the equipment manual library and trains field personnel in the proper use and care of equipment.

- The FOL is responsible for working with the equipment manager to make sure that the equipment is tested, cleaned, charged, and calibrated in accordance with the manufacturer's instructions before being taken to the job site.

The laboratory follows a well-defined program to prevent the failure of laboratory equipment and instrumentation. This preventative program, includes the periodic inspection, lubrication, cleaning, and replacement of parts of the equipment.

14.0 DATA ASSESSMENT PROCEDURES

14.1 Representativeness, Accuracy, and Precision

All data generated in the investigation will be assessed for its representativeness, accuracy, and precision. The completeness of the data will also be assessed by comparing the valid acquired data to the project objectives to see that these objectives are being addressed and met. The specific procedures used to determine data precision, accuracy, and completeness will be provided in the analytical reports. Accuracy will be determined using laboratory spiked samples and laboratory field blanks.

The representativeness of the data will be assessed by determining if the data are consistent with known or anticipated hydrogeologic or chemical conditions and accepted principles. Field measurements will be checked for completeness of procedures and documentation of procedures and results.

Precision and accuracy will be determined using replicate samples and blank and spiked samples, respectively. The specific procedures for determining PARCC parameters are outlined in Section 5.0.

14.2 Validation

Twenty-five percent of the analytical data packages for each media will be validated. If problems are found during this partial validation, then all the data packages will be validated.

14.3 Data Evaluation

The evaluation of the data collected during the field investigation will be a comparison of: chemical concentrations in the hydraulically upgradient groundwater wells versus the chemical concentration in the downgradient groundwater wells; chemical concentrations in groundwater versus ARARs (such as the Safe Drinking Water Act MCLs) and risk-based concentrations; and chemical concentrations in soils versus background and risk-based concentrations.

The chemical concentrations in the hydraulically upgradient groundwater versus downgradient groundwater will be compared to each other. Typically, a statistical approach (such as the t-test) can be used to determine is there is a significant increase in contaminant concentrations across a site. This increase would indicate that the site is a source of the contamination. However, because of the accelerated schedule of activities for this site, only one round of groundwater samples is being collected. This restricts the use of statistical approaches. The conclusions of the data collected at this time is expected to either conclusively indicate that the site is, or is not, causing groundwater contamination; or the data may be inconclusive and indicate that additional data collection is required. Relatively conclusive data that the site is causing groundwater contamination would occur if there is a significant (one or more orders of magnitude) increase in contaminant concentrations from the upgradient wells to the downgradient wells. If the contaminant concentrations are nearly identical (+/- 25%) in the upgradient and downgradient wells, then this would indicate that the site is not causing the groundwater contamination. Otherwise, the data is inclusive and additional rounds of groundwater sampling would be required to allow a statistical evaluation.

The approach for evaluating contaminant concentrations in soils is different than that for groundwater since TCL organics are not naturally found in soils; there is no upgradient sources of soil contamination (except that carried into the site by groundwater); and TCL inorganics are naturally found in soils. Any detectable concentration of TCL organic concentrations is potentially significant and is an indication of past spills or leaks. Contaminant fate and transport properties (using soil/water partitioning calculations) and risk-based calculations would be used to determine if the TCL organic chemicals in the soils represent a significant risk to groundwater (environment) or to human health.

A statistical approach (t-test) would be used to determine if the inorganic chemicals are present in the soils at concentrations above background (natural) concentrations. If contaminants are found at concentrations above background, then a risk assessment will be performed to determine if the contaminant concentrations represent a significant risk to human health. Soil/water partitioning calculations are not feasible for inorganic contaminants as they are for organic contaminants.

Therefore, if elevated inorganic concentration are found in the soils and in groundwater (above ARAR or risk-based concentrations), then additional partitioning tests would likely be required.

About four to six soil samples will be collected to determine background inorganic chemical concentrations. These samples will be obtained from NWIRP perimeter locations, away from areas of activity and at a depth of about 3 to 5 feet deep. These locations are the most likely points at the site to collect background soil samples.

15.0 CORRECTIVE ACTION

The QA program will enable problems to be identified, controlled, and corrected. Potential problems may involve nonconformance with the SOPs and/or analytical procedures established for the project or other unforeseen difficulties. Any person identifying an unacceptable condition will notify the project manager. The project manager, with the assistance of the project QA/QC officer, will be responsible for developing and initiating appropriate corrective action and verifying that the correction action has been effective. Corrective actions may include the following: resampling and/or reanalysis of sample, amending or adjusting project procedures. If warranted by the severity of the problem (for example, if a change in the approved work plan is required), the Navy will be notified in writing and their approval will be obtained prior to implementing any change. Additional work that is dependent on a nonconforming activity will not be performed until the problem has been eliminated.

The laboratory maintains an internal closed-loop corrective action system that operates under the direction of the laboratory QA coordinator.

16.0 QUALITY ASSURANCE REPORTS

The QA/QC advisor will review all aspects of the implementation of the QAPP on a regular basis and prepare a summary report. Reviews will be performed at the completion of each field activity and reports will be completed at this time. These reports will include an assessment of data quality and the results of system and/or performance audits. Any significant QA deficiencies will be reported and identified, and corrective action possibilities discussed. The laboratory will issue monthly progress reports. Other QA/QC reports are listed in Section 8.0.

17.0 REFERENCES

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APPENDICES

A

APPENDIX A

HALLIBURTON NUS SOPs

- GH - 1.2
- GH - 1.3
- GH - 1.4
- GH - 1.5
- GH - 1.6
- GH - 1.7
- GH - 2.5

NUS CORPORATION ENVIRONMENTAL MANAGEMENT GROUP	STANDARD OPERATING PROCEDURES	Number GH-1.2	Page 1 of 4
		Effective Date 05/04/90	Revision 1
		Applicability EMG	
		Prepared Earth Sciences	
Subject EVALUATION OF EXISTING MONITORING WELLS		Approved D. Senovich	

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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating existing monitoring wells, and to insure that the validity of data to be collected from these wells is usable during site investigations.

2.0 SCOPE

This procedure is applicable during stages of a site investigation. The procedures are applicable to all existing monitoring wells and, for the most part, are independent of construction materials and methods.

The program represents a comprehensive approach to evaluating existing monitoring wells. Because of its comprehensiveness, completion of the program as specified will result in some duplication of effort. The actual level of evaluation program will depend on the data that are available (or which can be made available), the use to which that data will be put (i.e., the data quality objectives), and the effect that data will have on the time, budget and data quality for the overall program.

3.0 GLOSSARY

Data Quality Objectives (DQO) - qualitative and quantitative statements specifying data quality (i.e. measurement of uncertainty) required to support the objectives of the groundwater monitoring program.

4.0 RESPONSIBILITIES

Site Geologist - responsible for overseeing field inspections and for assessing the structural integrity of the wells and related field conditions. The geologist will carry out well evaluation procedures and assess the physical condition of the wells. These results and conclusions concerning the conditions of existing monitoring wells should be discussed with the Site Manager and Field Operation Leader, who together, will then determine which of the existing monitoring wells can be utilized.

5.0 PROCEDURES

Accurate, valid and useful groundwater monitoring requires that four important conditions be met:

- Proper characterization of site hydrogeology;
- Proper design of the groundwater monitoring program, including adequate numbers of wells installed at appropriate locations and depths;
- Satisfactory methods of groundwater sampling and analysis to meet the data quality objectives (DQOs);
- The assurance that specific monitoring well samples are representative of water quality conditions in the monitored interval.

To insure that these conditions are met, adequate descriptions of subsurface geology, well construction methods and well testing results must be available. The following steps will help to insure that the required data are available to permit an evaluation of the utility of existing monitoring wells for collecting additional samples.

5.1 PRELIMINARY EVALUATION

A necessary first step in evaluating existing monitoring well data will be the study and review of the original work plan for monitoring well installation (if available). This will help to familiarize the geologist with specific site conditions requiring analysis, will promote an understanding of the original purpose of the monitoring wells and will help to determine if the well installation can meet the current DQOs. For example, existing wells may be sufficient for RCRA compliance but not for contaminant plume identification. Of particular interest during this phase of the project will be the rationale for the horizontal location of the wells and the vertical position and length of the monitored interval.

The next step of the evaluation should involve a review of all available information concerning borehole drilling and well construction. This will allow interpretation of groundwater flow conditions and area geology and will help to establish consistency between hydraulic properties of the well to physical features of the well or formation. The physical features which should be identified and detailed, if available, include:

- The well identification number, permit number and location by referenced coordinates the distance from prominent site features, or the location of the well on a map;
- The installation dates, drilling methods, well development methods, and contractors;
- The depth to bedrock -- where rock cores were not taken, auger refusal, drive casing refusal or penetration test results (blow counts for split-spoon sampling) may be used to estimate bedrock interface;
- The soil profile and stratigraphy;
- The borehole depth and diameter;
- The elevation of the top of the protective casing, the top of the well riser, and the ground surface;
- The total depth of the well;
- The type of well materials, screen type, slot size, and length, and the elevation/depths of the screen, interval, and/or monitored interval;
- The elevation/depths of the tops and bottom of the filter pack and well seals and the type and size;.

5.2 FIELD INSPECTION

During the onsite inspection of existing monitoring wells, features to be noted include:

- The condition of the protective casing, cap and lock;
- The condition of the cement seal surrounding the protective casing;
- The presence of depressions or standing water around the casing;
- The presence of any electrical cable and its connections.

If the protective casing, cap and lock have been damaged or the cement collar appears deteriorated, or if there are any depressions around the well casing capable of holding water, surface water may have infiltrated into the well. This may invalidate previous sampling results since the time when leakage started is unknown.

The routine physical inspection must be followed by a more detailed investigation to identify other potential routes of contamination or sampling equipment malfunction. Any of these may invalidate previously-collected water quality data. If the monitoring well is to be used in the future, the steps described above should be taken to rehabilitate the well. After disconnecting any wires, cables or electrical sources, remove the lock and open the cap. Check for the presence of organic vapors with a PID or FID meter and combustible gas meter to determine the appropriate worker safety level. The following information should be noted:

- Cap function;
- Physical characteristics and composition of the inner casing or riser, including inner diameter and annular space;
- Presence of grout between the riser and outer protective casing and the existence of drain holes in the protective casing;
- Presence of a riser cap, method of attachment to casing, and venting of the riser;
- Presence of dedicated sampling equipment; if possible, remove such equipment and inspect size, materials of construction and condition.
- The final step of the field inspection is to confirm previous hydraulic or physical property data and to obtain data not previously available. Specific field investigative activities which should be carried out include:
- This includes the determination of static water levels, total well depth and well obstruction. This may be accomplished using a weighted tape measure which can also be used to check for sediment (the weight will advance slowly if sediment is present, and the presence of sediment on the weight upon removal should be noted). If sediment is present, the well be should be redeveloped before sampling.
- As a final step, the location, condition and expected water quality of the wells should be reviewed in light of their usefulness for the intended purpose of the investigation.

6.0 RECORDS

A record of all field procedures, tests and observations should be recorded in a field log book. Entries in the log book should include the individuals participating in the field effort, and the date and time. The use of annotated sketches may help to supplement the evaluation.

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		Applicability EMG	
		Prepared Earth Sciences	
Subject SOIL AND ROCK SAMPLING		Approved D. Senovich	

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this procedure is to identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

2.0 SCOPE

The methods described within this procedure are applicable while collecting surface and subsurface soil samples; obtaining rock core samples for lithologic and hydrogeologic evaluation; excavation/foundation design and related civil engineering purposes.

3.0 GLOSSARY

Hand Auger- A sampling device used to extract soil from the ground in a relatively undisturbed form.

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches O.D. and 18 to 54 inches long. A stationary piston device may be included in the sampler to reduce sampling disturbance and increase sample recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split spoon sampler (used for performing Standard Penetration Tests) is 2 inches outside diameter (OD) and 1-3/8 inches inside diameter (ID). This standard spoon typically is available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. These split-spoon samplers range in size from 2-inch O.D. to 3-1/2-inch O.D., depending upon manufacturer. The larger sizes are commonly used when a larger volume of material is required.

Rock Coring - A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring - As an alternate for conventional coring, this is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for overall management of field activities and ensuring that the appropriate sampling procedures are being implemented.

Site Geologist - The site geologist directly oversees the sampling procedures, classifies soil and rock samples, and directs the packaging and shipping of soil samples. Such duties may also be performed by geotechnical engineers, field technicians, or other qualified field personnel.

5.0 PROCEDURES

5.1 SUBSURFACE SOIL SAMPLES

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, DQOs, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

5.1.1 Equipment

The following equipment is used for subsurface soil sampling and test boring:

- Drilling equipment, provided by subcontractor.
- Split barrel (split spoon) samplers, OD 2 inches, ID 1-3/8 inches, either 20-inch or 26 inches long. Larger O.D. samplers are available if a larger volume of sample is needed. A common size is 3-inch O.D. (2-1/2-inch I.D.).
- Thin walled tubes (Shelby), O.D. 2 to 5 inches, 18 to 54 inches long.
- Drive weight assembly, 140-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 30 inches (± 1 inch).
- Drive weight assembly, 300-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 18 inches (± 1 inch).
- Accessory equipment, including labels, logbook, paraffin, and sample jars.

5.1.2 Split Barrel (Split Spoon) Sampling (ASTM D1586-84)

The following method will be used for split barrel sampling:

- Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation. In saturated sands and silts, withdraw the drill bit slowly to prevent loosening of the soil around the hole and maintain the water level in the hole at or above groundwater level.

- Side-discharge bits are permissible. A bottom-discharge bit shall not be used. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.

- Install the split barrel sampler and sampling rods into the boring to the desired sampling depth. After seating the sampler by means of a single hammer blow, three 6-inch increments shall be marked on the sampling rod so that the progress of the sampler can be monitored.

- The 2-inch OD split barrel sampler shall be driven with blows from a 140-lb. (± 2 lb.) hammer falling 30 inches (± 1 inch) until either a total of 50 blows have been applied during any one of the three 6-inch increments, a total of 100 blows have been applied, there is no observed advance of the sampler for 10 successive hammer blows, or until the sampler has advanced 18 inches without reaching any of the blow count limitation constraints described herein. This process is referred to as the Standard Penetration Test.

- A 300-lb. weight falling 18 inches is sometimes used to drive a 2-1/2-inch or 3-inch O.D. spoon sampler. This procedure is used where dense materials are encountered or when a large volume of sample is required. However, this method does not conform the ASTM specifications.

- Repeat this operation at intervals not greater than 5 feet in homogeneous strata, or as specified in the sampling plan.

- Record the number of blows required to effect each 6 inches of penetration or fraction thereof. The first 6 inches is considered to be seating drive. The sum of the number of blows required for the second and third 6 inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last 1 foot penetrated.

- Bring the sampler to the surface and remove both ends and one half of the split barrel so that the soil recovered rests in the remaining half of the barrel. Describe carefully the sample interval, recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil then put a representative portion of each sample into a jar, without ramming. Jars with samples not taken for chemical analysis shall be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture, if the sample is to be later evaluated for moisture content. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms. Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area. Pertinent data which shall be noted on the label or written on the jar lid for each sample includes the project number, boring number, sample number, depth interval, blow counts, and date of sampling.

- An addition to the sampler mentioned above is an internal liner, which is split longitudinally and has a thin-wall brass, steel, or paper liner inserted inside, which will preserve the sample. However, since the development of the thin-walled samplers (mentioned below) the split barrel sampler with liner has declined in use.

5.1.3 Thin Walled Tube (Shelby Tube) Sampling (ASTM D1587-83)

When it is desired to take undisturbed samples of soil, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method will be used:

- Clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated materials, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and maintain the water level in the hole at or above groundwater level.

- The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.

- A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the sampling rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

- To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they are more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at the groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.

- Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape in the caps place, and dip the ends in wax.

- Affix labels to the tubes as required and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms. Do not allow tubes to freeze and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Denison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and therefore their use shall be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt shall be made with a split barrel sampler at the same depth so that at least a sample can be obtained for classification purposes.

5.1.4 Continuous Core Soil Samples

The CME continuous sample tube system provides a method of sampling soil continuously during hollow stem augering. The 5-foot sample barrel fits within the lead auger of a hollow auger column. The samping system can be used with a wide range of I.D. hollow stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailigs, etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required.

5.2 SURFACE SOIL SAMPLES

For loosely packed earth or waste pile samples, stainless steel scoops or trowels can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

- Use a soil auger for deep samples (6 to 24 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collection of soil. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site.
- Use a new or freshly-decontaminated sampler for each sample taken. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, Chain-of-Custody record, and other required forms.
- Pack and ship accordingly.
- When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles shall be full) shall be placed in a decontaminated stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected.

5.3 WASTE PILE SAMPLES

The use of stainless steel scoops or trowels to obtain small discrete samples of homogeneous waste piles is usually sufficient for most conditions. Layered (nonhomogeneous) piles require the use of tube samplers to obtain cross-sectional samples.

- Collect small, equal portions of the waste from several points around the pile, penetrating it as far as practical. Use numbered stakes, if possible, to mark the sampling locations and locate sampling points on the site sketch.

- Place the waste sample in a glass container. Attach a label and identification tag. Record all the required information in the field logbook and on the sample log sheet and other required forms.

For layered, nonhomogeneous piles, grain samplers, sampling triers, or waste pile samplers must be used at several representative locations to acquire a cross-section of the pile. The basic steps to obtain each sample are

- Insert a sampler into the pile at a 0- to 45-degree angle from the horizontal to minimize spillage.

- Rotate the sampler once or twice to cut a core of waste material. Rotate the grain sampler inner tube to the open position and then shake the sampler a few times to allow the material to enter the open slits. Move the sampler into position with slots upward (grain sampler closed) and slowly withdraw from the pile.

5.4 ROCK SAMPLING (CORING) (ASTM D2113-83)

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. It can, however, proceed for thousands of feet continuously, depending on the size of the drill rig. It yields better quality data than air rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average output in a 10-hour day ranges from 40 to over 200 feet. Downhole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Attachment No. 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross contamination of aquifers.

ATTACHMENT 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring bit size	Nominal *		Set size *	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	.735
EWT	1 1/2	29/32	1.470	.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.890	3.187
HWG	3 29/32	3	3.890	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line ⊥/	1 7/8	1	1.875	1.000
BX Wire line ⊥/	2 3/8	1 7/16	2.345	1.437
NX Wire line ⊥/	3	1 15/16	2.965	1.937

* All dimensions are in inches; to convert to millimeters, multiply by 254.

⊥/ Wire line dimensions and designations may very according to manufacturer.

ATTACHMENT 1
PAGE TWO

Size Designations			Casing coupling					Approximate core diameter	
Casing; Casing coupling; Casing bits, Core barrel bits	Rod; Rod couplings	Casing O.D., inches	O.D., inches	I.D., inches	Casing bit, O.D., inches	Core barrel bit O.D., inches*	Drill rod O.D., inches	Normal, inches	Thinwall, inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	—	.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	.845	.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush joint	No coupling	1.485	1.160	1.094	—	.735
EW	EW	1.812			1.875	1.470	1.375	.845	.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	—	5.500			5.650	—	—	—	—
SW	—	6.625			6.790	—	—	—	—
UW	—	7.625			7.800	—	—	—	—
ZW	—	8.625			8.810	—	—	—	—
—	AX 1/	—	—	—	—	1.875	1.750	1.000	—
—	BX 1/	—	—	—	—	2.345	2.250	1.437	—
—	NX 1/	—	—	—	—	2.965	2.813	1.937	—

* For hole diameter approximation, assume 1/16 inch larger than core barrel bit.

1/ Wire line size designation, drill rod only, serves as both casing and drill rod. Wire line core bit, and core diameters vary slightly according to manufacturer.

NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES. (DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889.

Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

5.4.1 Diamond Core Drilling

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split spoon sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used.

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross contamination of aquifers in the unconsolidated materials is unlikely, it may be omitted.

- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole, and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equpment is the most commonly used size.

- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split Barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling) for Sampling of Soils (see Section 5.1.1 and 5.1.2). Resume diamond core drilling when refusal materials are again encountered.

- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as the conditions warrant.

- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.4.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in Procedure GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Site Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box (see Attachment 2). The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

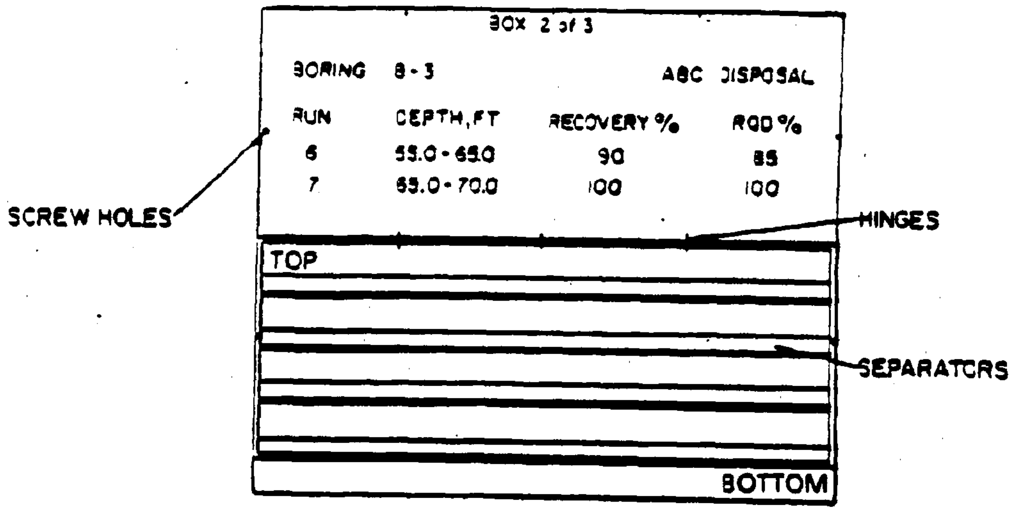
The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name
- Project number
- Boring number
- Run numbers
- Footage (depths)
- Recovery
- RQD (%)
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

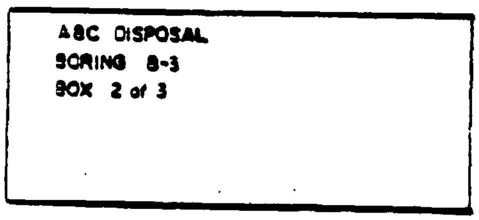
For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number. Attachment No. 2 illustrates a typical rock core box.

Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

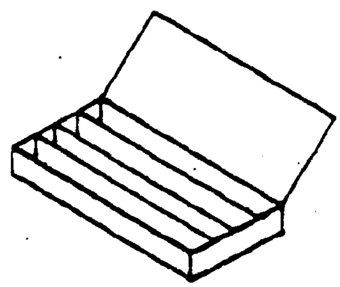
ATTACHMENT 2

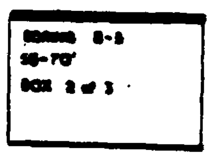


CORE BOX (OBLIQUE VIEW)



CORE BOX (TOP VIEW)





CORE BOX (END VIEW)

TYPICAL ROCK CORE BOX

NOT TO SCALE

NUS CORPORATION
A Halliburton Company

6.0 REFERENCES

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U.S. Department of the Interior, 1974, Earth Manual, A Water Resources Technical Publication, 810 pages.

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7.0 RECORDS

None.

NUS CORPORATION

ENVIRONMENTAL MANAGEMENT GROUP

STANDARD OPERATING PROCEDURES

Number	GH-1.4
Page	1 of 20
Effective Date	05/04/90
Revision	1
Applicability	EMG
Prepared	Earth Sciences
Approved	D. Senovich

Subject: SOIL AND ROCK DRILLING METHODS

TABLE OF CONTENTS

SECTION

1.0 PURPOSE

The purpose of this procedure is to describe the methods, the sequence of operations and the equipment necessary to perform soil and rock borings.

2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

3.0 GLOSSARY

Boulders - Rounded, semi-rounded or naturally angular particles of rock larger than 12 inches in diameter.

Clay - Fine grained soil or portions of soil having certain physical properties, composition and texture. Clay exhibits plastic properties within a range of water contents and exhibits considerable strength when air dried. Clay consists usually of fragments of hydrous aluminum or magnesium silicate minerals, and it consists predominantly of grains with diameters of less than 0.005 mm.

Cobbles - Rounded, semi-rounded or naturally angular particles of rock between 3 inches and 12 inches in diameter.

Gravel - Rounded or semirounded particles of rock that will pass a 3 inch sieve (7.62 cm) and be retained on a No. 4 U.S. standard sieve (4.76 mm). Coarse gravel is larger than 3/4-inches, while fine gravel is finer than 3/4-inches.

Stone - Crushed or naturally angular particles of rock that will pass a 3 inch sieve (7.62 cm) and be retained on a No. 4 U.S. standard sieve (4.76 mm).

Rock - Any consolidated or coherent and relatively hard, naturally formed mass of mineral matter.

Sand - Particles of rock that will pass a No. 4 U.S. standard sieve (4.76 mm) and be retained on a No. 200 U.S. standard sieve (0.074 mm). Coarse sand is larger than a No. 10 sieve, and fine sand is finer than a No. 40 sieve (0.42 mm).

Silt - Material passing the No. 200 U.S. standard sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air dried.

Soil - Sediments or other unconsolidated accumulations of solid particles that are produced by the physical and chemical disintegration of rock and that may contain organic matter.

Undisturbed Sample - A soil sample that has been obtained by methods in which every precaution has been taken to minimize disturbance to the sample.

Water Table - A surface in an aquifer where groundwater pressure is equal to atmospheric pressure.

4.0 RESPONSIBILITIES

Site Manager - In consultation with the project geologist, responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. He should also determine the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Site Geologist/Rig Geologist - Responsible for insuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see Attachment A of Procedure GH-1.7). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan.

Field Operations Leader - Responsible for overall supervision and scheduling of drilling activities.

Drilling Subcontractor - Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the Field Operations Leader within 24 hours, and must provide advance written notification for any changes in field procedures describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the Field Operations Leader.

The drilling subcontractor will be responsible for following decontamination procedures specified in the Work Plan. Upon completion of the work, the Drilling Subcontractor will be responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 GENERAL

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site, and
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned using appropriate decontamination procedures (see Procedure GH-1.6 and SF-2.3) between samples and borings. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see Procedure GH-1.5) unless the FSAP specifically states that logging is not required. Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 DRILLING METHODS

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, purpose of drilling, waste conditions at the site, and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of screwing augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole. However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations will require the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.
- No drilling fluids are required.
- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.
- The inside diameter of hollow stem augers used for well installation should be at least four inches greater than the well casing. Use of such large diameter hollow stem augers is more expensive than the use of small diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.
- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.
- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet. Hollow stem auger drilling is the preferred method of drilling. Most alternative

methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods great care must be taken to ensure that the method does not interfere with the collection of a representative sample which is the object of the construction. With this in mind, the preferred order of choice of drilling method after hollow stem augering (HSA) is:

- Cable tool
- Casing drive (air)
- Air rotary
- Mud rotary
- Drive and wash
- Jetting

However, the use of any method will also depend on efficiency and cost-effectiveness. In many cases, mud rotary is the only feasible alternative to hollow stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The hollow stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

When taking soil samples for chemical analysis, the hollow-stem auger shall be plugged until the desired sampling depth is reached. Samples can be taken using split-spoon or thin wall tube samplers driven into the formation in advance of the auger (see Procedure GH-1.3). If the sample is to be taken at a relatively deep point, the auger may be advanced without a plug to within five feet of the sample depth. Then clean out the auger stem, insert a plug and continue to the sampling depth. The plug is then removed and samples taken as specified by the rig geologist. Samples should be taken according to the specifications of the sampling plan. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. The sequence shall be repeated for each sample desired.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation.

When drilling below the water table, specially-designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see GH-1.7 for Well Development Procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

At the option of the Field Operations Leader, when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations it may be prudent to also grout borings which only penetrate the water table aquifer, since loose soil backfill in the boring would still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This method is similar to hollow-stem augering. Practical application of this method is severely restricted as compared with hollow stem augers. Split barrel (split-spoon) sampling cannot be done without pulling the augers which may allow the hole to collapse. The method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable as in the case of the hollow stem auger, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to remain open after the augers are withdrawn. Alternatively, the technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.2.3 Rotary Drilling

Direct rotary drilling includes air-rotary and fluid-rotary drilling. Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injec d to keep down dust).
- The borehole diameter is large, to allow room for prop well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.

- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.

- In-situ samples cannot be taken, unless the hole is cased.

- Casing must generally be used in unconsolidated materials.

- Air rotary drill rigs are large and heavy.

A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air-rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split barrel (split-spoon) or thin-wall tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow stem auger method if split barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This will require either constant replenishment of the drilling fluid, or the use of casing through this formation.
- Drill rigs are large and heavy, and must be supported with supplied water.
- Ground water samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and ram range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Soil samples shall be taken as specified by the Work Plan or more frequently if requested by the field geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the site geologist.

5.2.4 Reverse Circulation Rotary Drilling

The common reverse-circulation rig is a water or mud rotary rig with a large diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water-quality sampling wells because of the use of drilling muds and the large diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air rotary rig.

Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.2.5 Drill-through Casing Driver

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig or an air hammer and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage). A continuous record is kept of the blows per foot in driving the casing (see Procedure GH-1.5). The casing is normally advanced by a 300-pound hammer falling freely through a height of 30-inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations between which water is used in driving the casing should be recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least four inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).
- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

5.2.6 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water need be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilit:es and rough water quality data from different zones penetrated can be obtained by skille operators.

- The cable-tool rig ca erate satisfactorily in all formations, but is best suited for caving, boulder, c or coa avel type formations (e.g., glacial till) or formations with large cavities abo. ne wat le (such as limestones).

- When casing is used, casing seals formation water out of the hole, preventing down-hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.

- Split barrel (split spoon) or thin-wall tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.

- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.

- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required, such as use of a hollow stem auger.

- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

5.2.7 Jet Drilling (Washing)

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2 to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch diameter casing in shallow, unconsolidated sand formations but has been used to install 3- to 4-inch diameter casings to 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.
- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.
- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.
- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.
- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.
- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).
- Large quantities of water are often needed.

5.2.8 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the Work Plan. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). This technique is slow but effective where larger pieces of equipment do not have access and where very shallow holes are desired (less than 5 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.9 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond studded bit attached to the outer core barrel in a double tube core barrel. The use of single tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation to this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the Work Plan. The most common core barrel diameters are listed in Attachment A. Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole, causing unsatisfactory coring, the hole should be reamed and a flush joint casing installed to a point below the broken formation. The size of the flush joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).

- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

5.2.10 **Drilling & Support Vehicles.**

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment, and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain, to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand-carried to the borehole site. Drilling/sampling methods used with such equipment include:
  - Hand augers and lightweight motorized augers
  - Retractable plug samplers-driven by hand (hammer)
  - Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small diameter cased borings. This rig is sometimes called a "monkey on a stick."
- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.
- Small truck-mounted drilling equipment uses a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.
- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.
- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided

with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.

- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles includes:

  - Barrel float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallc drums or similar flotation units.

  - Barge-mounted drill rigs.

  - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.

  - Drill ships - for deep ocean drilling.

In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

5.2.11 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8" or 7-7/8" bits will nominally drill 6" and 8" holes, respectively).

For obtaining split-barrel samples of a formation, samplers are manufactured in sizes ranging from 2-inches to 4-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used, and driven by a 140-pound (± 2 pound) hammer dropping 30-inches (± 1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the Work Plan.

5.2.12 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30' to 50') boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud Rotary Drilling	100' (cuttings samples)
Reverse Circulation Rotary	100' (cuttings samples)
Skid Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

5.3 PREVENTION OF CROSS-CONTAMINATION

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe, (a method similar to the rock coring method described in Section 5.2.9, except that larger casing is used) or a driven-casing method (see Section 5.2.5 of this guideline), and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing usually of 8-inch diameter is installed followed by installation of the well casing (6-inch diameter is common for 2-inch wells). This well casing is driven into the confining layer to insure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end is installed to the surface.

Clean sand is placed in the annulus around and to a point about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

5.4 CLEANOUT OF CASING PRIOR TO SAMPLING

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward directed jet which will disturb the underlying soil. When clean-out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split barrel (split-spoon) sampler with the ball check valve removed as the clean out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the cleanout auger, a split-barrel sample can be taken to remove it. Bailers and sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions on the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.

- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.

- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string; then to measure the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches for cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

5.5 MATERIALS OF CONSTRUCTION

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in FT-7.01. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods are procedures for their use must be provided by the site geologist and approved by the site manager. The specific slurry composition and the concentration of selected chemicals for each site must be known.

For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field at the judgment of the site geologist and noted in the Site Logbook, and only after approval by the site manager, a vegetable oil or silicone based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

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7.0 ATTACHMENTS

Attachment A - Drilling Equipment Sizes

ATTACHMENT A

DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (in)	O.D. (in)	I.D. (in)	Coupling I.D. (in)
Hollow-Stem Augers (Ref 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	-
	7 1/4	6 1/4	3 1/4	-
	13 1/4	12	6	-
Thin Wall Tube Samplers (Ref 7)	-	2	1 7/8	-
	-	2 1/2	2 3/8	-
	-	3	2 7/8	-
	-	3 1/2	3 3/8	-
	-	4 1/2	4 3/8	-
	-	5	4 3/4	-
Drill Rods (Ref 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (in)
Driven External Coupled Extra Strong Steel* Casing (Ref 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

ATTACHMENT A

DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (in)	O.D. (in)	I.D (in)	Coupling I.D. (in)
Flush Coupled Casing (Ref 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref 7)	EWM	1 1/2	7/8 **	
	AWM	1 7/8	1 1/8 **	
	BWM	2 3/8	1 5/8 **	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 X 3 7/8	3 7/8	2 11/16	
	4 X 5 1/2	5 1/2	3 15/16	
	6 X 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16 **	
	BQ (wireline)	2 23/64	1 7/16 **	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small diameter core (1 3/8") is not recommended.

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		Prepared Earth Sciences	
Subject BOREHOLE AND SAMPLE LOGGING		Approved D. Senovich	

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist - Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used onsite the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 MATERIALS NEEDED

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute HCl
- Ruler (marked in tenths and hundreths of feet)
- Hand Lens

5.2 CLASSIFICATION OF SOILS

All data shall be written directly on the boring log (Exhibit 4-1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Exhibit 4-2. This method of classification identifies soil types on the basis of grain size and cohesiveness.

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

Coarse grained soils shall be divided into rock fragments, sand, or gravel. The terms and sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as (1/4 inch⌀-1/2 inch⌀)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

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

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

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.2. Those designations are:

Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140 pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, and SC (see Exhibit 4-2).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Exhibit 4-3. Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Exhibit 4-2).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength) or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are as follows:

Consistency	Unc. Compressive Str. Tons/Square Foot	Standard Penetration Resistance (Blows per Foot)	Field Identification Methods
Very soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb
Medium stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb
Very stiff	1.0 to 2.0	8 to 15	Readily indented by thumb
Hard	2.0 to 4.0	15 to 30	Readily indented by thumbnail
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail

5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
trace	0 - 10 percent
some	11 - 30 percent
and or adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Exhibit 4-4.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

5.3 CLASSIFICATION OF ROCKS

Rocks are grouped into three main divisions, including sedimentary, igneous and metamorphic rocks. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.

- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. ractures irregularly. Medium thick to thick bedded.

- Claystone - Vary fine grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.

- Shale - A fissile very fine grained rock. Fractures along bedding planes.

- Limestone - Rock made up predominantly of calcite ($CaCO_3$). Effervesces strongly upon the application of dilute hydrochloric acid

- Coal - Rock consisting mainly of organic remains.

- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. These include conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

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

5.3.1 Rock Type

As described above, there are numerous names of sedimentary rocks. In most cases a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Exhibit 4-5 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a handlens, the rock is a siltstone. If the grains are not distinguishable with a handlens, the rock is a claystone.

5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock Color Charts shall not be used unless specified by the project manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification will also be used for rock classification.

5.3.4 Hardness

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

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the works "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

5.3.5 Fracturing

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

- Very broken (V. BR.) - Less than 2 in. spacing between fractures
- Broken (BR.) - 2 in. to 1 ft. spacing between fractures
- Blocky (BL.) - 1 to 3 ft. spacing between fractures
- Massive (M.) - 3 to 10 ft. spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

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

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

l = Total length of the coring run.

5.3.6 Weathering

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

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.

- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.

- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified)
- Description of any filled cavities or vugs.
- Cementation (calcoreous, siliceous, hematitic)

- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inch or less), probably continuous layer.

- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."

- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."

- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."

- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.

- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.

- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.

- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.

- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse grained dark igneous rock.

The following are some basic names that are applied to metamorphic rocks:

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

5.4 ABBREVIATIONS

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine grained
Tr - Trace		

5.5 BORING LOGS AND DOCUMENTATION

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceeding sections shall be used to complete the logs. A sample boring log has been provided as Exhibit 4-6. The field geologist/engineer shall use this example as a guide in completing each borings log. Each boring log shall be fully described by the geologist/engineer <u>as the boring is being drilled</u>. Every sheet contains space for 25 feet of log. Information regarding classification details is provided on the back of the boring log, for field use.

5.5.1 <u>Soil Classification</u>

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology à 13.7 feet, shall be lined off at the proportional location between the 13 and 14 foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.

- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.

- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.

- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart of back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.

- Enter color of the material in the appropriate column.

- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:

  - Trace 0 - 10 percent
  - Some 11 - 30 percent
  - And 31 - 50 percent

- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.

- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.

- The following information shall be entered under the Remarks Column and shall include, but is not limited by the following:

  - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

  - Angularity - describe angularity of coarse grained particles using Angular, Subangular, Subrounded, Rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.

  - Particle shape - flat, elongated, or flat and elongated.

  - Maximum particle size or dimension.

  - Water level observations.

  - Reaction with HCl - none, weak or strong.

- Additional comments:

  - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.

  - Indicate odor and HNu or OVA reading if applicable.

  - Indicate any change in lithology by drawing in line through the lithology change column and indicate the depth. This will help later on when cross-sections are constructed.

  - At the bottom of the page indicate type of rig, drilling method, hammer size and drop and any other useful information (i.e., borehole size, casing set, changes in drilling method).

  - Vertical lines shall be drawn (as shown in Exhibit 4.6) in columns 5 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.

  - Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 <u>Rock Classification</u>

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent and core recovery under the appropriate columns.

- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.

- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.

- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.

- Enter brokeness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.

- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
  - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
  - Indicate calcareous zones, description of any cavities or vugs.
  - Indicate any loss or gain of drill water.
  - Indicate drop of drill tools or change in color of drill water.

- Remarks at the bottom of Boring Log shall include:
  - Type and size of core obtained.
  - Depth casing was set.
  - Type of Rig used.

- As a final check the boring log shall include the following:
  - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
  - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 <u>Classification of Soil and Rock from Drill Cuttings</u>

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5 foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date etc.). Cuttings shall be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.

- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.

- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.

- Record this and any other useful information onto the boring log as provided in Exhibit 4-1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 REVIEW

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs
- Checking for conformance to the guideline
- Checking to see that all information is entered in their respective columns and spaces

6.0 REFERENCES

Unified Soil Classification System (USCS)

ASTM D2488, 1985

Earth Manual, U.S. Department of the Interior, 1974

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.

Subject	Number	Page
BOREHOLE AND SAMPLE LOGGING	GH-1.5	15 of 26
	Revision 2	Effective Date 05/04/90

EXHIBIT 4-1

BORING LOG ***NUS CORPORATION***

PROJECT: .... BORING NO.: ....
PROJECT NO.: .... DATE: .... DRILLER: ....
ELEVATION: .... FIELD GEOLOGIST: ....
WATER LEVEL DATA: ....
(Date, Time & Conditions) ....

SAMPLE NO. & TYPE OR RQD	DEPTH (Ft.) OR RUN NO.	BLOWS/ 6" OR RQD (%)	SAMPLE RECOVERY/ SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/Ft.) OR SCREENED INTERVAL	MATERIAL DESCRIPTION: SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS

REMARKS ______________________________________

BORING ________

PAGE ____ OF ____

D334901

EXHIBIT 4-2

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)

COARSE GRAINED SOILS — More than half of material is LARGER than No. 200 sieve size

		FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3" & basing fractions on estimated weights)	GROUP SYMBOL	TYPICAL NAMES
GRAVELS 50% (+) > 1/4" Ø	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel sand mixtures, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
	GRAVELS W/FINES (Appreciable amt. of fines)	Non plastic fines (for identification procedures see ML).	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
		Plastic fines (for identification procedures see CL).	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
SANDS 50% (+) < 1/4" Ø	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
	SANDS W/FINES (Appreciable amt. of fines)	Non plastic fines (for identification procedures see ML).	SM	Silty sands, poorly graded sand-silt mixtures.
		Plastic fines (for identification procedures see CL).	SC	Clayey sands, poorly graded sand-clay mixtures.

FINE GRAINED SOILS — More than half of material is SMALLER than No. 200 sieve size

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3" & basing fractions on estimated weights) — Identification procedures on fraction smaller than No. 40 sieve size

	DRY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)	GROUP SYMBOL	TYPICAL NAMES
SILTS & CLAYS Liquid limit < 50	None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity
	Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity
SILTS & CLAYS Liquid limit > 50	Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays
	Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other organic soils

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.
All sieve sizes on this chart are U.S. standard.

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE - BLOWS/FOOT
Very loose	0-4
Loose	5-10
Medium dense	11-30
Dense	31-50
Very dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC. COMPRESSIVE STR. TONS/SQ. FT.	STANDARD PENETRATION RESISTANCE - BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb
Medium stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb
Very stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)

DESCRIPTIVE TERMS	SCREWDRIVER OR KNIFE EFFECTS	HAMMER EFFECTS
Soft	Easily gouged	Crushes when pressed with hammer
Medium soft	Can be gouged	Breaks (one blow) Crumbly edges
Medium hard	Can be scratched	Breaks (one blow) Sharp edges
Hard	Cannot be scratched	Breaks conchoidally (several blows) Sharp edges

ROCK BROKENNESS

DESCRIPTIVE TERMS	ABBREVIATION	SPACING
Very broken	(V. Br.)	0-2"
Broken	(Br.)	2"-1'
Blocky	(Bl.)	1'-3'
Massive	(M.)	3'-10'

LEGEND

SOIL SAMPLES - TYPES

S - 2" O.D. Split Barrel Sample
ST - 3" O.D. Undisturbed Sample
O - Other Samples, Specify in Remarks

ROCK SAMPLES - TYPES

A - NX (Conventional) Core (~2-1/8" O.D.)
Q - NQ (Wireline) Core (~1-7/8" O.D.)
Z - Other Core Sizes, Specify in Remarks

WATER LEVELS

12/18 ▽ 12:15 Initial Level w/Date & Depth
12/18 ▼ 12:15 Stabilized Level w/Date & Depth

EXHIBIT 4-3

CONSISTENCY FOR COHESIVE SOILS

Consistency	(Blows per Foot)	Unconfined Compressive Strength (tons/square foot by pocket penetration	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented by thumbnail

EXHIBIT 4-4

BEDDING THICKNESS CLASSIFICATION

Thickness (Metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

EXHIBIT 4-5

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4-64 mm
Granules	2-4 mm
Very Coarse Sand	1-2 mm
Coarse Sand	0.5-1 mm
Medium Sand	0.25-0.5 mm
Fine Sand	0.125-0.25 mm
Very Fine Sand	0.0625-0.125 mm
Silt	0.0039-0.0625 mm

After Wentworth, 1922

BORING LOG — **NUS CORPORATION**

PROJECT: HEBELKA SITE — BORING NO.: MW 3A
PROJECT NO.: 619Y — DATE: 9-21-87 — DRILLER: B. GOLLIHUE
ELEVATION: 510.07 — FIELD GEOLOGIST: SJ CONTI
WATER LEVEL DATA (Date, Time & Conditions): WL 26.35 - TPVC 10-16-87

Sample No. & Type/ RQD	Depth (Ft.) / Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Int.	Soil Density/Consistency or Rock Hardness	Color	Material Classification	USCS	Remarks
S-1	0.0 / 1.5	3 / 6 / 6	1.5/1.5		STIFF	BRN	CLAYEY SILT - TR SHALE FRAG - TR ORG.	ML	0-6" TOPSOIL MOIST 0PPM RESIDUAL SOIL.
	5.0								
S-2	6.0	11 / 100/.5	0.8/1.0	5.5 / 6.0	M.SOFT TO M.HARD	GRAY BRN	DEC SHALE AND SILT	VBR	DAMP 0PPM REFUSAL @ 6' 5.5 TOP OF DEC ROCK AUGERED TO 15' W/SOLID STEM AUG. CUTTING MOIST @ ±8' WATER @ 11'± WL @ 12:10 PM WAS ± 9' FROM G.S. SET 4" PVC CAS. @ 15.0'
9-21 / 9-22	15.0								
0.2/10.0	①	0%/10	7.8/10.0		M.HARD	BRN GRAY	SILTY SHALE - FEW QUARTZ PCS	VBR	0 PPM SEVERAL Fe STAINED JOINTS ON CORE THRUOUT RUN. JOINTS AND BREAKS ARE HORIZ TO LO ∠. W/ VUGS ON LOWER PORTION 23 TO 25 OF CORE
	25.0								

REMARKS: ACKER AD II RIG - SOLID STEM AUGERS USED TO ADVANCE BORING - 140 LB WT & 30" DROP - TO TAKE 2" Φ SP. SPOON SAMPLES - SETUP OVER HOLE @ 11:10 AM. WILL SAMPLE THIS HOLE - SET 4" CASING THEN DO SHALLOW WELL. STARTED TO CORE 9-22-87 USING THE WIRE-LINE CORING METHOD.

* See Legend on Back

BORING MW 3A

PAGE 1 OF 3

BORING LOG — NUS CORPORATION

PROJECT: HEBELKA SITE — BORING NO.: MW 3A
PROJECT NO.: 619Y — DATE: 9-22-87 — DRILLER: B. GOLLIHUE
ELEVATION: — FIELD GEOLOGIST: SJ CONTI
WATER LEVEL DATA
(Date, Time & Conditions)

	Sample No. & Type / RQD	Depth (ft) / RUN	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth ft)	Material Description*: Soil Density/Consistency or Rock Hardness	Color	Material Classification	USCS	Remarks
9-22	▼	25.0		▼		M.HARD	GRAY	SILTY SHALE	VBR	SHALE IS VBR w/ HORIZ TO LO ∠ JNTS
						↓	↓	(SILTSTONE)	↓	≈26 TO 27 2 - VERT
								- FEW QUARTZ		JOINTS. IRON STAINS ON JNTS
								SEAMS		ROCK BECOMES AND BREAKS MORE LIKE
								↓		A SILTSTONE WITH DEPTH.
	0/10.0	②	0%	8.7/10.0					↓	
									BR	≈32 TO 33 FEW QUARTZ PIECES w/
									VBR	VUGS. SL. MICACEOUS
									↓	VF QUARTZ GRAINS IN MATRIX - 30X MAG.
	◆	35.0		◆		↓	↓	↓	↓	≈34 TO 35 · 2 VERT JOINTS
						M.HARD	GRAY	SILTY SHALE (SILTSTONE)	VBR	35.0-35.5 QUARTZ PIECES
						↓	↓	- FEW QUARTZ	BR	
								SEAMS	VBR	BECOMES SL. CALCAR. @ 37± THIN CALCITE
								↓	↓	LAMINATIONS. WATER STAINED JNTS
									BR	THRUOUT RUN MORE SO 35-37±
	1.0/10.0	③	10%	4.3/10.0					VBR	39.5 → 42.0
									↓	42.7 → 43.0 HI ∠ JNT
									BR	42.4 → 42.7 VERT JNT
									↓	
	◆	45.0		◆					VBR	
									↓	45.3 → 45.5 VERT JNT. & VBR
									↓	47.5 VERT JOINT
									BR	48. HI ∠ JOINT
									↓	SLIGHTLY CALCAREOUS MORE CALCITE
						↓	↓	↓	↓	PRESENT

REMARKS ______

BORING MW 3A

PAGE 2 OF 3

* See Legend on Back

BORING LOG — **NUS CORPORATION**

PROJECT HEBELKA SITE — BORING NO MW3A
PROJECT NO 619Y — DATE 9-22-87 — DRILLER B. GOLLHUE
ELEVATION — FIELD GEOLOGIST SJ CONTI
WATER LEVEL DATA
(Date, Time & Conditions)

Sample No & Type	Depth (ft)	Blows 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth ft)	Soil Density Consistency or Rock Hardness	Color	Material Classification	USCS	Remarks
1.9/10.0	④	19%/0	10.0/10.0		M.HARD	GRAY	SILTY SHALE (SILTSTONE)	VBR	50.5 → 51.0 VBR
							SL. CALCAREOUS	BR	51.5 → 54.0 BR w/ SEV LO & JOINTS
	55.0								
								VBR	POOR RECOVERY w/ SOFT ZONES.
0/10	⑤	0%/0	1.8/10.0						
	65.0								
				66					
									68.0 - DRILLER NOTED SOFT AREA - LOSS OF 1/3 OF WATER - CHANGE IN COLOR OF DRILL WATER TO YELLOW BROWN
0/0	⑥	0%/0	1.5/10.0						
									POOR RECOVERY
									FEW CALCAREOUS ZONES.
	75.0			76					

REMARKS AT 75' @ 1:45 PM - PULLING TOOLS - TO REAM HOLE.
AT 1:50 PM CORED HOLE TO 75' REAMED TWICE
DUE TO RUNNING SAND (FRACTURE) AT ? GR. REAMED
2ND TIME TO 81'. SET WELL 66-76'.

BORING MW3A
PAGE 3 OF 3

* See Legend on Back

0334901

NYSDEC 031068

EXHIBIT 4-6

BORING LOG — **NUS CORPORATION**

PROJECT: WESTLINE SITE — BORING NO: MW 013
PROJECT NO: 473Y — DATE: 7-7-87 — DRILLER: B ERICSON
ELEVATION: 1462.37 — FIELD GEOLOGIST: SJ CONTI — PENN - DRILL
WATER LEVEL DATA: 5.54' @ 8:50 AM 7-23-87 T-PVC — ACKER AD-II
(Date, Time & Conditions)

Sample No & Type or RQD	Depth (Ft) or Run No	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft) or Screen Int	Soil Density Consistency or Rock Hardness	Color	Material Classification	USCS	Remarks (HNU) HEAD SP
	0.0	5 / 3	1.4/1.5		Loose	BLK BRN	CLAYEY SILT AND CINDER	ML	MOIST (OPPM)
S-1		2			↓	↓	TR. COAL FELS	↓	3/4" Ø FRAG- NEAR OLD RR. LINE.
							TR. CC FRAG		
							(FILL)		
	5.0				↓	RED	↓	↓	
S-2		1 / 1	1.3/1.5	6.0	V. LOOSE	BRN TO GRAY	SANDY SILT - TR ORG TO	SM	MOIST TO WET (OPPM)
	6.5	3					SILTY SAND - TR GRAVEL		GRAY SAND @ 6' ± NICKELOUS LOOK NOTICED
									DRILLER NOTE H2O 8-10'
	10.0				↓	↓	↓	↓	
S-3		11 / 23	1.2/1.5		DENSE	BRN	SILTY SAND AND S.S.	GM	WET (OPPM)
	11.5	27					FRAGS. (GRAV)		1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUNDED GRAVEL
	15.0				↓	↓	↓	↓	
S-4		7 / 47	1.0/1.5		V. DENSE	BRN	SILTY FINE TO C. SAND	GM	WET (OPPM)
	16.5	43					AND GRAVEL		1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUNDED GRAVEL
	20.0				↓	↓	↓	↓	
S-5	20.9	17 / 50/.4	.4/.9		V. DENSE	ORANG BRN	SILTY SAND - SOME	GM	WET (OPPM)
							GRAVEL AND		MOIST
							S.S FRAGS		BECOMES MORE LIKE SANDY SILT AT BOTM OF SAMPLE
					↓	↓	↓	↓	

REMARKS: STARTED 1:15 PM - 7-7-87 USING 4 1/4" ID HOLLOW STEMS
S-4 @ 3:30 PM - TO ADVANCE THE BORING USING
S-5 @ 4:30 PM ACKER DRILL - MOUNTED ON
FORD 8000 TRUCK
SAMPLES TAKEN
USING 140 lb WT AND 30 INCH DROP.

BORING: MW 013
PAGE 1 OF 4

BORING LOG — **NUS CORPORATION**

PROJECT: WESTLINE SITE
BORING NO.: MW013
PROJECT NO.: 473Y
DATE: 7-7-87
DRILLER: [illegible] ERICSON
ELEVATION:
FIELD GEOLOGIST: SJ CONTI
WATER LEVEL DATA
(Date, Time & Conditions)

	SAMPLE NO. & TYPE OR RQD	DEPTH (Ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/Ft.) OR SCREEN INT.	MATERIAL DESCRIPTION: SOIL DENSITY/CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS (HNU)
	S-6	25.0	6 / 17	1.1/1.5		DENSE	OLIVE BLUE	SILTY SAND - SOME	GM	WET 0 PPM
		26.5	30			↓	GRAY	GRAVEL - TR CLAY	↓	S.S. IS FRIABLE FIRST CHANGE IN
								TR. SS FRAG		COLOR. NOT ENOUGH CLAY TO BE CONFINING
								↓		NOTES: MAY SET ZONE 2
7/7		30.0				↓	MOTTLED	↓	↓	CASING ≈ 28'
7/8	S-7		17 / 27	1.4/1.5		V. DENSE	[illegible] BLUE	SILTY SAND - SOME GRAVEL	SM/	MOIST → WET (0 PPM)
		31.5	36			↓	[illegible]	[illegible]	GM	[illegible] BLUE
								TR CLAY		GRAY; FRIABLE. [illegible]
										NOT [illegible] CLAY - BUT MAY BE SEMI-CON-
		35.0				↓	↓	↓	↓	FINING.
	S-8	35.3	30 / 50/0.3	0.7/0.9		V. DENSE	BLUE GRAY	SILTY F TO C SAND -	SM/	MOIST → WET (0 PPM)
								SOME GRAVEL	GM	V. SL. TR. CLAY - LESS
								TR. SS FRAG.		THAN S-7 [illegible] FRAG. - MORE
										[illegible] THAN ABOVE.
		40.0				↓	BLUE	↓	↓	POSSIBLE 35 TO 45 SCREEN LOC. SQUEEZED
	S-9		31 / 34	1.2/1.5		V. DENSE	GRN GRAY	SILTY SAND (FINE TO M.)	SM	HOLDS [illegible] WHEN MOIST → WET (0 PPM)
		41.5	24					SOME GRAVEL - TR	/GM	LITTLE MORE CLAY THAN
								CLAY		S-8 SUBROUNDED GRAVEL
										VERY SLOW DRILLING 40-45 (RIG STALLS)
		45.0				↓	BLUE	↓	↓	LESS CLAY LAST 3" OF SAMPLE.
	S-10		18 / 35	1.2/1.5		V. DENSE	GRN GRAY	SILTY SAND (FINE TO M.)	SM	MOIST → WET (0 PPM)
		46.5	50					SOME GRAVEL - TR	/GM	1" Ø SIZE - HOLDS TO- GETHER WHEN SQUEEZED
								CLAY		BUT NOT COHESIVE CLASS- IFICATION
										[illegible] CONTINUING TO 50'
						↓	↓	↓	↓	

REMARKS: S-6 @ 4:40 PM
S-8 @ 8:36 AM 7-8-87
S-10 @ 10:40 AM S-11 @

BORING MW013

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BORING LOG — NUS CORPORATION

PROJECT: WESTLINE SITE   BORING NO.: MW-013
PROJECT NO.: 473Y   DATE: 7-8-87   DRILLER: B. ERICKSON
ELEVATION: FIELD GEOLOGIST: SJ COUTI
WATER LEVEL DATA:
(Date, Time & Conditions)

	Sample No. & Type or RQD	Depth (Ft.) or Run No.	Blows 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Int.	Soil Density / Consistency or Rock Hardness	Color	Material Classification	USCS	Remarks
	S-11	50.0	15 / 41	1.9/1.3		V. DENSE	MOTTLED BUFF	SILTY SAND - SOME GR.	SM	MOIST - (0PPM)
		51.3	50/.3				GRAY	TR CLAY	SM	MOTTLED W/ PCS OF BLACK COAL/LIGNITE
										MORE CLAY THAN ABOVE PORTIONS OF SAMPLE - COHESIVE [illegible]
		55.0			55.0					
	S-12		11 / 15 / 26	1.4/1.5		V. STIFF TO STIFF	GRAY ORANGE BRN	SANDY CLAY / CLAYEY SAND SOME GRAVEL	SC	MOIST → WET (0PPM) NOTE COLOR CHANGE ALSO - MORE CLAY THAN ANY SAMPLE - SUB-ROUNDED GRAINS FIRST COHESIVE TYPE CLASSIF.
		56.5								
		60.0	40							
	S-13	60.9	50/.4	0.9/0.9		V. DENSE	ORANGE BRN	SANDY CLAY / CLAYEY SAND - SOME GRAVEL	SC / GW	MOIST → WET (0PPM) NOT AS MUCH CLAY AS S-12 BUT VERY COMPACT. SUBROUNDED GRAINS SET CAS. @ 62'.
		65.0								
7/13	S-14	65.8	37 / 50/.3	0.7/0.8		V. DENSE	BRN ORANGE	SILTY SAND - SOME GR. AND ROCK FRAG - TR. CLAY	SM / GW	MOIST (0PPM) MORE CLAY TOWARDS TOP OF SAMPLE MAX 3/4" Ø SIZE
					68.0		YELLOW BRN			COLOR CHANGE AT 68' MORE SAND PER DRILLER - BOTM OF SEMI COHESIVE LAYER ?
		70.0								
7/14	S-15		35 / 38 / 41	1.0/1.5		V. DENSE	YELLOW BRN	CLAYEY SAND (F. TO C.) SOME GRAVEL - TR ROCK FRAG.	SC / GC	MOIST → WET (0PPM) 1" MAX GRAVEL. MORE GRAVEL @ 72' PER DRILLER
		71.5								

REMARKS: USING HOLLOW STEM TO ADVANCE BORING - WASHING OUT THRU AUGERS, WHEN NEEDED TO OBTAIN SAMPLE
S-12 @ 1:46 PM
S-13 @ 3:32 PM - LOGGED IN BY 3:47 PM
SET 6" Ø STEEL CASING TO 62' - WILL DRILL BELOW CASING AFTER GROUT SETS UP. S-14 @ 3:30 PM 7-13-87
S-15 @ 7:57 AM 7-14-87

BORING MW-013
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BORING LOG — **NUS CORPORATION**

PROJECT: WESTLINE SITE — BORING NO. MW013
PROJECT NO.: 437Y — DATE: 7-13-87 / 7-14-87 — DRILLER: B. ERICSON
ELEVATION: — FIELD GEOLOGIST: SJ. CONTI
WATER LEVEL DATA
(Date, Time & Conditions)

SAMPLE NO. & TYPE OR RQD	DEPTH (FT.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth ft.) OR SCR. INT.	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS (HNU)
S-16	75.0	28 / 50/ .5	0.9/1.0		V. DENSE	GRAY ORANG BRN	FINE TO C. CLAYEY SAND - SOME	SC	WET (0PPM)
	76.0						GRAVEL - TR		NOT AS MUCH CLAY AS S-15 - BOTM OF
							ROCK FRAG (S.S.)		SAMPLE BECOMES MORE SANDY
									MAX 1" ø RC.
	80.0								NO SAMPLE @ 80' - DECIDED TO GO TO 85'
	85.0	50/ .4	0.4/0.4		V. DENSE	GRAY ORANG BRN	SILTY F. TO C. SAND - SOME	GW	WET (0PPM)
S-17	85.4			85			GRAVEL - TR		SUBROUNDED GRAINS
							S.S. FRAG - TR		V. SL TR CLAY - WILL
							CLAY		SET SCREEN ≈ 75' TO 85' IN THIS BORING.
							BOTM OF HOLE		
							@ 85.0'		

REMARKS: S-17 @ 2:20 PM 7-14-87 - METHOD: BEGIN 6" CASING SPUN 4" ø - 5⅞" OD. ROLLING TO BOTM. USING WATER AS DRILLING FLUID

BORING MW 013

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Subject DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

TABLE OF CONTENTS

<u>SECTION</u>

1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the appropriate procedures to be followed when conducting decontamination activities of drilling equipment and monitoring well materials used during field investigations.

2.0 SCOPE

This procedure addresses only drilling equipment and monitoring well materials decontamination, and shall not be considered for use with chemical sampling and field analytical equipment decontamination.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for ensuring that project specific plans and the implementation of field investigations are in compliance with these procedures.

5.0 PROCEDURES

To insure that analytical chemical results are reflective of the actual concentrations present at sampling locations, various drilling equipment involved in field investigations must be properly decontaminated. This will minimize the potential for cross-contamination between sampling locations, and the transfer of contamination off site.

Prior to the initiation of a drilling program. all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental sample. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens.

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

In certain cases, due to budget constraints, such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. The location of the steam cleaning area shall be on site in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Rinsate samples of well casing and screens may be necessary if specifically required for a given site. If required, at least 1 percent, and no more than 5 percent of steam cleaned lengths of casing and screens combined shall be sampled.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

6.0 RECORDS

None.

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		Effective Date 05/04/90	Revision 1
		Applicability EMG	
		Prepared Earth Sciences	
Subject GROUNDWATER MONITORING POINT INSTALLATION		Approved D. Senovich	

TABLE OF CONTENTS

1.0 PURPOSE

This procedure describes methods for proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of permanent monitoring wells at hazardous waste sites. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be ascertained during the development of the investigation and any required permits which may have to be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is properly screened (if screening is necessary), cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface to which water in an aquifer would rise by hydrostatic pressure.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force to perform all phases of proper monitoring well installation and construction. He may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Rig Geologist - The rig geologist supervises well installation and construction by the Driller, documents all phases of well installation and construction, and insures that well construction is adequate to provide representative ground water data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

5.0 PROCEDURES

5.1 EQUIPMENT/ITEMS NEEDED

Below is a list of items that may be needed while installing a monitoring well.

- Health and safety equipment as required by the site safety officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineers tape, water level indicator, retractable engineers rule electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installations tools (Sledge Hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 WELL DESIGN

The objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials to be used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity)

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, these can be determined through the review of geologic data and the site terrain. In addition, production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary phase to determine groundwater flow direction.

5.2.1 <u>Well Depth, Diameter, and Monitored Interval</u>

The well depth, diameter, and monitored internal must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the levels at which contaminants are present. Conversly, a fully penetrating well is usually not used to quantify or vertically locate a contamination plume, since groundwater samples collected in wells that are screened over the full thickness of the water bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in water bearing zone. The well diameter would depend upon the hydraulic characteristics of the water bearing zone. Sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following information:

- The vertical location of the contaminant source in relation to the water bearing zone.
- The depth, thickness and uniformity of the water bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (1 to 2 feet) are usually required where flow lines are not horizontal, (ie., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs

Standard monitoring well diameters are 2, 4, 6, or 8 inches. However, drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open hole monitoring wells are required. In the smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced, however, the type of sampling devices that can be used are limited. In specifying well diameter, sampling requirements must be considered. Up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples. The water in the monitoring well available for sampling is dependent on the well diameter as follows:

Casing Inside Diameter, Inch	Standing Water Depth to Obtain 1 Gal Water (feet)	Total Depth of Standing Water for 4 Gal. (feet)
2	6.13	25
4	1.53	6
6	0.68	3

However, if a specific well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells; however, in small diameter wells.in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength" and Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation;-risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials in which the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC, galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive discussion on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed and are compared in Attachment B. Stainless steel is preferred where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, and ease of manipulation; however, there are also some questions about organic chemical sorption and leaching that are currently being researched (see Barcelona et al., 1983). Concern about the use of PVC can be minimized if PVC wells are used strictly for geohydrologic measurements and not for chemical sampling. The crushing strength of PVC may limit the depth of installation, but schedule 80 materials normally used for wells greater than 50 feet deep may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps to be used for sampling or testing. Due to this problem, the minimum well pipe size recommended for schedule 80 wells is 4 inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe, may corrode and release metal ions or chemically react with organic constituents, but this is considered by some to be less of a problem than the problem associated with PVC material. Galvanized steel is not recommended for metal analyses, as zinc and cadmium levels in groundwater samples may be elevated from the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints at slightly more costs. Welded-joint steel casing is also acceptable. Glued PVC may release organic contamination into the well and therefore should not be used if the well is to be sampled for organic contaminants.

When the water bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary and the screened interval is artificially packed with a fine sand. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The rig geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. (For example, as a standard procedure, a Morie No. 1 or Ottowa sand may be used with a 0.010-inch slot screen, however, with a 0.020-inch slot screen, the filter pack material must be the material retained on a No. 20 to No. 30 U.S. standard sieve.)

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a fine to medium grained well graded, silica sand. The quantity of sand placed in the annular space is dependent upon the length of the screened interval but should always extend at least 1 foot above the top of the screen. At least one to three feet of bentonite pellets or equivalent shall be placed above the sand pack. The cement-bentonite grout or equivalent extends from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally, i.e., no artificial sand pack will be installed, and the natural formation material will be allowed to collapse around the well screen after the well is installed. This method has been utilized where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging and to provide a better seal. However, in boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of two assemblages of material, i.e., a cement-bentonite grout. A cement bentonite grout normally is a mixture of cement, bentonite and water at a ratio of one 90-pound bag of Portland Type I cement, 3-5 pounds of granular or flake-type bentonite and 6 gallons of water.. A neat cement is made up of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets or equivalent. A short (1'-2') section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is often placed over the top for the well. This casing generally has a hinged cap and can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A Protective casing which is level with the ground surface is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter protective sleeve is set into the wet cement around the well with the top set level with the pavement. A manhole type lid placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 MONITORING WELL INSTALLATION

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineers rule to ensure proper well placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, then the sand pack can be installed. A weighted tape measure must be used during the procedure in order to carefully monitor installation progress. The sand is poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur.

After the sand pack is installed to the desired depth, (at least 1 foot above the top of the screen) then the bentonite pellet seal or equivalent, can be installed, in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack.

The cement-bentonite grout is then mixed and either poured or tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

In stable formations where borehole collapse does not occur, the well can be installed as discussed above, and the use of a temporary casing is not needed. However, centralizers may have to be installed, one above, and one below the screen, to assure enough annular space for sand pack placement. A typical overburden monitoring well sheet is shown.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large diameter boring through the upper aquifer, 1 to 3 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting the outer casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells, with the exception of not using a temporary casing during installation. Sufficient time which will be determined by the rig geologist, must be allowed for setting of the grout prior to drilling through the confined layer. A typical confining layer monitoring well sheet is shown in Attachment C.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 feet into the bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout is cured, a smaller diameter boring is continued through the bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. However, if a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be installed temporary until final well installation is completed. Typical well construction forms for bedrock monitoring wells are shown in Attachment C.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be driven to depths exceeding 10 feet.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only one or two small-diameter tubes extending to the surface. Manufacturers of these types of samplers claim that four samplers can be installed in a 3-inch diameter borehole. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross contamination from sampling equipment. These samplers also perform well when the water table is within 25 feet from the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of

Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each offers various construction materials.

Two additional types of multilevel sampling systems have been developed. Both employ individual screened openings through a small-diameter casing. One of these systems (marketed by Westbay Instruments Ltd. of Vancouver, British Columbia, Canada) uses a screened port and a sampling probe to obtain samples and head measurements or perform permeability tests. this system allows sampling ports at intervals as close as 5 feet, if desired, in boreholes from 3 to 4.8 inches in diameter.

The other system, developed at the University of Waterloo at Waterloo, Ontario, Canada, requires field assembly of the individual sampling ports and tubes that actuate a simple piston pump and force the samples to the surface. Where the depth to ground water is less than 25 feet, the piston pumps are not required. The assembly is made of easily obtained materials; however, the cost of labor to assemble these monitoring systems may not be cost-effective.

5.4 WELL DEVELOPMENT METHODS

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) that sufficient development is reached. The selection of the well development method (shall) be made by the rig geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

Overpumping and Backwashing - Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

Surging with a Surge Plunger - A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is used to agitate the water, causing it to move in and out of the screens. This movement of water rpulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

Compressed Air - Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping the well is subsequently done with the air lift method.

High Velocity Jetting - In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 REFERENCES

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Barcelona, M. J., P. P. Gibb and R. A. Miller, 1983. A Guide to the selection of Materials for Monitoring Well Construction and Groundwater Sampling. ISWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois.

U.S. EPA, 1980. Procedures Manual for Groundwater Monitoring of Solid Waste Disposal Facilities. Publication SW-611, Office of Solid Waste, U.S. EPA, Washington, D.C.

Driscoll, Fletcher G., 1986. Groundwater and Wells. Johnson Division, St. Paul, Minnesota, 1989 p.

7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the field notebook. The Geologist must record the exact depths of significant hydrogeological features screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (Attachment C) shall be used which allows the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information (shall) include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. The documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded.depending on whether the well is completed in overburden, in a confined layer, in bedrock with a cased well, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The Geologist shall calculate the annular space volume and have a general idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in. Any problems with rig operation or down time shall be recorded and may determine the driller's final fee.

ATTACHMENT A

TABLE 7-4 RELATIVE COMPATIBILITY OF RIGID WELL-CASING MATERIAL (PERCENT)

	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless steel 304	Stainless steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Miner Acid/High Solids	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials

1 Teflon®
2 Stainless Steel 316
3 Stainless Steel 304
4 PVC 1
5 Lo-Carbon Steel
6 Galvanized Steel
7 Carbon Steel
* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®*	Silicone	Neoprene	Teflon®*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/High Solids	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials

1 Teflon®
2 Polypropylene (PP)
3 PVC flexible/PE linear
4 Viton®
5 PE Conventional
6 Plexiglas/Lucite (PMM)
7 Silicone/Neoprene
Source: Barcelona et al., 1983
* Trademark of DuPont

ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength not critical.
Weight	Relatively heavier	Lightweight, floats in water
Cost	Relatively expensive	Relatively inexpensive
Corrosivity	Deteriorates more rapidly in corrosive water	Non-corrosive--may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated HC
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work in the field.
Preparation for Use	Should be steam-cleaned for organics sampling	Never use glue fittings--pipes should be threaded or pressure-fitted. Should be steam cleaned if used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized	May sorb or release organic substances.

* See also Attachment A.

ATTACHMENT C

NUS CORPORATION
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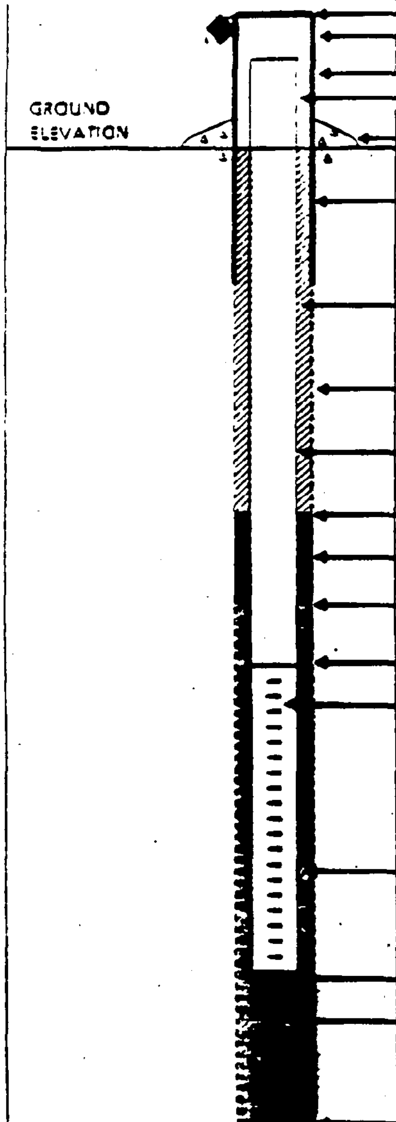
BORING NO. ____________

OVERBURDEN MONITORING WELL SHEET

PROJECT ____________ LOCATION ____________
PROJECT NO. ____________ BORING ____________
ELEVATION ____________ DATE ____________
FIELD GEOLOGIST ____________

DRILLER ____________
DRILLING METHOD ____________
DEVELOPMENT METHOD ____________



ELEVATION OF TOP OF SURFACE CASING: ____________
ELEVATION OF TOP OF RISER PIPE: ____________
STICK - UP TOP OF SURFACE CASING: ____________
STICK - UP RISER PIPE: ____________
TYPE OF SURFACE SEAL: ____________
I.D. OF SURFACE CASING: ____________
TYPE OF SURFACE CASING: ____________
RISER PIPE I.D. ____________
TYPE OF RISER PIPE: ____________
BOREHOLE DIAMETER: ____________
TYPE OF BACKFILL: ____________
ELEVATION / DEPTH TOP OF SEAL: ____________
TYPE OF SEAL: ____________
DEPTH TOP OF SAND PACK: ____________
ELEVATION / DEPTH TOP OF SCREEN: ____________
TYPE OF SCREEN: ____________
SLOT SIZE x LENGTH: ____________
I.D. OF SCREEN: ____________
TYPE OF SAND PACK: ____________
ELEVATION / DEPTH BOTTOM OF SCREEN: ____________
ELEVATION / DEPTH BOTTOM OF SAND PACK: ____________
TYPE OF BACKFILL BELOW OBSERVATION WELL: ____________
ELEVATION / DEPTH OF HOLE: ____________

ATTACHMENT C
PAGE TWO

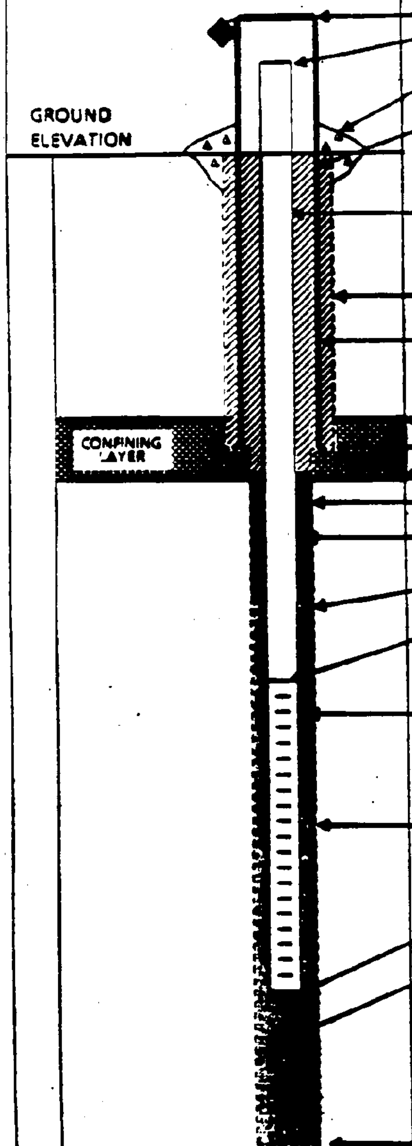
BORING NO.: ________

NUS CORPORATION

CONFINING LAYER
MONITORING WELL SHEET

PROJECT ________ LOCATION ________
PROJECT NO. ________ BORING ________
ELEVATION ________ DATE ________
FIELD GEOLOGIST ________

DRILLER ________
DRILLING METHOD ________
DEVELOPMENT METHOD ________



ELEVATION OF TOP OF PERM. CASING: ________
ELEVATION OF TOP OF RISER PIPE: ________
TYPE OF SURFACE SEAL: ________
I.D. OF PERM. CASING: ________
TYPE OF SURFACE CASING: ________
RISER PIPE I.D. ________
TYPE OF RISER PIPE: ________
BOREHOLE DIAMETER: ________
PERM. CASING I.D. ________
TYPE OF CASING & BACKFILL: ________
ELEVATION / DEPTH TOP CONFINING LAYER: ________
ELEVATION / DEPTH BOTTOM OF CASING: ________
ELEVATION / DEPTH BOT. CONFINING LAYER: ________
ELEVATION / DEPTH TOP OF SEAL: ________
TYPE OF SEAL: ________
DEPTH TOP OF SAND PACK: ________
ELEVATION/DEPTH TOP OF SCREEN: ________
TYPE OF SCREEN: ________
TYPE OF SAND PACK: ________
BOREHOLE DIA. BELOW CASING: ________
ELEVATION / DEPTH BOTTOM OF SCREEN: ________
ELEVATION / DEPTH BOTTOM OF SAND PACK: ________
TYPE OF BACKFILL BELOW OBSERVATION WELL: ________
ELEVATION / DEPTH OF HOLE: ________

ATTACHMENT C
PAGE THREE

NUS CORPORATION
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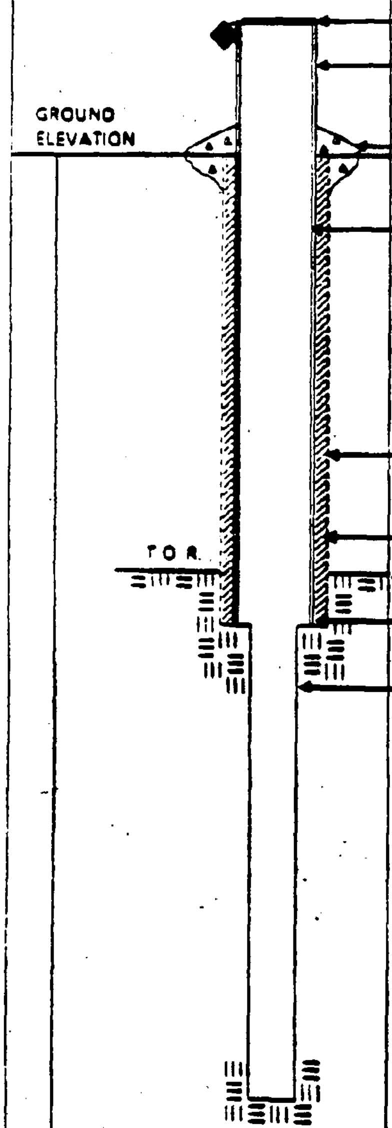
BORING NO.: ________

BEDROCK
MONITORING WELL SHEET
OPEN HOLE WELL

PROJECT ________ LOCATION ________
PROJECT NO. ________ BORING ________
ELEVATION ________ DATE ________
FIELD GEOLOGIST ________

DRILLER ________
DRILLING METHOD ________
DEVELOPMENT METHOD ________



ELEVATION OF TOP OF CASING: ________

STICK UP OF CASING ABOVE GROUND SURFACE: ________

TYPE OF SURFACE SEAL: ________

I.D. OF CASING: ________
TYPE OF CASING: ________

TEMP. / PERM.: ________

DIAMETER OF HOLE: ________

TYPE OF CASING SEAL: ________

DEPTH TO TOP OF ROCK: ________

DEPTH TO BOTTOM CASING: ________

DIAMETER OF HOLE IN BEDROCK: ________

DESCRIBE IF CORE / REAMED WITH BIT:
____
____
____

DESCRIBE JOINTS IN BEDROCK AND DEPTH:
____
____
____

ELEVATION / DEPTH OF HOLE: ________

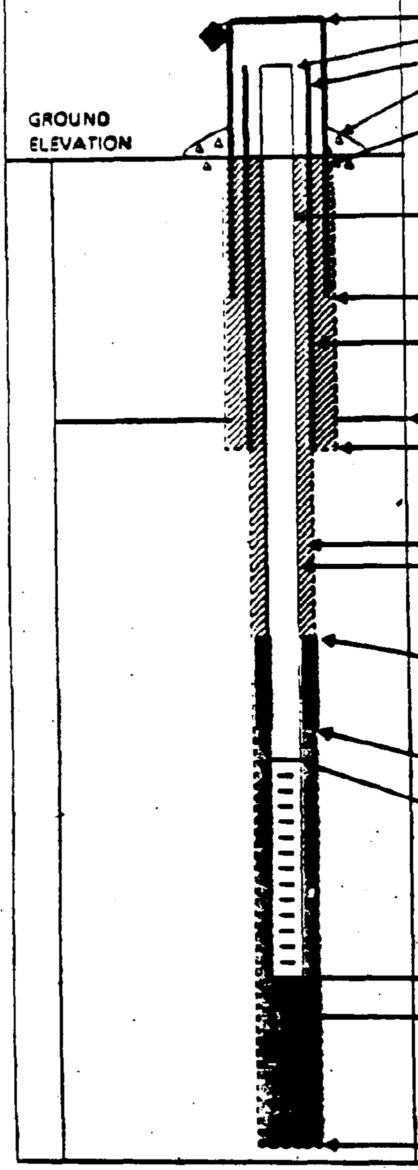
D334901

ATTACHMENT C
PAGE FOUR

BORING NO.: ____________

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT ____________ LOCATION ____________ DRILLER ____________
PROJECT NO. ____________ BORING ____________ DRILLING METHOD ____________
ELEVATION ____________ DATE ____________ DEVELOPMENT METHOD ____________
FIELD GEOLOGIST ____________



ELEVATION OF TOP OF SURFACE CASING: ____________
ELEVATION OF TOP OF RISER PIPE: ____________
ELEVATION TOP OF PERM. CASING: ____________
TYPE OF SURFACE SEAL: ____________
I.D. OF SURFACE CASING: ____________
TYPE OF SURFACE CASING: ____________
RISER PIPE I.D. ____________
TYPE OF RISER PIPE: ____________
BOREHOLE DIAMETER: ____________
PERM. CASING I.D. ____________
TYPE OF CASING & BACKFILL: ____________
ELEVATION / DEPTH TO BEDROCK: ____________
ELEVATION/DEPTH BOTTOM OF CASING: ____________
BOREHOLE DIA. BELOW CASING: ____________
TYPE OF BACKFILL: ____________
ELEVATION / DEPTH TOP OF SEAL: ____________
TYPE OF SEAL: ____________
ELEVATION / DEPTH TOP OF SAND PACK: ____________
ELEVATION/DEPTH TOP OF SCREEN: ____________
TYPE OF SCREEN: ____________
TYPE OF SAND PACK: ____________
ELEVATION / DEPTH BOTTOM OF SCREEN: ____________
ELEVATION / DEPTH BOTTOM OF SAND PACK: ____________
TYPE OF BACKFILL BELOW OBSERVATION WELL: ____________
ELEVATION / DEPTH OF HOLE: ____________

D334901

ATTACHMENT C
PAGE FIVE

NUS CORPORATION
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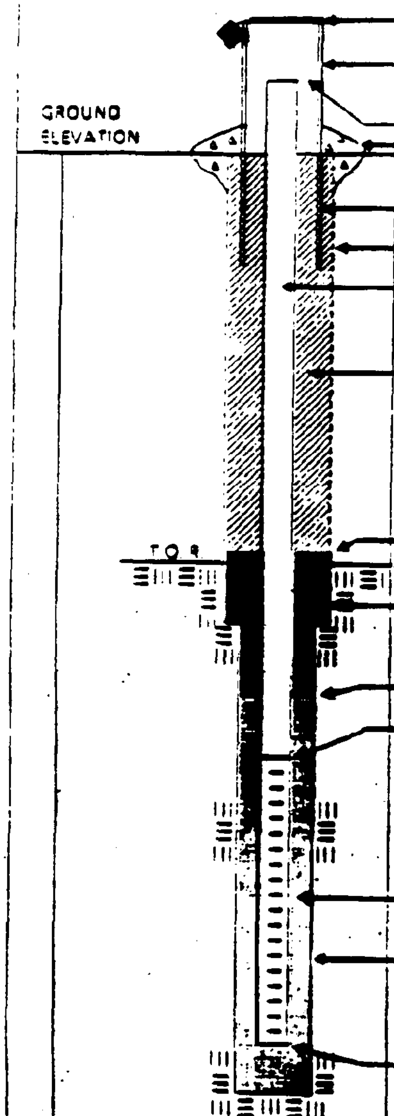
BORING NO ________

BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT ________ LOCATION ________ DRILLER ________
PROJECT NO. ________ BORING ________ DRILLING METHOD ________
ELEVATION ________ DATE ________ DEVELOPMENT METHOD ________
FIELD GEOLOGIST ________



ELEVATION OF TOP OF SURFACE CASING: ________

STICK UP OF CASING ABOVE GROUND SURFACE: ________

ELEVATION TOP OF RISER: ________

TYPE OF SURFACE SEAL: ________

I.D. OF SURFACE CASING: ________

DIAMETER OF HOLE: ________

RISER PIPE I.D.: ________

TYPE OF RISER PIPE: ________

TYPE OF BACKFILL: ________

ELEVATION / DEPTH TOP OF SEAL: ________

ELEVATION / DEPTH TOP OF BEDROCK: ________

TYPE OF SEAL: ________

ELEVATION / DEPTH TOP OF SAND: ________

ELEVATION / DEPTH TOP OF SCREEN: ________

TYPE OF SCREEN: ________

SLOT SIZE x LENGTH: ________

I.D. SCREEN: ________

TYPE OF SAND PACK: ________

DIAMETER OF HOLE IN BEDROCK: ________

CORE / REAM: ________

ELEVATION / DEPTH BOTTOM SCREEN: ________

ELEVATION / DEPTH BOTTOM OF HOLE: ________

STANDARD OPERATING PROCEDURES

Number	GH-2.5
Page	1 of 10
Effective Date	05/04/90
Revision	1
Applicability	EMG
Prepared	Earth Sciences
Approved	D. Senovich

Subject: WATER LEVEL MEASUREMENT/CONTOUR MAPPING

TABLE OF CONTENTS

1.0 PURPOSE

The objective of this procedure is to provide general reference information and technical guidance on the measurement of hydraulic head levels and the determination of the direction of groundwater flow, using contour maps of the water table or the potentiometric surface of an unconfined or confined aquifer.

2.0 SCOPE

This procedure gives overall technical guidance for obtaining hydraulic head measurements in wells (frequently conducted in conjunction with groundwater sampling) and preparation of groundwater contour maps. The specific methods could be modified by requirements of project-specific plans.

3.0 GLOSSARY

Hydraulic Head - The height to which water will rise in a well.

Water Table - A surface in an unconfined aquifer where groundwater pressure is equal to atmospheric pressure (i.e., the pressure head is zero).

Potentiometric Surface - A surface which is defined by the levels to which water will rise in wells which are screened or open in a specified zone of an unconfined or confined aquifer.

Unconfined (water table) Aquifer - An aquifer in which the water table forms the upper boundary.

Confined Aquifer - An aquifer confined between two low permeability layers (aquitards).

Artesian Conditions - A common condition in a confined aquifer in which the water level in a well completed within the aquifer rises above the top of the aquifer.

Flow Net - A diagram of groundwater flow, showing flow lines and equipotential lines.

Flow Line - A line indicating the direction of groundwater movement within the saturated zone. Flow lines are drawn perpendicular to equipotential lines.

Equipotential Line - A contour line on the potentiometric surface or water table showing uniform hydraulic head levels. Equipotential lines on the water table are also called water-table contour lines.

4.0 RESPONSIBILITIES

Project Hydrogeologist - has overall responsibility for obtaining water level measurements and developing groundwater contour maps. The hydrogeologist shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number of data points needed and which wells shall be used for a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - must have a basic familiarity with the equipment and procedures involved in obtaining water levels, and must be aware of any project-specific requirements.

5.0 PROCEDURES

5.1 GENERAL

Groundwater level measurements can be made in monitoring wells, private or public water wells, piezometers, open boreholes, or test pits (after stabilization). Groundwater measurements should generally not be made in boreholes with drilling rods or auger flights present. If groundwater sampling activities are to occur, groundwater level measurements shall take place prior to well evacuation or sampling.

All groundwater level measurements shall be made to the nearest 0.01 foot, and recorded in the geologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A), along with the date and time of the reading. The total depth of the well shall be measured and recorded, if not already known. Weather changes that occur over the period of time during which water levels are being taken, such as precipitation and bariometric pressure changes, should be noted.

In measuring groundwater levels, there shall be a clearly-established reference point of known elevation, which is normally identified by a mark on the upper edge of the inner well casing. The reference point shall be noted in the field notebook. To be useful, the reference point should be tied in with an established USGS benchmark or other properly surveyed elevation datum. An arbitrary datum could be used for an isolated group of wells if necessary.

Cascading water within a borehole or steel well casings can cause false readings with some types of sounding devices (chalked line, electrical). Oil layers may also cause problems in determining the true water level in a well. Special devices (interface probes) are available for measuring the thickness of oil layers and true depth to groundwater if required.

Water level readings shall be taken regularly, as required by the site hydrogeologist. Monitoring wells or open-cased boreholes that are subject to tidal fluctuations should be read in conjunction with a tidal chart (or preferably in conjunction with readings of a tide staff or tide level recorder installed in the adjacent water body); the frequency of such readings shall be established by the site hydrogeologist. All water level measurements at a site used to develop a groundwater contour map shall be made in the shortest practical time to minimize affects due weather changes, and at least during the same day.

5.2 WATER LEVEL MEASURING TECHNIQUES

There are several methods for determining standing or changing water levels in boreholes and monitoring wells. Certain methods have particular advantages and disadvantages depending upon well conditions. A general description of these methods is presented, along with a listing of various advantages and disadvantages of each technique. An effective technique shall be selected for the particular site conditions by the onsite hydrogeologist.

In most instances, preparation of accurate potentiometric surface requires that static water level measurements be obtained to a precision of 0.01 feet. To obtain such measurements in individual accessible wells, the Chalked Tape or Electrical Water Level Indicator methods have been found best, and thus are the most often utilized. Other, less precise methods, such as the Popper or Bell Sound or Bailer Line methods, may be appropriate for developing preliminary estimates of hydraulic conditions. When a large number of (or continuous) readings are required, time-consuming individual readings are not usually feasible. In such cases, it is best to use the Float Recorder or Pressure Transducer methods. When conditions in the well limit readings (i.e., turbulence in the water surface or limited access through small diameter tubing), less precise, but appropriate, methods such as the Air Line or Capillary Tubing methods can be used.

5.2.1 Methods

Water levels can be measured by several different techniques, but the same steps shall be followed in each case. The proper sequence is as follows:

1. Check operation of recording equipment above ground. Prior to opening the well, don personal protective equipment as required.

2. Record all information specified below in the geologist's field notebook or on the Groundwater Level Measurement Sheet.

   a. Well number.
   b. Record water level to the nearest 0.01 foot (0.3 cm). Water levels shall be taken from the surveyed reference mark on the top edge of the inner well casing.
   c. Record the time and day of the measurement.

Water level measuring devices with permanently marked intervals shall be used when possible. If water level measuring devices marked by metal or plastic bands clamped at intervals along the measuring line are used, the spacing and accuracy of these bands shall be checked frequently as they may loosen and slide up or down the line, resulting in inaccurate reference points (see Section 5.2.3).

5.2.2 Water Level Measuring Devices

Chalked Steel Tape

The water level is measured by chalking a weighted steel tape and lowering it a known distance (to any convenient whole foot mark) into the well or borehole. The water level is determined by subtracting the wetted chalked mark from the total length lowered into the hole.

The tape shall be withdrawn quickly from the well because water has a tendency to rise up the chalk due to capillary action. A water finding paste may be used in place of chalk. The paste is spread on the tape the same way as the chalk, and turns red upon contacting water.

Disadvantages to this method include the following: depths are limited by the inconvenience of using heavier weights to properly tension longer tape lengths; ineffective if borehole/well wall is wet or inflow is occurring above the static water level; chalking the tape is time consuming; difficult to use during periods of precipitation.

Electric Water Level Indicators

These devices consist of a spool of small-diameter cable and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated monitoring well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, steel well casing, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe shall be lowered slowly into the well. The electric tape is marked at the measuring point where contact with the water surface was indicated. The distance from the mark to the nearest tape band is measured using an engineer's folding ruler or steel tape and added to the band reading to obtain the depth to water. If band is not a permanent marking band, spacing shall be checked periodically as described in Section 5.2.3.

- **Popper or Bell Sounder**

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "plopping" or "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight strikes the water. This method is not sufficiently accurate to obtain water levels to 0.01 feet, and thus is more appropriate for obtaining only approximate water levels quickly.

Float Recorder

A float or an electromechanically actuated water-seeking probe may be used to detect vertical changes of the water surface in the hole. A paper-covered recording chart drum is rotated by the up and down motion of the float via a pulley and reduction gear mechanism, while a clock drive moves a recording pen horizontally across the chart. To ensure continuous records, the recorder shall be inspected, maintained, and adjusted periodically. This type of device is useful for continuously measuring periodic water level fluctuations, such as tidal fluctuations or influences of pumping wells.

Air Line

An air line is especially useful in pumped wells where water turbulence may preclude the use of other devices. A small-diameter weighted tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air (from a compressor, bottled air, or air pump) is used to purge the water from the tube, until air begins to escape the lower end of the tube, and is seen (or heard) to be bubbling up through the water in the well. The pressure needed to purge the water from the air line multiplied by 2.307 (feet of water for 1 psi) equals the length in feet of submerged air line. The depth to water below the center of the pressure gauge can be calculated by subtracting the length of air line below the water surface from the total length of the air line.

The disadvantages to this method include the need for an air supply and lower level of accuracy (unless a very accurate air pressure gauge is used, this method cannot be used to obtain water level readings to the nearest 0.01 ft).

Capillary Tubing

In small diameter piezometer tubing, water levels are determined by using a capillary tube. Colored or clear water is placed in a small "U"-shaped loop in one end of the tube (the rest of the tube contains air). The other end of the capillary tube is lowered down the piezometer tubing until the water in the loop moves, indicating that the water level has been reached. The point is then measured from the bottom of the capillary tube or recorded if the capillary tube is calibrated. This is the best method for very small diameter tubing monitoring systems such as Barcad and other multilevel samples. Unless the capillary tube is calibrated, two people may be required to measure the length of capillary tubing used to reach the groundwater. Since the piezometer tubing and capillary tubing usually are somewhat coiled when installed, it is difficult to accurately measure absolute water level elevations using this method. However, the method is useful in accurately measuring differences or changes in water levels (i.e., during pumping tests).

Pressure Transducer

Pressure transducers can be lowered into a well or borehole to measure the pressure of water and therefore the water elevation above the transducer. The transducer is wired into a recorder at the surface to record changes in water level with time. The recorder digitizes the information and can provide a printout or transfer the information to a computer for evaluation (using a well drawdown/recovery model). The pressure transducer should be initially calibrated with another water level measurement technique to ensure accuracy. This technique is very useful for hydraulic conductivity testing in highly permeable material where repeated, accurate water level measurements are required in a very short period of time. A sensitive transducer element is required to measure water levels to 0.01 foot accuracy.

Borehole Geophysics

Approximate water levels can be determined during geophysical logging of the borehole (although this is not the primary purpose for geophysical logging and such logging is not cost-effective if used only for this purpose). Several logging techniques will indicate water level. Commonly-used logs which will indicate saturated/unsaturated conditions include the spontaneous potential (SP) log and the neutron log.

Bailer Line Method

Water levels can be measured during a bailing test of a well by marking and measuring the bailer line from the bottom of the bailer (where water is first encountered) to the point even with the top of the well casing. This is a useful technique during bailing tests (particularly if recovery is rapid) if the bailer is heard hitting the water. However, it is not recommended for measuring static water levels because it is not usually as accurate as some of the other methods described above.

5.2.3 Data Recording

Water level measurements, time, data, and weather conditions shall be recorded in the geologist's field notebook or on the Groundwater Level Measurement Sheet. All water level measurements shall be measured from a known reference point. The reference point is generally a marked point on the upper edge of the inner well casing that has been surveyed for an elevation. The exact reference point shall be marked with permanent ink on the casing since the top of the casing may not be entirely level. It is important to note changes in weather conditions because changes in the barometric pressure may affect the water level within the well.

5.2.4 Specific Quality Control Procedures for Water Level Measuring Devices

All groundwater level measurement devices must be cleaned before and after each use to prevent cross contamination of wells.

Some devices used to measure groundwater levels may need to be calibrated. These devices shall be calibrated to 0.01 foot accuracy periodically. A water level indicator calibration sheet shall be completed each time the measuring device is checked. A water level indicator calibration form is shown in Attachment A. The "actual reading" column on the sheet is the actual length of the interval from the end of the indicator to the appropriate marked depth interval. In many cases, these measurements are different because the water level measuring device is connected to the end of the measuring tape or line, and may extend beyond "0" feet on the measuring line.

5.3 POTENTIOMETRIC SURFACE MAPPING

5.3.1 Selection of Wells

All wells used to prepare a flow net in a plan or map view should represent the same hydrogeologic unit, be it aquifer or aquitard. All water level measurements used shall be collected on the same day.

Before mapping, review the recorded water levels and monitoring-well construction data, site geology and topographic setting to ascertain that the wells are completed in the same hydrogeologic unit and to determine if strong vertical hydraulic gradients may be present. Such conditions will be manifested by a pronounced correlation between well depth and water level, or by a difference in water level between two wells located near each other but set to different depths or having different screen lengths. Professional judgment of the hydrogeologist is important in this decision. If vertical gradients are significant, the data to be used must be limited vertically, and only wells finished in a chosen vertical zone of the hydrogeologic unit can be used.

At least three wells must be used to provide an estimation of the direction of groundwater flow, and many more wells will be needed to provide an accurate contour map. Generally, shallow systems require more wells than deep systems for accurate contour mapping.

5.3.2 Construction of Equipotential Lines

Plot the water elevations in the chosen wells on a site map. Other hydrogeologic features associated with the zone of interest -- such as seeps, wetlands, and surface-water bodies -- should also be plotted along with their elevations.

The data should then be contoured, using mathematically valid and generally accepted techniques. Linear interpolation is most commonly used, as it is the simplest technique. However, quadratic interpolation or any technique of trend-surface analysis or data smoothing is acceptable. Computer-generated contour maps may be useful for large data sets. Contour lines shall be drawn as smooth, continuous lines which never cross one another.

Inspect the contour map, noting known features, such as pumping wells and site topography. The contour lines must be adjusted in accordance with these, utilizing the professional judgment of the hydrogeologist. Closed contours should be avoided unless a known sink exists. Groundwater mounding is common under landfills and lagoons; if the data imply this, the feature must show in the contour plot.

5.3.3 Determination of Groundwater-Flow Direction

Flow lines shall be drawn so that they are perpendicular to equipotential lines. Flow lines will begin at high head elevations and end at low head elevations. Closed highs will be the source of additional flow lines. Closed depressions will be the termination of some flow lines. Care must be used in areas with significant vertical gradients to avoid erroneous conclusions concerning gradients and flow directions.

5.4 HEALTH AND SAFETY CONSIDERATIONS

Groundwater contaminated by volatile organic compounds may release toxic vapors into the air space inside the well pipe. The release of this air when the well is initially opened is a Health/Safety hazard which must be considered. Initial monitoring of the well headspace and breathing zone concentrations using a PID (HNU) or FID (OVA) and combustible gas meters shall be performed to determine required levels of protection.

6.0 REFERENCES

Freeze, R. A. and J. A. Cherry, 1979. Groundwater. Prentice-Hall, Englewood Cliffs, New Jersey, 604 pp.

Cedergren, H. R., 1977. Seepage, Drainage and Flow Nets (2nd edition). John Wiley and Sons, New York.

Fetter, C. W., 1980. Applied Hydrogeology. Me ', Columbus, Ohio, 488 pp.

7.0 ATTACHMENTS

Attachment A - Groundwater Level Measurem heet

Attachment B - Water Level Indicator Calibration Sheet.

ATTACHMENT A

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: ______________________
Project No.: ______________________
Personnel: ______________________
Date: ______________________

LOCATION

Municipality: ______________________
County: ______________________
State: ______________________
Street or Map Location (If Off-Site) ______________________

WEATHER CONDITIONS

Temperature Range: ______________________
Precipitation: ______________________
Barometric Pressure: ______________________

Equipment No.: ______________________
Equipment Name: ______________________
Latest Calibration Date: ______________________

Tidally-Influenced: [ ] Yes [ ] No

Well or Piezometer Number	Date/Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Adjusted Depth (Feet)*	Groundwater Elevation (Feet)*

* All elevations to nearest 0.01 foot.

ATTACHMENT B

WATER LEVEL INDICATOR CALIBRATION SHEET

Project Name ____________________ Date ____________________

Project No. ____________________

Equipment No. ____________________

Equipment Name ____________________

Water Level Indicator Marking (Feet)	Actual Reading* (Feet)
0.0	
5.0	
10.0	
15.0	
20.0	
25.0	
30.0	
35.0	
40.0	
45.0	
50.0	
55.0	
60.0	
65.0	
70.0	
75.0	
80.0	
85.0	
90.0	
95.0	
100.0	

* **Record readings to the nearest 0.01 foot. The actual reading may be different than marking because the water level measuring device (electrode, popper, etc.) may extend beyond the "0" feet mark on the measuring line.**

B

APPENDIX B

CHAIN-OF-CUSTODY FORM AND SAMPLING FORM

NUS CORPORATION — *CHAIN OF CUSTODY RECORD*

PROJECT NO.:

SITE NAME:

SAMPLERS (SIGNATURE):

STATION NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CON-TAINERS							REMARKS

RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED FOR LABORATORY BY (SIGNATURE):	DATE/TIME:	REMARKS:	

NUS 440 34 0484

NYSDEC 031105

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SAMPLE LOG SHEET

Page ____ of ____

Case # __________

By __________

☐ Monitoring Well Data
☐ Domestic Well Data
☐ Other __________

Project Site Name __________ Project Site Number __________

NUS Source No. __________ Source Location __________

	Purge Data				
Total Well Depth:	Volume	pH	S.C.	Temp. (°C)	Color & Turbidity
Well Casing Size & Depth:					
Static Water Level:					
One Casing Volume:					
Start Purge (hrs.):					
End Purge (hrs.):					
Total Purge Time (min.):					
Total Amount Purged (gal.):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:					

	Sample Data			
Sample Date & Time:	pH	S.C.	Temp. (°C)	Color & Turbidity
Sampled By:				

Signature(s):

Observations / Notes:

Type of Sample

☐ Low Concentration
☐ High Concentration
☐ Grab
☐ Composite
☐ Grab - Composite

Analysis:	Preservative

	Organic	Inorganic
Traffic Report #		
Tag #		
AB #		
Date Shipped		
Time Shipped		
Lab		
Volume		

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SAMPLE LOG SHEET

Page ____ of ____

Case # ____________

By ____________

☐ Surface Soil
☐ Subsurface Soil
☐ Sediment
☐ Lagoon / Pond
☐ Other ________

Project Site Name ______________________ Project Site Number ______________

NUS Source No. ______________________ Source Location ______________

	Composite Sample Data		
Sample Method:	**Sample**	**Time**	**Color / Description**
Depth Sampled:			
Sample Date & Time:			
Sampled By:			
Signature(s):			
Type of Sample ☐ Low Concentration ☐ High Concentration ☐ Grab ☐ Composite ☐ Grab - Composite			

Sample Data	
Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)

Analysis:

Observations / Notes

	Organic	Inorganic
Traffic Report #		
Tag #		
AB #		
Date Shipped		
Time Shipped		
Lab		
Volume		

NYSDEC 031107

HALLIBURTON NUS
Environmental Corporation