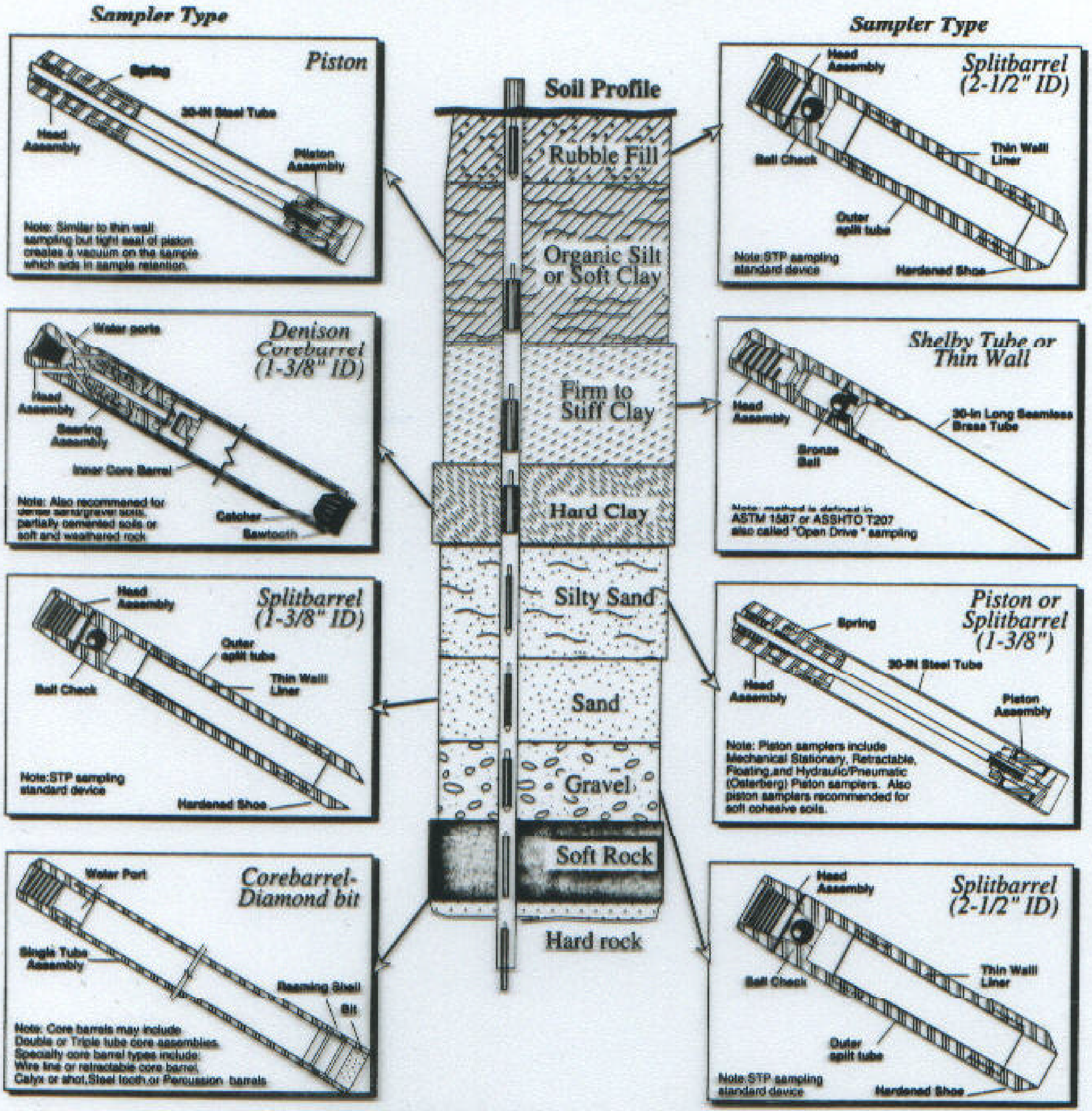
Table 1. Well-Drilling Selection Guide

Drilling Method	Drilling Fluid	Casing Advance	Type of Material Drilled	Nominal Drilling Depth, in ft 1_/	Nominal Range of Borehole Sizes, in in.	Samples Obtainable 2_/	Coring Possible	Reference Section
Power Auger (Hollow Stem)	None, Water, Mud	Yes	Soil, Weathered rock	<150	5 - 22	S, F	Yes	6.2
Power Auger (Solid Stem)	Water, Mud	No	Soil, Weathered Rock	<150	2-10	s	Yes	6.3
Power Bucket Auger	None, Water (below water table	No	Soil, Weathered rock	<150	18 -48	S	Yes	6.4
Hand Auger	None	No	Soil	<70 (Above Water Table Only)	2 - 6	S	Yes	6.5
Direct Fluid Rotary	Water, Mud	Yes	Soil, Rock	>1000	2 - 36	S, R	Yes	7.3
Direct Air Rotary	Air, Water, Foam	Yes	Soil, Rock	>1500	2 - 36	S, R, F	Yes	7.4
DTH Hammer	Air, Water, Foam	Yes	Rock, Boulders	<2000	4 - 16	R	Yes	7.5.1
Wireline	Air, Water, Foam	Yes	Soil, Rock	>1000	3-6	S, R, F	Yes	7.6
Reverse Fluid Rotary	Water, Mud	Yes	Soil, Rock	<2000	12 - 36	S, R, F	Yes	7.8
Reverse Air Rotary	Air, Water, Foam	Yes	Soil, Rock	>1000	12 - 36	S, R, F	Yes	7.7
Cable Tool	Water	Yes	Soil, Rock	<5000	6-8	S, R, F (F- Below Water Table)	Yes	8
Casing-Advancer	Air, Water, Mud	Yes	Soil, Rock, Boulders	<2000	2 -16	S, R, F	Yes	9
Direct-Push Technology	None	Yes	Soil	<100	1.5 - 3	F	Yes	10
Sonic (Vibratory)	None, Water, Mud, Air	Yes	Soil, Rock, Boulders	<500	4 -12	S, R, F	Yes	11
Jet Percussion	Water	No	Soil	<50	2 - 4	S	No	12
Jetting	Water	Yes	Soil	<50	4	S	No	12

1/ Actual achievable drilled depths will vary depending on the ambient geohydrologic conditions existing at the site and size of drilling equipment used. For example, large, high-torque rigs can drill to greater depths than their smaller counterparts under favorable site conditions. Boreholes drilled using air/air foam can reach greater depths more efficiently using two-stage positive-displacement compressors having the capability of developing working pressures of 250 to 350 psi and 500 to 750 cfm (particularly when submergence requires higher pressures). The smaller rotary-type compressors are only capable of producing a maximum working pressure of 125 psi. and produce 500 to 1200 cfm. Likewise, the rig mast must be constructed to safely carry the anticipated working loads expected. To allow for contigencies, it is recommended that the rated capacity of the mast be at least twice the anticipated weight load or normal pulling load. 2/ Soil = S (Cuttings), Rock = R (Cuttings), Fluid = F (Some samples might require accessory sampling devices to obtain.)

COMMON SAMPLING TOOLS FOR SOIL AND ROCK



Note: Similar to thin wall sampling but tight seal of piston creates a vacuum on the sample which aids in sample retention.

Note: Also recommened for dense sand/gravel soils, partially cemented soils or soft and weathered rock

Note:STP sampling standard device

Note: Core barrels may include Double or Triple tube core assemblies. Specialty core barrel types include: Wire line or retractable core barrel, Calyx or shot,Steel tooth,or Percussion barrels

Note:STP sampling standard device

Note: method is defined in ASTM 1587 or ASSHTO T207 also called "Open Drive " sampling

Note: Piston samplers include Mechanical Stationary, Retractable, Floating,and Hydraulic/Pneumatic (Osterberg) Piston samplers. Also piston samplers recommended for soft cohesive soils.

Note:STP sampling standard device

FIELD INSPECTION SHOULD DOCUMENT:

1. Driving Energy
2. Sampler Type
3. Sampling Conditions
4. Sampling Sequence
5. Sample Identification
6. Sample Preservation
7. Soil Conditions at Sampling Depth
8. Ground water Measurements
9. Depth of Boring
10. Sample Recovery/percentage

Modified form Hunt(1984)

Figure 4-18a Soil Sampling Methods

Table 9-5. Soil sampler descriptions, advantages, and limitations (modified from Acker, 1974; Rehm et al., 1985; Aller et al., 1989).

METHOD DESCRIPTION	ADVANTAGES	LIMITATIONS
SPLIT-SPOON (SPLIT-BARREL) SAMPLERS The Standard Penetration Test procedure for driving a split-spoon sampler to obtain a representative soil sample and a measure of soil penetration resistance is described by ASTM Test Method D1586-84. The split-spoon sampler is 18 to 30 inches long with a 1½-inch ID and made of steel. It is attached to the end of drill rods, lowered (typically through a hollow-stem auger) to the bottom of the borehole which must be clean, and then hammered into the undisturbed soil by dropping a 140-lb weight a distance of 30 inches onto an anvil that transmits the impact to the drill rods. The number of blows required to drive the sampler each 6-inch interval is counted to determine penetration resistance. Continuous or noncontinuous samples can be taken, and various other split-barrel diameter sizes are available. These samplers can also be pushed into the ground rather than hammered.	• High quality samples can be evaluated for mineralogical, stratigraphic, physical, and chemical properties • Steel, brass or plastic liners can be used with split-spoon samplers so that samples can be sealed to minimize changes in sample chemical and physical conditions prior to delivery to a laboratory • Relatively inexpensive • Widely available	• Hammering creates a stress that can consolidate and alter the sample • Sample transfer from the split spoon can result in disaggregation of cohesionless soil • Sample handling exposes soil to atmosphere and may result in loss of volatile chemicals • Cannot penetrate rock, cobbles, and some gravels • Poor recovery of some loose or flowing cohesionless samples (although sample retainers can be used to minimize this problem)
THIN-WALL (SHELBY) OPEN-TUBE SAMPLERS Open-tube thin-wall samplers consist of a connector head and a 30 or 36 inch long thin-wall steel, aluminum, brass, or stainless steel tube which is sharpened at the cutting edge. The wall thickness should be less than 2½% of the tube outer diameter, which is commonly 2 or 3 inches. The sampler is attached via its connector head to the end of drill rods, lowered (typically through a hollow-stem auger) to the bottom of the borehole which must be clean, and then pushed down into the undisturbed soil using the hydraulic or mechanical pulldown of the drill rig. This procedure is described by ASTM Method D1587-83. The Central Mining Company (CME) recently developed a 5-ft long continuous thin-wall sampling system. The tube is kept in place by a latching mechanism that allows the sample to be retracted by wireline when full and replaced with an empty tube.	• Provides undisturbed samples in stiff, cohesive soils and representative samples in soft to medium cohesive soils • High quality samples can be evaluated for mineralogical, stratigraphic, physical, and chemical properties • Sample can be preserved and stored within the sample tube by sealing its ends, thereby minimizing sample disturbance prior to lab analysis • Widely available • Relatively inexpensive	• The sampler should be at least six times the diameter of the longest particle size to minimize disturbance of the sample • Large gravel or cobbles can disturb the finer grained soil within which they are embedded and/or can damage the sampler walls • Due to thin wall and limited structural strength, the sampler cannot be easily pushed into dense or consolidated materials • Generally not effective for cohesionless soils
THIN-WALL PISTON CORE SAMPLERS These samplers consist of a thin-wall tube, with an internal piston, and mechanisms to control movement between the piston and tube. Thin-wall piston samplers are typically set up and pushed into the ground in the same manner as thin-wall open-tube samplers. The internal pistons generate a vacuum on the sample as the sampler is withdrawn from the hole. Starr and Ingleton (1992) recently developed a drive point piston sampler to collect high quality core samples of sands, silts, and clays without drilling fluids or a drilling rig to a depth of approximately 30 ft.	• Provides undisturbed samples in cohesive soils, silts, and sands above or below the water table • Vacuum enables recovery of cohesionless soils • High quality samples can be evaluated for mineralogical, stratigraphic, physical, and chemical properties • Sample can be preserved and stored within the sample tube by sealing its ends, thereby minimizing sample disturbance prior to lab analysis	• As with open-tube sampler, large particles may disturb sample or damage sampler walls and the sampler cannot be easily pushed into dense or consolidated materials • If used with a clam shell fitted auger head, only 1 sample can be obtained per borehole because the clam shell will not close after being opened; continuous sampling not possible • Some piston samplers require use of drilling fluid for hydrostatic control • Not as widely available as split-spoon or open-tube samplers • Relatively expensive
CORE BARREL SAMPLERS (see ROCK CORING description in Table 9-3)	See ROCK CORING advantages in Table 9-3	See ROCK CORING limitations in Table 9-3

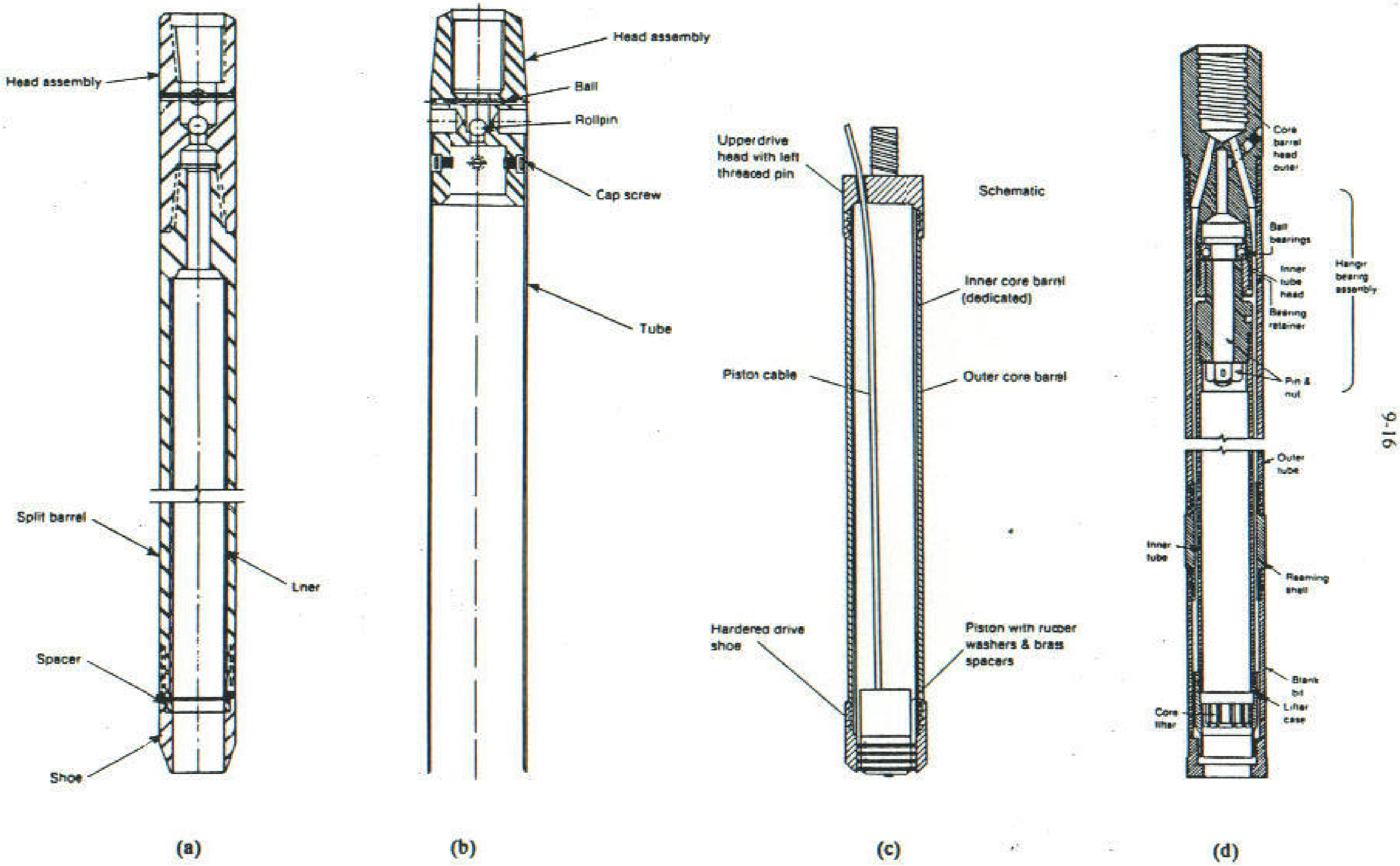


Figure 9-3. Schematic diagrams of a (a) split-spoon sampler, (b) thin-wall open-tube sampler, and (c) thin-wall piston sampler used to obtain undisturbed soil samples; and of a (d) double-tube core barrel used to obtain rock core (modified from Aller et al., 1989).

Table 9-6. Comparison of trichloroethene (TCE) concentrations determined after storing soil samples in jars containing air versus methanol; showing apparent volatilization loss of TCE from soil placed in jars containing air (from WCGR, 1991).

SPLIT-SPOON SAMPLE PLACED IN WIDE-MOUTH JAR CONTAINING AIR AND THEN SUB-SAMPLED, EXTRACTED, AND ANALYZED		SPLIT-SPOON SAMPLE PLACED IN WIDE-MOUTH JAR CONTAINING METHANOL TO PRESERVE VOLATILES AND SUBSEQUENT ANALYSIS OF THE SOLVENT	
Sample Depth (ft BGS)	TCE Concentration (mg/Kg)	Sample Depth (ft BGS)	TCE Concentration (mg/Kg)
5.0 - 7.0	2.2	7.0	3,100
20.0-20.5	9.2	20.0	420
30.0-30.5	<0.022	30.0	210

PROJECT 881-3042

RECORD OF BOREHOLE 34B

SHEET 1 OF 2

LOCATION SEE. FIGURE

INCLINATION AZIMUTH

BORING DATE JUNE 6/88

MONITORING WELL INSTALLED JUNE 9/88

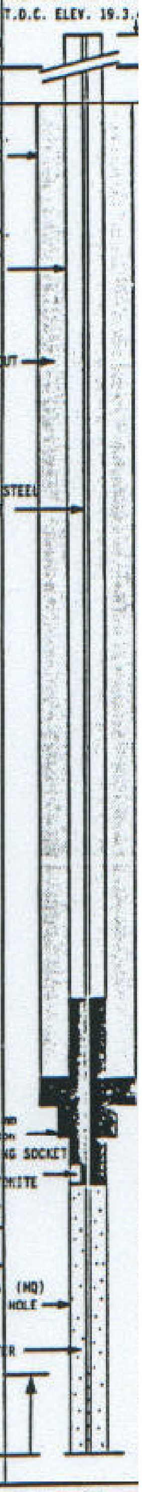
DATUM GEODETIC

SAMPLER / PENETRATION TEST HAMMER WEIGHT N/A DROP N/A

PRELIMINARY

DEPTH METRES	DRILLING RECORD	DESCRIPTION	ELEV DEPTH	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	ADDITIONAL TESTING WATER LEVELS AND NOTES
		GROUND SURFACE	192.49					
0	POWER AUGER - 150mm DIAM. HOLLOW STEM 100mm NOM. DIAM. GROUTED STEEL CASING	Brown becoming grey with depth, FISSURED SILTY CLAY, trace to some sand, trace of gravel (GLACIOLACUSTRINE TILL) Fissures generally near vertical and occ. infilled with silt	0.00					250 mm DIA. AUGER HOLE 100 mm NOM. DIA. STEEL CASING CEMENT GROUT 42 mm ST. STEEL RISER PIPE
6	150mm DIA. TRICONE CASING SOCKET		185.59					
7		brown SILTY SAND, some gravel, trace of clay (TILL)	6.90					
		BEDROCK SURFACE	185.28					
	AIR FLUSH ROTARY CORE DRILLING HQ ROCK CORE - 96mm DIA. HOLE	ERAMOSA FORMATION (7.21 - 12.47 m) Fresh to moderately weathered, medium brown to brownish grey, medium grained, medium bedded DOLOSTONE with occ. stylolites and black bituminous bedding partings.	7.21	RC 1	HQ RC	–	SL. WEATHERED WEATH VERTICAL JOINT [illegible] MOD. WEATH BITUMINOUS BEDDING PARTING (BIT B.P.)	RANGE OF WATER LEVEL IN WELL NO. 34B JULY 4, 1988 TO AUG. 23, 1988 150 mm TRICON CASING SOCKET
8			184.72 7.77				MOD. WEATH BIT. B.P. GALENA MIN.	BENTONITE SEAL
		7.77 to 8.24 - moderately weathered, porous, vuggy dolostone with traces of tabulate coral and galena mineralization, occ. dolomite crystals and sacc. dolomite in vugs	184.25 8.24	RC 2	"	–	FT. WEATH B.P. WEATH BIT. B.P.	96 mm DIA (HQ) HOLE
9							MOD. WEATH BIT. B.P.	SAND FILTER
			183.01 9.48				FT. WEATH B.P. FT. WEATH BIT B.P.	
			9.60					
10		CONTINUED ON SHEET 2.	182.49 10.00					

INSTRUMENTATION T.D.C. ELEV. 19.3



DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.D DRAWN SF
DATE AUG 17, 1988 CHECKED

FORM: G.A.-D-34 REDUCE TO 66 % OF ORIGINAL SIZE

Table 9-2. Information to be considered for inclusion in a drill or test pit log (modified from USEPA, 1987; Aller et al., 1989).

General:
- Project name/number
- Hole name/number
- Date started and finished
- Hole location; map and elevation
- Weather conditions
- Rig type, bit size/auger size
- Classification system used (e.g., Unified Soil Classification)
- Geologist's name
- Driller's name
- Sheet number

Information Columns:
- Depth
- Sample location/number
- Low counts and advance rate
- Percent sample recovery
- Narrative description
- Depth to saturation
- Well construction details
- Other remarks

Narrative Geologic Description:
- Soil/rock type
- Soil/rock texture and structure
- Color (Munsell) and stain
- Petrology and mineralogy
- Friability
- Moisture content (dry, moist, wet)
- Degree of weathering
- Presence of carbonate
- Fractures, joints (orientation, size, and spacing)
- Bedding nature and spacing
- Soil gradation or plasticity
- Discontinuities descriptions
- Water-bearing zones
- Formation strike and dip
- Fossils
- Depositional structures
- Organic content
- Solution cavities
- Rock core total breakage and breaks/ft
- Particle roundness or angularity
- Estimate of density of granular soil or consistency of cohesive soil (usually based on standard penetration test)
- Slickensides
- Roots, rootholes
- Residual or relict structure
- Buried horizons
- Disturbed earth, waste materials
- Rock Quality Designation (RQD)

Sampling Information:
- Types of sampler(s) used
- Diameter and length of sampler(s)
- Number of each sample
- Start and finish depth of each sample
- Percent sample recovery
- Split-spoon sampling
  - + size and weight of drive hammer
  - + number of blows required to penetrate each 6-inch interval
  - + free fall distance used to drive sampler
- Thin-walled sampling
  - + ease or difficulty pushing sampler
  - + psi required to push sampler
- Rock coring
  - + core barrel drill bit design
  - + penetration rate
  - + fluid gain or loss

Drilling Observations:
- Loss of circulation
- Advance rates
- Rig chatter
- Water-levels
- Changes in drilling method/equipment
- Drilling difficulties
- Amount of water yield/loss during drilling at different depths
- Caving/hole stability
- Amount of air used; air pressure
- Running sands
- Amounts and types of drilling fluids used

Well Construction Details:
- Well Design:
  - + casing length, schedule, and diameter
  - + joint type
  - + screen length, schedule, and diameter
  - + screen slot size
  - + percent open area in screen
  - + filter pack depth interval
  - + elevations of top of casing, bottom and top of protective casing, ground surface, bottom of borehole, bottom and top of well screen, annular seal and grout intervals, etc.
  - + well location coordinates and map
  - + other backfill materials and intervals
- Materials:
  - + casing and screen
  - + filter pack (i.e., grain size analysis)
  - + seal and physical form
  - + slurry or grout mix
- Installation:
  - + drilling method
  - + drilling fluids
  - + source of water
  - + timing
  - + method of sealant/grout emplacement
  - + volumes of all materials used
- Development:
  - + time and date
  - + water level elevation before after development
  - + development method
  - + time spent developing well
  - + volume of fluid removed
  - + volume of fluid added
  - + clarity of water and sediment before and after development
  - + amount of sediment at well bottom
  - + pH, specific conductance, and temperature readings

Other Remarks:
- Chemical odors
- Sample fluorescence
- NAPL sheens or presence
- HNU or OVA readings
- Sample shipping reference
- Equipment failures
- Deviations from drilling protocols
- Photograph cross-reference
- Air-monitoring data
- Hydrophobic dye test results
- Equipment decontamination procedures