United States Department of Agriculture
Natural Resources Conservation Service

Part 631 Geology
National Engineering Handbook

Chapter 5 Engineering Geology Logging, Sampling, and Testing

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Issued __________

Chapter 5 Engineering Geology Logging, Sampling, and Testing

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NEH Part 631

Chapter 5 – Engineering Geology Logging, Sampling, and Testing

631.0500 Introduction

This chapter briefly outlines geological investigation methods, equipment, and sampling for use by geologists and others in designing conservation practices and systems.

631.0501 Safety

A. Field Operation Safety

(1) Field investigations must comply with all applicable governmental regulations and laws and according to Natural Resources Conservation Service (NRCS) Title 210 National Engineering Manual, Part 503 Safety. Use personal protective equipment, such as safety helmets, safety glasses, gloves, and steel-toed shoes. When working close to machinery in operation or in transit, do not wear loose clothing. Loose clothing can get caught in moving parts. Machinery must be equipped with fully functional safety guards.

(2) Equipment operators should not run the equipment more than the limits of capability and safety as established and designated by the manufacturer. Do not assume that equipment is in safe operating condition unless adequately checked by a competent, responsible person. The equipment should be checked for safety and suitability to carry out the investigation prior to deployment.

(3) Complete regular condition checks on all equipment and report results. Use caution when operating equipment in the vicinity of power transmission lines. Adhere to Occupational Safety and Health Administration (OSHA)1926.1407 through 1926.1411 Power line safety to determine safe operating distances from power lines.

(4) Locate all underground utility lines in the area of the subsurface investigation prior to the investigation. Contact location services as required by state and local laws in the required time in advance of any investigation.

(5) Wire ropes or cables used with truck winches frequently break. Stay clear of the reach of the cable during operations of the winch.

(6) Crews using geophysical instruments or investigations involving explosive charges should be well acquainted with the precautions necessary to avoid accidents. Request and secure all required Federal, State, local, and tribal permits.

(7) Where trench or pit excavations require side supports of cribbing, ensure that cribbing material has adequate strength and is installed to prevent slumping, caving, and sliding. Figure 5-1 summarizes OSHA trench safety requirements. Review trenching or pitting regulations with all personnel involved in geologic investigations.

Figure 5-1. OSHA Trenching safety requirements

OSHA® QUICK CARD™

Working Safely in Trenches

When done safely, trenching operations can reduce worker exposure to cave-ins, falling loads, hazardous atmospheres, and hazards from mobile equipment.

OSHA standards require that trenches and protective systems be inspected daily and as conditions change by a competent person before work begins.

Never enter a trench unless:

- It has been properly inspected by a competent person.
- Cave-in protection measures are in place.
- There is a safe way to enter and exit.
- Equipment and materials are away from the edge.
- It is free of standing water and atmospheric hazards.

Prevent trench collapses:

- Trenches 5 feet deep or greater require a protective system.
- Trenches 20 feet deep or greater require a protective system designed by a registered professional engineer.

Protective systems for trenches:

- SLOPE or bench trench walls by cutting back the trench wall at an angle inclined away from the excavation.
- SHORE trench walls by installing aluminum hydraulic or other types of supports to prevent soil movement.
- SHIELD trench walls by using trench boxes or other types of supports to prevent soil cave-ins.

For more information:

U.S. Department of Labor

OSHA® Occupational Safety and Health Administration

www.osha.gov (800) 321-OSHA (6742)

OSHA 3243-09R 2018

(8) Cover or backfill test pits and compact materials to the original grade before ground disturbance when the site investigation is completed. An open hole is a potential danger to people and livestock. After backfilling, level test pits and trenches when site investigations are completed. Where stabilized ground water level measurements are needed (for 24-hour readings), temporary caps should be used, such as flagstones or wood.
(9) Exercise caution when handling hazardous materials.
(10) First aid kit and fire extinguisher are required to be onsite.
(11) Use caution when moving drilling equipment on roads, streets, and highways.
(12) Avoid adding bran or other grain derivatives to drilling mud because this mixture is detrimental to livestock.
(13) Use non-toxic dye tracers for groundwater investigations. For a list of common non-toxic dye tracers, see NEH Part 631 Groundwater Investigations, section 631.3110 (L), Tracers and Dyes.
(14) A safety plan should be developed and evaluated, particularly for drilling operations. This should include:
(i) Identifying the location of the nearest hospital and a plan for emergency.
(ii) Plan for working in inclement weather [lightning, rain, extreme temperatures (cold and heat), and flooding].
(iii) Checking cell phone coverage (in remote locations, satellite phone is an option).
(iv) Evaluate local hazards such as Lyme disease, plants, bugs, and animals. For a list of potential hazards, see Title 210 NEM Part 503 Safety, Subpart C, Safety During Geologic Investigations.
(v) Evaluate non-biological local hazards such as uneven terrain (slips, trips, and falls).
(vi) Conduct a safety meeting prior to the start of the project and daily before work begins.

631.0502 Logging Earth Materials

A. Recording and Logging of Data

(1) Logging is the recording of data concerning the materials and conditions in individual test holes, pits, trenches, or exposures. Accurate logging is imperative for proper evaluation to provide a true concept of subsurface conditions. Of equal importance is ensuring that recorded data are concise, complete, and presented in descriptive terms that are understood and evaluated in the field, laboratory, and design office.
(2) Logging is the geologic description of the material between specified depths or elevations, or at exposures. Description includes information such as name, texture, structure, color, mineral content, moisture content, relative permeability, age, and origin, plus any information that indicates engineering properties of the materials. Examples are gradation, plasticity, and the Unified Soil Classification System (USCS, ASTM D2488). Record results of field testing. For example, record standard penetration test (SPT) blow counts (following ASTM D1586) with the specific vertical interval tested. Always use the most recent version of an ASTM Standard.
(3) Photographing soil and rock samples is part of recording and logging data. Photograph samples in the sample barrel sleave before placing in a sample bag or core box to represent conditions before disturbance. Figure 5-2 is an example of core photographed immediately after extrusion.

Figure 5-2. Photograph of core in sleeve before placing in a core box.

B. Field Notes

(1) Log data on NRCS-ENG 533 (or equivalent) form or in a separate all-weather notebook. Field notes should contain all the data for both graphic and written logs and any information used to make interpretations but not entered in the log. Items for consideration in logging a test hole are shown in figure 5-3.
(2) Preserve field logs and notes as part of the project file.
(3) Tablet computers and mobile software applications are acceptable for collecting geotechnical field data. The user can customize the data collection parameters, data can be shared in real-time, and data can be transferred to logging software so that input time and errors are reduced.
(4) All logs and field notes are considered official records of the investigation. These include written and digital data and records.

C. Written Logs

(1) Use form NRCS-ENG-533 Log of Test Holes, and Form ENG-533A, Continuation Sheet or equivalent form that will display all information. Written logs are prepared from field notes and are limited to factual information, and data collected. These logs are detailed and concise narrative descriptions of the materials in easily understood terms. See figure 5-3 for test hole logging entry considerations.
(2) In addition to figure 5-3, log entries describe the type and size of sampler used for sampling or advancing a hole. Examples are bucket auger, tube, stationary-piston sampler, double-tube soil-core barrel type, or double-tube rock-core barrel. Figure 5-4 identifies abbreviations for the different sampling methods.
(3) Show the sampling horizon and whether the sample is “disturbed” (D), “undisturbed” (U), or “rock core” (R). Show the sample recovery ratio (S), which is equal to L/H where L is the length of sample recovered and H is the length of penetration, as a percentage. This may be an important factor in the determination of fissures, cavities, or soft interbedded materials in consolidated rock.
(4) For dams and other Group A structures (210-NEM-531.1), collect and record discontinuity information (e.g., joint, fault, shear, bedding, foliation; see Barton and Choubey 1977), discontinuity shape (figure 5-5), surface roughness (figure 5-6), and infilling (calcite, quartz, clay). For infilling, see NEH Part 631 Geology, Chapter 4 – Engineering Classification of Rock Materials, figure 4-26.

Figure 5-3. Earth material log entries

Item	Description
Hole number, location, and surface elevation	Number holes in the sequence in which they are drilled within each area of investigation. These areas have been assigned standard hole numbers. Show test hole location by station number or by reference to a base. Show elevation above mean sea level if it is known, or elevation from an assumed datum. Use the numbering system from NEH Part 631, Chapter 2 – Engineering Geology. section 631.0205, General Guidance for Engineering Geologic Investigations for Dams, subsection D, Numbering Test Holes and Logs.
Depth	Record the depth to the upper and lower limits of the layer being described. Show the depth in feet from the surface (0.0) to the bottom of the first stratum, or the depth from top to bottom of any underlying stratum.
Classification	In unconsolidated materials, use the Unified Soil Classification System (USCS, ASTM D2488), record the name of the primary constituent first, then as a modifier the name of the second most prominent constituent; for example, "sand, silty" (two constituents are enough). If it is desirable to call attention to a third, use the abbreviation "w/" after the name; for example, "sand, silty w/cbls" (with cobbles).
Texture	Record size, particle shape. See NEH Part 631, Chapter 3 Engineering Classification of Earth Materials, section 631.0301, subsection A (3), Shape (figure 3-3) and arrangement of individual minerals or grains. In consolidated rock, descriptive adjectives are usually sufficient. In unconsolidated material, use descriptive adjectives for size and give an average maximum size in inches or millimeters. Record shape by terms such as equidimensional, tabular, and prismatic and by the degree of roundness. Record arrangement by estimated relative amounts. Record the gradation for coarse-grained unconsolidated materials and the sorting for poorly graded materials.
Structure	Describe features of rock structure observed, such as bedding, laminations, cleavage, jointing, concretions, or cavities (see NEH Part 631, Chapter 4 Engineering Classification of Rock Materials, section 631.0402, subsection F, Rock Structure). Where applicable, include information on size, shape, color, composition, and spacing of structural features.
Color	Record color for purposes of identification and correlation. See NEH Part 631 Chapter 3, Engineering Classification of Earth Materials, section 631.0301, subsection (7), Color. Color may change with water content.
Moisture	Note whether the material is dry, moist, or wet. See NEH Part 631 Chapter 3 Engineering Classification of Earth Materials, section 631.0301, subsection (10) Moisture, and figure 3-8.
Mineral content	Record identifiable minerals and the approximate percentage of the more abundant minerals. Describe any mineral that is characteristic of a specific horizon and record its approximate percentage even though it occurs in very minor amounts. See NEH Part 631 Chapter 3 Engineering Classification of Earth Materials, section 631.0301, subsection (4), Mineral Composition. Record the kind of cementation if present.
Permeability	Estimate the relative permeability. If a field permeability test is run, describe the test and record the results. See NEH Part 631.31 Groundwater Investigations.
Age, name, and origin	Record geologic age, name, and origin; for example, Jordan member, Trempeleau Formation, Cambrian Age; Illinoian till; Recent alluvium. These labels can be useful in correlating known strata. Use the term "Modern" for sediments resulting from culturally accelerated erosion. Distinguish between Recent and Modern deposits. For valley sediments, record their apparent genesis. Such identification helps in correlation and for interpreting data from test holes. Similarly, knowing that a material is of lacustrine or eolian origin, or that it is part of a slump or other form of mass movement, helps in evaluating a proposed structure site.

Figure 5-3. Earth material log entries (cont.).

Item	Description
Strength and condition of rock	Record rock condition by strength, degree of weathering, degree of cementation, and RQD (Rock Quality Designation) (ASTM D6032/D6032M -17) where applicable. For consolidated rock, include kind of rock, color, grain or crystal size, degree of weathering, cementation, fracturing (amount per foot), rock hardness, rock material strength (Barton and Choubey 1977), and structural and other features in the description. See NEH Part 631 Chapter 4–Engineering Classification of Rock. Include the geologic name and age of the formation if it is known. Use the scale of rock strength to describe the ease of excavation. Show the USCS symbol as determined by field tests. A column is provided for a description of type and size of sampler used for sampling or advancing a hole. Examples are bucket auger (ASTM D1452), tube, stationary-piston sampler (ASTM D6519), double-tube soil-core barrel type, or double-tube rock-core barrel. Abbreviations that should be used for the different types of samplers are given in the following list in figure 5-4. Consider Mohs hardness scale for field determination of rock hardness.
Consistency and degree of compactness	Describe consistency of fine materials as very soft, soft, medium, stiff, very stiff, and hard. See NEH Part 631 Chapter 3–Engineering Classification of Earth Materials, section 631.0301, subsection (8) Consistency. Describe degree of compactness of coarse-grained soils as very loose, loose, medium, dense, and very dense.
USCS symbol	Assign a USCS symbol (ASTM D2488) for all unconsolidated materials. Borderline materials are given hyphenated symbols, such as CL-ML and SW-SM. Ordinarily, this borderline classification cannot be determined in the field. If there is doubt about the proper classification of material, record it as “CL or ML” and “SW or SM” and not by the borderline symbols. Record the results of field-identification tests, such as dilatancy, dry strength, toughness, ribbon, shine, and odor.
SPT blow count	For standard penetration test (SPT), record the results and the test elevation or depth. See section 631.0505 B. Standard Penetration Testing (SPT) later in this chapter for procedures or ASTM D1586. This test shows the number of blows (N) under standard conditions that are required to penetrate 12 inches, or with refusal, the number of inches penetrated by 100 blows. The latter is commonly recorded as 100/d, where d equals the number of inches penetrated in 100 blows. Typically blows are counted every 6 inches for 1.5 feet with 50 blows/6 inches termination criteria. SPT N values also need corrected for hammer efficiency and weight to be used for parameter correlation.
Other field tests	If other field tests are made, record the results, and describe each test completely. Examples are vane-shear test (ASTM D2573), pressure test, field density test, field tests for moisture content, acetone test, and the use of an indicator such as sodium fluorescein dye to trace the flow of groundwater.
Miscellaneous information	Record any drilling difficulties, core and sample recovery, losses and reasons for losses, type and mixture of drilling mud used to prevent caving or sample loss, loss of drilling fluid, and any other information that may help in interpreting the subsurface condition such as start and stop of each run. NRCS prefers that no drilling fluid be used within an embankment. If it is necessary in rock, triple tube seated in rock is preferred to prevent pore pressures at embankment/rock interface.
Water levels	Record the static water level and date measured. Wait at least 24-hours after the hole has been drilled to measure the water level to allow time for stabilization.

Figure 5-4. Abbreviations for sampling methods used in logs of field testing and sampling

Sampling Method	Abbreviation
Bucket auger	BA
Double-tube rock-core barrel	RCd
Double-tube soil-core barrel (Denison)	D
Dry barrel	DB
Hand cut	HC
Piston (Osterberg type)	Pf
Single-tube rock-core barrel	RCs
Sonic drilling rig sample tube	SoDR
Split-tube sampling spoon	SpT
Stationary piston	Ps
Thin-wall open-drive (Shelby)	S

Figure 5-5. Discontinuity shape

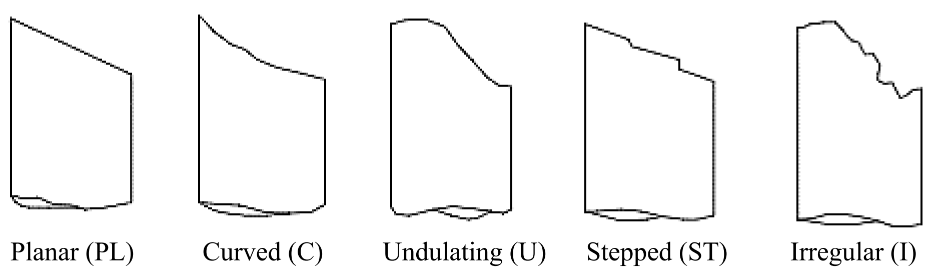
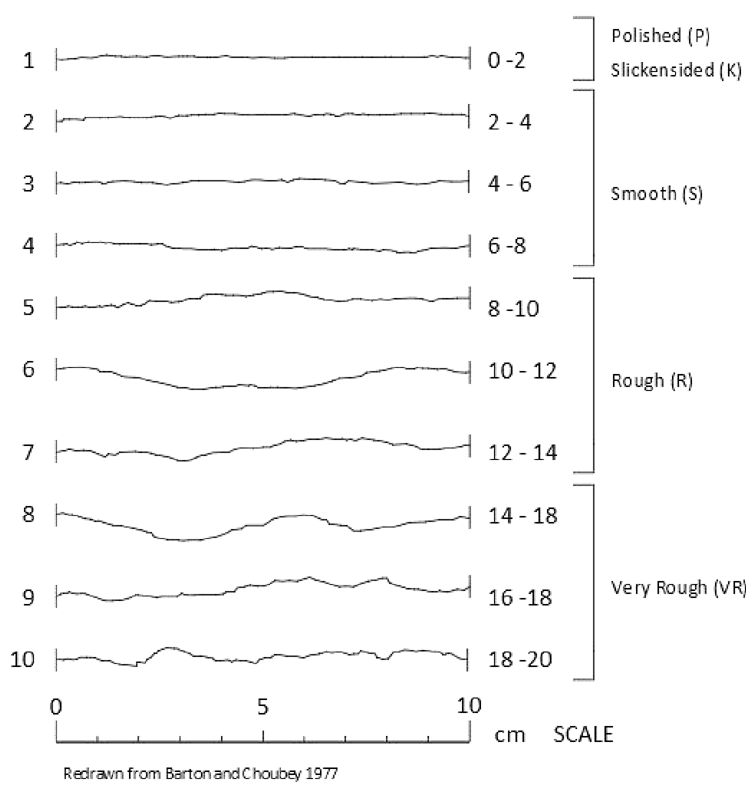


Figure 5-6. Typical Roughness Profiles



D. Graphic Logs

(1) Graphic logs are plotted at their correct location and elevation on engineering forms NRCS-ENG-35A, -35B, and -35C, Plan and Profiles for Geologic Investigation, or their equivalents. Plot graphic logs to scale and at accurate elevations. Use mean sea level (MSL) for the reference plane, if possible, or an assumed datum if MSL is not known.

(2) Graphic log correlation and interpretation identify the need for additional test holes and their location, permit plotting of stratigraphy and structure, and are the basis for development of complete geologic profiles. All forms with log correlation and interpretation must be marked "For in-service use only." Refer to 210-631 Ch. 2, 631.0206 B. (13), and 210-631 Ch. 2, 631.0206 C. (1) (ii). The plot with correlations and interpretations is not provided as part of any drilling services bid package.

(3) Next to each graphic log at the correct elevation identify the following as appropriate (see figures 5-7a and 5-7b for example logs):

(i) Static water level measurement and date of measurement

(ii) USCS symbol to further guide interpretation and sample requirements

(iii) SPT blow counts following ASTM D1586.

(iv) Use adjectives and their abbreviations given in the legend on Form NRCS-ENG-35A or equivalent for other salient features of the material; for example, wet, hard, massive (mas).

(v) Number each hole according to its location. Use the numbering system from NEH Part 631, Chapter 2 – Engineering Geology, section 631.0205 (D), Numbering of Test Holes.

Figure 5-7a. Geologic graphic log and profile example.

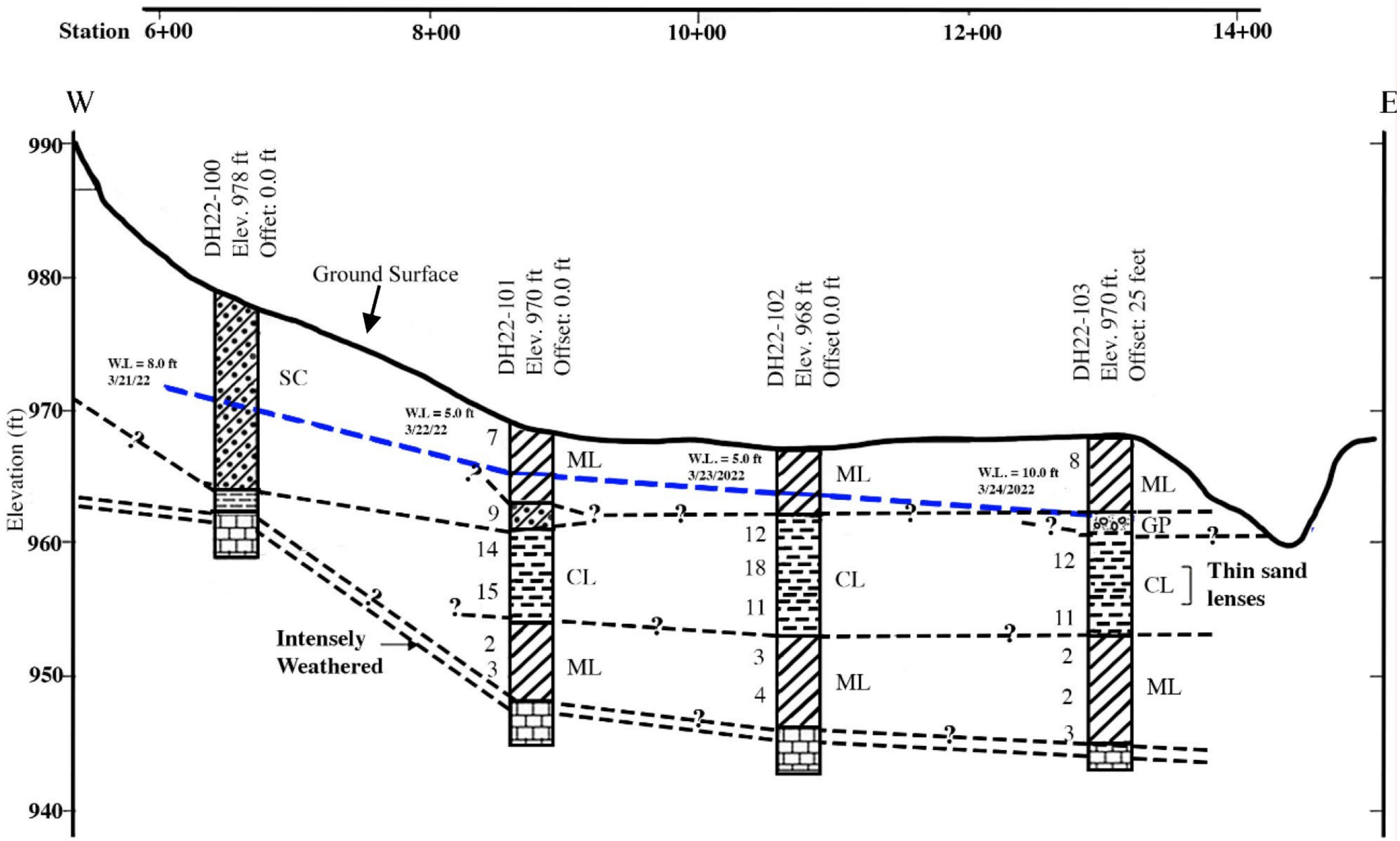
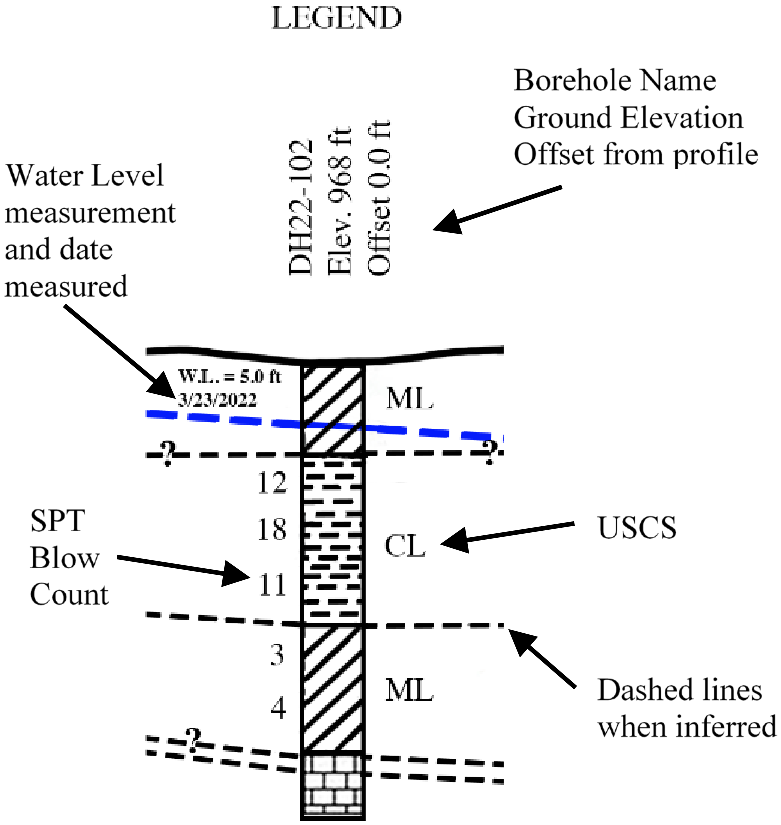


Figure 5-7b. Geologic graphic log and profile example.



E. Geologic Profile

(1) Develop tentative correlation lines to determine where additional test holes are needed. As more graphic logs are plotted, the stratigraphic relationships become more definite. Tentative correlation lines are often dashed. All forms with tentative correlation lines must be marked "For in-service use only". Refer to 210-631 Ch. 2, 631.0206 B. (13), and 210-631 Ch. 2, 631.0206 C. (1) (ii).

(2) Data interpretation in terms of the genetic classification of the deposits helps to establish correlation. Conversely, geologic profile development often helps to interpret the deposit's origin. A complete geologic profile provides an interpretation of the factual information from the logs in terms of the stratigraphic and structural relationships along the plotted profile. Add notations on important conditions or characteristics, such as groundwater level, permeability, density, genesis, sorting, degree of weathering or cementation, upstream and downstream mineralogy, and rock structure.

(3) Figures 5-7a and 5-7b show part of the geologic profile along the centerline of a proposed structure and illustrates some of these points. Plot profiles or sections drawn normal to the direction of streamflow as though the observer is looking downstream. Plot those drawn parallel to the direction of streamflow so that streamflow is from left to right.

(4) When a graphic log is located off the centerline profile, show the log above or below the ground level on the profile, depending on the boring's ground elevation. Make a notation at the top of the log identifying the boring location relative to the centerline of the profile.

(5) Use a horizontal and vertical scale that allows enough space for graphic log legibility. Figure 5-8 shows recommended scales for different site features.

Figure 5-8. Recommended scales for plotting logs of earth materials.

Scale Direction	Feature Plot Recommendations		
Vertical	1 inch = 10 feet. Increase to 1 inch = 5 feet for special situations, such as complex logs where thin horizons need to be delineated accurately		
Horizontal	Plan of site (all components)		1 inch = 100 feet.
	Profiles	Centerline of dam, auxiliary spillway, and borrow grids	1 inch = 100 feet
		Centerline of principal spillway and the stream channel below the outlet end of the principal spillway	1 inch = 50 feet
		Centerline of foundation drains, relief-well collector lines, and sediment-pool drain lines	1 inch = 50 feet
		Cross section of stream channel	1 inch = 20 feet. A scale that requires no more than 2 inches for the plotted bottom width and no more than 6 inches for the entire cross section.
		Cross section of auxiliary spillway	1 inch = 20 feet to 1 inch = 100 feet. A scale that results in a plotted bottom width of at least 2 inches.

F. Geologic Plan

(1) Show the location of holes by the proper symbol on a topographic or surface geology map. Label each test hole, pit, and trench using naming convention shown in figure 2-6 in NEH Part 631, Chapter 2 – Engineering Geology. Include ground elevation of each feature.

(2) Include a north arrow and scale and show section lines as needed.

G. Subsurface Data and Reporting Software

(1) Software can help manage data and produce written and graphic logs, profiles, fence diagrams, and site plan maps. Several different licensed programs are available for geologic logging and profiles, including the following. Trade names are listed without specific recommendations for use.
(i) Bentley's gINT©
(ii) Autodesk Civil 3D©
(iii) ArcGIS©
(iv) Bentley's Holebase©
(v) Rockware©
(vi) MicroStation©

631.0503 Sampling Earth Materials

A. Exposed Profiles

(1) Natural Exposures

(i) Natural exposures provide a basis for guiding subsurface investigations, testing, and sampling of earth materials. Natural exposures, when described in detail, serve the same purpose as other logs in establishing stratigraphy and other geologic conditions.

(ii) A fresh surface is required for the preparation of adequate descriptions. An ordinary hand shovel or geologist's pick may be required for preparing the surface of a natural exposure for accurate logging.

(2) Trenching and Test Pitting

(i) Trenching and test pitting are simple exploration methods in easily excavated rock or soil materials. Visual inspection of a wide section of strata is of great value in logging profiles and selecting samples. If bedrock is anticipated at a shallow depth, locate trenches and test pits on the centerline of the proposed structure and dig them parallel with it. If bedrock is not at shallow depths, offset deep trenches or test pits from the centerline to avoid damaging the foundation of the structure. Shallow trenches or test pits may be dug adjacent to the centerline for correlation purposes.

(ii) When pits or trenches penetrate or pass through foundation materials, backfill and compact to the density of the original in-place material. NRCS recognizes that certain limitations exist in the use of trenching and test-pit excavating equipment for compacting fill material. However, make every practical effort to re-establish the in-place densities of foundation materials.

(iii) Trenches are long, narrow excavations. They are advantageous for studying earth materials on steep slopes and in exposed faces. Trenches made by power equipment, such as backhoes, power shovels, and bulldozers, may require hand trimming of the sides and bottom to reach relatively undisturbed material. Trenching is valuable in delineating the rock surface beneath the principal spillway, in abutments, and in exploring auxiliary spillway materials, and may be the most feasible method for investigating materials containing cobbles or boulders. Trenches may yield valuable information on potential rock rippability and core trench depth along the centerline of the structure, depending on its design.

(iv) Test pits are large enough to accommodate a person with sampling equipment. They may be excavated by hand or by power equipment such as a backhoe or excavator. Use extreme caution when approaching the depths for undisturbed samples.

(v) Cribbing and egress are required in both trenches and pits greater than four-feet-deep when personnel enter the excavation. Refer to OSHA 1926.651(c)(2) and figure 5-1.

(vi) During excavations, keep excavated materials at a minimum of two feet from the test trench or pit edges to prevent materials from falling into the excavation. For more information see OSHA 1926.651(c)(2) and figure 5-1.

(3) Procedures for Obtaining Undisturbed Samples from Exposed Profiles

(i) Collect undisturbed hand-cut samples from exposed profiles above the water table. Undisturbed samples may be obtained as box, cylinder, or chunk samples.

(ii) Samples are hand-cut and trimmed to cubical dimensions and placed in individual boxes for handling and shipping. They should have a minimum dimension of six inches. Preserve samples with plastic wrap or wax to keep the natural moisture content.

(iii) Cylinder samples from 4 to 8 inches in diameter and 6 to 12 inches long can also be hand-cut by sliding a cylinder over a column of soil which is trimmed to approximate size in advance of the cylinder. Cylinder samples may also be obtained by jacking or otherwise pushing drive samples into exposed surfaces using a continuous steady pressure.

(iv) Hydraulic power equipment is used to push Shelby tubes into exposed undisturbed soil to collect undisturbed samples, such as the sampler mounted on a backhoe in figure 5-9.

(v) Chunk samples are of random size and shape and are broken away from the soil mass, with or without trimming. Chunk samples are difficult to package and ship but are simple to obtain.

Figure 5-9. Shelby tube sampler mounted to a backhoe bucket.

B. Soil Sampling Tools

(1) See figure 5-10 for disturbed and undisturbed sampling tools for different soil types.

Figure 5-10. Soil types and sampling tools

Type of Soil	Sampling Tools	
	Logging of Disturbed Samples	**Undisturbed Samples**
Common cohesive and plastic soils.	Bucket-type augers[1/] all types of drive samplers, dry barrel.	Thin-wall open-drive sampler. Piston sampler. Double-tube core barrel
Slightly cohesive and brittle soils including silt and loose sand above the water table.	Same as above.	Thin-wall open-drive samplers. Piston samplers[2/] below water table. Double-tube soil core barrel (with liner).
Very soft and sticky soils.	Closed bucket auger[1/], dry barrel piston sampler[2/] or open drive with core retainers.	Thin-wall or piston samplers[2/].
Saturated silt and loose sand.	As above. Overdrive push-tubes to retain sample.	Piston sampler[2/] with heavy mud.
Compact or stiff and brittle soils including dense sands, partially dried soils.	Bucket-type auger[1/] Thick-wall drive sampler.	Double-tube soil core barrel.
Hard, highly compacted or partially cemented soils, no gravel or cobbles.	Bucket auger[1/] Thick wall drive sampler and hammer. Double-tube core barrel	Double-tube soil core barrel.
Coarse, gravelly, and stony soils including compact and coarse till.	Bucket auger [1/, 3/] Large diameter thick wall drive sampler.	Not practical.
Organic clay, silt, or sand.	As above according to basic soil type.	Thin-wall piston. Measure length of drive and original volume of sample carefully.

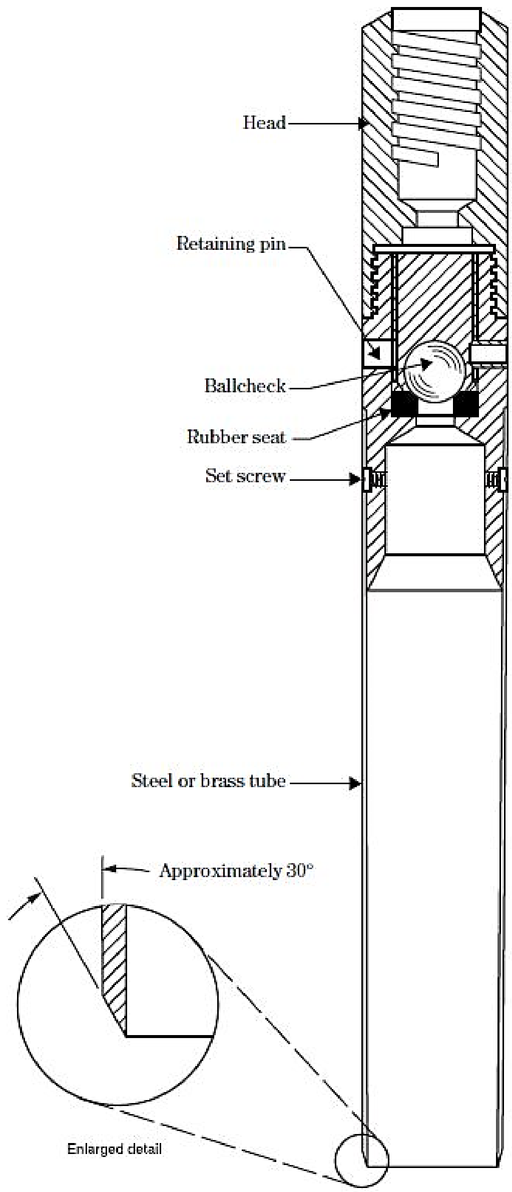
[1/] Homogeneous soils only (ASTM D1452).
[2/] ASTM D6519
[3/] Power equipment such as backhoes or bulldozers may be more suitable.

(2) Soil and Soft Rock Samplers

(i) Open-drive samplers

- Open-drive samplers are cylindrical samplers which are pushed or driven into the sampled materials. A drive sampler equipped with a piston is known as a piston sampler. Many drive and piston samplers are available on the market. They are manufactured in a variety of diameters, tube thicknesses, and tube lengths. They are generally known as thick wall, thin wall, and split barrel (ASTM D1587).
- Thin-wall Open-drive Samplers consist of hollow thin-wall steel barrels, manufactured in a variety of lengths, diameters, and wall thicknesses. They must be equipped with bails or other types of check valves for satisfactory performance.
- The simplest type of open drive sampler is the “Shelby Tube” (figure 5-11). Shelby tubes are 24 inches long and 3 to 5 inches in diameter. The tube is attached to a head assembly by means of set screws. This head assembly contains a ball check valve. After the sample is obtained, the tube is detached from the head, sealed, and shipped to the laboratory where the sample is removed for conducting tests.

Figure 5-11. Thin-walled open-drive sampler "Shelby tube"



After ASTM D1587

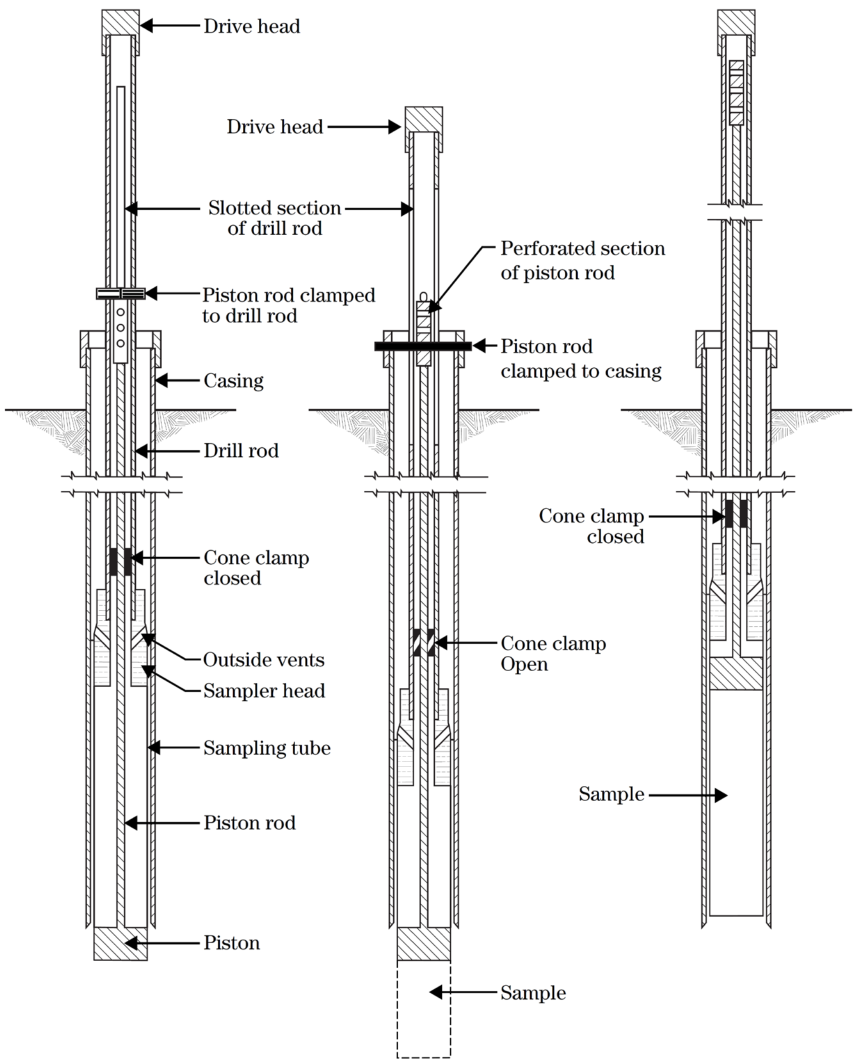
- Thin-wall samplers do not have cutting shoes but rather a sharpened cutting edge. To provide clearance in certain materials, the edge may be swaged to cut a sample smaller than the inside diameter. Thin-wall drive-samplers provide good undisturbed samples of certain soil materials, if proper methods of operation are used. The sampler must be advanced by a uniform and uninterrupted push without rotation. No additional drive should be made after the sampler stops.
- Thin-wall open-drive sampling methods are most practical in fine-grained, plastic, or peaty soils. The method is not suited for sampling brittle, cemented, or gravelly soils. The amount of disturbance in drive samples depends on the dimensions of the sample tube. The thinner the wall and the larger the diameter, the less the disturbance will be.

- Extruded samples are excellent for logging purposes. If desired for this purpose, the drill rig must be equipped with a sample ejector. The sample should be extruded through the top of the sampler. Undisturbed samples for laboratory analysis should not be removed from the sampling tube in the field but sealed in the tube, and the tube sent to the laboratory. Either 3-inch or 5-inch diameter undisturbed samples should be taken, depending on the type of laboratory test desired.

(ii) Piston-drive Samplers

- Piston-drive samplers are thin-wall samplers like "Shelby" thin-wall samplers but contain a piston to facilitate sampling (ASTM D6519). This sampling method is designed for collecting soft or medium soils samples and sands, silts, and cohesive soils below the water table. The stationary-piston sampler (figure 5-12) is lowered to the test hole bottom with the piston held in the lower end of the sampler. The piston is then locked into position by means of actuating rods which extend to the surface within the drill rods. The tube is forced into the materials by steady pressure, while the piston remains stationary at constant elevation to obtain the sample.

Figure 5-12. Stationary piston sampler



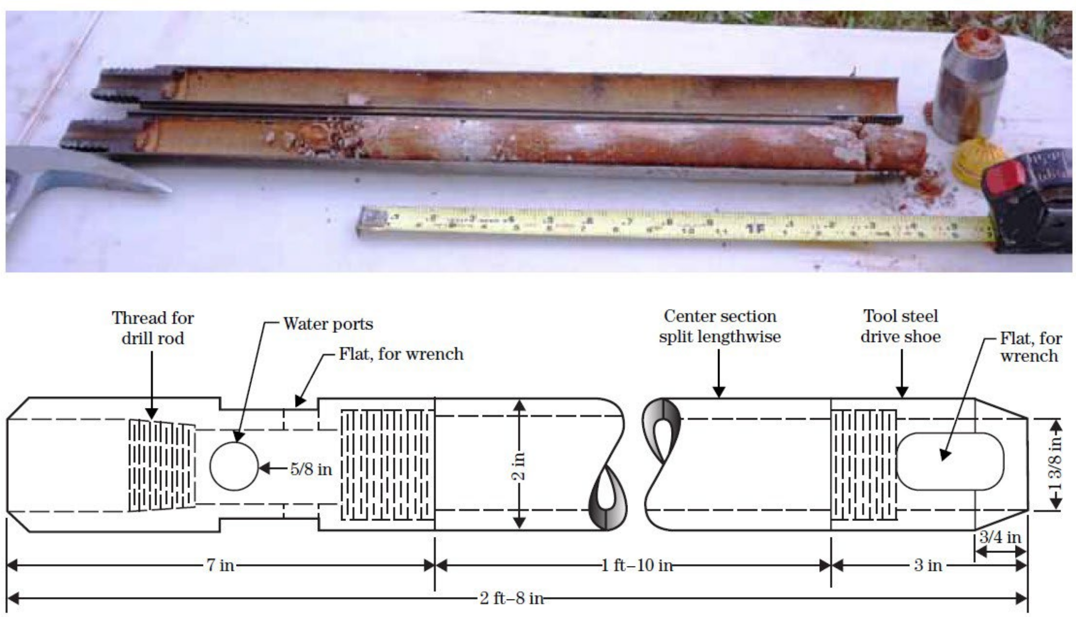
After ASTM D6519

- Sampler is equipped with a vented head to permit escape of air above the piston. The piston creates a vacuum which holds the sample in the tube while it is being brought to the surface. Stationary-piston samplers are available in sizes up to 30 inches in length with I.D. up to 4-3/8 inches. A modification of the above sampler (Osterberg type) requires lowering of the sampler in the test hole and hydraulically forcing the sampling tube into the soil. This type of sampler is available in 3-inch and 5-inch diameters.

(iii) Split-barrel Sampler

- The split-barrel sampler consists of a head, barrel, and cutting shoe. The barrel is split longitudinally so that it can be taken apart after removal of the head and the shoe, and the sample removed for visual inspection or packing in jars or other containers for shipment to the laboratory. The split-barrel sampler can withstand hard driving into soil materials. Since cutting shoes often become damaged by driving, a supply of additional cutting shoes should always be available during the site investigation. See the section on Standard Penetration Test, 631.0505 (B), (ASTM D1586) for more information on the split-tube sampler (figure 5-13).
- Split-barrel samplers are typically 24-inches long. The 2-inch O.D. sampler is recommended for logging purposes and is required for the standard penetration test. Split barrel samplers are not suitable for taking undisturbed samples because of sample disturbance from the thick cutting shoe and driving action of the hammer. Split-barrel samplers are adapted for accurate logging of thin-bedded materials.

Figure 5-13. Split-tube or split-barrel sampler



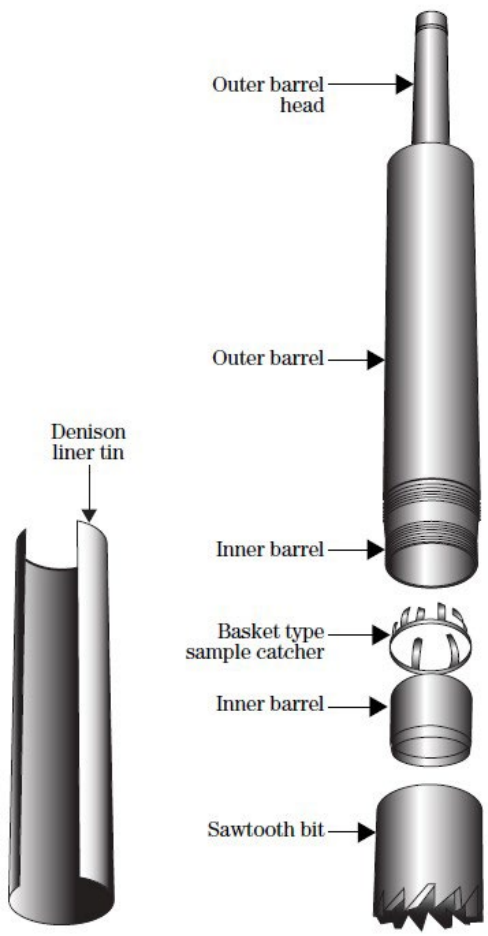
(iv) Double-tube Soil Core Barrel (Denison Type)

- Double-tube soil core barrels with liner are most suited for obtaining nearly undisturbed soil samples of highly compacted, hard, stiff, uncemented, or slightly cemented materials, (figure 5-14). Denison samples of cohesive soils are obtained with the least amount of disturbance.
- Denison barrels are used to sample a wide variety of materials, including some rock, such as soft shales and soft and friable sandstones. However, this method is not satisfactory for undisturbed samples of soft, loose, cohesionless silts and sands below

the water table, or very soft and plastic cohesive materials where the structure is destroyed by core barrel whip. Core barrel whip occurs when the bit of a core barrel cuts a larger hole than the diameter of the barrel. This over-sized hole can cause the barrel to vibrate (whip) in the hole during drilling.

- Denison barrels are not suitable for sampling gravels and cobbles. The double-tube soil core barrel is advanced by rotating the outer barrel, which cuts a circular groove and loosens the soil material to be displaced by the two barrels. Drilling fluid is forced downward through the drill stem between the barrels and carries the cuttings to the surface outside the tubes and drill stem. The inner barrel, which does not rotate, moves downward over the undisturbed sample being cut by the rotating outer barrel. A liner is inserted in the inner barrel before the barrel is assembled. After drilling the required length, the sampler is withdrawn, and the liner removed and prepared for shipping.

Figure 5-14. Double-tube soil core barrel (Denison type)



- Basket or spring-type core retainers may be used. Several types, using a different number and flexibility of springs, are available for use in different materials. The tapered, split-ring core retainer used in rock core barrels is not satisfactory for use in soil. A check valve is provided to relieve pressure over the core. The coring bits used usually have hard-surfaced steel teeth.

- Double-tube soil core barrels with liners come in various sizes which obtain untrimmed soil samples ranging from 4-3/4 inches to 6 inches in diameter. The diameter of undisturbed core needed depends on the kind of laboratory test required. Core barrels capable of collecting 2-foot-long undisturbed samples are recommended. Sectional liners are recommended for use in Denison-type core barrels when taking undisturbed samples for laboratory analyses.

C. Rock-sampling Tools

(1) Rock core barrel samplers are of two types: single tube and double tube. The single tube is designed primarily for boring in sound rock or for taking large cores in all types of rock. Double-tube rock core barrels are particularly useful for drilling small holes in sound rock, for drilling fissured rock, and for drilling soft rock where the core needs to be protected from the erosive action of drilling water.

(i) The fluid passes between the inner and outer barrels, eliminating its erosive action. There are two types of double-tube core barrels: “rigid” and “swivel.” In the rigid type, the inner tube and outer tube rotate together, while in the swivel-type double-tube core barrel, the inner tube does not rotate. The double-tube rock barrel (figure 5-15) differs from the soil-coring barrel in that it does not have a removable liner to hold the sample, and in the relationship of the cutting shoe to the inner shoe.

(ii) The cutting shoe trims the core at slightly less than that of the inner barrel, and the sample is retained in the inner barrel by means of a core lifter (figure 5-15). The rock core barrel obtains a sample of rock in the shape of a cylindrical core. The circular bit cuts the core, and the barrel slides down over it. A ball-check valve relieves water pressure, and a core catcher assists in retaining the core in the barrel.

(iii) Triple tube uses auger seated in rock, and two rock coring tubes to reduce the potential for pore pressure accumulation at the rock/embankment interface in earthen dams.

Figure 5-15. Swivel-type, double-tube rock core barrels

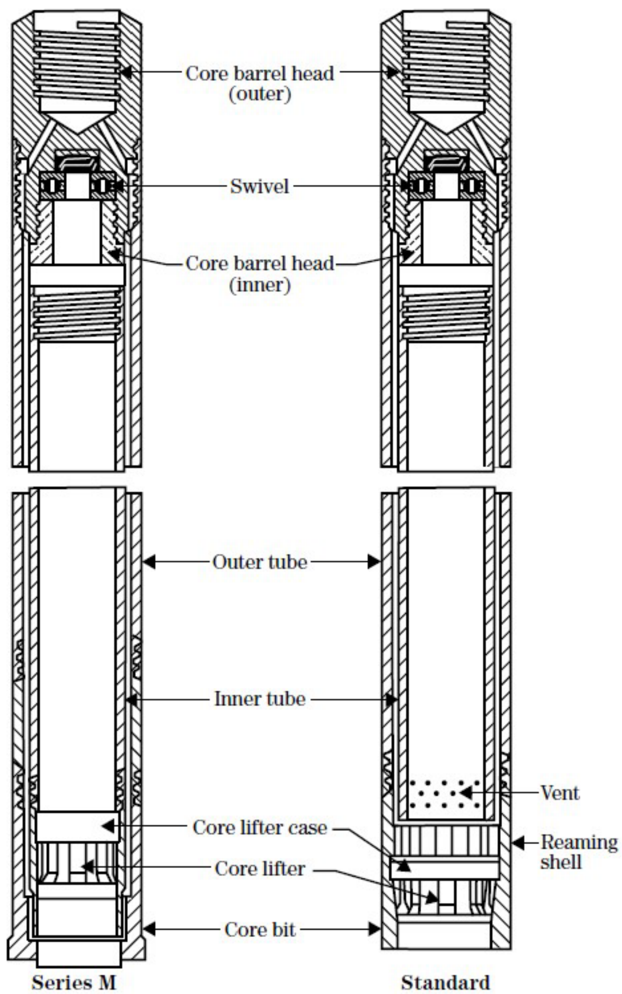
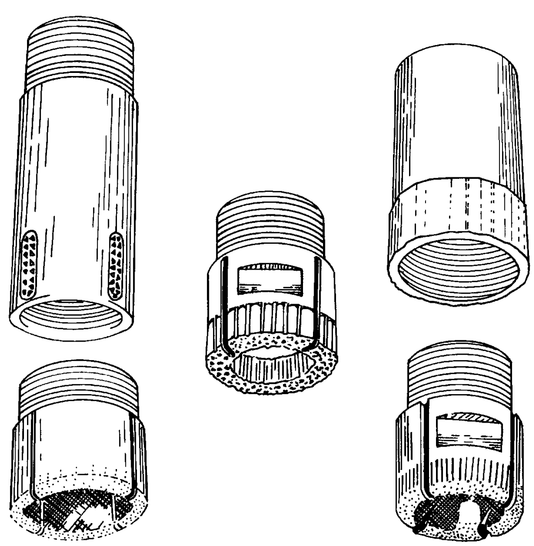


Figure 5-16. Diamond bits and reaming shells



(2) Air Percussion

(i) Air percussion drilling is used most frequently in the mineral and water exploration industries and is often used in conjunction with auger boring. The driller uses a down-the-hole or piston-driven hammer to drive a heavy drill bit into the rock. The cuttings or chips are blown up the outside of the rods and are collected and examined or logged at surface. The cuttings provide only low-quality samples. Air or a combination of air and foam lift the cuttings. If water is found in the hole, the borehole may become clogged.

(ii) Air percussion drilling is used to advance boreholes in bedrock in water wells, geothermal wells, production wells, and environmental monitoring wells. This method of drilling is useful for identifying voids or weathered zones in competent rock.

(3) Wireline Samplers

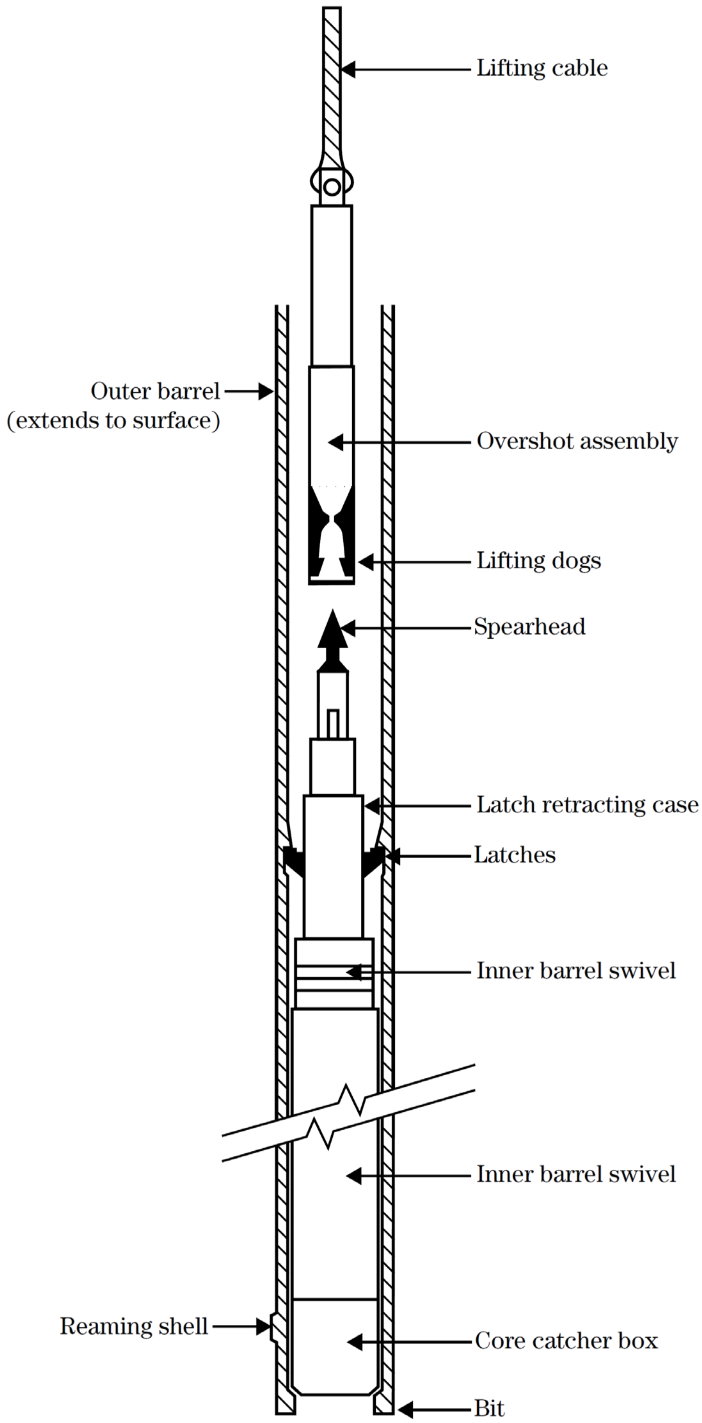
(i) Wireline core barrel systems reduce the amount of time required to recover conventional core barrels from deeper holes. Wireline core barrels are double-tube type barrels with an inner tube that is held in place with a latch during coring. Figure 5-17 shows a cross-section of a wireline sampler. When the run is completed, an overshot is lowered down the bore of the drill rods with a small cable (wireline) and hooks onto the spear of the inner tube head. Tension on the head releases the latch and frees the inner tube which is then raised to the surface through the drill rods.

(ii) After removing the core, the inner tube is lowered back into the outer tube, and coring is ready to start again. The drill string remains in the hole unless the core bit needs to be replaced due to wear.

(iii) Modern coring equipment and practice generally uses long-stroke automatic drills and conventional double-tube core systems to depths of 200 to 300 feet. At shallower depths, the automatic feeding of rods and connection make-up, combined with faster coring with conventional core barrels, are faster than wireline systems. Coring speed is inversely proportional to the "kerf," the width of the cut. Thinner kerfs are associated with faster drilling, and thicker kerfs slow the drilling process. Conventional core barrels cut a thinner kerf and core faster than wireline barrels. Below 200-300 feet, wire line systems generally become more efficient.

(iv) Single tube core barrels are almost never used in modern coring practice.

Figure 5-17. Diagram of wireline core barrel sampler



631.0504 Samples

A. Purpose of Samples

(1) Obtain samples for correlations, future reference, and soil mechanics testing to determine the physical properties of materials and how they behave under specific conditions. Results provide a basis for predicting the behavior of the materials during construction and operation of a structure to provide a safe, economical, and practical structure. Samples must be representative of the soil horizon or rock strata sampled and must be a suitable size and character to perform necessary testing.

(2) The kind of samples taken at a particular site depends on the nature of the materials, testing procedures planned, and on the size and purpose of the structure. The number of samples needed depends on the variability of the materials and the information required to adequately model and analyze the site.

B. Soil Sample Size Requirements for Soil Mechanics Laboratory Testing

(1) For more detailed information about collecting, logging, tagging, storing, transporting, and handling soil samples, refer to appropriate ASTM D4220. Refer to NEM, Part 531 – Geology for specific policies on shipping or transporting soil materials (APHIS requirements).

(i) APHIS Plant Protection and Quarantine (PPQ) program safeguards U.S. agriculture and natural resources against spread of regulated pests. APHIS updates the Federal Domestic Soil Quarantine Map for shipping domestic soil samples for analysis. See https://www.aphis.usda.gov/aphis/ourfocus/planthealth for more information about shipping and importing soil (accessed 4/2022).

(ii) The Federal Domestic Soil Quarantine Map provides general guidance. Contact your local APHIS State Plant Health Director for specific quarantine information boundaries and requirement for moving domestic soil. Soil from Guam, Hawaii, Puerto Rico, and the Virgin Islands is handled as a foreign soil. Contact the Soil Mechanics Laboratory for specific instructions before shipping soil samples.

(2) Figure 5-18 lists the major laboratory tests that can be performed on four sample sizes and provides a general description of the information provided by the test results.

(3) Figure 5-19 indicates minimum sample sizes required based on gradation. Soils that contain gravel (or larger) sized particles or unweathered bedrock require larger quantities of samples for determining gradation and for other test requirements.

Figure 5-18. Sample Size for Soil Test Requirements[1/]

Sample Size	Comments	Tests available	Information from Testing
Extra Small "XS"	Typically, when sample sizes are limited by investigation, i.e., SPT, poor recovery, stratification in undisturbed samples, etc.	Hydrometer analysis and sand sieve	Gradations of fine particles and sands
		Water content	Natural water content
		Soluble salt	Percent soluble salts by weight
		Crumb and double hydrometer	Determine whether soils are dispersive (ASTM D6572)
		Possibly a 1-point Atterberg or determination of non-plastic	Estimated plasticity
		Plasticity	
Small "S"	Typically bagged disturbed samples or relatively homogeneous, undisturbed Shelby tube samples.	*Tests listed for "XS" samples plus the following:*	
		Sieve analysis for gravel and sand	Gradations of sands and gravels to complement fine gradation determined from hydrometer analysis
		Grain size distribution	
		Hydrometer analysis	
		Atterberg limits[1/]	Plasticity (LL, PL, PI)
		Pinhole test if needed	Clarification of crumb and double hydrometer dispersion test results
		Chemical test if requested (this test conducted by NSSL in Lincoln, NE)	More specific determination of dispersion
		Specific gravity	Specific gravity of fine particles
		Consolidation (undisturbed)	Settlement characteristics and qualitative strength information
		Dry Unit Weight (undisturbed)	In situ density and water content
		Unconfined Compression Test (for cohesive undisturbed samples)	Saturated undrained cohesive strength representing short term strength
		Triaxial Shear (undisturbed – possible when adequate quantity of similar materials captured in one or more samples from the same stratum and 3 specimens of representative material can be carved)	Consolidated undrained strength with pore pressures measured providing both effective and total strength parameters and or unconsolidated undrained strength
		Flexible Wall Permeability (undisturbed)	In situ permeability rate and/or seepage rate and dry unit weight
Large "L"	Typically, not feasible from undisturbed Shelby samples due to limited volume in the tube.	*Tests listed for "XS" and "S" samples plus the following:*	
		Standard or Modified Proctor Density Test (Compaction)	Moisture/density relationships of soils to be used as earthfill or for which other complex tests require density information.
		Remolded Shear tests	Strength parameters for unconsolidated undrained strength of compacted fill

Figure 5-18. Sample size for soil test requirements[1/] (cont.)

Sample Size	Comments	Tests available	Information from Testing
		Remolded Flexible Wall Permeability tests	Permeability rate associated with a soil under specified conditions such as density and the addition of additives and/or unit seepage of that soil under a given hydraulic gradient.
		Determination of additive rates for special applications[2]	Permeability rate associated with soils treated with additives. Necessary rate of additive to treat dispersive clays. Necessary rate of additive to reduce plasticity and raise pH in highly plastic fill materials.
		Bulk Specific Gravity	Specific gravity and percent absorption of rock/gravel fraction of the sample
Extra Large "XL"		Tests described in "XS," "S," and "L" samples, plus special filter-design tests, large diameter shear tests, soil-cement tests, breakdown on degradable rocks, slake durability, and riprap durability tests. Please call the Soil Mechanics Lab to discuss these or other special testing requests prior to collecting or sending samples.	

[1/] The size of the sample to be sent to the laboratory varies with the maximum size of the material sampled. Most laboratory tests are performed on materials passing a No. 4 sieve. Larger samples are therefore needed of materials that contain significant amounts of larger particles. Modified from NRCS Geology Note 5, 1991, archived.
[2/] If fly ash or other non-traditional chemical treatments are desired, samples of these chemicals from the expected source must also be submitted with the soil samples. Approximately 5 pounds of these chemicals are needed.

Figure 5-19. Minimum field-sample size for various gradations of material[1/]

Gradation of material and sample size group	Maximum particle size	Minimum field sample size (pounds)
Gradation No. 1 Natural materials with 90% or more passing the No. 4 sieve:		
"XS" sample	≤3/4 inches	2 (all SPT, whatever size)
"S" sample	3 inches	10
"L" sample	3 inches	50
"XL" sample	3 inches	100
Gradation No. 2 Natural materials with 50 to 89% passing the No. 4 sieve:		
"XS" sample	3 inches	20
"S" sample	3 inches	75
"L" sample	3 inches	150
"XL" sample	6 inches	200
Gradation No. 3 Natural materials with less than 50% passing the No. 4 sieve:		
"XS" sample	3 inches	40
"S" sample	3 inches	100
"L" sample	3 inches	200
"XL" sample	6 inches	250

[1/] Note that the maximum particle size to be included in field samples varies. Estimate the percentage of over-size materials excluded from the field samples and record it along with descriptions of the samples on the Log of Test Holes (Form NRCS-ENG-533 or equivalent) and on the Soil Sample List (Form NRCS-ENG-534 or equivalent). It is not necessary to screen samples to determine the exact amounts of the various particle sizes. Visual estimates of the particle sizes and the quantities involved are adequate.

C. Sample Documentation

(1) Take detailed field notes for each undisturbed sample. Include the following items as appropriate:
(i) Hole number and location
(ii) Complete log of hole above and below samples
(iii) Method of drilling and size of hole
(iv) Type and size of test pit
(v) Casing (type and size) or drilling mud mixture used
(vi) Groundwater elevation and date and time measured
(vii) Length of drive and length of sample recovered, or percent recovery
(viii) Size of sample (diameter)
(ix) Elevations or depths between which sample was taken
(x) Method of cleaning hole before sampling
(xi) Other items, such as difficulties in obtaining sample

(2) Label the sample container with a permanent marker. Record the following information on the label:
(i) State
(ii) Watershed, site number, and location (Centerline of dam, borrow, etc.)
(iii) Date
(iv) Hole number and sample number
(v) Elevations or depths between which sample was taken
(vi) Top clearly identified
(vii) Name of person who took the sample
(viii) Weather conditions under which sampling occurred.

(3) The placement of an aluminum or plastic tag with pertinent information in the storage container helps the laboratory when exterior labels are lost or damaged.

(4) Undisturbed samples should be handled in the same orientation as sampled and stored in the same orientation as well.

(5) Undisturbed samples should be laboratory tested as soon after sampling as possible.

D. Determining Sampling Needs

(1) The geologist and engineer must determine what materials to sample and what tests are needed. Material characteristics and the type of laboratory tests govern the size and kind of sample required. The selection of equipment and the method of obtaining samples are controlled by site conditions, character of the material, depth of sampling, and the size and kind of samples needed. The kinds of samples taken at different locations and testing types are outlined below.

(2) Foundation

(i) Take undisturbed samples of questionable materials at the intersection of the centerline of the dam with the centerline of the principal spillway. Take undisturbed samples at other points along the centerline of the dam if materials of questionable bearing strength, compressibility, or permeability are encountered that cannot be correlated with strata at the intersection of the centerlines of the dam and principal spillway.

(ii) Take 25-pound disturbed samples from each distinct horizon in a proposed cutoff-trench area for compaction analysis, if the material that might be excavated is suitable for use in the embankment. Take 4-pound disturbed samples of all other soil horizons and of the same horizons from different holes, if they are needed to verify correlation.

(iii) Take cores of compaction-type shales for slaking (wetting-drying) and freezing-thawing tests. Foundations of these materials may require special treatment during construction, such as spraying with asphalt or immediate backfilling of the cutoff trench on exposure.

Rebound following unloading may also be a problem in some types of shale. The geologist and engineer should jointly decide what laboratory tests are needed for soil and rock.

(3) Principal Spillway

(i) In addition to samples from intersection of centerlines of the dam and spillway, take additional undisturbed samples beneath the centerline of the proposed principal spillway.

(ii) Collect undisturbed rock cores when rock excavation is planned. Samples should be stored indoors to protect from direct sunlight, weathering, and freezing. Rock selected for testing should be wrapped in plastic wrap and sealed in a bag as soon as it is retrieved. Some rock may deteriorate rapidly upon drying and may not represent its in situ state.

(iii) Dip auger samples selected for laboratory testing in paraffin.

(4) Auxiliary Spillway

(i) Take large, disturbed samples of any material proposed for use in the embankment. Collect rock cores when rock excavation is planned. Although soft shales may be classified as common excavation, obtain cores for later inspection by prospective contractors. If there is any question about rock suitability for use in the dam, send cores or samples to the laboratory for freezing-thawing, wetting-drying, rattler, and other tests that will help to determine their physical characteristics.

(ii) Collect undisturbed rock cores when rock excavation is planned. Samples should be stored indoors to protect from direct sunlight, weathering, and freezing.

(iii) Dip samples selected for laboratory testing in paraffin.

(5) Borrow Areas

(i) Collect disturbed samples of each unconsolidated material zone or horizon, including those horizons with limited extent. Although these less abundant materials generally are mixed with adjoining materials during borrowing operations, their inclusion in samples from the more abundant materials or more extensive borrow zones may result in erroneous evaluation. Laboratory tests of the index properties of these less abundant materials results in better evaluation of the effect and use of various mixtures.

(ii) Collect composite samples when a test hole has materials with the same visual USCS classification and from the same horizon and zone. Do not collect composite samples from significantly different stratigraphic elevations.

(iii) Do not take composite samples in areas where high salt content, montmorillonite clay, or dispersion are suspected. Instead, collect small individual samples. Samples with like characteristics are composited in the laboratory or testing section after the index properties have been evaluated. The geologist and engineer should furnish guidance on laboratory compositing, based on field distribution of materials.

(iv) On the soil sample list, NRCS-ENG-534 or equivalent, show from what holes and at what depths a composite sample was taken. Give estimates of the quantity of borrow material in the geologic report.

(v) Sampling surface soil from a stockpile used on the completed embankment is not necessary. Surface soil is not compacted to a required density, and compaction tests are not needed.

(vi) If borrow material will remain wet during construction, retain several samples in sealed jars or plastic bags. These samples are needed to determine the field moisture content.

(vii) In borrow areas where the water table is permanently high, the collection of borrow samples below the water table serves no useful purpose, unless the area is to be drained.

(viii) In the geologic report and on Form NRCS-ENG-356 or equivalent, specify what tests other than compaction are needed. Show the location of all samples on the plan and the cross sections of the borrow area on the geologic investigation sheets.

(6) Reservoir Basins
   (i) Take large, disturbed samples that are representative of the bottoms and sides of farm ponds and storage reservoirs for sites where moderate seepage or leakage is suspected. If local borrow sources are used for blanketing or sealing, obtain at least 50-pounds of sample for each material.
   (ii) To determine permeability of reservoirs or pond basins, collect samples from the surface to 12 inches of the present or proposed bottom and sides. Where borrow is planned for removal from the pond area, take samples from below the proposed borrow depth for permeability tests.

(7) Relief Well and Foundation Drain Locations
   (i) Take undisturbed samples of permeable strata for permeability determinations. If the geologist and engineer conclude that relief wells or foundation drains are needed, the aquifer must be delineated, and representative samples taken. Take undisturbed samples of all strata from the surface to two feet below the bottom of the permeable stratum.
   (ii) Take representative samples of permeable materials for use in the design of the well and filter when undisturbed samples are not possible. Determine aquifer permeability or transmissibility (permeability times thickness) in the field by conducting field permeability tests. Special care should be taken in embankment dams for field permeability. A purge or slug test may incur less risk to the embankment than a packer test, for example.
   (iii) Where corrosion or encrustation of the relief-well screen is a problem, collect a sample (one quart) of the groundwater and send it to the laboratory to test for alkalinity, chlorides, iron, total hardness, and pH value. Collect water samples according to ASTM D4448Standard Guide for Sampling Ground-Water Monitoring Wells.
   (iv) If investigations of the centerline of the dam indicate foundation drains are needed, take 4-pound disturbed samples for mechanical analysis of each horizon (permeable or non-impermeable) in which a drain may be placed.

(8) Stream Channel and Other Areas
   Take samples of gravels and sands from channels or other nearby areas for mechanical analysis. Material may be suitable for drains or filters.

(9) Soil Stabilization
   Collect representative samples of the area where the soil stabilization measures are planned for installation. The number of samples collected depends on the areal extent of the treatment and types of materials. Tests for soil cement or other chemical soil-stabilization measures require very large (75 pound) samples.

E. Undisturbed Samples

(1) Purpose of Undisturbed Samples
   (i) Undisturbed samples are taken so that the structure and moisture content of the original material are preserved to the maximum extent possible. Undisturbed samples are used to determine shear strength, consolidation, and permeability.
   (ii) Rock cores are used to determine strength, permeability, and weathering characteristics. Undisturbed samples are generally collected from foundation materials beneath embankments and appurtenant concrete structures (including auxiliary spillways) when information on natural strength, consolidation, or permeability is needed. The important considerations for undisturbed samples are that they be representative and that any disturbance of structure and moisture conditions of the sample be reduced to an absolute minimum. This requires close attention to sampling procedures, tools, packaging methods, and transportation.

(iii) Undisturbed samples from a depth of more than 15 feet usually must be obtained with drilling equipment. In the absence of drilling equipment, their collection involves the excavation of test pits from which cubes or cylinders of soil can be taken. Cubes, cylinders, or clods of soil can also be cut from the sides of open pits and cut banks, both natural and artificial.

(iv) Testing should be done as soon as possible after sampling.

(2) Preparation and Shipment of Undisturbed Soil Samples

(i) Undisturbed soil samples collected during the preliminary or detailed site investigation represent a significant investment in time and funds. Therefore, preparation and shipment of these samples to the testing facility merit special attention. Refer to NEM Part 531 for APHIS requirements and restrictions on shipping or transporting soils samples (ASTM D4220).

(ii) All possible precautionary and preventative measures must be used to minimize the detrimental effects of disturbance due to shock, drying, and freezing during collection, preparation, and shipment. Relatively firm, cohesive, non-sensitive materials require a minimum of extra care in preparation and shipment. They should be packed and marked to ensure shipment in the upright position, to prevent damage or loss of individual tubes, and to prevent freezing. Samples should be secured in the same direction as sampled.

(iii) Samples shall remain in the sample tubes and in a vertical position from packing on-site to unpacking at the testing facility. Samples shall be handled and shipped in the same orientation in which they were sampled. Appropriate marking should be on the tubes and shipping container.

(iv) Saturated, dilatant soils, or sensitive materials (ML, SM, CL-ML, some CL) require special attention to keep sample disturbance to a minimum. These samples must be kept in a vertical orientation and always protected from shock during storage and transportation. If drainage is necessary to firm up the sample slightly, a perforated expanding packer should be inserted in the bottom of the tube prior to disconnecting it from the drill stem. The sample should then be carried to a suitable drainage rack.

- When visual examination indicates that an adequate degree of drainage has been achieved, both ends should be sealed with non-perforated expanding packers. At this time, the tubes should be packed on site, prior to any vehicular transportation. Some fragile or brittle materials are susceptible to fracturing or cracking within the tubes if they are bumped or jarred, and they also require special handling. Various types of protective containers have been constructed and used to ship core samples to testing facilities.
- Typically, the ends are sealed with wax, then any voids are filled with sand. Then plastic end caps are placed and duct-taped on to the Shelby tube.

(v) Containers should incorporate the following features:

- Sample tubes are maintained in a vertical position from packing on-site to unpacking at the testing facility.
- For sensitive soils, design features and packing materials will cushion or isolate the tubes from the adverse effects of jarring or shocks while in transit.
- Internal packing and external marking should be provided to protect against freezing and undesirable temperature changes.

(vi) Examples of shipping containers for undisturbed samples that have been used successfully are shown in figures 5-20a, 5-20b, 5-20c, and 5-20d.

Figure 5-20a. Shipping containers for undisturbed samples

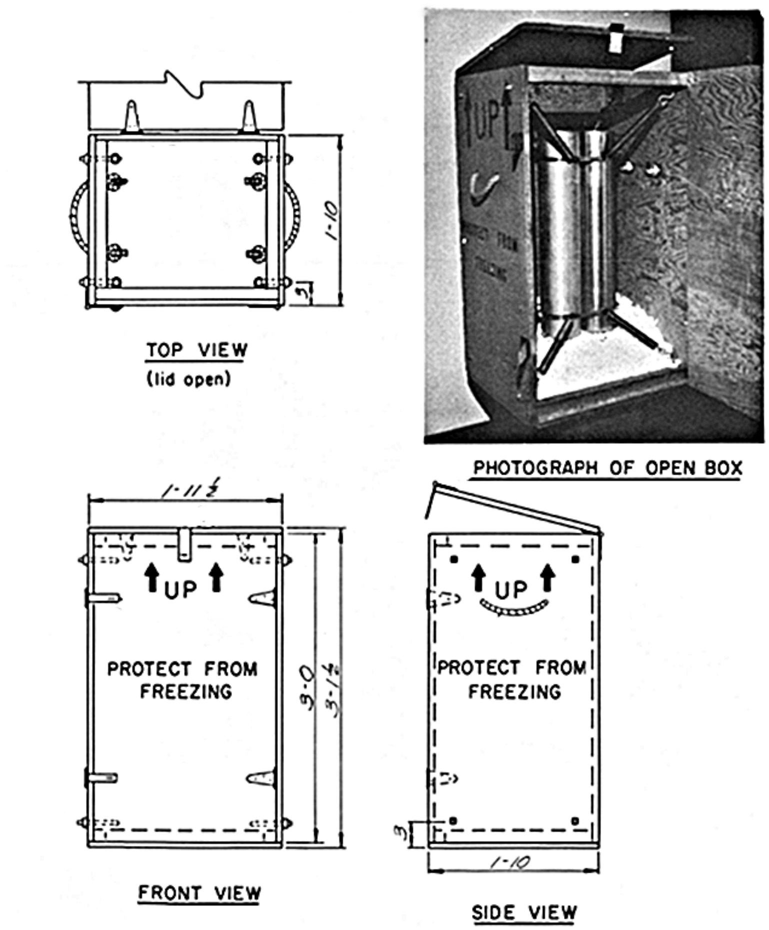


Figure 5-20b. Shipping containers for undisturbed samples

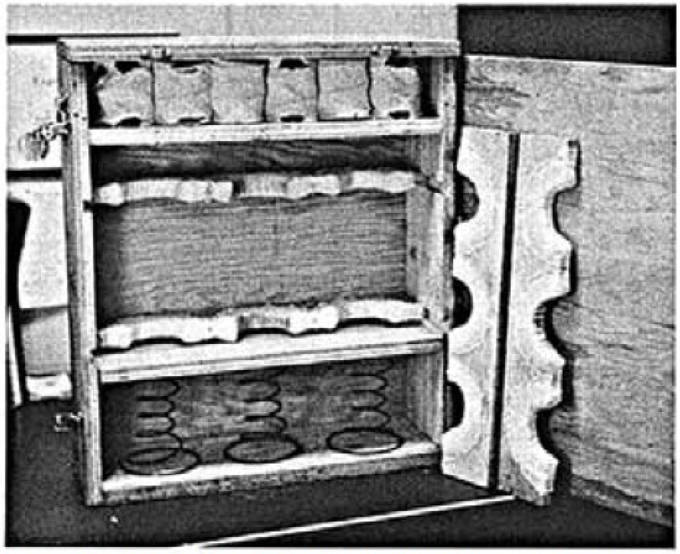


Photo shows spring supported, floating base for sample tubes; floating top plate with foam rubber packing; shaped, rubber padded lateral supports.

Photo shows spring-supported, floating base for sample tubes, floating top plate with foam rubber packing, shaped rubber padded lateral supports.

Sample tube supported vertically by spring action and laterally by shaped, rubber-padded inserts.

Sample tube supported vertically by spring action and laterally by shaped, rubber padded inserts.

Figure 5-20c. Shipping containers for undisturbed samples

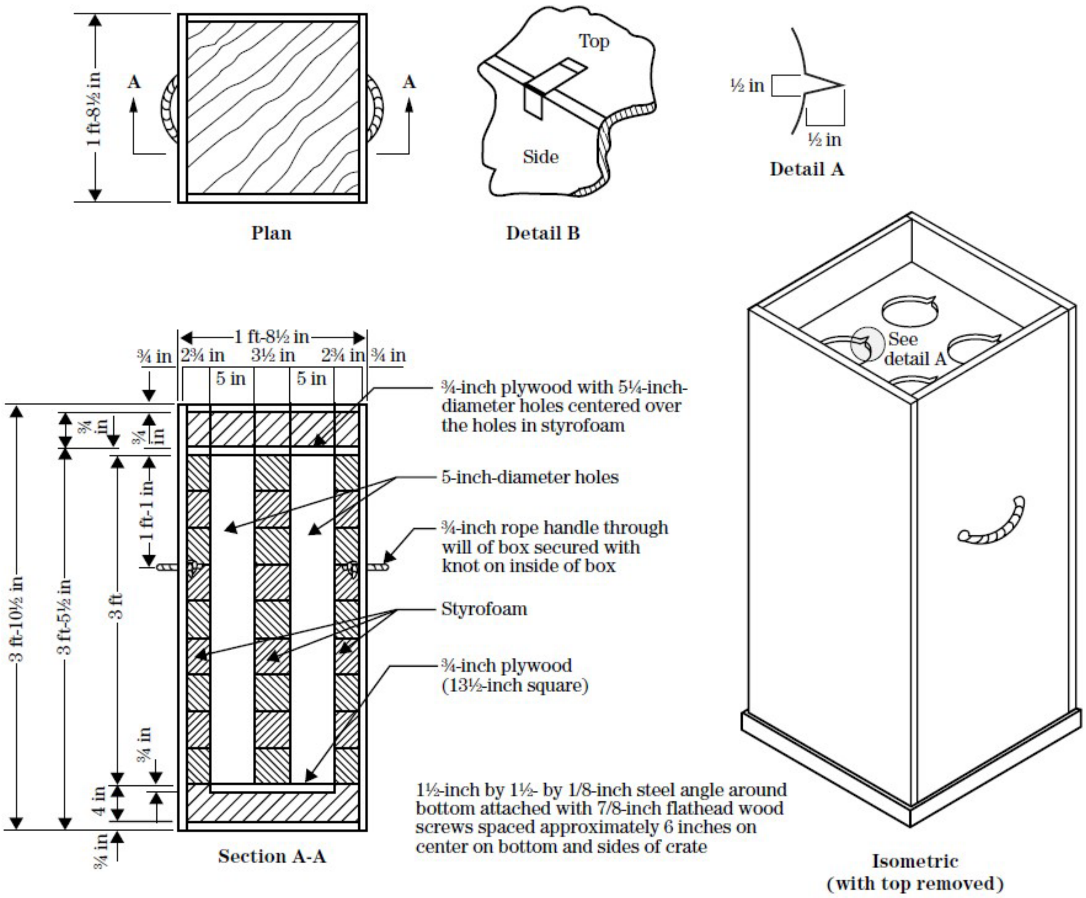


Figure 5-20d. Shipping containers for undisturbed samples

F. Disturbed Samples

(1) Purpose of Disturbed Samples

(i) Disturbed samples must be representative of the stratum, material, or area being sampled. They are used to make qualitative estimates of probable behavior of materials. This kind of sample is the easiest to obtain and is important for the classification of materials and for many soil mechanics analyses. But if quantitative information on in-place strength, consolidation, or permeability is needed, disturbed samples are of little value.

(ii) The important consideration for disturbed samples is that they be representative of strata from which they are taken.

(2) Methods of Obtaining

(i) Representative disturbed samples are obtained by hand excavation or, at a greater depth, by bucket-type augers or drive samplers. Be careful not to contaminate the sample with materials from other strata. Continuous-flight augers and wash borings are unsatisfactory.

(ii) Take proportionate volumes of all material between the selected elevations in the sample hole. If the sample is too large, it can be reduced by quartering after it is thoroughly mixed.

(3) Sample Containers

(i) Place disturbed samples in polyethylene plastic liners, resealable plastic bags or glass jars and store and ship in five-gallon plastic buckets. Each State should maintain a supply of plastic bags and polyethene plastic shipping buckets.

(ii) Retain the field moisture content for laboratory determination, such as in borrow material that is wet and is expected to remain wet. Use polyethylene plastic liners, resealable plastic bags, or glass jars.

(4) Labeling, Numbering, and Shipping

(i) Tag bag samples of disturbed material with cloth (linen) shipping tags or heavy-duty polyethylene write-on bags that show the following information:

- Location of project (State and town or community)
- Site or project name and number
- Classification of project (CO-1, etc.)
- Where sample was taken (centerline station, borrow grid, etc.)
- Test hole number
- Field number assigned to sample
- Depth of sample
- Date collected
- Name of collector

(ii) Number composite samples and show this number on the tag. Record the numbers of the individual holes from which the composite was taken and the field numbers of the samples on Form NRCS-ENG-534 or equivalent. Since tags are often pulled off in transit, place a duplicate tag inside the bag. To expedite the sorting, numbering, and handling of samples in the laboratory, the field number of a sample should start with the test-hole number followed by a decimal that indicates the number of the sample from that hole. Examples are sample Numbers 1.1, 1.2, 1.3, which are three samples from test hole Number 1 (in the centerline of the dam), and sample Numbers 101.1 and 101.2, which are two samples from hole Number 101 (borrow area). Under separate cover, send the standard forms containing the descriptions of the samples and logs of the test holes to the laboratory, along with copies of plans and profiles at the same time the samples are shipped.

(iii) Send a copy of the geologic report to the laboratory as soon as possible. A summary of the material to be sent to the laboratory follows:

- Form NRCS-ENG-356, Request for Soil Laboratory Services (or equivalent).
- Form NRCS-ENG-533, Log of Test Holes (or equivalent).
- Form NRCS-ENG-534, Soil Sample List-Soil (or equivalent) and Foundation Investigations. On this list show the individual holes, or the samples, included in composited samples if such mixtures are prepared in the field. Record the method of shipping or transportation and information concerning Government bills of lading.

List the samples on Form NRCS-ENG-534 in this order: foundation area, principal spillway, drainage and relief wells, channel, auxiliary spillway, pool area, and borrow area.

- Forms NRCS-ENG-35A, -35B, and -35C (or their equivalents), Plan for Investigations.
- Copy of geologic report, including the supplement on interpretations and conclusions on Form NRCS-ENG-376A, B and C (or their equivalents).

(iv) At the time the samples are sent to the laboratory, send copies of the various forms, logs, and the geologic report, including the supplement, to the State Office.

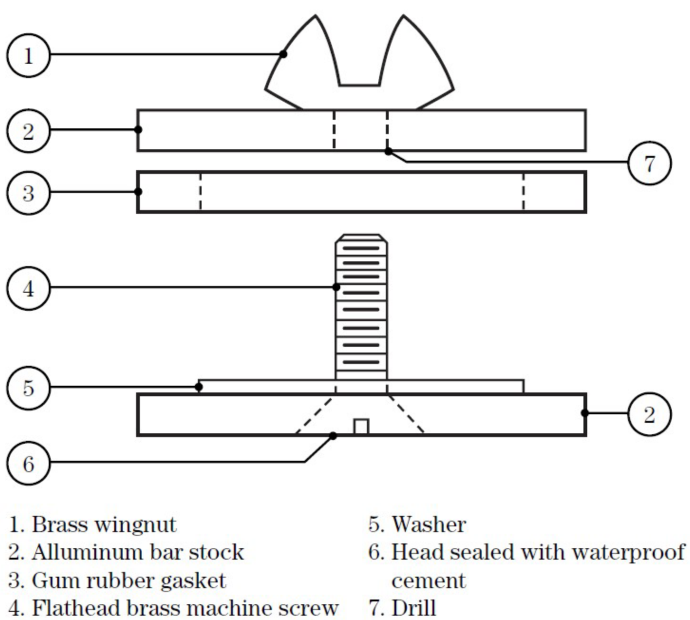
(5) Packaging

(i) Samples collected in a double-tube core barrel are encased in metal liners when they are removed from the sampler. Plug both ends of these containers with expanding packers or caps made of plastic or metal.

(ii) Expanding packers (figure 5-21) are preferred for sealing the ends of thin-wall tubes, but plastic caps secured with tape, or wax can also be used. Be careful that there is no air space between the sample and the seal. Place labels and all identification on the tube or the liner, not on the ends.

(iii) If they are tightly confined, samples collected by hand excavation can be placed in tin cans, Denison tins, or similar containers.

Figure 5-21. Expanding packer for sample tube



(iv) Seal all undisturbed samples thoroughly with a high-melting-point wax. Beeswax or a mixture of beeswax and paraffin is recommended. The wax seal should fill all spaces between the sample and the container, and cover both ends of the sample. Pack all undisturbed samples in excelsior, sawdust, or other shock-absorbent material and crate them. Two or more samples can be boxed together for shipment, but they should not touch each other.

(v) Use reusable containers when possible. They may be returned by the laboratory (thin-wall tubes, Denison liners, brass liners, expanding packers, and the caps for tubes and liners).

(vi) Label the containers with precautionary information such as “Handle with Care,” “This Side Up,” ”Do Not Drop,” and “Protect from Freezing.”

G. Disposition of Rock Cores

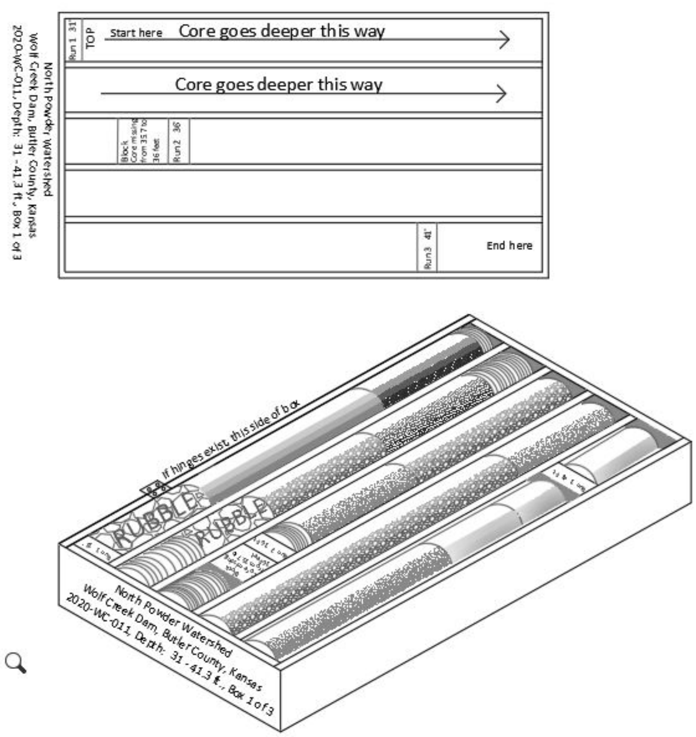
(1) Handling and Storage of Rock Cores

(i) Store samples of easily weathered rock cores, such as shale, at the nearest NRCS office. If they are left outdoors and allowed to weather, they may give prospective contractors an erroneous impression of their original hardness.

(ii) Handle rock cores carefully and store them in boxes of dressed lumber or other suitable materials. The core boxes should be about four feet long, with no more than four cores stored in each box. The cores should be separated by longitudinal partitions. Use separation blocks wherever a core or a section of the core is lost or not recovered during the drill run. The length of the lost section should be noted on the separation block. Embossed metal tape or other acceptable materials can be securely fastened in the box to indicate by elevation the beginning and end of each reach of core in proper sequence as taken from the boring.

(iii) Place cores first in the top compartment and proceed toward the front of the box in the order that the cores were taken from the drill hole, filling each compartment from left to right in turn (as one reads a book). Figure 5-22 shows the core box notation. Note the depths on separation blocks for those sections in which a core could not be obtained. On the inside of the box write the box number, project name, site number, hole number, and interval contained within the box. Record the same information on the outside of both ends of the box.

Figure 5-22. Core box



(iv) Open areas of the core box should be filled with foam to prevent movement of the samples.

(2) Photographic Documentation of Rock Core Samples

(i) Photographic documentation is a vital part of geologic documentation. Use proper equipment to obtain high resolution images and pay attention to detail for accuracy. Distorted images, poor focusing, and lack of core run depths or scale are not acceptable technical documentation. Good images can save considerable time and money throughout the design, construction, and operational phases of the engineered structure. Photographs become the only visual record when core samples are disposed. Advantages of photographs include:

- Provides a permanent visual record of the rock condition, including in situ color weathering condition and void filling.
- Provides a graphic record of structural features exposed in the rock core, from which angular and spatial relationships can be measured.
- Provides convenient graphic illustration for geologic reports and presentations during design, construction, and operation.
- May be enlarged to provide examination of mineral and microstructure characteristics in place of actual core samples. These enlargements can also be cut and pasted on the master drill logs.

(ii) Photographs must follow minimum standards:

- Photograph core boxes in natural light and orient to eliminate shadows.
- A digital camera or smart phone can be used to make photo documentation.
- Photograph core boxes in both wet and dry conditions.
- Keep camera lens perpendicular to the core box to minimize distortion of core and linear features. See figures 5-23 and 5-24.
- Lay out or affix a measuring scale along or adjacent to the edge of each core box as a size reference.
- A color proof strip (a multi-color chart can be obtained online or from a photo shop) should be included in the documentation to ensure true color reproduction.
- Include the following index information:
  - Reference data such as project name, hole and box number, date collected, core interval, and hole location. This information is typically written on the box lid and end. An example is provided in figures 5-25 and 5-26.
  - Identification and scaling data such as project name, hole number, box number, core run depth, reference scale in inches and tenths, hole completion date, and color index strip. These data are provided in or along the edge of the core box and are included within the photograph as shown in figure 5-27. The lettering on the core box should not be less than one inch in height.

(iii) Photograph cores while still in the sleave before placing in the core box to document core condition, and photograph after samples are boxed. Include in each photograph a scale, project name with site name if applicable, borehole number, run number, interval of run, date collected, and initials of project geologist or engineer. Stereoscopic pairs of photos can, at times, be useful to study cores. These can be taken in the following manner:

- Take one photo of the cores in a dry condition.
- Wet the cores (a spray bottle can be used to put water on the cores).
- Move about 0.5 feet to the left or right from where the original photo was taken, then focus the camera on the same spot as the first photo and take a second photo.

Figure 5-23. Setting up rock core boxes for photography. Note that camera distance may vary, depending on type used. For example, pictures taken with a cell phone camera may require a perpendicular distance different from an SLR digital camera.

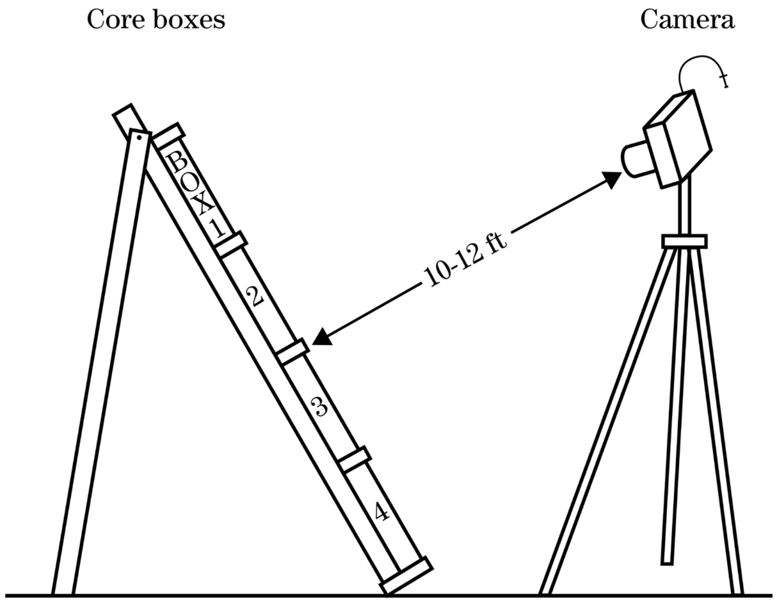
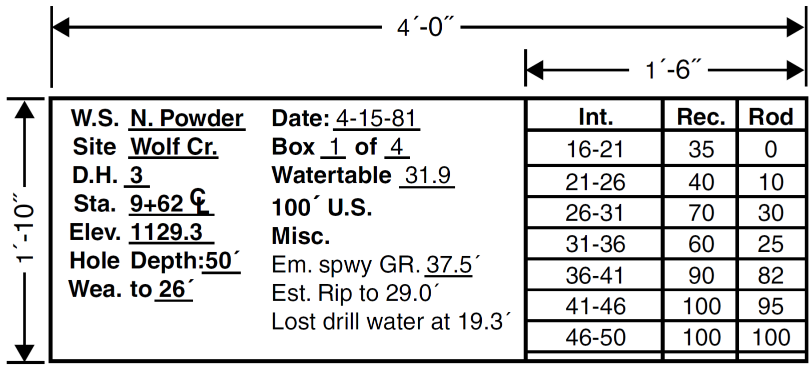


Figure 5-24. Portable core box rack

Figure 5-25. Rock core sampling information on inside lid of core box



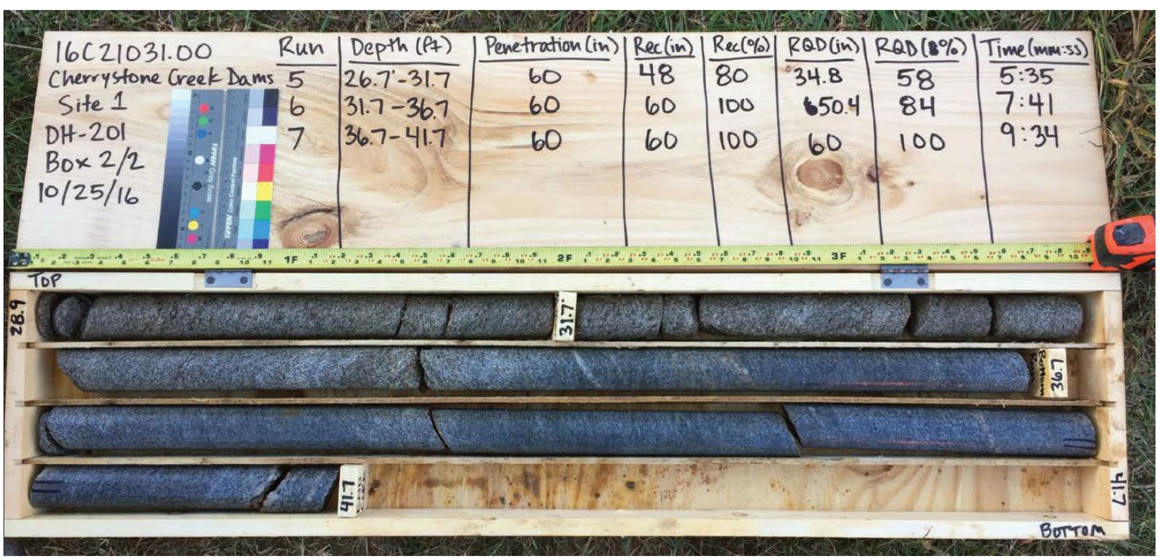
(vi) A diagram of a core box end is shown in Figure 5-26 below:

Figure 5-26. Sample data inscription on core box end

North Powder Watershed
Wolf Creek Dam, Butler County, Kansas
2020-WC-011, Depth: 31 - 41.3 ft., Box 1 of 3

(iv) Core boxes can be included as part of the drilling investigation contract. Record project and drilling information on the inside of the lid as shown in figure 5-27.

Figure 5-27. Sample photograph of core box



631.0505 Testing Earth Materials

A. Test Holes

(1) Test holes are drilled to obtain representative disturbed and undisturbed samples to:
  (i) Advance and clean holes to specific horizons for logging, sampling, and conducting tests
  (ii) Advance holes to bedrock to delineate rock surface
  (iii) Install piezometers and relief wells

(2) Disturbed samples are commonly obtained using a core split-spoon sample barrel or Standard Penetration Test split-spoon sampler. Undisturbed samples are obtained by pushing or coring a tube into in situ soil materials. A common undisturbed sampling method is the hydraulic pushing of a Shelby tube, referred to as a "push-tube sample."

(3) Test holes may be augered by hand, or through powered truck mounted drill rigs, all-terrain rig, all-terrain vehicles, tracks, or on a barge. Selecting a drilling method depends on:
  (i) Access (terrain roughness, space, and height limitations)
  (ii) Types of tests or samples needed for the investigation and design needs
  (iii) Disposal of drilling fluids and cuttings (contaminated cuttings and groundwater may have to be handled as hazardous waste), lithology (soil composition or soil classification, such as sand, clay, and boulders), rock type, and aquifer characteristics (depth to water)
  (iv) Address local ordinances.

(4) Hand Auger Borings
  (i) Hand augers are useful for advancing holes to shallow depths but are normally limited to less than 20 feet. A bucket-type hand auger provides samples useful for logging and interpretation (ASTM D6907).
  (ii) Motorized hand augers (post-hole augers) are available but are limited to six feet in depth.

(5) Power-auger Boring
  (i) Truck or trailer-mounted power augers are used for dry boring in unconsolidated materials (ASTM D1452 and LSASD 2020). Test holes are advanced by rotating a cutting bit into the materials. Power augers can bore through a wide variety of materials but are not generally suitable for use in materials containing cobbles or gravel, hard cemented soils, or saturated cohesionless soils. Unstable materials require casing, particularly below the water table.
  (ii) Power-auger boring uses two different techniques to sample earth materials:
    - Method 1: Screw the auger into the soil like a corkscrew for a set distance, then pull auger from the hole and collect drill cutting samples from the flight auger. The downward auger advancement should match the auger rotation, so the sample is not mixed. With plastic clays, short sample intervals give better sample recovery.
    - Method 2: Screw the auger into the soil like a corkscrew, then spin until material at the leading edge of the auger is brought to the surface. This method is used when the power auger lacks the power to pull the auger from the soil after screwed in. Soils are logged and sampled as they are transported to the surface.

(6) Continuous Sampling

(i) Direct push technology (ASTM D6286) uses the static weight of the rig combined with a drive or hydraulic hammer to advance a soil sampling tool or soil probe. Direct push soil sampling tools do not remove cuttings from the hole but depend on compression of the soil to permit advancement of the tool string. This method consists of forcing a tube into soil materials and withdrawing material retained inside the tube. Continuous drive test holes can be made in clays, silts, and relatively stable materials free from gravel, cobbles, and boulders. The sampler, when withdrawn, acts as a piston in the hole, causing more excessive caving than other methods of boring. See NEH Part 631 Engineering Geology, section 631.0205 (A), Drilling Methods.

(ii) Continuous sample tube system collect soil samples in conjunction with the hollow-stem auger drilling process. The five foot (1.5 m) solid or split sample tube does not rotate with the hollow-stem augers so representative samples are obtained. Even minor changes in soil materials are visible when the sample is extruded, or the split sample barrel is opened.

B. Standard Penetration Test (SPT)

(1) Standard penetration testing provides a measure of the resistance of soil to the penetration of the sampler. Testing also furnishes samples of the material penetrated for identification, classification, and other test purposes. This test is used to indicate relative in-place density of cohesionless and relative in-place consistency of cohesive foundation materials and for logging. Figure 5-28 shows the relative density and consistency for various soils and blow counts. Refer to ASTM D1586, A Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils.

Figure 5-28. Standard penetration resistance

Coarse-Grained Soils (Noncohesive)	
Blows per foot	**Relative Density**
< 4	Very loose
4 – 10	Loose
10 – 30	Medium
30 – 50	Dense
50	Very dense

Fine-Grained Soils (Cohesive)	
Blows per foot	**Consistency**
< 2	Very soft
2 – 4	Soft
4 – 8	Medium
8 – 15	Stiff
15 – 30	Very stiff
> 30	Hard

(2) The standard penetration test is recommended for use in NRCS work and is most applicable to nonlithified soils and soils with maximum particle size is approximately less than one-half of the samples diameter. Different size samplers exist to accommodate larger expected particle sizes. This may be mentioned in the ASTM document.

(3) Drilling Equipment

(i) Any equipment may be used that will provide a reasonably clean hole to ensure that the test is performed on undisturbed material and that will drive and reclaim the sampler according to the procedure outlined below. Where necessary, casing, or hollow stem auger are used to prevent caving.

(4) Split-tube Sampler

(i) The split-tube sampler has an outside diameter of two inches and a hardened steel driving shoe at least three inches in length with an inside diameter at the cutting head of 1 3/8 inches. The drive shoe is sharpened by tapering the last 3/4 inch to a cutting edge not greater than 1/16 inch thick. Do not use dented, distorted, or broken shoes as this can impact your testing results. A split spoon sampler is shown in figure 5-13.

(ii) A California-Modified style split-spoon sampler is used to collect wider diameter samples (for use with brass liners). The outside diameter is 2 ½ inches and has a hardened steel driving shoe at least three inches in length, with the length of barrel 18-inches or 24-inches. A correction factor is applied to the blow counts to compute N, the standard penetration resistance.

(5) Hammer

(i) The drive hammer weighs 140 pounds and has a 30-inch stroke (free fall). Any type of hammer may be used if there is no interference with its free fall, and its energy is not reduced by friction on the drill rod, guides, or other parts of the equipment. Most modern drill rigs have an automatic hammer that delivers the same energy mechanically. The advantages of the automatic hammer are increased safety and, by reducing the chance for human error, more consistent, repeatable results.

(ii) Routinely check the hammer to ensure it is operating at the correct blow rate and drop height. Measure hammer energy according to ASTM D4633.

(6) Procedure for Performing the SPT (ASTM D1586)

(i) Cleaning Hole

- Clean the hole to the sampling elevation by use of equipment that will not disturb the material to be sampled. Do not use bottom discharge fishtail bits, jetting through an open tube, or sand water bailers.
- Take samples at each change in stratum and at intervals not greater than five feet. Never drive casing (or hollow stem auger) below the depth to which the hole is to be cleaned out.

(ii) SPT Procedure

- Lower the split-tube sampler to the bottom of the cleaned hole. Drive the sampler six inches with light blows so it will not be overdriven. This sets the sampler and prepares for the one-foot SPT.
- Drive the split-tube sampler 12 inches or to refusal by dropping the 140-pound hammer 30 inches sequentially and record separately the number of blows required for each six inches of this 12-inch penetration test drive.
- Penetration of less than one foot in 100 blows is generally considered refusal. The blow count is the total number of blows required to drive this one-foot interval or, with refusal, the number of inches penetrated by 100 blows.
- Remove the sampler from the hole, remove the drive shoe, and carefully split the sampler open. Identify and classify the material or materials, record the percent recovery, place typical sample or samples in jars (without jamming or compressing), seal jars, and label. Label to show site location, test hole number, sample number, date collected, location of hole and depth represented by sample, field classification, blow count, and percent recovery.

(iii) The following additional information is needed for liquefaction analyses in active seismic areas:

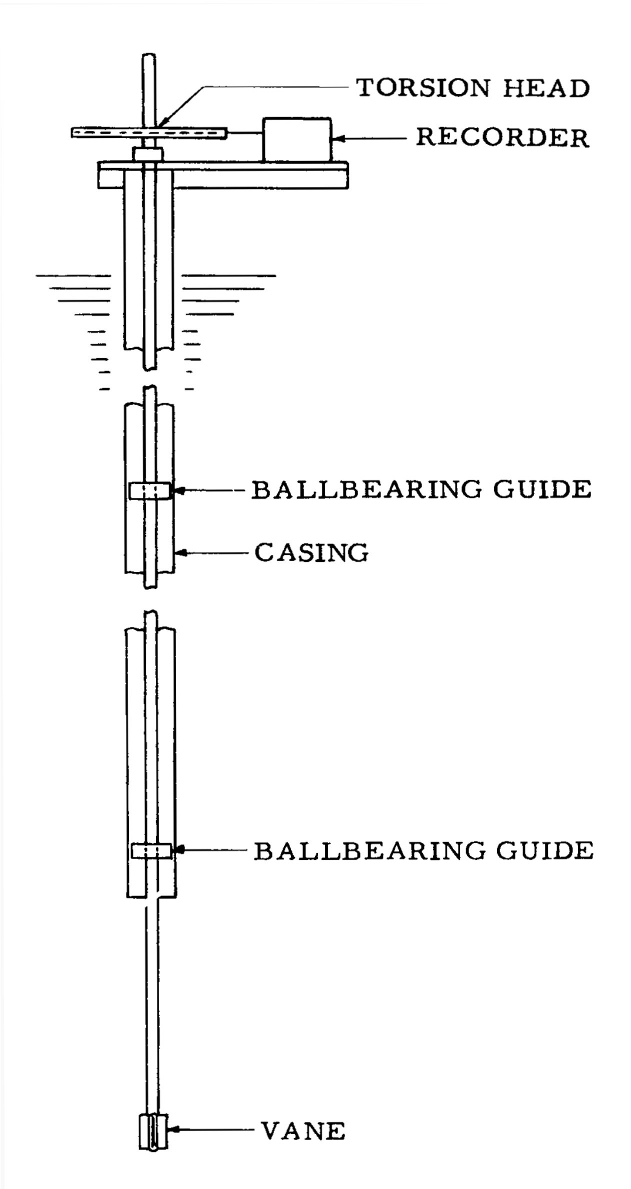
- hammer type
- rod length
- borehole diameter
- liner type if used

C. Vane Shear Test

(1) The vane shear test provides a field method for determining the shearing resistance of in situ earth material. See figure 5-29.

(2) The vane, attached to the end of a rod, is pushed into undisturbed soil and rotated at a constant rate by means of a torque wrench or other calibrated torsion device attached to the rod. A gauge, with a marked scale, on top of the rods measures the torque required to shear the soil. The scale provides a conversion from torque applied to shear strength. The vane is rotated until the soil shears and the gauge shows the maximum torque applied. There are at least three sized vanes, with the larger vanes used for softer soils. The moment or torque required to turn the vane is an indication of the shear strength of cohesive soils. See ASTM D2573 for the Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils.

Figure 5-29. Vane-shear tester and the pocket vane shear version



(3) Pocket vane shear test tools are available to provide quick information about shear strength of exposures of earth materials or in excavated pits or trenches (ASTM D8121). This is a hand-held device that measures the maximum shear strength value of the earth material in the field or in the laboratory. The device usually comes with three vanes to test a wide range of consistencies. See figure 5-30.

(i) Regular vane (0 to 1 kg/cm^2): used for fully saturated cohesive soils with undrained strength independent of normal pressure. The stress range permits it to be used for clays varying in consistency from very soft to stiff.

(ii) Large vane (0.2 kg/cm^2: use with remolded samples.

(iii) Small vane (2.5 kg/cm^2): for stiffer clays.

Figure 5-30. Pocket shear vane tool

D. Pocket Penetrometer

(1) The pocket penetrometer is a light-weight instrument used to estimate the unconfined compressive strength of cohesive soils. The values may be correlated with shear strength and consistency. See figure 5-31.

(2) The "pocket penetrometer" is specifically used to determine the penetration resistance of top layers (measuring depth five mm) and of samples in the field or in the laboratory.

Figure 5-31. Pocket penetrometer

E. Cone Penetrometer Testing (CPT)

(1) Cone penetration testing (CPT) is a fast, effective, and relatively inexpensive system for collecting important soils parameters during a geotechnical site investigation. When used in conjunction with conventional drilling and sampling methods, it provides a more complete description of the subsurface conditions, thereby reducing uncertainty in design and construction.

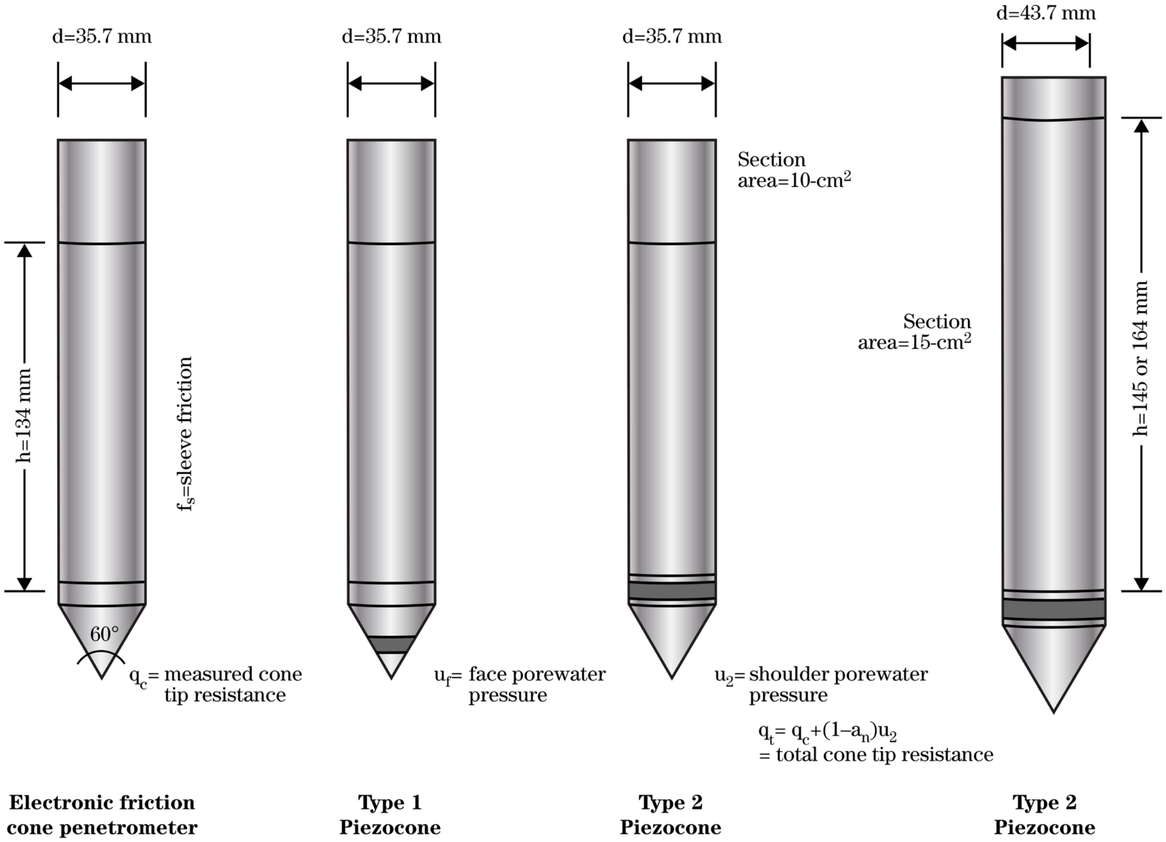
(2) Cone penetration testing with modern equipment provides continuous readings of point load or tip resistance, sleeve friction, and porewater pressure. The tip of a cone penetrometer is shown in figure 5-32 and standard sizes in figure 5-33.

(3) Tip resistance is theoretically related to the undrained shear strength of a saturated, cohesive material and measured with an embedded load cell. The sleeve friction is theoretically related to the friction of the horizon being penetrated and is measured using tension load cells embedded in the sleeve. CPT results may be correlated with Standard Penetration Tests and laboratory test information from collected samples. See ASTM D3441 for the Standard Test Method for Mechanical Cone Penetration Testing of Soils.

Figure 5-32. Cone penetrometer tip

Photo courtesy of Gregg Drilling & Testing, Inc.

Figure 5-33. Dimensions and measurements taken by the standard 10-cm^2 and 15-cm^2 penetrometers



(After ASTM D5778)

F. Permeability Investigations

(1) Groundwater is an important natural resource. Unlike surface water, however, groundwater cannot be seen, and it is often overlooked. Groundwater investigations determine the geologic and hydrologic characteristics of subsurface material. Information is used to establish project feasibility, basis for estimating costs, and the need and intensity for further study.

(2) Permeability investigations estimate the amount of water pumped from a given aquifer to estimate safe yield of groundwater reservoirs, and the time required to recharge such reservoirs.

(3) Permeability tests are an important part of any investigation to determine structure stability and safety. Tests provide approximate permeability or hydraulic conductivity values, and reliability depends on strata homogeneity and testing methods. Tests provide relative values at various depths and in different strata; and they are simple procedures performed during normal drilling operations. Several types of permeability tests include:

(i) Aquifer testing
(ii) Permeameter testing
(iii) Pressure permeability testing

(4) For more information about permeability and permeability testing, see NEH Part 631 Chapter 31 Groundwater Investigations, section 631.3104 Hydraulic Material Properties and section 631.3112 Groundwater Aquifer Testing, United States Bureau of Reclamation (USBR) Engineering Geology Field Manual Volume 2, Chapter 17 Water Testing for Permeability and Freeze and Cherry (1979).

631.0506 References

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