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| **Title:** | **GEOLOGIC LOGGING** |
| **Category:** | GEO 4.8 |
| **Revised:** | March 1998 |



STANDARD OPERATING PROCEDURE

# GEOLOGIC LOGGING



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# 1. Introduction

Geologic logging involves keeping detailed records during the drilling of boreholes, the installation of monitoring wells, and the excavation of test pits, and entering the geologic descriptions of the soil and rock samples recovered on a standardized form. E & E has adapted a standardized geotechnical logbook (see DOC 2.4 in E & E's Standard Operating Procedures [SOPs]) that contains items deemed important to record when installing monitoring wells, piezometers, and/or soil borings. This document discusses general procedures for completing geologic logs.

# 2. Drilling Logs

## 2.1 Basic Documentation

When drilling boreholes, the project geologist should maintain a log that describes each borehole. The E & E Geotechnical Logbook contains records for boreholes. The following basic information should be entered on the heading of each drilling log sheet (see Figure 1):

- Borehole/well number;
- Project name;
- Site location;
- Dates and times that drilling was started and completed;
- Drilling company;
- E & E geologist's name;
- Drill rig type used to drill the borehole;
- Drilling method(s) used to drill the borehole;

DRILLING LOG FOR ______________________

Project Name ______________________

Site Location ______________________

______________________

Date Started/Finished ______________________

Drilling Company ______________________

Driller's Name ______________________

Geologist's Name ______________________

Geologist's Signature ______________________

Rig Type(s) ______________________

Drilling Method(s) ______________________

Bit Size(s) __________ Auger Size(s) __________

Auger/Split Spoon Refusal ______________________

Total Depth of Borehole is ______________________

Total Depth of Corehole is ______________________

| Water Level (TOIC) | | |
|---|---|---|
| Date | Time | Level (Feet) |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Well Location Sketch

N

| Depth (Feet) | Sample Number | Blows on Sampler | Soil Components CL SI S GR | Rock Pile | Penetration Times | Run Number | Core Recovery | RQD | Fracture Sketch | HNu/OVA (ppm) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 11 | | | | | | | | | | | |
| 12 | | | | | | | | | | | |
| 13 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |

**Figure 1 Drilling Log**

- Bit and auger size(s);
- Depth of auger/split barrel sampler refusal;
- Total depth of borehole;
- Total depth of corehole (if applicable);
- Water level at time of completion measured from top of inside casing (TOIC); and
- A well location sketch.

## 2.2 Technical Information

During the drilling of a borehole, specific technical information about the unconsolidated material and rock encountered should be recorded on the drilling log sheet. The following minimum technical information should be recorded:

- Depth that sample was collected or encountered;
- Sample number assigned (if applicable);
- The number of blow counts required to drive the split barrel sampler 2 feet at 6-inch intervals (see Table 1);
- Description of soil components (see Figure 2);
- Description of rock profile (see Figure 3);
- Rock qualitative designation (RQD) (see Figure 4);
- Rock penetration time;
- Core run number (if applicable) and percent recovery; and
- Organic vapor readings in the sample.

**Table 1 Standard Penetration Test for Soil Density**

| N-Blows/Feet | Relative Density |
|---|---|
| **Cohesionless Soils** | |
| 0 - 4 | Very loose |
| 4 - 10 | Loose |
| 10 - 30 | Medium |
| 30 - 50 | Dense |
| 50 | Very dense |
| **Cohesive Soils** | |
| 2 | Very soft |
| 2 - 4 | Soft |
| 4 - 8 | Medium |
| 8 - 15 | Stiff |
| 15 - 30 | Very stiff |
| 30 | Hard |

# 3. Soil Classification

Soils should be described using the Unified Soil Classification System (USCS) in the narrative lithologic description section of Figure 5. Figure 6 is a summary of the American Society for Testing and Materials (ASTM) criteria for describing soils. Soil descriptions should be concise, stressing major constituents and characteristics, and should be given in a consistent order and format. The following order is recommended by the ASTM:

1. Soil name. The basic name of the predominant constituent and a single-word modifier indicating the major subordinate constituent.

2. Gradation or Plasticity. Granular soils (i.e., sands or gravels) should be described as well-graded, poorly-graded, uniform, or gap-graded, depending on the gradation of the minus 3-inch fraction. Cohesive soils (i.e., silts and clays) should be described as nonplastic, slightly plastic, moderately plastic, or highly plastic, depending on results of the manual evaluation for plasticity.

3. Particle size distribution. An estimate of the percentage and grain-size range of each subordinate constituent of the soil. This description may also include a description of angularity (see Figure 7).

4. Color. The basic color of the soil.

## SOIL AND SEDIMENT CLASSIFICATION

### GRAIN-SIZE SCALE (Modified Wentworth Scale)

| phi | mm | Inches | U.S. Standard Sieve Series | Grade Name | | |
|---|---|---|---|---|---|---|
| -12 | 4096 | 161.30 | | | | |
| | | | | very large | | |
| -11 | 2048 | 80.60 | | | | |
| | | | | large | | |
| -10 | 1024 | 40.30 | | | Boulders | |
| | | | | medium | | |
| -9 | 512 | 20.20 | | | | |
| | | | | small | | |
| -8 | 256 | 10.10 | | | | |
| | | | | large | | |
| -7 | 128 | 5.00 | | | Cobbles | GRAVEL |
| | | | | small | | |
| -6 | 64 | 2.52 | 63.0 mm | | | |
| | | | | very coarse | | |
| -5 | 32 | 1.26 | 31.5 mm | | | |
| | | | | coarse | | |
| -4 | 16 | 0.63 | 16.0 mm | | | |
| | | | | medium | Pebbles | |
| -3 | 8 | 0.32 | 8.0 mm | | | |
| | | | | fine | | |
| -2 | 4 | 0.16 | No. 5 | | | |
| | | | | very fine | | |
| -1 | 2 | 0.08 | No. 10 | | | |
| | | | | very coarse | | |
| 0 | 1 | 0.04 | No. 18 | | Sand | SAND |
| | | | | coarse | | |
| +1 | 0.500 | | No. 35 | | | |
| | | | | medium | | |
| +2 | 0.250 | | No. 60 | | | |
| | | | | fine | | |
| +3 | 0.125 | | No. 120 | | | |
| | | | | very fine | | |
| +4 | 0.062 | | No. 230 | | | |
| | | | | coarse | | |
| +5 | 0.031 | | | | Silt | |
| | | | | medium | | |
| +6 | 0.016 | | | | | |
| | | | | fine | | |
| +7 | 0.008 | | | | | MUD |
| | | | | very fine | | |
| +8 | 0.004 | | | | | |
| | | | | coarse | | |
| +9 | 0.002 | | | | | |
| | | | | medium | | |
| +10 | 0.001 | | | | | |
| | | | | fine | | |
| +11 | 0.0005 | | | | | CLAY SIZE |
| | | | | very fine | | |
| +12 | 0.00025 | | | | | |

### PROPORTIONS USED IN DESCRIBING SOILS

Trace - Particles are present but estimated to be less than 5%
Few - 5 to 10%
Little - 15 to 25%
Some - 30 to 45%
Mostly - 50 to 100%

I.e.: Sand with a trace of silt = 95% Sand, < 5% Silt

(When sampling gravelly soils with a standard split spoon, the true percentage of gravel is often not recovered due to relatively small sample diameter.)

### Soil Density from Standard Penetration Test (ASTM D1586)

| Granular Soils | Cohesive Soils |
|---|---|
| 0 - 10: Loose | 0 - 4: Soft |
| 10 - 30: Medium Dense | 4 - 8: Medium Stiff |
| 30 - 50: Dense | 8 - 15: Stiff |
| Over 50: Very Dense | 15 - 30: Very Stiff |

### CLASSIFICATION CHART(United Soil Classification System)

| MAJOR DIVISIONS | | | Symbols | TYPICAL NAMES |
|---|---|---|---|---|
| Coarse Grained Soils | (More than 1/2 of soil > no 200 sieve size) | GRAVELS (More than 1/2 of coarse fraction > No. 4 sieve size) | GW | Well-graded gravels or gravel-sand mixtures,little or no fines |
| | | | GP | Poorly graded gravels or gravel-sand mixtures little or no fines |
| | | | GM | Silty gravels, gravel-sand-silt mixture |
| | | | CC | Clayey gravels, gravel-sand-clay mixtures |
| | | SANDS (More than 1/2 of coarse fraction < No. 4 sieve size) | SW | Well-graded sands or gravelly sands, little or no fines |
| | | | SP | Poorly graded sands or gravelly sands, little or no fines |
| | | | SM | Silty sands, sand-silt mixtures |
| | | | SC | Clayey sands, sand clay mixtures |
| Fine Grained Soils | (More than 1/2 of soil < no 200 sieve size) | SILTS AND CLAYS LL< 50 | ML | Inorganic silts, and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity |
| | | | CL | Inorganic clays, of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays |
| | | | OL | Organic silts and organic clays of low plasticity |
| | | SILTS AND CLAYS LL> 50 | MH | Inorganic silts, micaceous or diatamaceous, fine sandy or silty soils, elastic silts |
| | | | CH | Inorganic clays of high plasticity, fat clays |
| | | | OH | Organic clays of medium to high plasticity, organic silty clays, organic silts |
| HIGHLY ORGANIC SOILS | | | Pt | Peat and other highly organic soils |

**Figure 2 USCS Soil Classification Chart**

## ROCK DESCRIPTIVE TERMS

| Term | | Defining Characteristics | |
|---|---|---|---|
| Hardness | Soft | Scratched by fingernail | |
| | Moderately Hard | Scratched easily by penknife | |
| | Hard | Difficult to scratch with a penknife | |
| | Very Hard | Cannot be scratched by penknife | |
| Weathering | Unweathered | Rock is unstained. May be fractured, but discontinuities are not stained. | |
| | Slighty | Rock is unstained. Discontinuities show some staining on the surfaces of rocks, but discoloration does not penetrate rock mass. | |
| | Moderate | Discontinuity surfaces are stained. Discoloration may extend into rock along discontinuity surfaces. | |
| | High | Individual rock fragments are thoroughly stained and may be crumbly. | |
| | Severe | Rock appears to consist of gravel-sized fragments in a "soil" matrix. Individual fragments are thoroughly discolored and can be broken with fingers. | |
| Bedding Planes | Laminated | < .04 in. | < 1 mm |
| | Parting | .04 in. - .24 in. | 1mm - 6mm |
| | Banded | .24 in. - 1in. | 6 mm - 3 cm |
| | Thin | 1 in. - 4 in. | 3 cm - 9.1 cm |
| | Medium | 4 in. - 12 in. | 9.1 cm - 30.5 cm |
| | Thick | 12 in.- 36 in. | 30.5 cm - 1m |
| | Massive | > 36 in. | > 1 m |
| Joints and Fracture Spacing | Very tight | < 2 in. | < 5.1 cm |
| | Tight | 2 in. - 1ft. | 5.1 - 30.5 cm |
| | Moderately tight | 1ft. - 3 ft. | 30.5 cm - 91.4 cm |
| | Wide | 3 ft. - 10 ft. | 91.4 cm - 3 M |
| | Very wide | > 10 ft. | > 3 M |
| Voids | Porous | Smaller than a pinhead. Their presence is indicated by the degree of absorbency. | |
| | Pitted | Pinhead size to a 1/4 inch. If only thin walls separate the individual pits, the core may be described as honeycombed. | |
| | Vug | 1/4 inch to the diameter of the core. The upper limit will vary with core size. | |
| | Cavity | Larger than the diameter of the core. | |

**Rock Particle Percent Composition Estimation**


**Figure 3 Rock Descriptive Terms**

## ROCK QUALITY DESIGNATION (RQD) AND FRACTURE FREQUENCY

Core borings are a useful means of obtaining information about the quality of rock mass. The recoverable core indicates the character of the intact rock and the number and character of the natural discontinuities.

Another quantitative index that has proved useful in logging NX core is a rock quality designation (RQD) developed by Deere (1963). The RQD is a modified core recovery percentage in which all the pieces of sound NX core over 4 inches long are counted as recovery. The length of the core run is the distance to the nearest tenth of a foot from the corrected depth of the hole at the end of the previous run to the corrected depth of the hole at the end of subject run. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. The RQD is a more general measure of the core quality than the fracture frequency. Core loss, weathered and soft zones, as well as fractures, are accounted for in this determination. The RQD provides a preliminary estimate of the variation of the <u>in situ</u> rock mass properties from the properties of the "sound" portion of the rock core. Thus, a general estimate of the behavior of the rock mass can be made. An RQD approaching 100 percent denotes an excellent quality rock mass with properties similar to that of an intact specimen. RQD values ranging from 0 to 50 percent are indicative of a poor quality rock mass having a small fraction of the strength and stiffness measured for an intact specimen.

RQD (Rock Quality Designation)

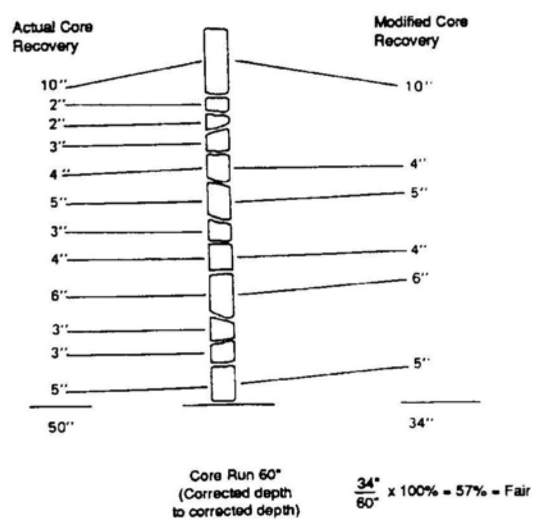
| | |
|---|---|
| 0 - 25 | Very Poor |
| 25 - 50 | Poor |
| 50 - 75 | Fair |
| 75 - 90 | Good |
| 90 - 100 | Excellent |

An example of determining the RQD from a core run of 60 inches measured from corrected depth to corrected depth is given in Diagram 1. For this particular case, the core recovery was 50 inches and the modified core recovery was 34 inches. This yields an RQD of 57 percent, classifying the rock mass in the fair category.

Problems arise in the use of RQD for determining the in situ rock mass quality. The RQD evaluates fractures in the core caused by the drilling process, as well as in natural fractures previously existing in the rock mass. For example, when the core hole penetrates a fault zone or a joint, additional breaks may form that, although not natural fractures, are caused by natural planes of weakness existing in the rock mass. These fresh breaks occur during drilling and handling of the core and are not related to the quality of the rock mass. The skill of the driller will affect the amount of breakage and the core loss that occurs. Poor drilling techniques will "penalize" the rock by lowering its apparent quality. It is difficult to distinguish between drilling breaks and those natural and incipient fractures that reflect the quality of the rock mass. In certain instances, it may be advisable to include all fractures when estimating RQD. Obviously, some judgement is involved in core logging.

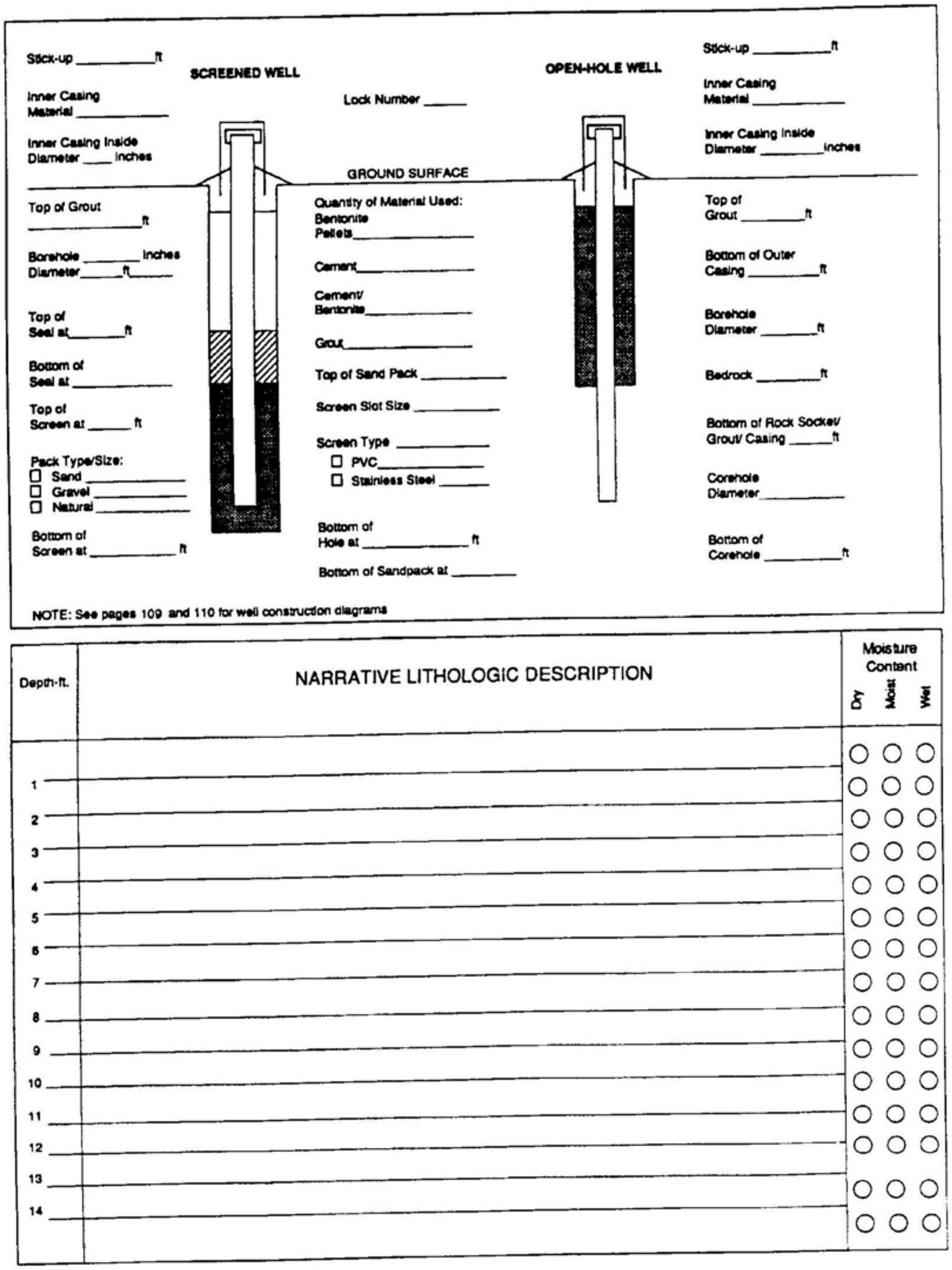
Another problem with the use of the RQD index is that the determinations are not sensitive to the tightness of the individual joints, whereas in some instances, the <u>in situ</u> deformation modulus may be strongly affected by the average joint opening.

RQD OF A SINGLE CORE RUN *




* Typical calculation of RQD of a single core run. Note that the run is calculated from corrected depth to corrected depth.

**Figure 4 Rock Qualitative Designation (RQD)**



Stick-up ________ ft

SCREENED WELL

Inner Casing Material ________

Inner Casing Inside Diameter ____ inches

Top of Grout ________ ft

Borehole ________ inches
Diameter ______ ft ______

Top of Seal at ______ ft

Bottom of Seal at ________

Top of Screen at ______ ft

Pack Type/Size:
- ☐ Sand ________
- ☐ Gravel ________
- ☐ Natural ________

Bottom of Screen at ________ ft

Lock Number ______

GROUND SURFACE

Quantity of Material Used:
Bentonite Pellets ________
Cement ________
Cement/ Bentonite ________
Grout ________

Top of Sand Pack ________

Screen Slot Size ________

Screen Type ________
- ☐ PVC ________
- ☐ Stainless Steel ________

Bottom of Hole at ________ ft

Bottom of Sandpack at ________

OPEN-HOLE WELL

Stick-up ________ ft

Inner Casing Material ________

Inner Casing Inside Diameter ________ inches

Top of Grout ________ ft

Bottom of Outer Casing ________ ft

Borehole Diameter ________ ft

Bedrock ________ ft

Bottom of Rock Socket/ Grout/ Casing ______ ft

Corehole Diameter ________

Bottom of Corehole ________ ft

NOTE: See pages 109 and 110 for well construction diagrams

| Depth-ft. | NARRATIVE LITHOLOGIC DESCRIPTION | Moisture Content: Dry | Moist | Wet |
|---|---|---|---|---|
| | | ○ | ○ | ○ |
| 1 | | ○ | ○ | ○ |
| 2 | | ○ | ○ | ○ |
| 3 | | ○ | ○ | ○ |
| 4 | | ○ | ○ | ○ |
| 5 | | ○ | ○ | ○ |
| 6 | | ○ | ○ | ○ |
| 7 | | ○ | ○ | ○ |
| 8 | | ○ | ○ | ○ |
| 9 | | ○ | ○ | ○ |
| 10 | | ○ | ○ | ○ |
| 11 | | ○ | ○ | ○ |
| 12 | | ○ | ○ | ○ |
| 13 | | ○ | ○ | ○ |
| 14 | | ○ | ○ | ○ |

**Figure 5 Narrative Lithologic Description**

**ASTM CRITERIA FOR DESCRIBING SOIL**

**Criteria for Describing Angularity of Coarse-Grained Particles**

| Description | Criteria |
|---|---|
| Angular | Particles have sharp edges and relatively plane side with unpolished surfaces |
| Subangular | Particles are similar to angular description but have rounded edges |
| Subrounded | Particles have nearly plane sides but have well-rounded corners and edges |
| Rounded | Particles have smoothly curved side and no edges |

**Criteria for Describing Dilatancy**

| Description | Criteria |
|---|---|
| None | No visible change in the specimen. |
| Slow | Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing. |
| Rapid | Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing. |

**Criteria for Describing Toughness**

| Description | Criteria |
|---|---|
| Low | Only slight pressure is required to roll the thread near the plastic limit . The thread and the lump are weak and soft. |
| Medium | Medium pressure is required to roll the thread to near plastic limit. The thread and the lump have medium stiffness. |
| High | Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness. |

**Criteria for Describing Dry Strength**

| Description | Criteria |
|---|---|
| None | The dry specimen crumbles into powder with mere pressure of handling |
| Low | The dry specimen crumbles into powder with some finger pressure |
| Medium | The dry specimen breaks into pieces or crumbles with considerable finger pressure |
| High | The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface. |
| Very High | The dry specimen cannot be broken between the thumb and shard surface |

**Criteria for Describing Structure**

| Description | Criteria |
|---|---|
| Stratified | Alternating layers of varing material or color with layers at least 6 mm thick; note thickness. |
| Laminated | Alternating layers of varying materials or color with the layers less than 6 mm thick; note thickness. |
| Fissured | Breaks along definite planes of fracture with little resistance to fracturing. |
| Slickensided | Fracture planes appear polished or glossy, sometimes striated. |
| Blocky | Cohesive soil that can be broken down into small angular lumps which resist further breakdown. |
| Lensed | Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness. |
| Homogeneous | Same color and appearance throughout. |

**Figure 6 ASTM Criteria For Describing Soil**

**CRITERIA FOR DESCRIBING SOIL (Cont.)**

**Criteria for Describing the Reaction with HCl**

| Description | Criteria |
|---|---|
| None | No visible reaction |
| Weak | Some reaction, with bubbles forming slowly |
| Strong | Violent reaction, with bubbles forming immediately |

**Criteria for Describing Consistency**

| Description | Criteria |
|---|---|
| Very Soft | Thumb will penetrate soil more than 1 inch (25 mm) |
| Soft | Thumb will penetrate soil about 1 inch (25 mm) |
| Firm | Thumb will indent soil about 1/4 inch (6 mm) |
| Hard | Thumb will not indent soil but readily indented with thumbnail |
| Very Hard | Thumbnail will not indent soil |

**Criteria for Describing Cementation**

| Description | Criteria |
|---|---|
| Weak | Crumbles or breaks with handling or little finger pressure |
| Moderate | Crumbles or breaks with considerable finger pressure |
| Strong | Will not crumble or break with finger pressure |

**Criteria for Describing Particle Shape**

The particle shape shall be described as follows where length, width, and thickness refer to greatest, intermediate, and least dimensions of a particle, respectively (see page 104 ).

| | |
|---|---|
| Flat | Particles with width/thickness ratio > 3 |
| Elongated | Particles with length/width ratio > 3 |
| Flat and Elongated | Particles meet criteria for both flat and elongated |

**Criteria for Describing Plasticity**

| Description | Criteria |
|---|---|
| Nonplastic | A 1/8 inch (3 mm) thread cannot be rolled at any water content. |
| Low | The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit. |
| Medium | The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit. |
| High | It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit. |

**Identification of Inorganic Fine-Grained Soils from Manual Tests**

| Soil Symbol | Dry Strength | Dilatancy | Toughness |
|---|---|---|---|
| ML | None to low | Slow to rapid | Low or thread cannot be formed |
| CL | Medium to high | None to slow | Medium |
| MH | Low to medium | None to slow | Low to medium |
| CH | High to very high | None | High |

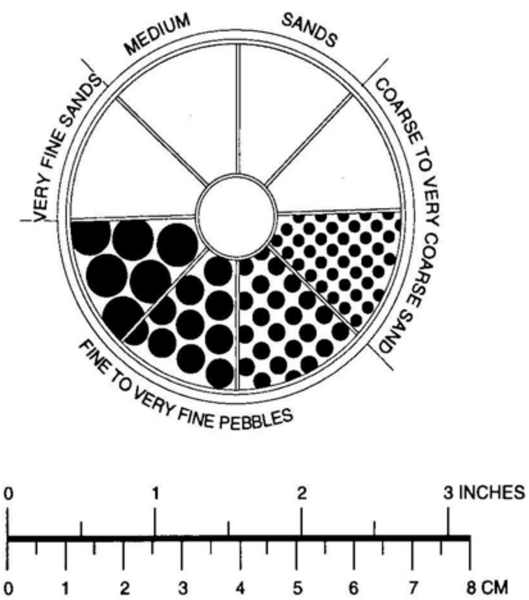
**Criteria for Describing Moisture Condition**

| Description | Criteria |
|---|---|
| Dry | Absence of moisture, dusty, dry to the touch |
| Moist | Damp but no visible water |
| Wet | Visible free water, usually soil is below water table |

**Figure 6 ASTM Criteria for Describing Soil (cont.)**

SEDIMENT PARTICLE SIZE AND SHAPE ESTIMATES

GRAPH FOR DETERMINING SIZE OF SEDIMENTARY PARTICLES




COBBLES RANGE FROM 6.4 TO 25.6 cm (~2.5 TO 10.1 INCHES)
BOULDERS ARE LARGER THAN 25.6 cm (>10.1 INCHES)

SEDIMENT PARTICLE SHAPES

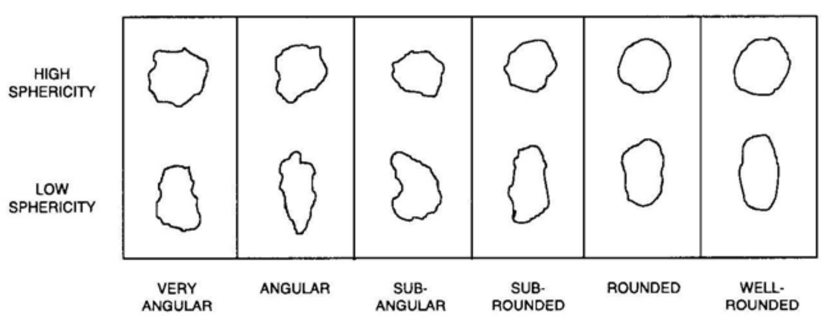



**Figure 7 Sediment Particle Size and Shape Estimates**

5. Moisture content. The amount of soil moisture (dry, moist, or wet).

6. Relative density or consistency. An estimate of density of a granular soil or consistency of a cohesive soil, usually based on the standard penetration test results (see Table 1).

7. Soil Structure or Mineralogy. Description of discontinuities, inclusions, and structures. Includes joints, fissures, and slickensides.

# 4. Core Logging

## 4.1 Handling of Core

After the core has been recovered from the corehole and the core barrel has been opened, the core should be placed in a core box. The top of the core should be placed at the back left corner of the core box, and the remaining core placed to the right of the preceding section (see Figure 8). The core box should be filled in this manner, moving to the front sections of the core box. The beginning of each run should be marked on the core and also noted with a marked wooden block.

## 4.2 Rock Description

Each stratigraphic unit in the core shall be logged. A line marking the depth of the top and the bottom of the unit shall be drawn horizontally. In classifying the rock, the geologist should avoid being too technical, as the information presented must be used by numerous people with widely divergent backgrounds.

The classification and description of each unit should be given in the following order, as applicable:

1. Unit designation (Miami oolite, Clayton Formation, Chattanooga shale);

2. Rock type;

3. Hardness;

4. Degree of weathering;

5. Texture;

6. Structure;

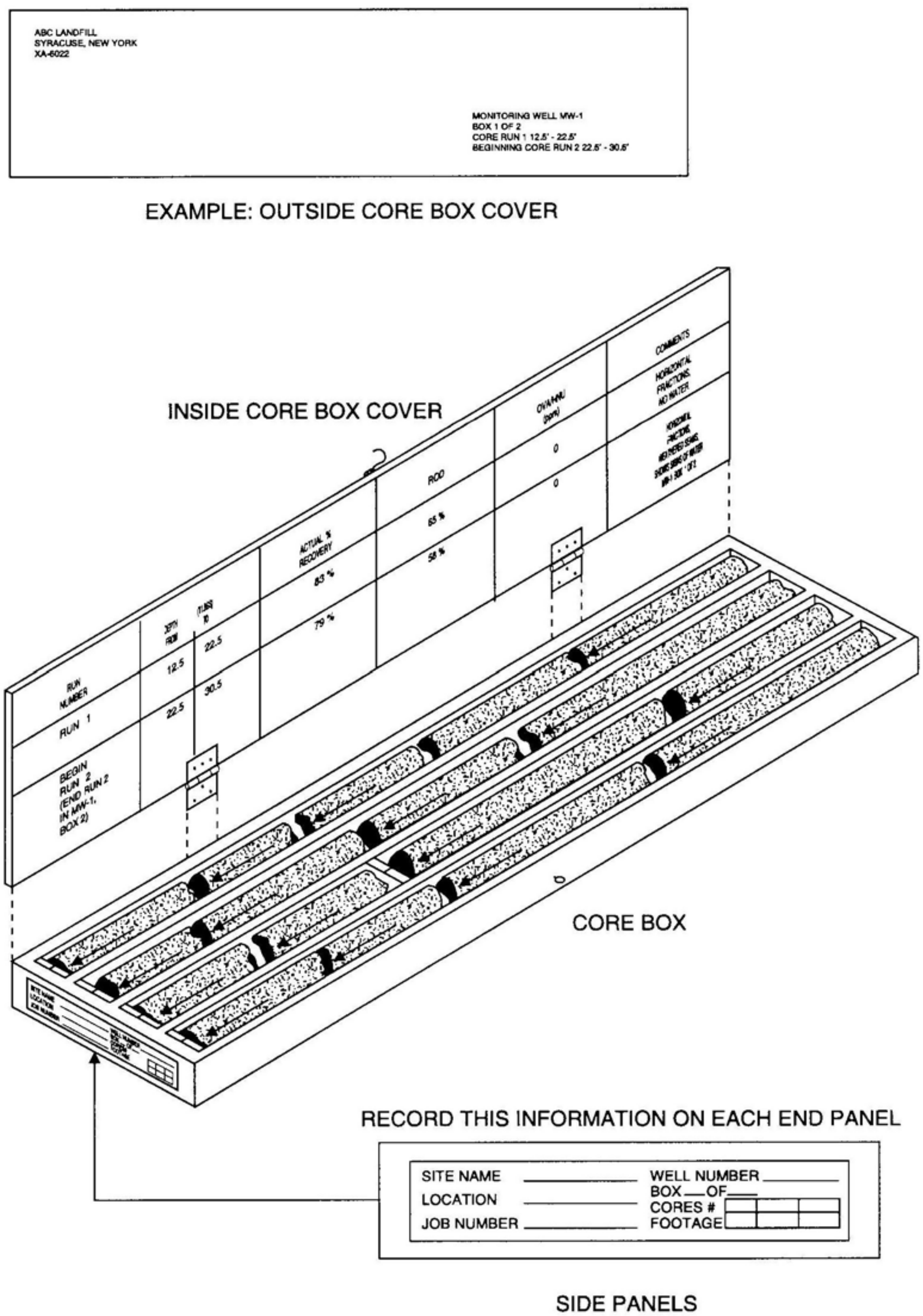



**Figure 8 Core Box**

7. Color;

8. Solution and void conditions;

9. Swelling properties;

10. Slaking properties; and

11. Additional description, such as mineralization, size, and spacing shale seams, etc.

Variations from the general description of the unit and features not included in the general description shall be indicated by brackets and lines to show the depth and the interval in the core where the feature exists. These variations and features shall be identified by terms that will adequately describe the feature or variation so as to delineate it from the unit. These may be zones or seams of different color, texture, etc., from that of the unit as a whole, such as staining; variations in texture; shale seams, gypsum seams, chert nodules, calcite masses, etc.; mineralized zones; vuggy zones, joints, fractures; open and/or stained bedding planes; faults, shear zones, gouge; cavities' thickness, open or filled, nature of filling, etc.; or any core left in the bottom of the hole after the final pull.

## Rock Type and Lithology

1. Rock will be classified according to the following 24 types:

   - Sandstone
   - Conglomerate
   - Coal
   - Compaction Shale
   - Cemented Shale
   - Indurated Clay
   - Limestone
   - Chalk
   - Gneiss
   - Schist

- Graywacke
- Quartzite
- Dolomite
- Marble
- Soapstone and Serpentine
- Slate
- Granite
- Diorite
- Gabbro
- Rhyolite
- Andesite
- Basalt
- Tuff or Tuff Breccia
- Agglomerate or Flow Breccia

2. Lithologic characteristics should be included to differentiate rocks of the same classification. These adjectives should be simple and easily understood, such as shaly, sandy, dolomitic, etc. Inclusions, nodules, and concretions should also be noted here.

3. It is important to maintain a simple but accurate rock classification. The rock type and lithologic characteristics are essentially used to differentiate the rock units encountered.

## Hardness

The terms for hardness, as outlined below, were modified to include the use of a rock hammer.

1. **Very soft** or plastic - can be deformed by hand (has a rock-like character but can be broken easily by hand).

2. **Soft** - can be scratched with a fingernail (cannot be crumbled between fingers but can be easily pitted with light blows of a geology hammer).

3. **Moderately hard** - can be scratched easily with a knife; cannot be scratched with a fingernail (can be pitted with moderate blows of a geology hammer).

4. **Hard** - difficult to scratch with a knife (cannot be pitted with a geology hammer but can be chipped with moderate blows of the hammer).

5. **Very hard** - cannot be scratched with a knife (chips can be broken off only with heavy blows of the geology hammer).

## Weathering

The degree and depth of weathering is very important and should be accurately detailed in the general description and clearly indicated on the drill log.

1. **Unweathered** - no evidence of any mechanical or chemical alteration.

2. **Slightly weathered** - superficial discoloration, alteration, and/or discoloration along discontinuities; less than 10% of the rock volume is altered; strength is essentially unaffected.

3. **Moderately weathered** - discoloration is evident; surface is pitted and altered, with alterations penetrating well below rock surfaces; 10% to 50% of the rock is altered; strength is noticeably less than unweathered rock.

4. **Highly weathered** - entire section is discolored; alteration is greater than 50%; some areas of slightly weathered rock are present; some minerals are leached away; retains only a fraction of its original strength (wet strength is usually lower than dry strength).

5. **Decomposed** - saprolite; rock is essentially reduced to a soil with a relic rock texture; can be molded or crumbled by hand.

## Texture

Texture is used to denote the size of the grains or crystals comprising the rock, as opposed to the arrangement of the grains or crystals, which is considered a structure.

1. **Aphanitic** - grain diameter less than 0.004 inch (0.1 mm); individual grains or crystals are too small to be seen with the naked eye.

2. **Fine-grained, finely crystalline** - grain diameter between 0.004 inch (0.1 mm) and 0.003 (1 mm); grains or crystals can be seen with the naked eye.

3. **Medium-grained, crystalline** - grain diameters between 0.003 foot (1 mm) and 0.0175 foot (5 mm).

4. **Coarse-grained, coarsely crystalline** - grain diameter greater than 0.0175 foot (5 mm).

## Structure

The structural character of the rock shall be described in terms of grain or crystal alignment, bedding, and discontinuities, as applicable. The terms may be used singularly or paired.

1. **Foliation and/or lineation** - give approximate dip uniformity, degree of distinctiveness, banding, etc.

2. **Joints:**
   a. Type - bedding, cleavage, foliation, extension, etc.
   b. Degree of openness - tight or open.
   c. Surface or joint plane characteristics - smooth, rough, undulating.
   d. Weathering - degree, staining.
   e. Frequency - see (4).

3. **Fractures, shears, gouge:**
   a. Nature - single plane or zone. (Note thickness.)
   b. Character of materials in plane or zone.
   c. Slickensides.

4. **Frequency:**
   a. Intact - spacing greater than 6 feet (2 m).
   b. Slightly jointed (fractured) - spacing 3 feet (1 m) to 6 feet (2 m).
   c. Moderately jointed (fractured) - spacing 1 foot (0.3 m) to 3 feet (1 m).
   d. Highly jointed (fractured) - spacing 0.3 foot (9.1 cm) to 1 foot (0.3 m).
   e. Intensely jointed (fractured) - spacing less than 0.3 foot (9.1 cm).

5. **Bedding** is used to describe the average thickness of the individual beds within recognized unit, and the terms thick, medium, or thin should not be applied to the individual beds. "Parting" and "band" are used to describe single stratum as outlined below:
   a. Massive - over 3 feet thick (1 m).
   b. Thick - 1 foot (30.5 cm) to 3 feet (1 m) thick.
   c. Medium - 0.3 foot (9.1 cm) to 1 foot (30.5 cm) thick.
   d. Thin - 0.1 foot (3.0 cm) to 0.3 foot (9.1 cm) thick.

e. Band - 0.02 foot (6 mm) to 0.1 foot (3.0 cm) thick, described to the nearest 0.01 foot.
f. Parting - less than 0.02 foot (6 mm).
g. Paper-thin parting.

The terms and descriptions for the structure of the rock are to be used to describe the character of the rock units recognized and are not to be used as a substitute for describing individual discontinuities. Except for areas where the rock is intensely fractured or jointed, each discontinuity should be described on the log as to position, dip, staining, weathering, breccia, gouge, etc.

**Color** is often valuable in correlating or differentiating samples, but can be misleading or uninformative. The color of a sample should represent the sample in terms of basic hues (i.e., red, blue, gray, black), supplemented with modifying hues as required (i.e., bluish gray, mottled brown). The core should be surface wet when describing the color; if it is dry, the log should indicate "dry color." Subjective colors, such as buff or maroon, should not be used. Specific color charts, such as the Mumsel Color Chart or the Color Index in the Colorado School of Mines, Quarterly, Volume 50, No. 1, are useful in describing color of samples. When such a chart or index is used, it should be noted on the log in the remarks column.

**Solution and Void Conditions** shall be described in detail, as these features can affect the strength of the rock and can indicate potential seepage paths through the rock. When cavities are detected by drill action, the depth to top and bottom of the cavity should be determined by measuring the stick-up of the drill tools when the cavity is first encountered and again at the bottom, as it is very difficult to reconstruct cavities from the core alone. Filling material, when present and recovered, should be described in detail opposite the cavity. When no material is recovered from the area of the cavity, the inspector should note the probable conditions of the cavity as determined from observing the drilling action and the color of the drill fluid. If the drill action indicated material was present (i.e., slow rod drop, no loss of drill water, noticeable change in color of water return), it should be noted on the log that the cavity was probably filled and the materials should be described as best as possible from the cuttings or traces left on the core. If drill action indicates the cavity was open (i.e., no resistance to the drill tools, loss of drill fluid), this should be noted on the drill log. Partially filled cavities should also be noted. All of these observations require close observation of the drill action and water return by both the inspector and the driller; accurate measurement of stick-ups; and detailed inspection of the core. When possible, filling material should be wrapped in foil if left in the core box. If the material is to be tested or examined in the lab, it should be sealed in a jar with proper labels and a spacer, with a note showing the disposition of the material should be placed in the core box at the point from which the material was taken. Terms to describe voids encountered shall be as follows:

1. **Porous** - voids less than 0.003 foot (1 mm) in diameter.

2. **Pitted** - voids 0.03 foot (1 mm) to 0.02 foot (6 mm) in diameter.

3. **Vug** - voids 0.02 foot (6 mm) to the diameter of the core.

4. **Cavity** - voids greater than diameter of the core.

### 4.3 Core Labeling

The top of the core should be shown on each piece of core with an arrow written in a black, waterproof marker. The arrow will indicate which end of the core is nearer the ground surface. Other core markings may include locations of mechanical breaks and drilling footages.

### 4.4 Core Box Labeling

Each core box should be labeled as follows:

- On the top left corner of the outer core box, the project name, site location (city and state), and project number should be written.
- On the lower right corner of the outer core box, the corehole number (e.g., MW1, BH2), core box number (e.g., 1 of 2, 2 of 2), and the interval of the core run contained in the core box should be written.
- The side panels should be marked as indicated in Figure 8.
- The inside of the core box cover should be marked as indicated in Figure 8.

### 4.5 Core Storage

It is important to use proper-sized (HQ or NQ) wooden core boxes for rock core storage. After labeling the box and before closing the box for final storage or shipment, wooden spacers should be inserted into each compartment that contains rock core. This will prevent lateral movement of the cores, which could damage the rock material during handling.

After properly logging, labelling, and packing the cores, the core boxes should be stored in a dry location, preferably off of the floor on a pallet. The boxes can be stacked to a reasonable height so as not to be unstable, with end labelling facing out.

## 5. References

American Society for Testing and Materials (ASTM), 1975, Test Method for Classification of Soils for Engineering Purposes, ASTM D2487-69, Philadelphia, Pennsylvania.

__________, 1975, Recommended Practice of Description of Soils, ASTM D2488-69, Philadelphia, Pennsylvania.

Deere, D.V., 1963, Technical Description of Rock Cores for Engineering Purposes: Rock Mechanics and Engineering Geology, Vol. 1, No. 1, pp. 16-22.

Dow Chemical, 1980, Field Data Handbook, Dowell Division of Dow Chemical Company, Houston, Texas.

Driscoll, J.T., R.V. Dietrich, and R.M. Foose, 1989, AGI Data Sheets for Geology in the Field, Laboratory, and Office, Third Edition, American Geological Institute, Alexandria, Virginia.

U.S. Army Corps of Engineers, St. Louis District, Inspector's Manual, St. Louis, Missouri.

U.S. Environmental Protection Agency (EPA), 1986, RCRA Groundwater Monitoring Technical Enforcement Guidance Document, Washington, D.C.