STANDARD OPERATING PROCEDURE NO. 17.0

DRILL HOLE LOGGING

January 2022

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to describe drill core during field activities performed at Building B.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The PI or Field Manager has the overall responsibility for implementing this SOP. She will be responsible for assigning appropriate environmental staff to implement this SOP and for ensuring that the procedures are followed by all personnel. A "site geologist" (geologist, hydrogeologist or geotechnical engineer) experienced in drill hole drilling and sampling will be present at each operating drill rig.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this SOP and receive specific training regarding these procedures, if necessary.

All project staff are responsible for reporting deviations from this SOP to the PI or Field Manager.

3.0 RELATED STANDARD OPERATING PROCEDURES

The procedure for borehole logging set forth in this SOP is intended for use with the following SOPs:

SOP No. 6.0	Decontamination of Sampling Equipment
SOP No. 9.0	Sample Management
SOP No. 16.0	Drilling and Sampling of Subsurface Materials

4.0 EQUIPMENT LIST

The following materials and equipment listed will be needed for borehole logging:

- Drill log forms (Figure 1)
- Waterproof pens
- Hand lens (10X magnification or stronger)
- Tape measure
- Knife, screwdriver, rock hammer
- Decontamination equipment and supplies
- Reference tables listing ASTM and other codes and descriptions
- Hydrochloric acid

Other materials and equipment may be needed based on field conditions.

5.1 PROCEDURES

The site geologist will be responsible for logging samples, monitoring drilling operations, recording water losses or gains, and preparing field drill logs. Procedures for completing drill logs are described below:

- Drill log information will be recorded on the drill log form.
- Logs will be prepared in the field by the site geologist as holes are drilled. The preparer will sign each log.
- All log entries will be legibly printed such that photo reproductions will be clear and legible.
- Drill hole depth information will be recorded to the nearest 0.1 foot.
- All relevant information in the log heading and log body will be completed. If surveyed horizontal control is not available at the time of drilling, location sketches referenced by measuring distances or prominent surface features shall be shown on, or attached to, the log.
- Each and every material type encountered will be described on the drill log form. Material types will be logged directly from samples and indirectly interpolated using professional judgment, drill cuttings, drill action, etc., between sampling intervals.
- Descriptions of intact unconsolidated soil samples will include parameters listed in Table 1. The information on the boring log includes the following:
    - Material type (i.e., sand [sandstone], silt [siltstone], clay [claystone], etc.)
    - Color
    - Grain size, sorting, rounding, and make-up of the material (for sand or gravel)
    - Types and amounts of secondary constituents
    - Other pertinent characteristics (plasticity, hardness, bedding, etc.)
    - Moisture content
    - USCS code (for unconsolidated material)
- In the field, visual estimates of the volume of secondary soil constituents will be reported by such terms as "trace" (1-3 percent), "slightly" (3-10 percent), "some" (10-25 percent), and "very" (25-50 percent) or by an estimated percentage.
- Consolidated material (e.g., sedimentary rocks) will be described by parameters listed in Table 2 and described in Tennisen (1983), ASTM D5434-97, “Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock”, and ASTM C294-86(1991), “Standard Descriptive Nomenclature for Constituents of Natural Mineral Aggregates”. Material will be logged using drill cuttings and/or rock core. The information on the boring log includes the following:
    - Rock Type
    - Color
    - Grain size and shape
    - Texture (stratification, foliation)
    - Mineral composition
    - Weathering and alteration

  - Strength
  - Other relevant notes
- For rock core, a scaled graphic sketch of the core breaks denoting the depth, location, and orientation will be drawn on the log. Bedrock coring information will be recorded in consecutively numbered runs and will include the start and stop time of each core run, the depth to top and bottom of each core run, the length of core recovered for each run, the size and type of coring bit and barrel, and the measured depth to the bottom of the hole after the core is removed from each run. Breaks believed to be machine induced, or purposely made so that the core could fit in the core box, will be so annotated. If fractures are too numerous to be shown graphically, they may be described in writing on the log. The intervals by depth of all lost core and hydrologically significant details will also be noted. This information will be recorded at the time of core logging.
- Drill cuttings will be described in terms of the appropriate parameters, to the extent practical. "Classification" will be minimally described for this material, along with a description of drilling actions and water losses/gains for the corresponding depth. Notations will be made on the log that these descriptions are based on observations of material other than formal samples (e.g., from cuttings).
- The drilling equipment used will be described on each log. Information such as drill rod size, bit size and type, and rig manufacturer and model will be recorded.
- All special problems encountered during drilling and their resolution will be recorded on the log. This would include loss of circulation, sudden tool drops, unrecovered tools in the borehole, and lost casing.
- The dates for the start and completion of borings will be recorded on the log. Changes in shift, day, driller, and site geologist will also be noted at the depth they occur.
- Stratigraphic/lithologic changes will be identified on the boring log by a solid horizontal line at the appropriate scale depth on the log that corresponds to measured borehole depths at which changes occur, measured and recorded to the nearest 0.5 foot. Gradational transitions and changes identified from cuttings or methods other than direct observation and measurement will be identified by a horizontal dashed line at the appropriate scale depth based on the best judgment of the logger.
- Logs will show drill hole and sample diameters and depths at which drilling or sampling methods or equipment change.
- Logs will show total depth of penetration and sampling. The bottom of the hole will be so identified on the log by solid double lines from margin to margin with the notation "bottom of borehole."
- Logs will identify the depth at which water is first encountered, the depth of water at the completion of drilling, and the stabilized depth to water. The absence of water in borings will also be indicated. Stabilized water-level data will include time allowed for levels to stabilize.
- Logs will identify any drilling fluid (water) losses, including depths at which they occur, rate of loss and total volume lost.
- Blow counts will be recorded in half-foot increments when a standard penetration test is performed. For penetration less than a half-foot, the count will be annotated with the distance over which the count was taken. Refusal, if reached, will be noted.
- Logs will include other information relevant to a particular investigation, but not limited to:

  - Odors
  - Field screening or test results (e.g., organic vapors and/or radiological)
  - Any observed evidence of contamination in samples, cuttings or drilling fluid
- Significant color changes in the drilling fluid return will be recorded, even when intact soil samples or rock core are being obtained. The color change (from and to), depth at which change occurred, and a lithologic description of the cuttings before and after the change will be recorded.
- Special abbreviations used on a log will be defined either in the log where used, or in a general legend.

6.0 DOCUMENTATION

Documentation of observations and data acquired in the field will provide information on the activities concluded and also provide a permanent record of field activities. The observations and data will be recorded on field data sheets.

6.1 DRILL LOG FORM

A field drill log form (Figure 1) will be completed summarizing field activities. The information on the drill log includes the following:

- Sampling locations
- Dates and time of sampling
- Weather conditions
- Person(s) performing sampling
- Drill log information
- Deviation from SOP
- Core box information

6.2 FIELD NOTES

Field notes will also be kept during drilling and logging activities. The following information will be recorded:

- Names of personnel
- Weather conditions
- Date and time of drilling and sampling
- Location and sample station number
- Times that procedures and measurements are completed
- Decontamination times
- Other applicable information

7.0 REFERENCES

ASTM D5434-97 Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock ASTM C294-86(1991) Standard Descriptive Nomenclature for Constituents of Natural Mineral Aggregates

ASTM International, Rev. 2002, Designation D6032 - 02, Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core, 5 p.

USEPA Manual 625/12-91/002 Description and Sampling of Contaminated Soils, Tennisen, A.C., 1983, Nature of Earth Materials, 2nd Edition, p.204-348.

TABLE 1
DESCRIPTION OF UNCONSOLIDATED SOIL

Parameter	Example
Depositional Environment and Formation, (if named and if known)	Alluvium, Twin Cities Formation
Unified Soil Classification System	Sandy Clay
Secondary Components and Estimated Quantities either by percentages or by descriptive percentage ranges (Note: terms used to indicate ranges should be described on the log or in a general legend)	sand: fine, with trace of med.
Color	gray
Consistency (cohesive soil). Use relative term	very soft, soft, medium, stiff, very stiff, hard
Density (non-cohesive soil). Use relative term	loose, medium, dense, very dense
Moisture Content. (Use relative term. Do not express as a percentage unless a value has been measured)	dry, damp, moist, wet, saturated
Texture/Fabric/Bedding	no apparent bedding, numerous vertical iron-stained tight fractures
Grain Shape	rounded sand grains
Sorting (sands)	poorly sorted
Structure	slickensides
Grain or fragment size	coarse
Note "Fill", "Top of Natural Ground", and "Top of Bedrock" where appropriate	

TABLE 2
DESCRIPTION OF CONSOLIDATED ROCK

Parameter	Description
Formation Name (if known)	
Depth	Depth in feet
% Recovery/size of core/RQD	Core loss interval and reason for loss if known or Unaccountable
Lithology	Rock type
Color	Use charts
Texture	Crystalline, porphyritic, glassy
Phenocryst Size	Very coarse-grained, coarse-grained, medium-grained, fine-grained, very fine- grained
Phenocryst Shape	Angular, subangular, subrounded, rounded, well-rounded
Alteration/weathering	Residual soil, completely weathered/altered, highly weathered/altered, moderately weathered/altered, slightly weathered/altered, fresh (see Table 3)
Structure/orientation	Parting band, thinly bedded, thickly bedded, very thickly bedded, laminated, provide thickness range, horizontal bedding, dipping beds at 30 degrees, highly fractured, open near vertical joints, healed 30 degree fractures, slickensides at 45 degree, fissile
Rock Strength/hardness	Extremely weak, very weak, weak, medium strong, strong, very strong, extremely strong
Mineralogy	Visual estimates
Fractures/fracture frequency	Abundance, width, and mineral linings and fillings of veins and fractures (see Table 4)
Contact of lower unit	
Comments	
Photographs	
Fabric	
Feldspar coloring	Use charts

The Rock Quality Designation (RQD) is a modified measure of recovery, calculated in order to estimate the quality of the intact rock mass. The Engineering Geologist is responsible for the determination of RQD. The RQD (in percent) is obtained by dividing the sum of all the recovered pieces of core equal to or greater than 4 in. (100 mm) in length by the total length of the core run, then multiplying by 100. In effect, the RQD is a measure of the spacing of the discontinuities (bedding, fractures, faults, joints, shear zones, etc.) in the rock mass. When calculating RQD, it is important to try to distinguish between naturally occurring discontinuities and mechanical breaks which occur during coring procedure. Only naturally occurring discontinuities will be considered when calculating RQD. When there is uncertainty about a break, it should be considered as natural in order to be conservative in the calculation of RQD. In addition, only sound bedrock is used in the calculation of RQD. Weak and/or weathered rock core is not included in the RQD calculation.

TABLE 3. Weathering Categories

DEGREE OF WEATHERING	DETAILED DESCRIPTION
Residual soil	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed. Large volume change.
Completely weathered	Minerals decomposed to soil but fabric and structure preserved (saprolite). Specimens easily crumbled or penetrated.
Highly weathered	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct but fabric preserved.
Moderately weathered	Discoloration throughout. Strength somewhat less than fresh rock but cores cannot be broken by hand or scraped with knife. Texture observed.
Slightly weathered	Slight discoloration inwards from open fractures.
Fresh	No visible sign of decomposition or discoloration.

TABLE 4. Fracture Density

DEGREE OF FRACTURING	DESCRIPTION
Unfractured	No observed fractures.
Very slightly fractured	Core recovered in lengths greater than 3 ft. (1 m).
Slightly to very slightly fractured	Core recovered in lengths from 1 to 3 ft. (0.3 to 1 m).
Slightly fractured	Core recovered mostly in lengths from 1 to 3 ft. (0.3 to 1 m) with few scattered lengths less than 1 ft. (0.3 m) or greater than 3 ft. (1 m).
Moderately to slightly fractured	Core recovered mostly in lengths averaging 1 ft. (0.3 m).
Moderately fractured	Core recovered mostly in lengths from 0.33 to 1 ft. (0.1 to 0.3 m) with most lengths about 0.67 ft. (0.2 m).
Intensely to moderately fractured	Core recovered mostly in lengths of 0.33 to 0.67 ft. (0.1 to 0.2 m) with most lengths about 0.5 ft. (0.15 m).
Intensely fractured	Core recovered mostly in lengths from 0.1 to 0.33 ft. (0.03 to 0.1 m) with most lengths less than 0.33 ft. (0.1 m) and with fragmented intervals.
Very intensely to intensely fractured	Core recovered as short core lengths

	averaging less than 0.1 ft. (0.03 m).
Very intensely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

Drill Hole No.____ Page ____ of _____

DRILL LOG—TAJO GRANITE, SOCORRO COUNTY, NEW MEXICO

HOLE NUMBER _____ DATE STARTED _____ COMPLETED _____ LOGGED BY _____ CORE CUTTINGS

LOCATION (UTM) _____ _____ COLAR ELEVATION _____ ft WEATHER _____

BOX NUMBER _____ INCLINATION _____ BEARING _____ SOP 17 DEVIATION FROM SOP _____

COMMENTS _____

Depth	% Recovery/ size of core/RDQ	Lithology	Color	Texture	Phenocryst Size	Phenocryst Shape	Alteration/ weathering	Structure/ orientation	Rock strength/ hardness	Mineralogy	Fractures/ fracture frequency	Contact of lower unit	Comments	Photograph	Fabric	Feldspar coloring	Depth

SOP 17

Depth	% Recovery/ size of core/RDQ	Lithology	Color	Texture	Phenocryst Size	Phenocryst Shape	Alteration/ weathering	Structure/ orientation	Rock strength/ hardness	Mineralogy	Fractures/ fracture frequency	Contact of lower unit	Comments	Photograph	Fabric	Feldspar coloring	Depth