Soil and Rock

Logging, Classification, and Presentation Manual

2010 Edition

State of California
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Division of Engineering Services
Geotechnical Services

Caltrans

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Preface

Detailed soil and rock descriptions are an essential part of the information developed to support Caltrans' design and construction processes. Subsurface information for any given area is, and can be, generated and accumulated over a prolonged period of time by various geotechnical practitioners for different projects and purposes. It is imperative that geotechnical practitioners working on Caltrans projects use standardized terminology and procedures to maintain consistency in borehole logging and reporting practices. Geotechnical Services in the Division of Engineering Services has published this Manual to ensure the Department's investment in maintaining consistent logging practices.

This Manual, "*Soil and Rock Logging, Classification, and Presentation Manual*", addresses the following:

- Serves as a comprehensive reference for Departmental staff, consultants, and contractors
- Provides standardized soil *description* and *identification* procedures utilizing field data
- Provides standardized soil *classification* procedures utilizing laboratory data
- Provides standardized rock *description* and *identification* procedures utilizing field and laboratory data
- Serves as a basis for Departmental products and tools, such as:
  - Boring Log presentation formats,
  - Log of Test Borings (LOTB) legend sheets,
  - Descriptive terminology presented in geotechnical reports, and
  - Geotechnical Data Management System

The information presented in this Manual is based predominantly on American Society for Testing and Materials (ASTM) standards and other publications. These references provide standardized methods for identifying, describing, or classifying soil and rock; however, they do not provide adequate descriptive terminology and criteria for identifying soil and rock for engineering purposes. Consequently, this manual extends, and in some cases modifies these standards to include additional descriptive terms and criteria.

In addition to soil and rock identification, description, or classification, this Manual contains instructions that present Departmental standards for borehole and sample identification, minimum material requirements for various laboratory tests, and boring log presentation formats.

Geotechnical Services staff and any other organization providing geotechnical reports or records of geotechnical investigations for the Department must use the procedures presented in this Manual.

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Section 1: Introduction

1.1 Intent of the Manual

This Manual defines the Department's practices and procedures for soil and rock description, identification, classification, and for preparation of boring logs.

Standardized terminology and consistent presentation procedures for projects statewide benefit the Department's staff, engineering consultants, bidders, and contractors. Geotechnical Services staff as well as any other organization providing geotechnical reports or records of geotechnical investigations to the Department must follow the procedures presented in this Manual.

The following terms are used throughout this Manual to convey the Department's policy:

Figure 1-1
Policy Terminology

	Definition
Must, Required	*Mandatory Standard*. The associated provisions shall be used. There is no acceptable alternative.
Should	*Advisory Standard*. The associated provisions are preferred practices.
May, Optional	*Permissive Standard.* Use or application of the associated provisions is left to the discretion of the Geoprofessional.

1.2 Limitations

Although this manual may be used to train new employees, this is not its primary intent.

This manual does not replace education or experience and must be used with professional judgment. Not all aspects of this manual may be applicable in all circumstances and thus it should be applied with consideration of a project's many unique aspects.

This manual does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish, or adhere to, appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. The reader must follow at a minimum, the *Caltrans Code of Safe Drilling Practices*.

1.3 Exceptions

Exceptions to the procedures set forth in this Manual (and Errata Sheet) require prior approval per the memorandum titled *Exception Process for Geotechnical Services Policies and Procedures*, dated December 7, 2009.

1.4 Quality Assurance

Prior to issuing a Log of Test Borings staff must complete the quality control and assurance (QC/QA) process as required per the memorandum titled *Quality Control/Quality Assurance Documentation on LOTB Sheets* dated July 1, 2007.

1.5 Revisions to the Manual

Staff may propose changes to the Manual by posting their comments on the Geotechnical Services Discussion Board found on the Caltrans intranet. Those who are not employed directly by Caltrans must submit their comments to the Committee Chairperson, who is identified on the Geotechnical Services webpage. Approved revisions will be issued via the Errata Sheet.

1.6 Organization of the Manual

The Manual is divided into five sections:

Section 1

- Explains the intent and organization of the Manual and the processes for requesting exceptions and proposing changes to it
- Presents an overview of the logging process and acceptable presentation formats

Section 2

- Presents the Department's field description and identification procedures for soil and rock, without laboratory testing
- Explains procedures for handling and labeling soil and rock samples
- Requires a quality check of borehole logs and soil and rock samples

Section 3

- Describes the Department's classification procedures for soil and rock samples using laboratory tests

Section 4

- Presents the process for developing and presenting geotechnical information on a *Log of Test Borings (LOTB)* or a *Boring Record (BR)*

Section 5

- Specifies presentation content and formats for the *Log of Test Borings (LOTB)* and *Boring Record (BR)*

1.7 Overview of the Logging Process and Presentation Formats

The Department presents subsurface information using:

- Log of Test Borings (LOTB), and/or
- Boring Record (BR)

An LOTB is typically associated with a structure and is attached to Project Plans. A BR is typically associated with an earthwork project and is attached to a Geotechnical Report.

The process of creating boring logs, i.e., Log of Test Borings (LOTB) and Boring Record (BR) can be summarized in four steps *(See Figure 1-2)*:

- Field sampling and descriptions *(Section 2)*
- Quality check of field descriptions and samples *(Section 2)*
- Refinement of descriptions, and classification of soil, based on laboratory test results, if performed *(Section 3)*
- Preparation of the boring log(s) *(Sections 4 and 5)*

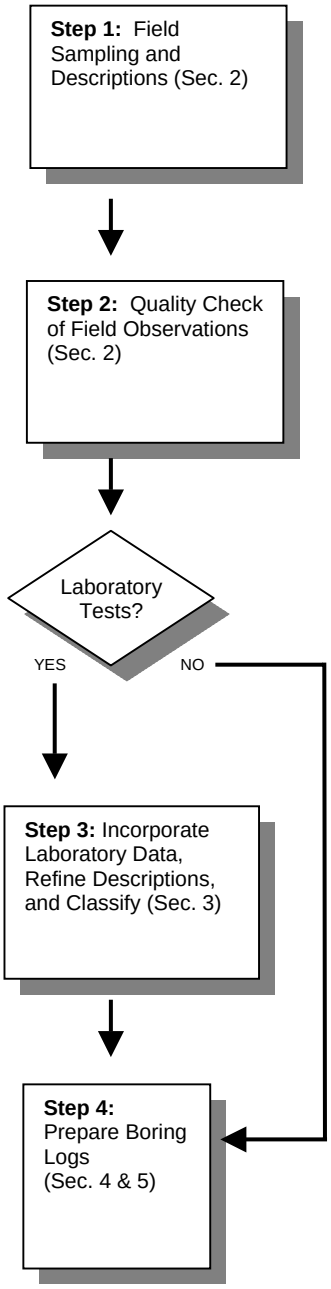
Prior to the field investigation, the geoprofessional should have a general understanding of the local soil and geologic information, and know the parameters and the basic descriptors required for the planned analyses. The need for specific laboratory tests, such as strength, consolidation, or permeability may govern the type of drilling and sampling used.

A combination of field observations and laboratory test results may be needed to describe or classify the soil or rock samples, and generate appropriate layer descriptions for the LOTB or BR *(Sections 2 and 3)*. In most cases, however, field identifications and descriptions are adequate for project design, bidding and construction.

If the results of laboratory tests differ from the field description of the sample, and, in the opinion of the geoprofessional, the test results represent the actual conditions of the soil or rock, the classification and/or description resulting from the laboratory tests must be used on the LOTB or BR, and in the geotechnical report. Disclosure of the tests on the LOTB and/or the BR may indicate the sample or layer description was modified based on laboratory test results. *(See Sections 4 and 5)*

Throughout this manual the terms *identification* and *classification* are used in context to differentiate the basis for assigning a soil's Group Name and Group Symbol. A soil's *classification* is only determined on the basis of laboratory test results (described in Section 3), whereas, its *identification* is determined by visual/manual methods (described in Section 2).

Figure 1-2
Logging and Presentation Process



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Section 2:
Field Procedures for Soil and Rock Logging, Description, and Identification

2.1 Introduction

This section presents the procedures for logging, describing, and identifying soil and rock samples in the field based on visual and manual procedures.

The information presented in this section is predominantly based on:

- American Society for Testing and Materials (ASTM) D 2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, and
- The *Engineering Geology Field Manual* published by the Bureau of Reclamation.

This Manual extends, and in some cases modifies, the ASTM standard to include additional descriptive terms and criteria. It is not our intent to replace the ASTM standards but to build on them, and make them better understood.

The identifications and descriptions in the field logs may be corrected, calibrated, or verified later based on laboratory test results (as described in Section 3) in order to develop the final boring logs.

In addition to soil and rock identification and description, this section contains instructions for hole and sample identification, and minimum material requirements for various laboratory tests.

2.2 Terms and Definitions

The following terms and definitions may be used to describe soil and rock description components.

Figure 2-1
Distribution Terms

		Examples
Scattered	Occurring at widely spaced and usually irregular intervals	Scattered thin shale interbeds
Sporadic	Occurring singly or widely apart	Sporadic boulders
Locally	Occurring at random locations	Moderately hard, locally very hard
Rhythmically	Occurring at regular, predictable locations	Rhythmically bedded sandstone and shale

Figure 2-2
Relational Terms

		Examples
to	Intermediate, having properties in between two adjacent descriptors, (borderline)	Moderately hard to moderately soft
and	Having roughly equal amounts of two or more descriptors	Fine and coarse sand Rounded and angular
From/to	Having properties of three or more descriptors, including all descriptors in range	From rounded to angular
Grading from/to or Increasing/Decreasing from/to	Denoting a gradual change with depth, may range over several descriptors	Grading from moderately weathered to fresh
Varies from/to or "-" (used with numerical ranges)	Denotes non-uniform variation, does not include all descriptors in range	Varies from soft to hard 4-6" Cobbles
Chaotic	No discernable pattern	Chaotic interbeds of silt, sand and clay
Predominantly	Having more than any other constituent	Predominantly Cobbles

Caution should be used to correctly apply the above terms as not all terms can be used with all descriptors. For example, a weathering description of "slightly weathered to fresh" is not acceptable because the term fresh indicates absence of any discoloration and oxidation. As such, the rock is either fresh or it isn't. Similarly, describing a soil's moisture to be "dry to moist" is incorrect because the soil either contains moisture (moist) or it doesn't (dry).

2.3 General Project and Hole Information

An important aspect of fieldwork is properly identifying the location of the project site, drilling tools and methods used, and the personnel involved in the fieldwork. Figure 2-3 presents the information to be recorded for every hole. This information may not necessarily be reported on the LOTB or BR.

Figure 2-3
Information Required for Field Log

	Description
1	**Date(s) of work**
2	**Hole Identification**
3	**Project and Site Information:** • Project Name • Structure/Bridge Name and Number (if available) • Project Number (Charge District - Expenditure Authorization, 8-digits) • District • County • Route • Postmile, range and prefix
4	**Borehole Location and Elevation:** • Location: o Station and offset (required if available) o Latitude and longitude, horizontal datum (optional) o Northing and Easting, local coordinate reference system (optional) *Note:* In the absence of accurate coordinate data, a suitable and verifiable field description may be temporarily used. (e.g. postmile and centerline offset, distance to fixed object or benchmark, etc.) • Elevation, vertical datum, benchmark location and description • Survey method(s) used, approximate accuracy (e.g. less than a foot)
5	**Personnel:** • Logger/Geoprofessional • Drillers
6	**Drilling and Sampling Equipment (verify with Driller):** • Drill rig (manufacturer and model, and Caltrans equipment identification number) • Drilling method (mud rotary, air rotary, solid auger, hollow stem auger. etc.) • Drill rod description (type, diameter) • Drill bit description • Casing (type, diameter) and installation depth • SPT Hammer Type: Safety/Automatic Hammer, etc. o Lifting mechanism (for safety hammer) o Hammer Energy Ratio (ER_i) • Type of sampler(s) and size(s) o Undisturbed Shelby tube o Undisturbed Piston o Split spoon (e.g. SPT, Cal Mod, etc.) o Core (both rock and soil) o Disturbed (include auger cuttings) o Other
7	**Groundwater** • Method (observed while drilling, measured in hole, etc.) • Date, time, and elevation of each reading
8	**Hole Completion** • Reason for termination (e.g., drilled to depth, refusal, early termination of traffic control, etc.) • Backfill Method (e.g., grout, soil cuttings, dry bentonite chips, piezometers installed, slope inclinometer installed, TDR, instrumentation, etc.)

2.4 Assignment of Hole Identification

Identify holes using the following convention:

$$H - YY - NNN$$

Where:

H: Hole Type Code (Figure 2-4)

YY: 2-digit year

NNN: 3-digit number (001-999)

The *YY-NNN* component of the hole identification is unique and matched to a Caltrans project expenditure authorization number (EA), site, structure, or bridge number. If two drilling methods are used, such as auger boring followed by rotary drilled boring, the predominant tool governs the selection of Hole Type Code (H).

Figure 2-4 (after ASTM D 6453)
Hole Type Code and Description

	Description
A	Auger boring (hollow or solid stem, bucket)
R	Rotary drilled boring (conventional)
RC	Rotary core (self-cased wire-line, continuously-sampled)
RW	Rotary core (self-cased wire-line, not continuously sampled)
P	Rotary percussion boring (Air)
HD	Hand driven (1-inch soil tube)
HA	Hand auger
D	Driven (dynamic cone penetrometer)
CPT	Cone Penetration Test
O	Other (note on LOTB)

2.5 Soil Description and Identification Procedures

This section presents the method for identification and description of soil after ASTM D 2488 and USBR (2001). The detail of description provided for a particular soil should be dictated by the complexity and objectives of the project. Optional descriptors, if presented, should be critical to the design and/or construction needs of the project.

It is recognized that the uncertainty in visual soil description may be greater than 5% for any given soil constituent. Proportional or percentage descriptions varying by up to 10% for individual constituents may be considered to be descriptions of the same material.

2.5.1 Soil Description and Identification

When describing and identifying soil, record the data in accordance with Figure 2-5, and present the information on the LOTB or BR in the sequence shown. Items marked "required" must be used, when applicable, to describe the soil sample. For example, percent cobbles and/or boulders is required only if cobbles and/or boulders are encountered. Do not report negative information (e.g. no boulders or cobbles).

Use semicolons between required descriptors, commas within a descriptive component for optional descriptors, and a period at the end of each descriptive sequence.

Report each soil component identified by sequence 7 in order of decreasing proportion (not particle size). Report particle size range and (optionally) angularity and shape, separated by commas. Separate soil components with semicolons. For example,

> *…moist; some SAND, coarse, subangular; little GRAVEL, fine, angular;…*

-or-

> *…moist; some coarse, subangular SAND; little fine, angular GRAVEL;…*

Figure 2-5
Identification and Description Sequence

		Refer to Section			Optional
1	Group Name	2.5.2	3.2.2	●	
2	Group Symbol	2.5.2	3.2.2	●	
3	Consistency of Cohesive Soil	2.5.3	3.2.3	●	
4	Apparent Density of Cohesionless Soil	2.5.4		●	
5	Color	2.5.5		●	
6	Moisture	2.5.6		●	
7	Percent or Proportion of Soil	2.5.7	3.2.4	●	
	Particle Size	2.5.8	2.5.8	●	
	Particle Angularity	2.5.9			○
	Particle Shape	2.5.10			○
8	Plasticity (for fine-grained soil)	2.5.11	3.2.5		○
9	Dry Strength (for fine-grained soil)	2.5.12			○
10	Dilatency (for fine-grained soil)	2.5.13			○
11	Toughness (for fine-grained soil)	2.5.14			○
12	Structure	2.5.15			○
13	Cementation	2.5.16		●	
14	Percent of Cobbles and Boulders	2.5.17		●	
	Description of Cobbles and Boulders	2.5.18		●	
15	Consistency Field Test Result	2.5.3		●	
16	Additional Comments	2.5.19			○

The following examples illustrate the application of the descriptive sequence based on field procedures.

1. Example of a complete descriptive sequence for a sample using required <u>and</u> optional components:

   Well-graded SAND with GRAVEL (SW); medium dense; brown and light gray; wet; 75% SAND, from coarse to fine, rounded; 20% GRAVEL, coarse, subrounded to rounded, flat and elongated; 5% fines; weak cementation.

   Example of a complete descriptive sequence for the same soil sample using <u>only</u> required components:

   Well-graded SAND with GRAVEL (SW); medium dense; brown and light gray; wet; mostly SAND, from coarse to fine; little coarse GRAVEL; trace fines; weak cementation.

   Example of the complete descriptive sequence for the same soil sample that omits the percent or proportion of the primary soil constituent and omits the particle size range, which may be done when the percentage or proportion and particle size range of the primary soil constituent are clearly inferred:

   Well-graded SAND with GRAVEL (SW); medium dense; brown and light gray; wet; little coarse GRAVEL; trace fines; weak cementation.

2. Example of a complete descriptive sequence that omits the percent or proportion of the primary and secondary soil constituents, which may be done when the percentage or proportion of the primary and secondary soil constituents can be clearly inferred:

   SANDY lean CLAY (CL); stiff; brown and light gray; wet; fine SAND; PP=1.5 tsf.

   Corresponds to the following complete description:

   SANDY lean CLAY (CL); stiff; brown and light gray; wet; mostly fines; some fine SAND; medium plasticity; PP=1.5 tsf.

2.5.1.1 Description of Pavement Structural Sections

Do not use the descriptive sequence (Figure 2-5) to describe pavement sections. Report each material and its thickness, e.g.,

- ASPHALT CONCRETE (12”)
- CONCRETE (24” bridge footing)
- AGGREGATE BASE (30”)

2.5.1.2 Description of Interbedded Soil

State the predominant soil group name and symbol followed by the bedding thickness (Figure 2-30) of the components and the group name and symbol of the secondary layers. Follow this with the complete individual descriptions of the layers, e.g., for a sample consisting of moderate beds of sand interbedded with thin beds of silt:

> *Poorly-graded SAND (SP) moderately bedded with thin interbeds of SILT (ML). SAND (SP); dense; brown; moist; fine SAND. SILT (ML); dense; brown; moist; nonplastic.*

2.5.1.3 Description of Fills

State the word “FILL” parenthetically after the soil descriptive sequence.

For complex fills (e.g. thinly-layered, chaotic, highly variable soil), state the predominant soil group name and symbol followed by the layer thickness (Figure 2-30) of the components and the group name and symbol of the secondary layers. This is followed by the complete individual descriptions of the layers, e.g.

> *Poorly-graded SAND (SP); thickly interlayered with thin layers of SILT (ML) and GRAVEL (GP); SAND (SP); dense; brown; moist; fine SAND; SILT (ML); dense; brown; moist; nonplastic; GRAVEL (GP); medium dense; gray; moist; coarse; (FILL).*

2.5.2 Group Name and Group Symbol

Identify a soil by assigning a group name and group symbol using the figures in the section for fine- or coarse-grained soil (Figure 2-6 or 2-8).

The ASTM procedure for identifying and describing fine-grained and coarse-grained soil is only applicable to material passing the 3-inch sieve. The percentage(s) of cobbles and/or boulders (if encountered) must be reported per Section 2.5.17.

Borderline Symbol – Because ASTM D 2488 is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to assign it a single group symbol. To indicate that the soil may fall into one of two groups, use a borderline symbol, which is two symbols separated by a slash, e.g., SC/CL or CL/CH.

A borderline symbol must be used when:

- The percentage of fines is estimated to be between 45 and 55%. One symbol must be for a coarse-grained soil with fines; the other for a fine-grained soil, e.g., GM/ML or CL/SC.
- The percentage of sand and the percentage of gravel are estimated to be about the same, e.g., GP/SP, SC/GC, GM/SM.
- The soil could be well- or poorly-graded, e.g., GW/GP, SW/SP.
- The dominant fine-grained component of the soil could be either silt or clay, e.g., CL/ML, CH/MH, SC/SM.

The group name for a soil with a borderline symbol must be the group name for the first symbol, except for:

- CL/CH lean to fat CLAY,
- ML/CL CLAYEY SILT, and
- CL/ML SILTY CLAY

Borderline symbols should not be used indiscriminately. Use of a single group symbol is preferable.

Dual Symbol – A dual symbol is two symbols separated by a hyphen, e.g., GP-GM, SW-SC, CL-ML. They are used to indicate that the soil has about 10% fines.

2.5.2.1 Fine-Grained Soil

Fines are particles that pass through a Number 200 sieve. A soil is considered to be fine-grained if it contains 50% or more fines. Assign a Group Name and Symbol to fine-grained soil according to Figure 2-6.

Figure 2-6
Identification of Fine-Grained Soil *(after ASTM D 2488)*

				Group Name
CL	<30% plus No.200	<15% plus No.200		Lean CLAY
		15-25% plus No.200	% sand ≥ % gravel	Lean CLAY with SAND
			% sand < % gravel	Lean CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY lean CLAY
			≥ 15% gravel	SANDY lean CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY lean CLAY
			≥ 15% sand	GRAVELLY lean CLAY with SAND
ML	<30% plus No.200	<15% plus No.200		SILT
		15-25% plus No.200	% sand ≥ % gravel	SILT with SAND
			% sand < % gravel	SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY SILT
			≥ 15% gravel	SANDY SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY SILT
			≥ 15% sand	GRAVELLY SILT with SAND
CH	<30% plus No.200	<15% plus No.200		Fat CLAY
		15-25% plus No.200	% sand ≥ % gravel	Fat CLAY with SAND
			% sand < % gravel	Fat CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY fat CLAY
			≥ 15% gravel	SANDY fat CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY fat CLAY
			≥ 15% sand	GRAVELLY fat CLAY with SAND
MH	<30% plus No.200	<15% plus No.200		Elastic SILT
		15-25% plus No.200	% sand ≥ % gravel	Elastic SILT with SAND
			% sand < % gravel	Elastic SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY elastic SILT
			≥ 15% gravel	SANDY elastic SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY elastic SILT
			≥ 15% sand	GRAVELLY elastic SILT with SAND
OL/ OH	<30% plus No.200	<15% plus No.200		ORGANIC SOIL
		15-25% plus No.200	% sand ≥ % gravel	ORGANIC SOIL with SAND
			% sand < % gravel	ORGANIC SOIL with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SOIL
			≥ 15% gravel	SANDY ORGANIC SOIL with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SOIL
			≥ 15% sand	GRAVELLY ORGANIC SOIL with SAND

Clay and Silt – Identify the soil as Lean CLAY (CL), Fat CLAY (CH), SILT (ML), or Elastic SILT (MH), using the criteria in Figure 2-7.

Figure 2-7
Identification of Clayey and Silty Soil

				Plasticity
ML	None to low	Slow to rapid	Low or thread cannot be formed	Low to nonplastic
CL	Medium to high	None to slow	Medium	Medium
MH	Low to medium	None to slow	Low to medium	Low to medium
CH	High to very high	None	High	High

Organic Soil – Identify the soil as organic, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soil is usually dark brown or black and may have an organic odor. Often, organic soil will change color, for example, black to brown, when exposed to the air. Some organic soil will lighten in color significantly when air-dried. Organic soil normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

Identification of Peat – Peat is an organic soil composed primarily of vegetation in various stages of decomposition. It has a fibrous to amorphous texture, usually dark brown or black, and an organic odor. Identify Peat with the Group Name and Symbol, PEAT (PT). There are no standardized criteria for describing peat, thus the descriptive sequence in Figure 2-5 need not be followed. The description presented should be determined based on the needs of the project.

2.5.2.2 Coarse-Grained Soil

A coarse-grained soil contains fewer than 50% fines. A coarse-grained soil is identified as gravel if the percentage of gravel is greater than the percentage of sand, or as sand if the percentage of gravel is equal to or less than the percentage of sand. A well-graded sand or gravel has roughly equal amounts of all particle sizes. A poorly-graded sand or gravel is missing one or more particle sizes.

Assign a Group Name and Symbol to coarse-grained soil according to Figure 2-8.

Figure 2-8
Identification of Coarse-Grained Soil *(from ASTM D-2488)*

						Group Name
Gravel	≤ 5%	Well		GW	< 15% sand	Well-graded GRAVEL
					≥ 15% sand	Well-graded GRAVEL with SAND
		Poorly		GP	< 15% sand	Poorly-graded GRAVEL
					≥ 15% sand	Poorly-graded GRAVEL with SAND
	10%	Well	ML or MH	GW-GM	< 15% sand	Well-graded GRAVEL with SILT
					≥ 15% sand	Well-graded GRAVEL with SILT and SAND
			CL or CH	GW-GC	< 15% sand	Well-graded GRAVEL with CLAY
					≥ 15% sand	Well-graded GRAVEL with CLAY and SAND
		Poorly	ML or MH	GP-GM	< 15% sand	Poorly-graded GRAVEL with SILT
					≥ 15% sand	Poorly-graded GRAVEL with SILT and SAND
			CL or CH	GP-GC	< 15% sand	Poorly-graded GRAVEL with CLAY
					≥ 15% sand	Poorly-graded GRAVEL with CLAY and SAND
	≥ 15%		ML or MH	GM	< 15% sand	SILTY GRAVEL
					≥ 15% sand	SILTY GRAVEL with SAND
			CL or CH	GC	< 15% sand	CLAYEY GRAVEL
					≥ 15% sand	CLAYEY GRAVEL with SAND
Sand	≤ 5%	Well		SW	< 15% gravel	Well-graded SAND
					≥ 15% gravel	Well-graded SAND with GRAVEL
		Poorly		SP	< 15% gravel	Poorly-graded SAND
					≥ 15% gravel	Poorly-graded SAND with GRAVEL
	10%	Well	ML or MH	SW-SM	< 15% gravel	Well-graded SAND with SILT
					≥ 15% gravel	Well-graded SAND with SILT and GRAVEL
			CL or CH	SW-SC	< 15% gravel	Well-graded SAND with CLAY
					≥ 15% gravel	Well-graded SAND with CLAY and GRAVEL
		Poorly	ML or MH	SP-SM	< 15% gravel	Poorly-graded SAND with SILT
					≥ 15% gravel	Poorly-graded SAND with SILT and GRAVEL
			CL or CH	SP-SC	< 15% gravel	Poorly-graded SAND with CLAY
					≥ 15% gravel	Poorly-graded SAND with CLAY and GRAVEL
	≥ 15%		ML or MH	SM	< 15% gravel	SILTY SAND
					≥ 15% gravel	SILTY SAND with GRAVEL
			CL or CH	SC	< 15% gravel	CLAYEY SAND
					≥ 15% gravel	CLAYEY SAND with GRAVEL

2.5.3 Consistency of Cohesive Soil

Cohesive soil derives its strength from cohesion (tendency of particles to stick together) rather than friction between particles. Clay (CL and CH) and elastic silt (MH) are cohesive; silt (ML) may or may not be cohesive. The required field procedure for the determination of consistency of cohesive soil is to perform tests with a pocket penetrometer or torvane on relatively undisturbed samples, or to perform down-hole vane shear tests. *(See Appendix A for details on the test procedures.)* The test result(s) are added to the descriptive sequence using the syntax "PP = measurement", "TV = measurement", or "VS = measurement" where the measurement is in units of tsf.

Use the terms and criteria in Figure 2-9 to describe the consistency of predominantly cohesive soil.

Figure 2-9
Consistency of Cohesive Soil (after AASHTO 1988 and Bureau of Reclamation 2001)

			Vane Shear Measurement, VS, (tsf)
Very Soft	PP < 0.25	TV < 0.12	VS < 0.12
Soft	0.25 ≤ PP < 0.5	0.12 ≤ TV < 0.25	0.12 ≤ VS < 0.25
Medium Stiff	0.5 ≤ PP < 1	0.25 ≤ TV < 0.5	0.25 ≤ VS < 0.5
Stiff	1 ≤ PP < 2	0.5 ≤ TV < 1	0.5 ≤ VS < 1
Very Stiff	2 ≤ PP < 4	1 ≤ TV < 2	1 ≤ VS < 2
Hard	4 ≤ PP	2 ≤ TV	2 ≤ VS

2.5.4 Apparent Density of Cohesionless Soil

Describe the apparent density of predominantly cohesionless soil (Figure 2-10).

Figure 2-10 (after AASHTO, 1988)
Apparent Density of Cohesionless Soil

	SPT N_{60} (blows/ft)
Very Loose	$N_{60} < 5$
Loose	$5 \leq N_{60} < 10$
Medium Dense	$10 \leq N_{60} < 30$
Dense	$30 \leq N_{60} < 50$
Very dense	$50 \leq N_{60}$

The apparent density of a coarse-grained (predominantly cohesionless) soil is based on a corrected Standard Penetration Test (SPT) N_{60} value (described in Appendix A) as follows:

$$N_{60} = N_{measured} * (ER_i / 60)$$

where,

$$ER_i = \textit{Hammer energy ratio (\%)}$$

Example: $N_{measured} = 8$, $ER_i = 90\%$

$N_{60} = 8*(90/60) = 12$

The soil is *medium dense*

2.5.5 Color

Use the *Munsell Soil Color Charts* to describe the color of a soil sample at its natural moisture content at the time of sampling. Describe the predominant colors or range of colors if there is substantial color variation using the terms in Figures 2-1, 2-2 and/or 2-11 as appropriate. For example:

Variegated brown and light yellowish brown

For additional information, see ASTM D 1535, *Standard Practice for Specifying Color by the Munsell System*.

Figure 2-11
Color Terms

		Examples
Variegated	Having streaks, marks, or patches of a different color or colors; varicolored.	Variegated green, gray and black
Mottled	Having spots or blotches of different colors	Mottled green, gray and black
Multicolored	Lots of colors (state predominant colors)	Multicolored, green, gray and black

2.5.6 Moisture

Describe the moisture condition (Figure 2-12).

Figure 2-12 (after ASTM 2488)
Moisture

	Criteria
Dry	No discernable moisture
Moist	Moisture present, but no free water
Wet	Visible free water

Soil determined to be ”moist” may be alternatively qualitatively described as “slightly moist” or “very moist” if needed.

2.5.7 Percent or Proportion of Soil

Report the percentage or proportion of gravel, sand, and fines, by weight of the total sample (excluding the cobbles and boulders), either by using a proportional descriptor (Figure 2-13) or as a weight percentage (not a range), estimated to the nearest 5 %, of the total sample (excluding the cobbles and boulders). Report the percents or proportions in order of decreasing abundance. Percentages must add up to 100%. Visual descriptors may be omitted if the proportions can be clearly inferred from the group name and soil description. Refer to Section 2.5.17 for reporting percent of cobbles and/or boulders.

Figure 2-13 (after ASTM 2488)
Percent or Proportion of Soil, Pp

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

2.5.8 Particle Size

Describe the size of particles (Figure 2-14).

Figure 2-14 (from ASTM D 2488)
Particle Size, Ps

		Approximate Particle Size (in)
Boulder	Greater than 12 in.	12 < Ps
Cobble	3 to 12 in.	3 < Ps ≤ 12
Coarse Gravel	3/4 to 3 in.	3/4 < Ps ≤ 3
Fine Gravel	No. 4 to 3/4 in.	1/5 < Ps ≤ 3/4
Coarse Sand	No. 10 to No. 4	1/16 < Ps ≤ 1/5
Medium Sand	No. 40 to No. 10	1/64 < Ps ≤ 1/16
Fine Sand	No. 200 to No. 40	1/300 < Ps ≤ 1/64
Silt and Clay	Passing No. 200	Ps ≤ 1/300

2.5.9 Particle Angularity

Describe the angularity of the sand (coarse grains only), gravel, cobbles, and boulders (Figure 2-15).

Figure 2-15 (after ASTM 2488)
Particle Angularity

	Criteria
Angular	Particles have sharp edges and relatively plane sides 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 sides and no edges

2.5.10 Particle Shape

Describe the shape of the gravel, cobbles, and boulders *if* they meet any of the criteria in Figure 2-16.

Figure 2-16 (after ASTM 2488)
Particle Shape

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

2.5.11 Plasticity (for Fine-Grained Soil)

Describe plasticity (Figure 2-17).

Figure 2-17 (after ASTM 2488)
Plasticity

	Criteria
Nonplastic	A 1⁄8-in. 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 rerolled 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.

2.5.12 Dry Strength (for Fine-Grained Soil)

Determine dry strength (Figure 2-18). *(See Appendix A for field test procedures.)*

Figure 2-18 (after ASTM 2488)
Dry Strength

	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 a hard surface.

2.5.13 Dilatancy (for Fine-Grained Soil)

Determine dilatancy (Figure 2-19). *(See Appendix A for field test procedures.)*

Figure 2-19 (after ASTM 2488)
Dilatancy

	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

2.5.14 Toughness (for Fine-Grained Soil)

Determine toughness (Figure 2-20). *(See Appendix A for field test procedures.)*

Figure 2-20 (after ASTM 2488)
Toughness

	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 the 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

2.5.15 Structure

Describe the structure of intact soil (Figure 2-21).

Figure 2-21 (after ASTM 2488)
Structure

	Criteria
Stratified	Alternating layers of varying material or color with layers at least ¼ in. thick; note thickness.
Laminated	Alternating layers of varying material or color with the layers less than ¼ in. 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 soil, such as small lenses of sand scattered through a mass of clay; note thickness.
Homogeneous	Same color and appearance throughout.

2.5.16 Cementation

Describe the cementation of intact coarse-grained soil (Figure 2-22).

Figure 2-22 (after ASTM 2488)
Cementation

	Criteria
Weak	Crumbles or breaks with handling or light finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

2.5.17 Percent of Cobbles and Boulders

Particles greater than 3 inches in diameter are identified and described as “COBBLES,” or “BOULDERS,” or “COBBLES and BOULDERS” as defined in Section 2.5.8. Cobbles and boulders must be reported by volume percentage (to the nearest 5%). Do not use the proportional descriptors defined in Figure 2-13.

Estimation of the volume of cobbles and/or boulders is based upon recovered intersected or observed lengths and/or drill rig behavior.

A subset of rock descriptors (Section 2.5.18) must be used to describe cobbles and boulders. Isolated boulders may be treated as individual units and described as such.

For example, it is estimated that 30% by volume of the material is cobbles, describe the sample as:

> *Well-graded SAND with GRAVEL and COBBLES (SW); medium dense; brown and light gray; wet; 75% from coarse to fine rounded SAND; 20% coarse subrounded to rounded, flat and elongated GRAVEL; 5% fines; weak cementation; 30% SANDSTONE COBBLES, 4-6 inches, hard.*

-or-

> *Well-graded SAND with GRAVEL and COBBLES (SW); medium dense; brown and light gray; wet; little coarse subrounded to rounded, flat and elongated GRAVEL; trace fines; weak cementation; 30% SANDSTONE COBBLES, 4-6”, hard.*

Note, the percentages of constituents in the first example do not add up to 100% as cobbles are estimated by total volume, but gravel, sand, and fines, are estimated by weight of the total sample excluding the cobbles and boulders, per Section 2.5.7.

If the predominant constituent of the layer is estimated to be cobbles and/or boulders, the group name must be “COBBLES” or “BOULDERS” or “COBBLES and BOULDERS” with the interstitial or matrix soil description following. There is no Group Symbol for cobbles and/or boulders. Note this is a departure from the descriptive sequence in Section 2.5.1 as Sequence 14 is reported after Sequence 1. For example, it is estimated that 60% by volume of the material is cobbles, describe the layer as:

> *COBBLES; 60%; SANDSTONE; hard; 8-10 inches; with interstitial well-graded SAND with GRAVEL (SW); brown and light gray; wet; rounded SAND; little coarse, subrounded to rounded, flat and elongated GRAVEL; trace fines; weak cementation.*

Or if there are 45% cobbles in a SW matrix:

> *COBBLES; 45%; SANDSTONE; hard; 8-10 inches; in a matrix of well-graded SAND with GRAVEL (SW); medium dense; brown and light gray; wet; rounded SAND; little coarse, subrounded to rounded, flat and elongated GRAVEL; trace fines; weak cementation.*

2.5.18 Description of Cobbles and Boulders

The description of cobbles and boulders must include, at minimum, the following information:

- Rock Type or Rock Name
- Rock hardness
- The intersected length(s)

An *intersected length* is the measured or observed length of cobble or boulder during drilling. This is not necessarily the maximum size of the cobble or boulder, e.g., a 10-inch intersected length may be identified as a boulder.

2.5.19 Additional Comments

Additional constituents and soil characteristics not included in the previous categories may be noted and described. Comments may include:

- Amount of roots or root holes
- Amount of mica, gypsum, etc.
- Amount of voids
- Surface coatings on coarse-grained particles
- Oxide staining
- Odor
- Cementing agents (e.g. calcium carbonate – see Appendix A.7)
- Geologic formation name or soil survey unit name, presented as the last term in the sequence capitalized in parenthesis, e.g. (BAY MUD), (FRANCISCAN FORMATION)

References for terms or procedures, not covered by this manual, presented under *Additional Comments*, must be presented in the "Notes" section on the LOTB sheet or Boring Record.

2.5.20 Other Drilling Observations

Other observations (not included in the descriptive sequence) that may be presented on the LOTB or BR as notes or remarks include:

- Caving or sloughing of borehole or trench sides
- Difficulty in drilling or excavating, etc.
- Ground water inflow, elevation(s), and estimated rate(s)
- Loss of drill fluid circulation
- Changes in drilling methods not clearly shown on the boring log

2.6 Rock Identification and Description Procedures

The procedures presented in this section are based on a hybrid of the International Society of Rock Mechanics (ISRM) (1981) standards and the Bureau of Reclamation (2001) standards.

Although not included in the descriptive sequence, Core Recovery (REC) and Rock Quality Designation (RQD) must be recorded and presented on the boring logs. Core Recovery and RQD must be reported for all rock coring operations as described in Appendices A.9 and A.10.

2.6.1 Rock Identification and Descriptive Sequence

Describe rock using Figure 2-23. The detail of description provided for a particular rock type should be dictated by the complexity and objectives of the project. Optional descriptors, if presented, must be relevant to the design and/or construction needs of the project.

Figure 2-23
Rock Identification and Descriptive Sequence

		Refer to Section			Optional
1	Rock Type	2.6.2		●	
2	Rock Name	2.6.2		●	
3	Rock Grain Size (Coarse-grained sedimentary rock)	2.6.4		●	
	Crystal Size (Igneous and Metamorphic rock)	2.6.4			○
4	Bedding Spacing	2.6.5		●	
5	Color	2.6.6		●	
6	Weathering Descriptors for Intact Rock	2.6.7		●	
7	Rock Hardness	2.6.8		●	
8	Fracture Density	2.6.9		●	
9	Fracture Condition	2.6.10			○
10	Rate of Slaking (Jar Slake Test)	2.6.11			○
11	Relative Strength of Intact Rock		3.3.1		○
12	Additional Comments	2.5.12			○

2.6.1.1 Description of Interbedded Rock

Describe interbedded rock as follows:

State the rock type and the predominant rock name followed by the bedding thicknesses (Figure 2-30) of the components and the rock name of the secondary layers. This is followed by the complete individual descriptions of the layers e.g, for a sample consisting of moderate beds of sandstone interbedded with thin beds of siltstone:

> *SEDIMENTARY ROCK (SANDSTONE) moderately bedded with thin interbeds of SILTSTONE. SANDSTONE; fine grained; gray; fresh; hard; slightly fractured; SILTSTONE; gray; slightly weathered; moderately hard; moderately fractured.*

2.6.1.2 Description for Intensely Weathered to Decomposed or Decomposed Rock

Intensely weathered to decomposed or decomposed rock that is friable and can be reduced to gravel size or smaller by normal hand pressure must be identified and described as rock as completely as possible, followed by the soil identification or classification, and description in parentheses (per Section 2.5). For example:

> *IGNEOUS ROCK (DIORITE); yellowish brown; intensely weathered to decomposed; very soft; unfractured; (Lean CLAY with SAND (CL); medium stiff; moist; little coarse SAND; PP=1 tsf).*

Or when a rock is decomposed, hardness and fracturing usually do not apply:

> *IGNEOUS ROCK (DIORITE); yellowish brown; decomposed; (Lean CLAY with SAND (CL); medium stiff; moist; little coarse SAND; PP=0.6 tsf).*

Note, color is not repeated in the descriptive sequence for soil.

2.6.1.3 Description of Poorly Indurated Rock

Poorly indurated formational materials such as siltstone, claystone, weakly cemented sandstone etc. which display both rock-like and soil-like properties, regardless of the degree of weathering, must be described as rock as completely as possible followed by the soil identification or classification and description in parentheses. Add "POORLY INDURATED" to the Rock Name, e.g.,

> *SEDIMENTARY ROCK (POORLY INDURATED SANDSTONE); medium grained; variably light gray and light yellowish brown; fresh; very soft; unfractured; (Poorly-graded SAND (SP); very dense; moist; medium sand; strong cementation).*

2.6.2 Rock Identification

Rock is identified by a combination of Rock Type (Igneous, Metamorphic or Sedimentary) followed by the Rock Name. Rock Name may be a generalized Family Name (e.g., Granite, Sandstone) or a more specific name (e.g., Granodiorite, Arkose) if the identification is made by a qualified geoprofessional, e.g.,

> *IGNEOUS ROCK (GRANITE)*

-or-

> *IGNEOUS ROCK (GRANODIORITE)*

Note that a specific rock name is usually not relevant for geotechnical work, the family name is generally sufficient and may often be found in published geologic maps. Figures 2-24, 2-25 and 2-26 present rocks commonly found in California. The lists of rock names presented in this section are not intended to be comprehensive.

2.6.2.1 Igneous Rock

Igneous rock is identified by a combination of three characteristics: chemical composition, texture, and method of emplacement.

<u>Chemical Composition:</u> Igneous rocks may be Felsic, characterized by light color and high silica and alkali metal content; Intermediate; or Mafic/Ultramafic, characterized by dark color and high iron and magnesium content.

<u>Texture:</u> Igneous rock may be coarse-grained (phaneritic) where individual minerals are identifiable with the naked eye, or fine-grained

(aphanitic) where individual minerals are not identifiable with the naked eye.

Method of Emplacement: Igneous rock may be formed deep underground (intrusive or plutonic rocks), typically coarse grained, or at or near the surface (extrusive or volcanic rock), typically fine-grained.

Volcanic rock may be further subdivided into lava flows, where molten rock flows over the landscape and solidifies into rock, and pyroclastic deposits which are formed from explosive eruptions where lava and rock particles are thrown into the air. Volcanic rocks may also be characterized by the method of emplacement and texture (Figure 2-24).

2.6.2.2 Sedimentary Rock

Sedimentary rock is formed by the process of induration or lithification whereby sediments compact under pressure and gradually become rock. Lithification includes all the processes which convert unconsolidated sediments into sedimentary rock.

Sedimentary rock may be well indurated or lithified as solid rock, or poorly indurated or poorly lithified and display soil-like characteristics. Poorly indurated rock should be distinguished from weathered rock as described in Section 2.6.1.3. Refer to Figure 2-25.

2.6.2.3 Metamorphic Rock

Metamorphic rock is igneous, sedimentary or other metamorphic rock that has been changed by heat and/or pressure. Metamorphism may be either regional metamorphism, due to widespread burial and heat, or contact metamorphism, due to heat from a nearby igneous intrusion.

The original rock character may or may not be discernable after metamorphism. If it is still discernable, the rock name may be the parent rock type or name with the prefix “meta”, e.g., Metavolcanic, Metasedimentary, Metasandstone, Metaandesite.

Regionally metamorphosed rock types are distinguished by mineralogy and texture. These vary according to the degree of metamorphism, or metamorphic grade. Foliation is an alignment of mineral grains or compositional banding. It varies from slatey cleavage due to the parallel growth of mica crystals, to a gneissic texture where minerals group in bands, which resemble bedding. Foliation is usually most common in rock derived from fine-grained sedimentary rock. Refer to Figure 2-26.

2.6.3 Rock Description

Rock description includes the Rock Type followed by the Rock Name (either specific, or family name, with modifiers such as scoria, ash fall etc) in parentheses followed by the required descriptors.

Examples:

IGNEOUS ROCK (BASALT); very thickly bedded; black; fresh; hard; slightly fractured.

IGNEOUS ROCK (RHYOLITE ASH FLOW); thickly bedded; white; slightly weathered; soft; slightly fractured.

METAMORPHIC ROCK (METASANDSTONE); thickly bedded; white, locally yellowish brown; slightly weathered; moderately soft; slightly fractured.

-or more specifically-

METAMORPHIC ROCK (QUARTZITE); thickly bedded; white, locally yellowish brown; slightly weathered; moderately soft; slightly fractured.

Figure 2-24
Igneous Rock

Typ			k Name		Typical Characteristics
Igneous	Felsic	Coarse-grained	**Granite**	Granite, Tonalite, Granodiorite, Quartz Monzonite	Light Colored; composed primarily of quartz and feldspar (plagioclase and orthoclase) with minor ferromagnesian minerals. Emplaced as large intrusive plutonic bodies.
		Fine-grained	**Rhyolite**	Rhyolite, Quartz Latite, Trachyte	As above, except emplaced as volcanic ash flows, ash falls, local flows and domes.
	Intermediate	Coarse-grained	**Diorite**	Diorite, Monzonite	Medium gray or medium green (intermediate colored); composed primarily of plagioclase feldspars with ~30-50% ferromagnesian minerals (absent or minor quartz). Emplaced as small to large intrusive plutonic bodies.
		Fine-grained	**Andesite**	Andesite, Latite, Dacite	As above, except emplaced as volcanic flows, mud flows and breccias.
	Mafic/ Ultramafic	Coarse-grained	**Gabbro**	Gabbro, Peridotite, Norite, Dunite	Dark gray or black (dark colored); composed primarily of ferromagnesian minerals with minor plagioclase feldspar. Typically emplaced in California as accretionary memtamorphosed bodies (e.g ophiolite complexes).
		Fine-grained	**Basalt**	Basalt, Picrite	As above, except emplaced as local to widespread volcanic lava flows and cinder cones.

Volcanic Rock Name Modifiers	
Lava flow	Typical of basalt.
Ash flow	Typical of rhyolite - An airborne deposit formed from lava and rock fragments, which flow through the air down the flanks of a volcano.
Ash fall	An airborne deposit formed from small rock fragments erupted to high altitudes, which then rain down.
Mudflow	Typical of andesite. May be a primary feature where erupting lava is mixed with snow or water and flows downhill, or may be a secondary feature where an existing volcanic deposit fails in a landslide.
Breccia	Flowing rock hardens, breaks up and is incorporated back into the flow.
Agglomerate	Volcanic rock formed primarily of volcanic bombs. Volcanic bombs are globs of lava thrown through the air and may gravel-sized or as large as a small car.
Obsidian	Volcanic rock consisting almost entirely of glass.
Pumice	Solidified lava froth – resembles a sponge with about 90% porosity, floats on water.
Scoria	Like pumice, but with larger vesicles (rounded voids) and thicker vesicle walls. Sinks in water.

Figure 2-25
Sedimentary Rock

				Characteristics
Sedimentary	Clastic Rocks	Coarse-grained	**Conglomerate**	Rock composed of rounded clasts of gravel, cobbles, and/or boulders with interstitial finer-grained material.
			Breccia	A conglomerate composed of angular clasts.
			Sandstone	Rock composed mostly of sand-sized particles.
			Graywacke	Sandstone characterized by well graded, usually angular, sand and gravel in a fine-grained matrix.
		Fine-grained	**Mudstone**	Poorly indurated, generally structureless rock composed of clay. Generally slakes in water.
			Claystone	Well indurated, generally structureless rock composed of clay.
			Shale	Well indurated mudstones or claystones which are fissile, or break along planes generally parallel to bedding planes.
			Siltstone	Rock composed mostly of silt-sized particles. May be structureless or display bedding. Usually not fissile unless there is significant clay content.
	Evaporites			Evaporites are generally identified by their primary mineral constituent, e.g., Gypsum, Borates, Halite (rock salt), Carbonate etc.
	Precipitates	Organic	**Limestone**	Well indurated rock composed of calcium carbonate or calcium-magnesium carbonate (dolomite) with or without shells or shell fragments.
			Chalk	Poorly indurated limestone.
			Diatomite	Poorly indurated rock comprised of diatom shells.
		Inorganic	**Chert**	Generally microcrystalline silica.

*Sedimentary rocks may be divided into three categories:

Clastic: Formed from particles of preexisting rocks transported and deposited primarily in water.

Evaporate: Formed by the precipitation of minerals due to the complete evaporation of relatively small bodies of surface water; generally identified by their primary mineral constituent.

Precipitate: Formed by the precipitation of minerals, generally in oceans.

Figure 2-26
Metamorphic Rock

			Characteristics
Metamorphic	Foliated	**Slate**	Usually fine-grained with well developed slatey cleavage (tendency to break along well defined planes).
		Phyllite	Coarser grained than slate with phyllitic texture, similar to slatey cleavage, but planes may be less well defined or wavy.
		Schist	Coarse-grained, significant alignment of minerals, some slatey cleavage.
		Gneiss	Coarse-grained, foliation entirely due to alignment and banding of minerals.
	Non-foliated or poorly foliated	**Granulite**	Higher degree of metamorphism than gneiss, resemble coarse-grained igneous rocks.
		Amphibolite	Nearly monomineralic coarse-grained rock composed of amphibole.
		Hornfels	Generally fine-grained contact-metamorphosed rock.
		Skarn	Usually coarse-grained contact metamorphic rock where significant metasomatism has occurred.

2.6.4 Rock Grain-size descriptors

Describe the grain or clast size in accordance with Figures 2-27, 2-28 and 2-29.

Figure 2-27
Grain-Size for Crystalline Igneous and Metamorphic Rock

	Average Crystal Size, S (in)
Very Coarse Grained or Pegmatitic	$3/8 \leq S$
Coarse-grained	$3/16 < S \leq 3/8$
Medium-grained	$1/32 < S \leq 3/16$
Fine-grained	$1/250 < S \leq 1/32$
Aphanitic	$S \leq 1/250$

Figure 2-28
Grain-Size (Clastic Rock)

	Lithified Product
Boulder	Boulder Conglomerate
Cobble	Cobble Conglomerate
Coarse Gravel	Coarse Gravel Conglomerate
Fine Gravel	Fine Gravel Conglomerate
Coarse Sand	Coarse Sandstone
Medium Sand	Medium Sandstone
Fine Sand	Fine Sandstone
Silt	Siltstone, Shale
Clay	Claystone, Shale

Figure 2-29
Grain-Size (Pyroclastic Igneous Rock)

		Size, S (in)
Block (Angular)	Volcanic Breccia	2.5 < S
Bomb (Rounded)	Agglomerate	
Lapilli	Lapilli Tuff	1/20 < S ≤ 2.5
Coarse Ash	Coarse Ash Tuff	1/400 < S ≤ 1/20
Fine Ash	Fine Ash Tuff	S ≤ 1/400

2.6.5 Bedding Spacing Descriptors

Describe the bedding thickness or spacing of sedimentary or bedded volcanic rock (Figure 2-30).

Figure 2-30 (after USBR 2001)
Bedding Spacing

	Thickness/Spacing, Sb
Massive	10 ft. < Sb
Very Thickly Bedded	3 ft. < Sb ≤ 10 ft.
Thickly Bedded	1 ft. < Sb ≤ 3 ft.
Moderately Bedded	4 in. < Sb ≤ 1 ft.
Thinly Bedded	1 in. < Sb ≤ 4 in.
Very Thinly Bedded	1/4 in. < Sb ≤ 1 in.
Laminated	Sb ≤1/4 in.

2.6.6 Rock Colors

Use the color name from the *Munsell Soil Color Charts*, which is based on the National Bureau of Standards/Inter Society Color Council system, to describe the rock at the time of sampling. If the sample contains layers or patches of varying colors, describe the predominant colors observed.

For additional information, see ASTM D 1535, *Standard Practice for Specifying Color by the Munsell System*.

2.6.7 Weathering Descriptors for Intact Rock

Describe the rock weathering (Figure 2-31).

Figure 2-31 (after USBR 2001)
Weathering for Intact Rock

	Diagnostic Features					General Characteristics
				ure and Leaching		
Fresh	No discoloration, not oxidized.	No discoloration or oxidation.	No separation, intact (tight).	No change	No leaching	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved	Minor leaching of some soluble minerals	Hammer rings when crystalline rocks are stuck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are “rusty,” feldspar crystals are “cloudy”.	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, see grain boundary conditions.	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitics are disaggregated.	Texture altered by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened.
Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay.		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Resistant minerals such as quartz may be present as “stringers” or “dikes.”

2.6.8 Rock Hardness

Describe the hardness of intact rock core (Figure 2-32).

Figure 2-32 (after USBR 2001)
Rock Hardness

	Criteria
Extremely Hard	Cannot be scratched with a pocketknife or sharp pick. Can only be chipped with repeated heavy hammer blows.
Very Hard	Cannot be scratched with a pocketknife or sharp pick. Breaks with repeated heavy hammer blows.
Hard	Can be scratched with a pocketknife or sharp pick with difficulty (heavy pressure). Breaks with heavy hammer blows.
Moderately Hard	Can be scratched with a pocketknife or sharp pick with light or moderate pressure. Breaks with moderate hammer blows.
Moderately Soft	Can be grooved 1/16 in. deep with a pocketknife or sharp pick with moderate or heavy pressure. Breaks with light hammer blow or heavy manual pressure.
Soft	Can be grooved or gouged easily with a pocketknife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a pocketknife. Breaks with light manual pressure.

2.6.9 Fracture Density

Fractures are defined in Section 2.6.10. The fracture density is based on the fracture spacing observed in recovered core, excluding mechanical breaks, measured along the core axis. Note that fracture density and RQD should correlate. Describe the fracture density (Figure 2-33).

Figure 2-33 (after USBR 2001)
Fracture Density

	Observed Fracture Density
Unfractured	No fractures.
Very Slightly Fractured	Core lengths greater than 3 ft.
Slightly Fractured	Core lengths mostly from 1 to 3 ft.
Moderately Fractured	Core lengths mostly 4 in. to 1 ft.
Intensely Fractured	Core lengths mostly from 1 to 4 in.
Very Intensely Fractured	Mostly chips and fragments.

2.6.10 Fracture Condition

Fracture is a term used to describe any break in geologic material, including shears and shear zones. Use a single description, or range of descriptors, to describe the fractures over the length of the core. Descriptors must be presented in the following order.

1. Fracture Group Identification
2. Dip Magnitude
3. Spacing
4. Width
5. Infilling
6. Composition of Infilling
7. Weathering or Alteration
8. Hardness
9. Healing
10. Roughness

e.g.,

SEDIMENTARY ROCK (GRAYWACKE); fine-grained; massive; gray; moderately weathered; hard; moderately fractured; (F1, 45 deg, 2-3' spacing, moderately wide, thin filling of clay, soft, slightly rough) (F2, 28 deg, 1' apparent spacing, open, very thin filling of calcite, hard, moderately healed, smooth).

2.6.10.1 Fracture Group Identification

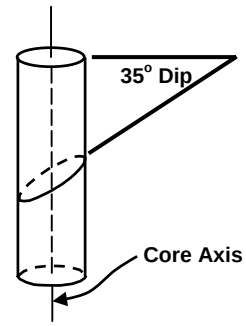
Uniquely identify each fracture group in the descriptive sequence using the terms F1, F2…Fx for fracture groups.

2.6.10.2 Fracture Dip Magnitude

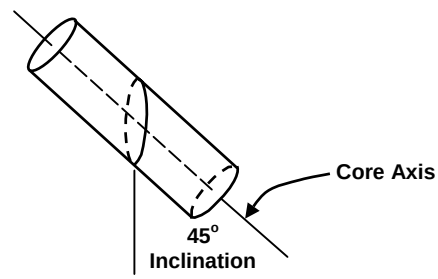
Report fracture dip magnitude. (Figure 2-34)

Figure 2-34
Fracture Dip Magnitude

Vertical Hole: True dip (but not strike unless from oriented core) is reported.



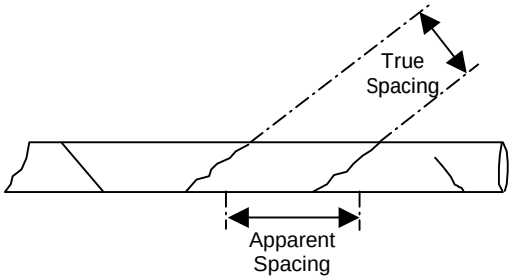
Angle Hole: True dip is usually not known; angle is measured from core axis and is called inclination.



2.6.10.3 Fracture Spacing

Fracture spacing is the distance measured between similar oriented fractures. Fracture spacing may either be presented as a single distance or as a range of distances measured for a fracture group. Spacing is measured as shown in Figure 2-35. Apparent spacing, if measured, must be described as such.

Figure 2-35
True and Apparent Fracture Spacing



2.6.10.4 Fracture Width

Measure the fracture width normal to the fracture surfaces (Figure 2-36).

Figure 2-36
Fracture Width (after USBR 2001)

	Fracture Width, FW (in)
Tight	No visible separation
Slightly Open	FW < 1/32
Moderately Open	1/32 ≤ FW < 1/8
Open	1/8 ≤ FW < 3/8
Moderately Wide	3/8 ≤ FW < 1
Wide	1 ≤ FW

2.6.10.5 Fracture Infilling

Describe the thickness of coatings or fillings (Figure 2-37).

Figure 2-37 (after USBR 2001)
Filling or Coating Thickness

	Fracture Filling, FF
Clean	No film coating
Very Thin	FF < 1/32 in.
Moderately Thin	1/32 in. ≤ FF < 1/8 in.
Thin	1/8 in. ≤ FF < 3/8 in
Moderately Thick	3/8 in. ≤ FF < 1 in.
Thick	1 in. ≤ FF

2.6.10.6 Composition of Infilling

Fractures may be filled with minerals or soil. Identify and describe the fracture fillings to convey properties that may be significant to the project design.

2.6.10.7 Weathering or Alteration

Describe the weathering or alteration of fracture infilling (excluding soil materials) using the weathering descriptors for intact rock (Figure 2-31)

2.6.10.8 Hardness

Describe the hardness of the infill material using either the hardness descriptors for rock (Figure 2-32) or estimate the consistency or apparent density descriptor for soil.

2.6.10.9 Healing

Describe the fracture healing (Figure 2-38).

Figure 2-38
Fracture Healing (after USBR 2001)

	Healing
Totally Healed	Fracture is completely healed or recemented to a degree at least as hard as surrounding rock.
Moderately Healed	Greater than 50 percent of fracture is healed or recemented.
Partly Healed	Less than 50 percent of fractured material, filling, or fracture surface is healed or recemented.
Not Healed	Fracture surface filling is not healed or recemented.

2.6.10.10 Roughness

Describe the fracture surface roughness (small scale asperities) (Figure 2-39).

Figure 2-39
Fracture Roughness (after USBR 2001)

	Roughness
Stepped	Near-normal steps and ridges occur on the fracture surface.
Rough	Large, angular asperities can be seen.
Moderately Rough	Asperities are clearly visible and fracture surface feels abrasive.
Slightly Rough	Small asperities on the fracture surface are visible and can be felt.
Smooth	No asperities, smooth to the touch.

2.6.11 Rate of Slaking

Slaking is the crumbling and disintegration of some rocks when exposed to air or moisture. Slaking may be partial (rock breaks up into smaller particles), or complete (rock is completely disintegrated to clay, silt, and sand).

Rocks that are prone to slaking include shale, siltstone, claystone, weakly welded tuff, and highly weathered crystalline igneous and metamorphic rocks. See Appendix A for test procedures. Describe rate of slaking (Figure 2-40).

Figure 2-40
Rate of Slaking (from Air Force Manual)

	Observed Behavior
1	Degrades to a pile of small particles or fragments.
2	Breaks rapidly and forms many fragments.
3	Breaks slowly and forms few fragments.
4	Breaks rapidly and develops several fractures.
5	Breaks slowly and develops few fractures.
6	No change to condition of the rock fragment.

2.6.12 Additional Comments

Note additional relevant rock characteristics not included in the previous categories.

References for terms or procedures, not covered by this manual, presented under *Additional Comments*, must be presented in the "Notes" section on the LOTB sheet or Boring Record.

2.6.13 Other Drilling Observations

Other observations (not included in the descriptive sequence) that may be presented on the LOTB or BR as notes or remarks include:

- Time for core run
- Difficulty in drilling or excavating, etc.
- Ground water inflow, elevation(s), and estimated rate(s)
- Loss of drill fluid circulation

2.7 Sample Preparation and Identification for Laboratory Testing and Storage

Geoprofessionals who drill, identify, sample, preserve, and transport soil samples play an important role in ensuring the quality of the laboratory test results. When performing field investigations, the geoprofessional must be familiar with the following ASTM standards:

- ASTM D 1586, "Test Method for Penetration Test and Split-Barrel Sampling of Soils"
- ASTM D 1587, "Practice for Thin-Walled Tube Sampling of Soils"
- ASTM D 3550, "Practice for Ring-Lined Barrel Sampling of Soils"
- ASTM D 4220, "Standard Practices for Preserving and Transporting Soil Samples"

The following information explains the procedures and information required to prepare soil and rock samples to the Caltrans Geotechnical Laboratory, an AASHTO Materials Reference Laboratory (AMRL) accredited facility located in Sacramento.

2.7.1 Sample Preparation and Identification for Laboratory Testing and Storage

All samples must be named according to the following convention:

Hole ID – SNN – T

Where,

Hole ID: Refer to Section 2.4

S: The Sample Type Code (Figure 2-41)

NN: 2-digit sample number (01–99), numbered from the top down.

T: 1-digit tube number, starting with the bottom tube numbered as 1.

For example:

A – 10 – 005 – U02 – 3

Figure 2-41
Sample Type Codes (after ASTM D 6453)

	Description
U	Undisturbed Shelby tube
P	Undisturbed Piston
S	Split spoon (includes SPT and Cal Mod Samplers)
B	Bulk
C	Core (both rock and soil)
D	Disturbed (include auger cuttings)
O	Other

Label brass and Shelby tubes and bagged samples (Figures 2-42 and 2-43).

Figure 2-42
Brass and Shelby Tube Label

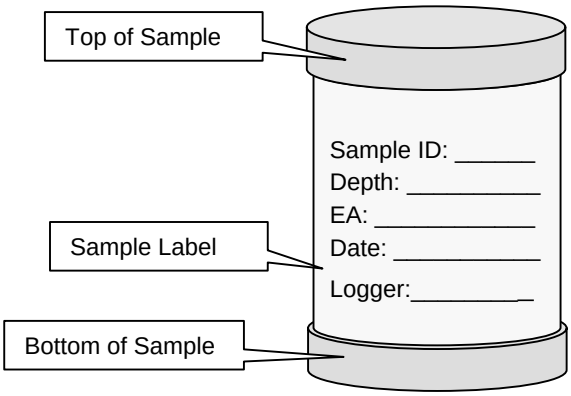
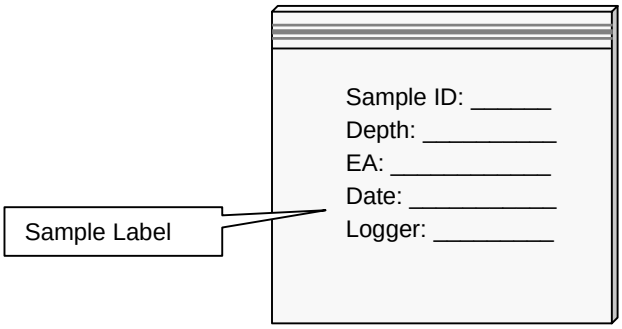


Figure 2-43
Bagged Sample Label



2.7.2 Identification of Large Soil Samples

In addition to the labeling requirements explained above, some soil samples must also be labeled with a Sample Identification Card (Caltrans Form TL-101), including:

- Samples weighing more than 5 lbs.
- Samples to be tested by the Materials Engineering and Testing Services (METS), test names are followed by "**" in Figure 2-44.

Place Form TL-101 inside a sealed plastic bag then put it inside the large plastic or canvas sample bag.

Figure 2-44
Minimum Material Requirements for Various Test Methods

				TL-101 Required
AASHTO T 265 ASTM D 2216	Moisture Content	0.5 lb	1/2 Tube	No
ASTM D 4767	Unit Weight	1 lb	1 Tube	No
AASHTO T 100	Specific Gravity	0.5 lb	1/2 Tube	No
ASTM D 422	Particle-Size Analysis	1 lb	1 Tube	No
AASHTO T 89 AASHTO T 90	Liquid Limit Plastic Limit, Plasticity Index	1 lb	1 Tube	No
ASTM D 2435	Consolidation Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No Yes
ASTM D 4546	Swell Potential Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No Yes
ASTM D 5333	Collapse Potential Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No Yes
ASTM D 3080	Direct Shear Undisturbed Remolded	 - 80 lb	 1 Tube 2 Full Canvas Bags	 No Yes
CTM 216	Relative Compaction (Compaction Curve Only)	80 lb	2 Full Canvas Bags	Yes
CTM 220	Permeability Undisturbed Falling Head Remolded Falling Head Constant Head	 - 80 lb 80 lb	 1 Tube 2 Full Canvas Bags 2 Full Canvas Bags	 No Yes Yes

				TL-101 Required
ASTM D 2166 ASTM D 2938	Unconfined Compression	-	1 Tube or Core	No
ASTM D 4767	Triaxial CU (3 points) Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.8" Diameter)	 - - 80 lb	 3 Tubes - in series 3 Tubes - in series 2 Full Canvas Bags	 No No Yes
ASTM D 2850	Triaxial UU (1 point) Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.8" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No Yes
ASTM D 427	Shrinkage Limit	1 lb	1 Tube	No
ASTM D 5731	Point Load	-	Rock Core	No
ASTM D 4829	Expansion Index	40 lb	1 Full Canvas Bag	Yes
CTM 217 AASHTO T 176	Sand Equivalent**	10 lb	1/4 Full Canvas Bag	Yes
CTM 301 AASHTO T 190	R-Value**	80 lb	2 Full Canvas Bags	Yes
CTM 643 CTM 417 CTM 422	Corrosion** Sulfates** Chlorides**	10 lb	1/4 Full Canvas Bag	Yes
EPA 9081	Organic Content** PH** Cation Exchange**	10 lb	1/4 Full Canvas Bag	Yes

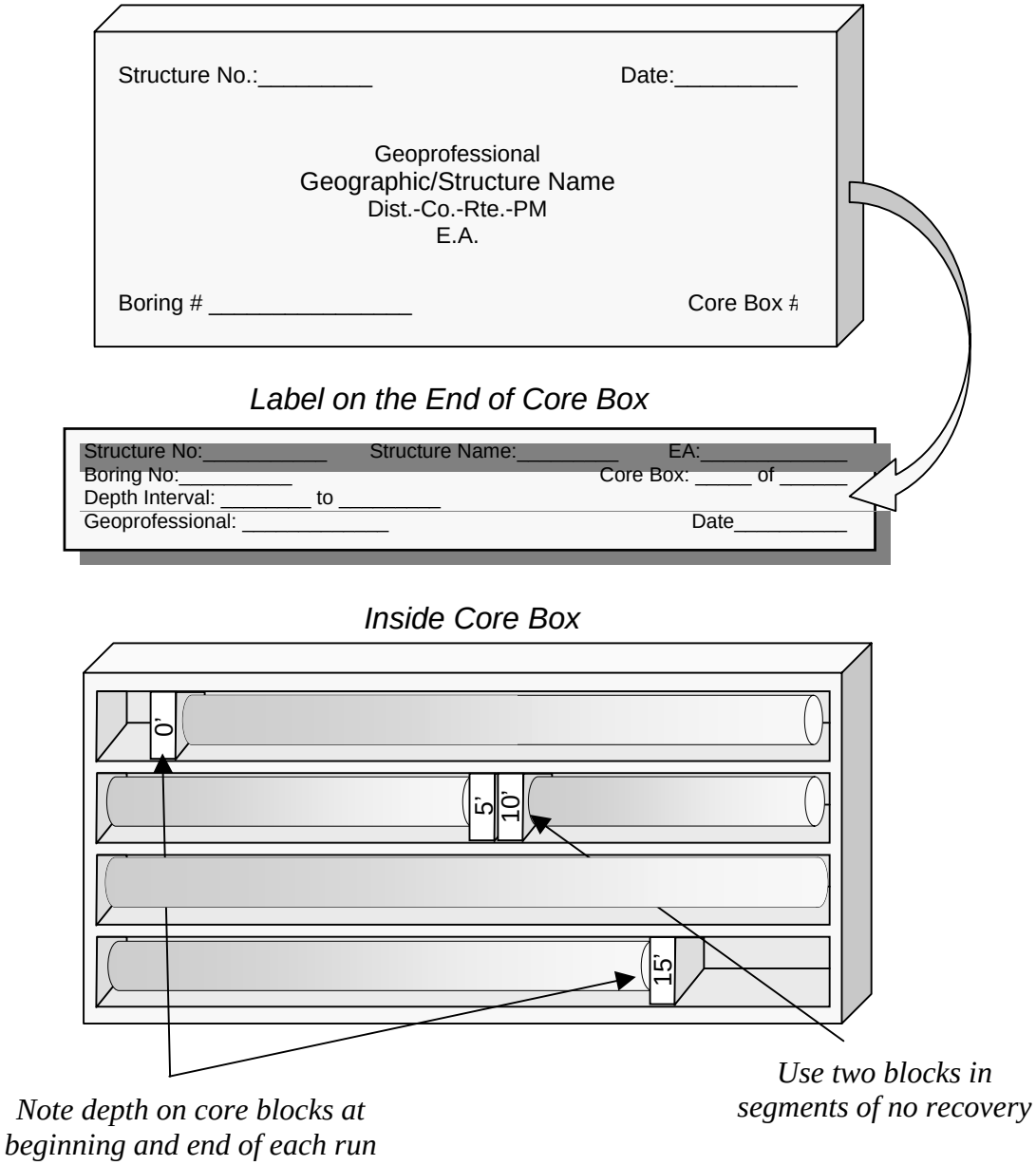
Notes:

1. ** Tests performed by Materials Engineering and Testing Services (METS)
2. A 12" by 24" canvas bag completely filled contains approximately 40 lb of material.
3. A 2" by 4" tube contains approximately 1 lb. of material.
4. Minimum material weights shown for remolded samples include sufficient material for the development of a moisture density curve.
5. Triaxial samples from Shelby tubes require a minimum sample length equal to three times the sample diameter.

2.7.3 Core Box Layout

Label core boxes as shown in Figure 2-45.

Figure 2-45
Core Box Layout and Label



2.8 Quality Check of Field Observations and Samples

The geoprofessional must conduct a quality check of his/her field notes and observations in the office. Sample descriptions and identifications must be reviewed and revised as necessary to ensure that they are in compliance with this manual. Sample descriptors that are subject to change due to time or environment, such as moisture or RQD, must not be revised.

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Section 3:
Procedures for Soil and Rock Description and/or Classification Using Laboratory Test Results

3.1 Introduction

Section 2 presents the procedures for describing and identifying soil and rock samples in the field using visual and manual methods and basic field-testing tools. Most of these field procedures are sufficient to identify and describe the soil and rock in qualitative terms, and are appropriate for reporting in final boring logs, as described in Sections 4 and 5. In many cases field-generated descriptors can be correlated to engineering parameters for use in geotechnical designs. In some cases, however, the geoprofessional may want to more quantitatively and definitively characterize a particular sample using laboratory test results.

This section addresses how to apply specific laboratory test results to revise and supplement the original field observations, identifications, and descriptions. The information presented in this Section is based largely on the American Society for Testing and Materials (ASTM) D 2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).*

3.2 Revising Soil Descriptions and Assigning Soil Classification Using Laboratory Test Results

Six components in the identification and descriptive sequence for soil (Section 2.5.1) may be revised with laboratory test results. They are:

- Group Name
- Group Symbol
- Consistency
- Percent or Proportion of Soil
- Particle Size Range
- Plasticity

The *Group Name* and *Group Symbol* are determined in the field using visual and manual procedures based on ASTM D 2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).* The field method requires the user to make judgments on a number of observations (e.g., percent of constituents by weight, whether a soil is well or poorly-graded, and whether the soil is a clay or silt or some combination thereof).

Laboratory particle-size analysis, liquid limit, and plasticity index provide a quantitative basis for *classification* of the soil. Furthermore, the laboratory procedure employs a much more comprehensive listing of possible Group Names, as compared to field methods.

Consistency is determined in the field using one or more of three methods (vane shear test, Torvane, or Pocket Penetrometer), with varying levels of accuracy and repeatability. Laboratory triaxial, direct shear, and unconfined compression tests provide less subjective undrained shear strength values that can be correlated to specific consistency descriptors.

Percent gravel, sand, and fines, and the range of particle sizes are estimated in the field using visual methods (e.g. jar test, visual approximation, etc.). The laboratory particle-size analysis test provides a quantitative distribution of particle sizes in proportion to the total sample weight.

3.2.1 Soil Classification and Description Descriptive Sequence

Use the descriptive sequence in Figure 2-5 when classifying and describing soil. Items indicated by a check mark in the "Required" column must be used to completely describe all the components of the soil. To incorporate laboratory test data in the classification and descriptive sequence, refer to the sections in this Manual noted in Figure 2-5 *(See "Lab" column).*

3.2.2 Group Name and Group Symbol

This section presents a procedure for classifying soil for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index. This method is based on the ASTM version of the Unified Soil Classification System (USCS).

The ASTM procedure for classifying and describing fine-grained and coarse-grained soil is only applicable to material passing the 3-inch sieve. If the sample includes cobbles and/or boulders, they must be reported per Section 2.5.17.

3.2.2.1 Procedure for Classification of Fine-Grained Soil

If 50% or more by dry weight of the test specimen passes the No. 200 sieve, the soil is fine-grained, and is classified using the liquid limit and plasticity index (Figures 3-1 and 3-2).

- In cases where the liquid limit exceeds 100, or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending all relevant lines.
- If the geoprofessional suspects there is sufficient organic matter to influence the soil classification, additional testing must be requested from the Geotechnical Laboratory.

Figure 3-1
Classification of Fine-Grained Soil

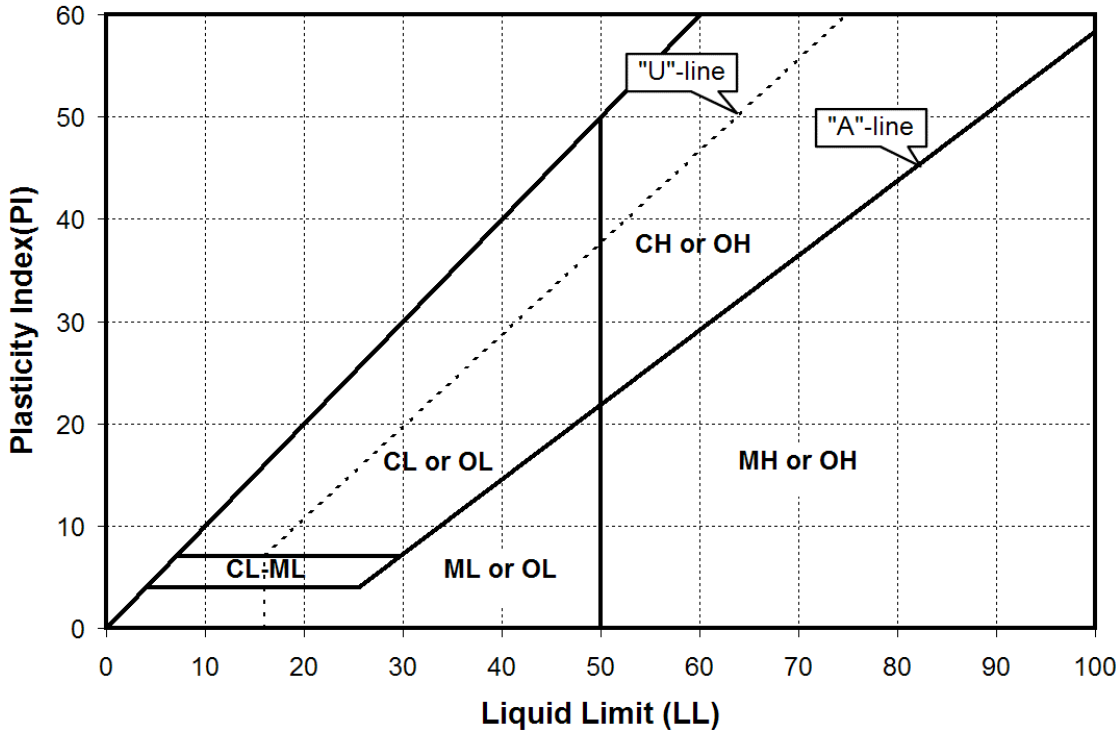


Figure 3-2
Classification of Fine-Grained Soil

							Group Name
LL<50	Inorganic	PI>7 and plots on or above "A"-line	CL	<30% plus No. 200	<15% plus No. 200		Lean CLAY
					15-30% plus No. 200	% sand ≥ % gravel	Lean CLAY with SAND
						% sand < % gravel	Lean CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY lean CLAY
						≥ 15% gravel	SANDY lean CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY lean CLAY
						≥ 15% sand	GRAVELLY lean CLAY with SAND
		4≤PI≤7 and plots on or above "A"-line	CL-ML	<30% plus No. 200	<15% plus No. 200		SILTY CLAY
					15-30% plus No. 200	% sand ≥ % gravel	SILTY CLAY with SAND
						% sand < % gravel	SILTY CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY SILTY CLAY
						≥ 15% gravel	SANDY SILTY CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY SILTY CLAY
						≥ 15% sand	GRAVELLY SILTY CLAY with SAND
		PI<4 or plots below "A"-line	ML	<30% plus No. 200	<15% plus No. 200		SILT
					15-30% plus No. 200	% sand ≥ % gravel	SILT with SAND
						% sand < % gravel	SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY SILT
						≥ 15% gravel	SANDY SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY SILT
						≥ 15% sand	GRAVELLY SILT with SAND
	Organic	PI≥4 and plots on or above "A"-line	OL	<30% plus No. 200	<15% plus No. 200		ORGANIC CLAY
					15-30% plus No. 200	% sand ≥ % gravel	ORGANIC CLAY with SAND
						% sand < % gravel	ORGANIC CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC CLAY
						≥ 15% gravel	SANDY ORGANIC CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC CLAY
						≥ 15% sand	GRAVELLY ORGANIC CLAY with SAND
		PI<4 or plots below "A"-line		<30% plus No. 200	<15% plus No. 200		ORGANIC SILT
					15-30% plus No. 200	% sand ≥ % gravel	ORGANIC SILT with SAND
						% sand < % gravel	ORGANIC SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SILT
						≥ 15% gravel	SANDY ORGANIC SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SILT
						≥ 15% sand	GRAVELLY ORGANIC SILT with SAND

Figure 3-2, continued

							Group Name
LL≥50	Inorganic	Plots on or above "A"-line	CH	<30% plus No. 200	<15% plus No. 200		Fat CLAY
					15-30% plus No. 200	% sand ≥ % gravel	Fat CLAY with SAND
						% sand < % gravel	Fat CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY fat CLAY
						≥ 15% gravel	SANDY fat CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY fat CLAY
						≥ 15% sand	GRAVELLY fat CLAY with SAND
		Plots below "A"-line	MH	<30% plus No. 200	<15% plus No. 200		Elastic SILT
					15-30% plus No. 200	% sand ≥ % gravel	Elastic SILT with SAND
						% sand < % gravel	Elastic SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY elastic SILT
						≥ 15% gravel	SANDY elastic SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY elastic SILT
						≥ 15% sand	GRAVELLY elastic SILT with SAND
	Organic	Plots on or above "A"-line	OH	<30% plus No. 200	<15% plus No. 200		ORGANIC CLAY
					15-30% plus No. 200	% sand ≥ % gravel	ORGANIC CLAY with SAND
						% sand < % gravel	ORGANIC CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC CLAY
						≥ 15% gravel	SANDY ORGANIC CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC CLAY
						≥ 15% sand	GRAVELLY ORGANIC CLAY with SAND
		Plots below "A"-line		<30% plus No. 200	<15% plus No. 200		ORGANIC SILT
					15-30% plus No. 200	% sand ≥ % gravel	ORGANIC SILT with SAND
						% sand < % gravel	ORGANIC SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SILT
						≥ 15% gravel	SANDY ORGANIC SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SILT
						≥ 15% sand	GRAVELLY ORGANIC SILT with SAND

3.2.2.2 Procedure for Classification of Coarse-Grained Soil

If more than 50% by dry weight is retained on the No. 200 sieve, the soil is coarse-grained. Coarse-grained soil is classified using the following procedure:

- The soil is gravel if more than 50% of the coarse fraction (plus No. 200 sieve) is retained on the No. 4 sieve.
- The soil is sand if 50% or more of the coarse fraction (plus No. 200 sieve) passes through the No. 4 sieve.
- Soil is classified as either well-graded or poorly-graded based on the coefficients of uniformity (Cu) and curvature (Cc), determined as follows:

  If 12% or less of the test specimen passes through the No. 200 sieve, plot the cumulative particle-size distribution and compute the coefficient of uniformity, Cu, and coefficient of curvature, Cc, as given in Equations 1 and 2.

Equation 1

$$Cu = \frac{D_{60}}{D_{10}}$$

Equation 2

$$Cc = \frac{(D_{30})^2}{(D_{10} \times D_{60})}$$

Where D_{10}, D_{30}, and D_{60} are the particle-size diameters corresponding to 10, 30, and 60 percentiles on the cumulative particle-size distribution curve. It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

Use the above results to determine the classification according to Figure 3-3.

Figure 3-3
Classification of Coarse-Grained Soil

						Group Name
Gravel	≤ 5%	Cu≥4 and 1≤Cc≤3		GW	< 15% sand	Well-graded GRAVEL
					≥ 15% sand	Well-graded GRAVEL with SAND
		Cu<4 and/or 1>Cc>3		GP	< 15% sand	Poorly-graded GRAVEL
					≥ 15% sand	Poorly-graded GRAVEL with SAND
	5-12%	Cu≥4 and 1≤Cc≤3	ML or MH	GW-GM	< 15% sand	Well-graded GRAVEL with SILT
					≥ 15% sand	Well-graded GRAVEL with SILT and SAND
			CL, CH or CL-ML	GW-GC	< 15% sand	Well-graded GRAVEL with CLAY (or SILTY CLAY)
					≥ 15% sand	Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
		Cu<4 and/or 1>Cc>3	ML or MH	GP-GM	< 15% sand	Poorly-graded GRAVEL with SILT
					≥ 15% sand	Poorly-graded GRAVEL with SILT and SAND
			CL, CH or CL-ML	GP-GC	< 15% sand	Poorly-graded GRAVEL with CLAY (or SILTY CLAY)
					≥ 15% sand	Poorly-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
	> 12%		ML or MH	GM	< 15% sand	SILTY GRAVEL
					≥ 15% sand	SILTY GRAVEL with SAND
			CL or CH	GC	< 15% sand	CLAYEY GRAVEL
					≥ 15% sand	CLAYEY GRAVEL with SAND
			CL-ML	GC-GM	< 15% sand	SILTY, CLAYEY GRAVEL
					≥ 15% sand	SILTY, CLAYEY GRAVEL with SAND
Sand	≤ 5%	Cu≥6 and 1≤Cc≤3		SW	< 15% gravel	Well-graded SAND
					≥ 15% gravel	Well-graded SAND with GRAVEL
		Cu<6 and/or 1>Cc>3		SP	< 15% gravel	Poorly-graded SAND
					≥ 15% gravel	Poorly-graded SAND with GRAVEL
	5-12%	Cu≥6 and 1≤Cc≤3	ML or MH	SW-SM	< 15% gravel	Well-graded SAND with SILT
					≥ 15% gravel	Well-graded SAND with SILT and GRAVEL
			CL, CH or CL-ML	SW-SC	< 15% gravel	Well-graded SAND with CLAY
					≥ 15% gravel	Well-graded SAND with CLAY and GRAVEL
		Cu<6 and/or 1>Cc>3	ML or MH	SP-SM	< 15% gravel	Poorly-graded SAND with SILT
					≥ 15% gravel	Poorly-graded SAND with SILT and GRAVEL
			CL, CH or CL-ML	SP-SC	< 15% gravel	Poorly-graded SAND with CLAY
					≥ 15% gravel	Poorly-graded SAND with CLAY and GRAVEL
	> 12%		ML or MH	SM	< 15% gravel	SILTY SAND
					≥ 15% gravel	SILTY SAND with GRAVEL
			CL or CH	SC	< 15% gravel	CLAYEY SAND
					≥ 15% gravel	CLAYEY SAND with GRAVEL
			CL-ML	SC-SM	< 15% gravel	SILTY, CLAYEY SAND
					≥ 15% gravel	SILTY, CLAYEY SAND with GRAVEL

3.2.3 Consistency of Cohesive Soil

Cohesive soil consistency descriptors must conform to Figure 3-5, generally after Das (1983) and Bureau of Reclamation standards (2001). Note that the terms to be used have been modified from those contained in both references.

Laboratory tests used to determine consistency of cohesive soil are triaxial or unconfined compression tests.

Figure 3-5
Consistency

	Shear Strength, Ss (tsf)
Very Soft	Ss < 0.12
Soft	0.12 ≤ Ss < 0.25
Medium Stiff	0.25 ≤ Ss < 0.5
Stiff	0.5 ≤ Ss < 1
Very Stiff	1 ≤ Ss < 2
Hard	2 ≤ Ss

3.2.4 Percent or Proportion of Soil

Laboratory percentages of gravel, sand, and fines must either be reported using qualitative proportional descriptors (e.g. some SAND) or parenthetical percentages following the qualitative descriptor (e.g. some SAND (37%))

> *SANDY SILT (ML); dense; gray; moist; some fine SAND; nonplastic.*

Indicating the sample contains “some SAND” (30-45%) per Figure 2-13.

-or-

> *SANDY SILT (ML); dense; gray; moist; some fine SAND (37%); nonplastic.*

Indicating the sample contains “some SAND” (30-45%), and the lab test indicates 37% SAND.

3.2.5 Plasticity (for Fine-Grained Soil)

Do not include field determination of plasticity in the descriptive sequence when Group Name and Group Symbol are based on liquid limit and plasticity index.

3.3 Strength of Intact Rock

The strength of intact rock is typically determined by unconfined compression laboratory testing. The test result is added to the descriptive sequence using the syntax “UC = strength”, where the strength is in units of psi.

Section 4: Presentation of Subsurface Information

4.1 Introduction

The process of creating boring logs, i.e., Log of Test Borings (LOTB) and Boring Records (BR) can be summarized in four steps:

- Field sampling and descriptions *(Section 2)*
- Quality check of field descriptions *(Section 2)*
- Refinement of descriptions, and classification of soil, based on laboratory test results, if performed *(Section 3)*
- Preparation of the boring logs *(Sections 4 and 5)*

This section presents the *Layer Presentation Method* and provides details and guidance for incorporating laboratory test data and preparing boring logs. Figure 4-1 illustrates the process from obtaining subsurface information to the creation of boring logs.

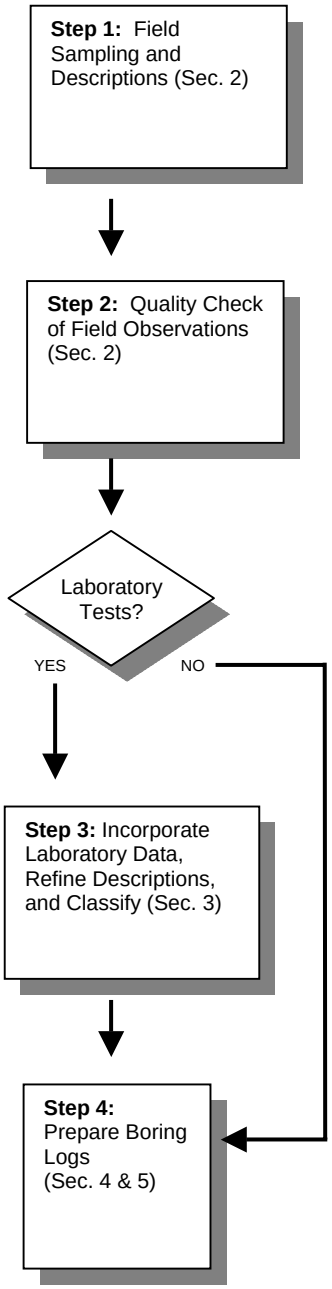
4.2 Factual vs. Interpretive Subsurface Data

FHWA guidelines state: "factual subsurface data which are pertinent to the project subsurface conditions should be presented in an easily understood fashion on the contract documents." However, the description of subsurface conditions always requires some degree of professional interpretation.

Some examples:

- Field description and identification procedures, according to ASTM D 2488, require estimation and interpretation.
- Sampling may occur at discrete intervals, yet layer boundaries may fall between sampling locations. The boundaries may be identified based on visual observations of cuttings and/or drill rig behavior during drilling. There may be uncertainty as to the depth at which a material change occurs.
- Continuity of material types between discrete sampling locations is sometimes difficult to confirm.

Figure 4-1



4.3 Layer Presentation Method

The Layer Presentation Method defines a layer as the limits of soil with one group symbol or the limits of rock with a single rock type. The layer presentation simplifies the boring log by:

- Eliminating presentation of duplicate descriptors.
- Presenting changes where they occur.
- Improving clarity to prospective bidders, contractors, and construction personnel.

4.3.1 Rules and Considerations

The following rules and considerations apply to the layer presentation method:

- The layer presentation must be made in such a way that the individual sample descriptions can be generally reconstructed.
- The descriptive sequence used to describe a sample of soil or rock must describe that sample in its entirety, and may describe all or part of a layer depending on the subsequent changes reported, if any.
- A change must be reported at the elevation where it is measured or inferred, which is not necessarily at a sample location, and the new description applies from that elevation to the bottom of the layer unless another change is reported. Leader lines (on LOTB) are used as appropriate to locate a descriptive change.
- A descriptor applies at the adjacent elevation unless a leader line (on LOTB) is used.
- A change in a soil's Group Symbol or a Rock Type must result in a new layer.
- A change in a soil's Group Name or Rock Name may result in a new layer.
- The first descriptive sequence in a layer must apply to the first sample and from the top of the layer and until a change is reported
- Laboratory and field test results apply only to the sample at the location of the laboratory test symbol or field test result. Individual descriptors, whether based on field observations or laboratory results, apply from the locations presented and until a change is reported.
- When performed, representative laboratory test results must be used to determine the applicable descriptors within the descriptive sequence (i.e. Group Name and Symbol, consistency, and gradation properties).
- Descriptors within a layer with the same field descriptions should be corrected based on the laboratory test(s) of one or more representative samples. For example, if three consecutive samples were field identified to contain "some silt", and a representative laboratory test reported "little silt", then the other two descriptors should be corrected to say "little silt".
- Descriptive sequences may be restated as appropriate to provide clarity after multiple changes have been presented.

4.3.2 Special Cases

- Parenthetical soil descriptions required per Section 2 for intensely weathered to decomposed or decomposed rock or poorly indurated rock are valid only until the rock becomes intensely or less weathered, or well indurated.
- For interbedded soil or rock, use the graphic for the predominant material.

4.4 Incorporating Laboratory Data, Refining Descriptions, and Classifying Soil

Use the most reliable data available to describe soil and rock. The data could be field-generated, or a combination of field- and laboratory-generated. If laboratory tests are performed, and in the opinion of the geoprofessional, the results represent the actual conditions of the soil or rock, the test results must control the identification, description, or classification of the soil or rock. Presence of a laboratory test symbol next to the LOTB stick (Section 5.2.5.2) indicates that a laboratory test was performed and that the related description is based on the laboratory test result. Conversely, if

laboratory tests are not shown as being performed, the descriptions presented on the LOTB are based solely on the visual practices described in this Manual.

The percent and/or proportion of constituents must be presented in one of two ways as illustrated in the following example.

Three consecutive samples were identified as SANDY SILT. Laboratory testing of the first sample indicate 37% sand.

> *SANDY SILT (ML); dense; gray; moist; some fine SAND; nonplastic.*

Indicating the entire layer contains some SAND (30-45%).

-or-

> *SANDY SILT (ML); dense; gray; moist; some fine SAND (37%); nonplastic.*

Indicating the entire layer contains some SAND (30-45%), but that the lab test indicates 37% SAND at the test location.

4.4.3 Example

The processes for developing boring logs have been presented in detail throughout this Manual. In general, field sample descriptions are corrected and calibrated based on laboratory results, layer boundaries are determined by grouping samples within the same Group Symbol or Rock Type, sample descriptions are consolidated into a single layer description, and, finally, description changes are noted with depth within layers.

The following example:

- Demonstrates how a geoprofessional develops a layer presentation, based on field descriptions and laboratory test results (Figure 4-2)
- Presents the LOTB for the layer presentation (Figure 4-3), and
- Presents how to interpret the LOTB and layer presentation (Figure 4-4)

Note the following in Figure 4-2:

- At the depth of 28 – 29 ft., required descriptors for rock hardness and fracture density are not presented as the sample was collected via a SPT.
- Group Name and Group Symbol for the clay layer are based upon ASTM D 2487 Laboratory test results for the samples at depths 18.5-20 ft and 23.5-25 ft.
- At the depth of 23.5 – 25 ft., the pocket penetrometer (PP) test result is not consistent with medium stiff consistency descriptor as the consistency descriptor is based on a laboratory triaxial (UU) test result. In this case, the PP result is still presented on the boring log.

Figure 4-2

						Final Layer Presentation
3.5-5	R-09-001-S01	SPT N = 4 N_{60} = 6	Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; little coarse and fine GRAVEL; trace fines; 10% IGNEOUS COBBLES, hard, 6-10”, subrounded; (FILL).		Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; little coarse and fine GRAVEL; trace fines; 10% IGNEOUS COBBLES, hard, 6-10”, subrounded; (FILL).	Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; little coarse and fine GRAVEL; trace fines; 10% IGNEOUS COBBLES, hard, 5-10 inches, subrounded; (FILL).
8.5-10	R-09-001-S02	SPT N = 8 N_{60}=12	Well-graded SAND with GRAVEL and COBBLES (SW); medium dense; yellowish brown; moist; little coarse and fine GRAVEL; trace fines; 10% IGNEOUS COBBLES, hard, 5-10”, subrounded; (FILL).	PA	Well-graded SAND with GRAVEL and COBBLES (SW); medium dense; yellowish brown; moist; sand (79%); little coarse and fine GRAVEL (17%); trace fines (4%); 10% IGNEOUS COBBLES, hard, 5-10”, subrounded; (FILL).	Medium dense
13.5-15	R-09-001-U03	PP=0.35	SANDY lean CLAY (CL); soft; dark bluish gray; moist; medium SAND; trace shell fragments; PP=0.35; (BAY MUD).		SANDY lean CLAY (CL); soft; dark bluish gray; moist; medium SAND; trace shell fragments; PP=0.35; (BAY MUD).	SANDY lean CLAY (CL); soft; dark bluish gray; moist; medium SAND; trace shell fragments; PP=0.35 tsf; (BAY MUD).
18.5-20	R-09-001-U04	PP=0.4	SANDY lean CLAY (CL); soft; dark bluish gray; moist; medium SAND; PP=0.4; (BAY MUD).	PA, PI UU=0.45 tsf	SANDY lean CLAY (CL); soft; dark bluish gray; moist; fines (62%); medium SAND (38%); PP=0.4; (BAY MUD).	No shell fragments; PP=0.4 tsf.
23.5-25	R-09-001-U05	PP=0.45	SANDY lean CLAY (CL); soft; dark gray; moist; medium SAND; PP=0.45; (BAY MUD).	PA, PI UU=0.55 tsf	SANDY lean CLAY (CL); medium stiff; dark gray; moist; fines (66%); medium SAND (34%); PP=0.45; (BAY MUD).	Medium stiff; dark gray; PP=0.45 tsf.
28-29	R-09-001-S06	SPT N = 60/6 N_{60}=90/6	SEDIMENTARY ROCK (SHALE); dark bluish gray with orange mottling; intensely weathered.		SEDIMENTARY ROCK (SHALE); dark bluish gray with orange mottling; intensely weathered.	SEDIMENTARY ROCK (SHALE); dark bluish gray with orange mottling; intensely weathered.
29-34	R-09-001-C07	REC=90% RQD=60%	SEDIMENTARY ROCK (SHALE); dark bluish gray; slightly weathered; moderately soft; moderately fractured.	UC=3600 psi	SEDIMENTARY ROCK (SHALE); dark bluish gray; slightly weathered; moderately soft; moderately fractured.	Dark bluish gray; moderately to slightly weathered; moderately soft; moderately fractured; UC=3600 psi.
34-39	R-09-001-C08	REC=100% RQD=90%	SEDIMENTARY ROCK (SHALE); dark bluish gray; fresh; moderately soft; slightly fractured.	UC=4100 psi	SEDIMENTARY ROCK (SHALE); dark bluish gray; fresh; moderately soft; slightly fractured.	Slightly fractured; UC=4100 psi.

The LOTB for the layer presentation developed in Figure 4-2 would appear as follows:

Figure 4-3
LOTB Example

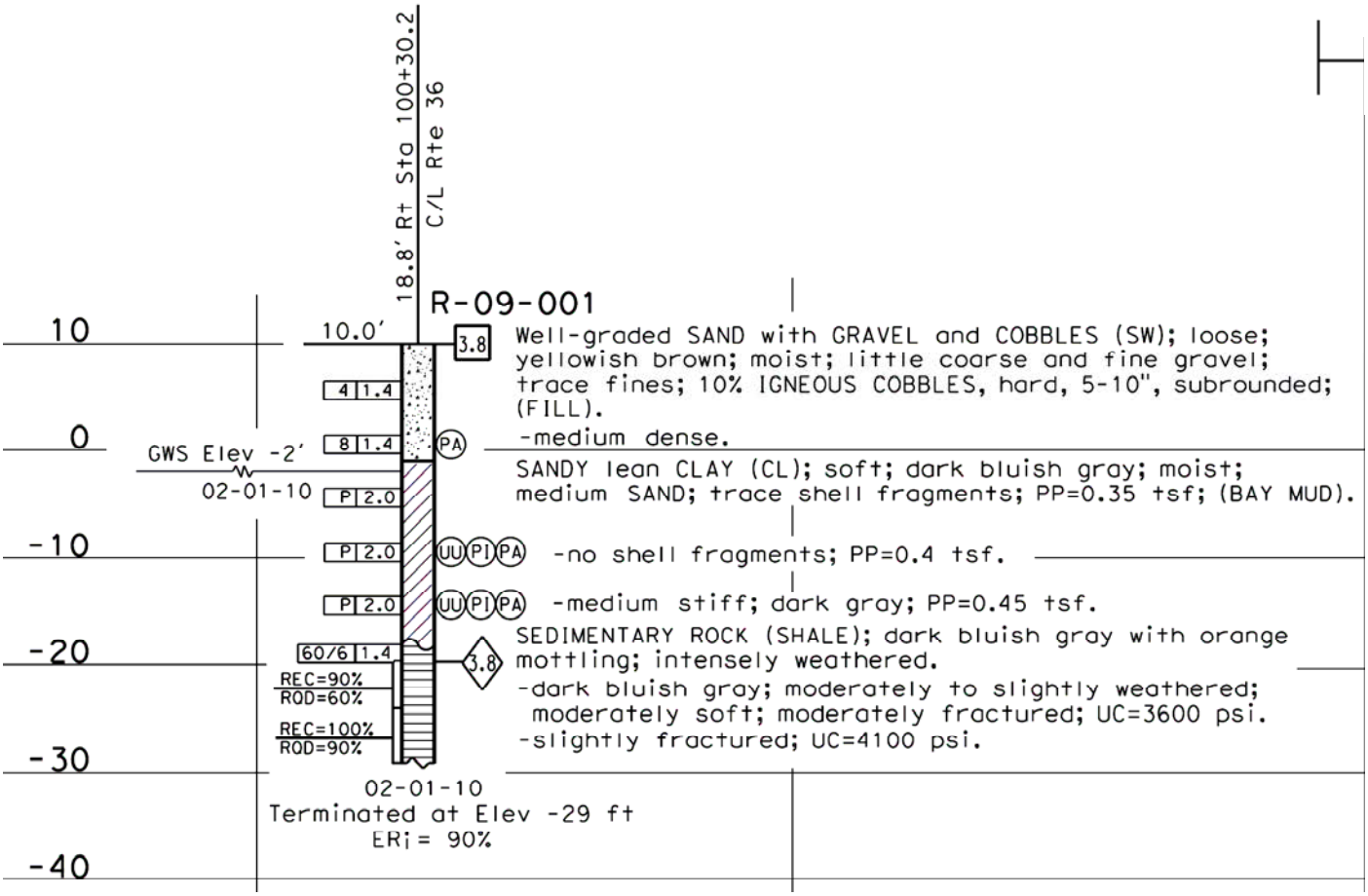


Figure 4-4 presents how to interpret the clay layer (elevation –1 ft to –18 ft) on the LOTB in Figure 4-3. Per the rules presented in Section 4.3.1, the uppermost soil description, located at the first sample location, represents the material from the top of the layer to the bottom of the layer unless modified by a subsequent descriptor. The arrows above and below each descriptor represent the range to which the descriptor applies, i.e., by definition the group symbol (CL) applies to the entire layer as indicated by the arrows.

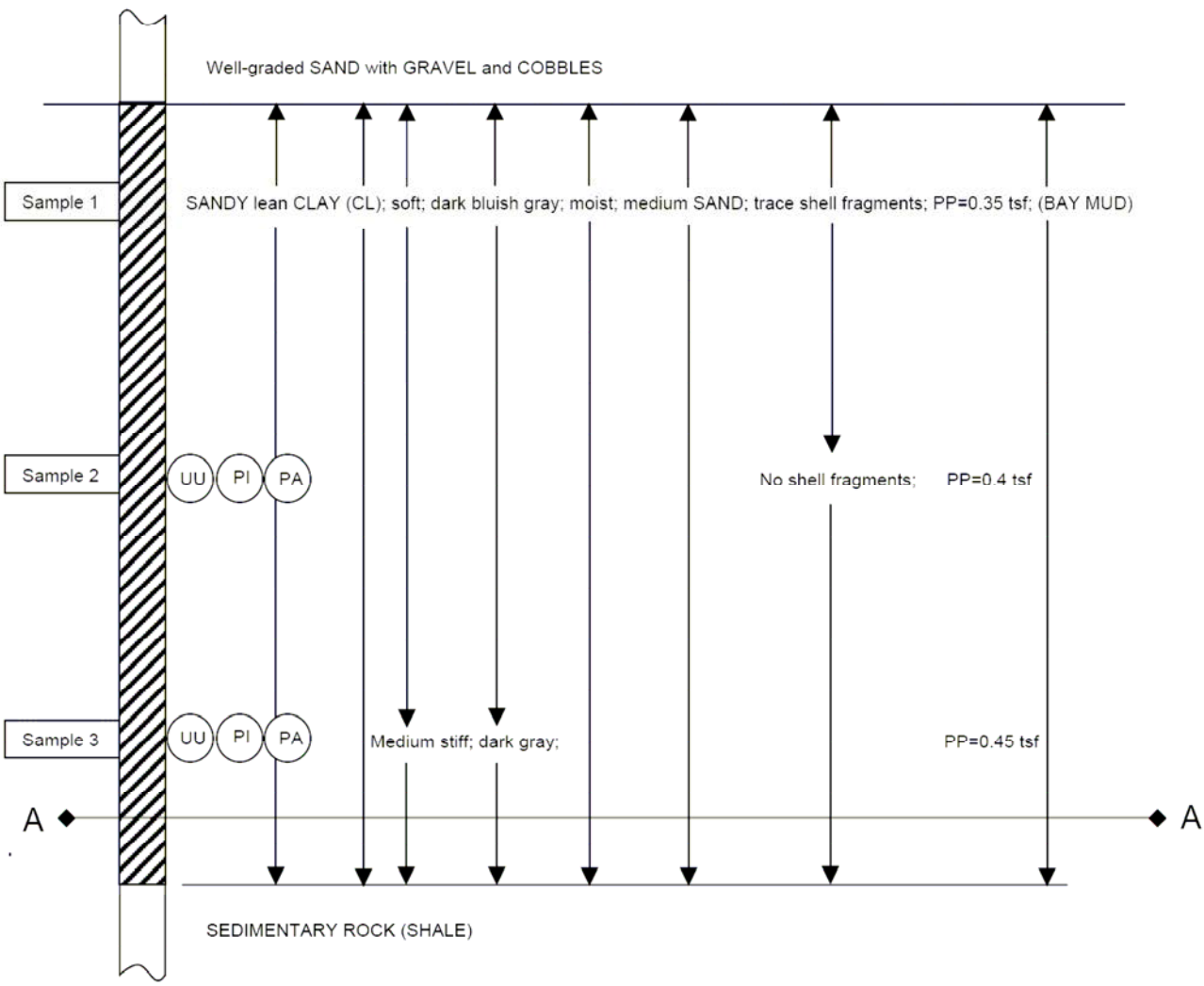
The soil description can be reconstructed at any location by drawing a horizontal line and identifying the appropriate descriptors by the intersected arrows. For example, the descriptive sequence between sample 3 and the rock layer (section A-A) is reconstructed as follows:

SANDY lean CLAY (CL); medium stiff; dark gray, moist; medium SAND; (BAY MUD).

Note the following:

- The pocket penetrometer test results apply only at the sample location
- "Trace shell fragments" would not appear in any descriptive sequence below Sample 2

Figure 4-4
Layer Interpretation



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Section 5:
Boring Log and Legend Presentation Formats

5.1 Introduction

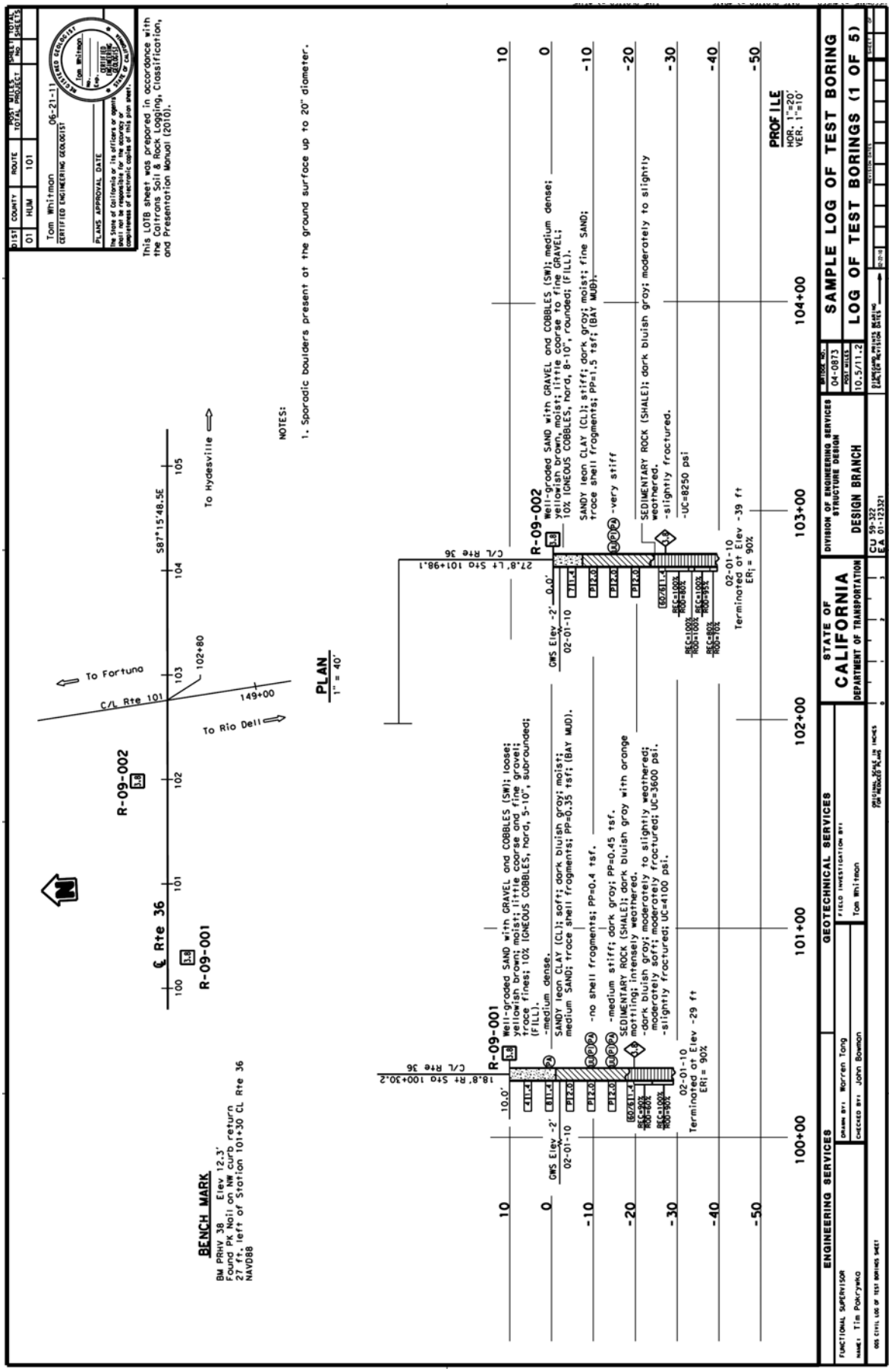
The Department uses the following formats to present subsurface information:

- Log of Test Borings (LOTB), and/or
- Boring Record (BR).

An LOTB is typically associated with a structure facility and is part of the Project Plans. A BR is typically associated with an earthwork facility and is attached to a Geotechnical Report. If a subsurface exploration was performed, there will be at least one type of log presentation.

5.2 Log of Test Borings

Figure 5-1
Example of LOTB


DIST COUNTY ROUTE POST MILES TOTAL PROJECT SHEET NO. TOTAL SHEETS
01 HUM 101
Tom Whitman 06-21-11
CERTIFIED ENGINEERING GEOLOGIST
PLANS APPROVAL DATE
This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (2010).
NOTES:
1. Sporadic boulders present at the ground surface up to 20" diameter.
PLAN
1" = 40'
To Fortuna
To Hydesville
To Rio Dell
C/L Rte 101
℄ Rte 36
S87°15'48.5E
R-09-002
R-09-001
BENCH MARK
BM PRHV 38 Elev 12.3'
Found PK Nail on ww curb return
27 ft. left of Station 101+30 CL Rte 36
NAVD88
PROFILE
HOR. 1"=20'
VER. 1"=10'
R-09-001
Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; little coarse and fine gravel; trace fines; 10% IGNEOUS COBBLES, hard, 5-10", subrounded; (FILL).
-medium dense.
SANDY lean CLAY (CL); soft; dark bluish gray; moist; medium SAND; trace shell fragments; PP=0.35 tsf; (BAY MUD).
-no shell fragments; PP=0.4 tsf.
-medium stiff; dark gray; PP=0.45 tsf.
SEDIMENTARY ROCK (SHALE); dark bluish gray with orange mottling; intensely weathered.
-dark bluish gray; moderately to slightly weathered; -moderately soft; moderately fractured; UC=3600 psi.
-slightly fractured; UC=4100 psi.
02-01-10
Terminated at Elev -29 ft
ERi = 90%
R-09-002
Well-graded SAND with GRAVEL and COBBLES (SW); medium dense; yellowish brown, moist; little coarse to fine GRAVEL; 10% IGNEOUS COBBLES, hard, 8-10", rounded; (FILL).
SANDY lean CLAY (CL); stiff; dark gray; moist; fine SAND; trace shell fragments; PP=1.5 tsf; (BAY MUD).
-very stiff
SEDIMENTARY ROCK (SHALE); dark bluish gray; moderately to slightly weathered.
-slightly fractured.
-UC=8250 psi
02-01-10
Terminated at Elev -39 ft
ERi = 90%
GWS Elev -2' 0.0'
02-01-10
C/L Rte 36
18.8' Rt Sta 100+30.2
27.8' Lt Sta 101+98.1
100+00
101+00
102+00
103+00
104+00
ENGINEERING SERVICES
GEOTECHNICAL SERVICES
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
STRUCTURE DESIGN
DESIGN BRANCH
SAMPLE LOG OF TEST BORING
LOG OF TEST BORINGS (1 OF 5)
FUNCTIONAL SUPERVISOR
NAME: Tim Pokrywko
DRAWN BY: Warren Tang
CHECKED BY: John Bowman
FIELD INVESTIGATION BY:
Tom Whitman
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
CU 59-322
EA 01-123321
04-0873
10.5/11.2
605 CIVIL LOG OF TEST BORINGS SHEET

5.2.1 Contents and Characteristics of the LOTB

The Log of Test Borings (LOTB) sheet is part of the project plans and:

- Presents the boring logs on an elevation scale.
- Presents a plan view showing the location of each boring relative to an alignment and/or existing or planned facility or structure.
- Presents the type(s) of drilling method(s) used to perform the investigation, the type(s) of sampling performed, and how the sampler was advanced.
- Presents the location and description, both graphical and written, of the types of soil and rock encountered within the borehole.
- Presents the types of field and laboratory testing performed.
- Present field and laboratory test data.
- Is optimized for printing on full-size plan sheets (24" x 36") and typically reproduced on 11" x 17" sized paper.
- Allows presentation of more than one boring log per plan sheet.
- Is accompanied by LOTB legend sheets.

5.2.2 Notes on the LOTB

Each LOTB sheet must contain a note section for presentation of relevant factual data and one of the following two notes:

If the procedures of this manual were followed without exception, then the note must read:

> *"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date)"*

If an exception to the procedures of this manual has been approved and implemented, then the note must be modified to read:

> *"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date) except as noted on the soil or rock legend or below"*

Optional notes may include:

- Changes in drilling equipment
- Site observations
- Other drilling observations

Do not repeat the procedures or requirements set forth in this manual in the notes section.

5.2.3 LOTB Sheet Formatting

LOTB sheets must be prepared in accordance with this manual and the Caltrans *Plans Preparation Manual*. The LOTB sheet border must present the following:

5.2.3.1 Signature Block (Upper Right Corner)

a) The State of California Registered Civil Engineer, Geotechnical Engineer, Certified Engineering Geologist, or Professional Geologist seal with the signature, date, license number, and registration certificate expiration date of the geoprofessional in responsible charge of the LOTB sheet;

b) Caltrans District, County, and Route;

c) Name and address of consultant firm in responsible charge of the LOTB sheet (if applicable);

d) Name and address of the lead local agency (if applicable); and

e) A disclaimer stating "The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet."

(The Office Engineer will provide the Post Miles Total Project, Sheet Number, Total Sheets, and Plans Approval Date.)

5.2.3.2 Title Block (Bottom, from left to right)

a) Titles "ENGINEERING SERVICES" and "GEOTECHNICAL SERVICES" for plans produced by or for Geotechnical Services. For consultant-prepared LOTB sheets, show the name of the Design Oversight (i.e., OSFP/OSCM Senior Liaison) Engineer and sign-off date.

b) “FUNCTIONAL SUPERVISOR”: The name of the person in charge of the functional unit responsible for providing oversight of the registered geoprofessional who developed the LOTB sheet.

c) “DRAWN BY”: The name of the person who prepared (drafted) the LOTB sheet

d) “CHECKED BY”: The name of the person who performed the quality control check of the LOTB sheet

e) “FIELD INVESTIGATION BY”: The name(s) of the field investigator(s);

f) A note stating "STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION" with a scale below the sub-block and a label on the left side stating "ORIGINAL SCALE IN INCHES FOR REDUCED PLANS." For consultant-prepared LOTB sheets, the note must state "PREPARED FOR THE STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION."

g) A note stating "DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN." For consultant-prepared LOTB sheets, instead of this note, show the name of the Project Engineer;

h) The Caltrans Contract Expenditure Authorization (CU and EA) numbers;

i) The State-assigned Bridge (or Structure) Number, Postmile, and the State-assigned Bridge (or Structure) Name;

j) The initial drawn by, and subsequent revision dates; and

k) A label stating "LOG OF TEST BORINGS _ OF _" (if applicable).

(The Office Engineer will provide the Sheet Number and Total Sheets Number.)

5.2.3.3 Plan View

a) The Plan View must be shown at the top of the first LOTB sheet. When the site is sufficiently large or complex, the first LOTB sheet should be used entirely for the Plan View.

b) Multiple LOTB sheets must be numbered with reference to the stationing of the control line (i.e., showing sheet No. 1 with the lowest stationing and the last sheet with the highest stationing).

c) A distinct Plan View of the project site that is independent of the Profile View must be shown on the LOTB.

d) Show the location, description, and elevation of the benchmark used for determining the top of boring elevations at the top left side of the Plan View under the heading “BENCHMARK”. Identify the vertical datum (National Geodetic Vertical Datum, U.S. Geological Survey, U.S. Coast & Geodetic Survey, District, etc.) used to determine the benchmark elevations.

e) Show the scale directly below the Plan View label.

f) Show a North arrow.

g) Lines or control lines shown in the Plan View must be consistent with those shown on the General Plan sheet.

h) Show stationing and names for control lines. Stationing must increase from left to right. Show a minimum of two stations on all lines.

i) Show control line intersection stationing and bearings.

j) Show names and directions of nearest cities.

k) Show names and directions of stream flows when applicable.

l) Plot boring locations with symbols as shown in the legend to identify drilling methods (e.g., auger hole, rotary hole, cone

penetration). The Hole Identification must be presented with each symbol.

5.2.3.4 Profile View

a) Show the control line, increasing from left to right, horizontally across the bottom of the Profile View.

b) Show the elevations and grid lines on both the left and right margins. Numerical values must be in multiples of 10 (e.g. 20, 10, 0, -10, -20).

c) Show the Hole Identification, top of hole elevation, stationing, and offset at the top of each boring log.

d) Show types and diameters of drill tools.

e) Show the completion date of boring (m/d/y) at the bottom of each boring log.

f) Show "Terminated at EL. XX'" to indicate the bottom of boring elevation.

g) Show the SPT hammer energy ratio, "Hammer Energy Ratio (ER_i) = XX%," at the bottom of each boring.

h) Provide groundwater information for each boring. If groundwater was measured, show the date(s) and elevation(s) of groundwater measurement(s). If groundwater was not encountered, state "*Groundwater was not encountered in boring(s) ####*". If groundwater was encountered but not measured, state "*Groundwater was encountered in boring(s) ####, but elevation was not measured*."

i) Show results from field penetration tests at relevant elevations along the boring log.

j) Show types of field and laboratory tests with symbols as indicated in the legend, at relevant elevations along the right side of the boring log.

k) Show the Profile scales (horizontal and vertical) under the heading "PROFILE".

5.2.4 As-Built LOTB Sheet Formatting

As-Built LOTB sheet(s) must be prepared according to the following standards.

5.2.4.1 Obtaining and Reproducing the As-Built LOTB Sheet

a) Reproducible copies of As-Built LOTB sheets may be obtained from the Microfilm Services Units in the Caltrans District Offices. If the As-Built LOTB sheets provided to Local Agencies or consultants by the Caltrans District Offices are not legible, a full sized copy should be requested from Geotechnical Services.

b) As-Built LOTB sheets must be size "D" (24" by 36"). The As-Built LOTB title block must be sized to fit and placed over any open space (preferably toward the top) on the As-Built LOTB sheet.

c) Information on the As-Built LOTB sheet must be clear and legible. In order to improve the legibility of the information, it may be necessary to darken the line work and the notations.

5.2.4.2 Typical Modifications to As-Built LOTB Sheets

If As-Built LOTB sheets are shown in metric units, the offset and stationing location of each boring must be converted to imperial units and presented in a table. The table must show the station and offset in relation to the new English line. The General Plan will show the current English control line.

5.2.4.3 The As-Built LOTB Title Block must include the following information for the current project

a) A note stating "GEOTECHNICAL SERVICES -- DIVISION OF ENGINEERING SERVICES" (if applicable).

b) Caltrans District, County, Route, Post Miles - Total Project, State-assigned Bridge (or Structure) Number and Name, and Expenditure Authorization (CU and EA) numbers. The Office Engineer will provide the Sheet Number and Total Sheets Number.

c) The State of California Registered Civil Engineer, Geotechnical Engineer, Certified Engineering Geologist, or Professional Geologist seal with the signature, date, license number, and registration certificate expiration date of the geoprofessional in responsible charge of the LOTB sheet

d) A note stating, "As-Built Log of Test Borings sheet is considered an informational document only. As such, the State of California registration seal with signature, license number and registration certificate expiration date confirm that this is a true and accurate copy of the original document. It does not attest to the accuracy or validity of the information contained in the original document. This drawing is available and presented only for the convenience of any bidder, contractor or other interested party." (Figure 5-2).

e) Identification of the original vertical datum and any conversion to the current project datum, i.e.,

As-Built Vertical Datum: NGVD29

Datum Conversion: NAVD88 = NGVD29 + 3.2 ft

f) A sub-box stating "LOG OF TEST BORINGS _ OF _" (if applicable).

g) A note stating "A COPY OF THIS LOG OF TEST BORINGS IS AVAILABLE AT OFFICE OF STRUCTURE MAINTENANCE AND INVESTIGATIONS, SACRAMENTO, CALIFORNIA" (if applicable).

5.2.5 The LOTB Legend Sheets

The soil and rock legend sheets are standard forms that provide convenient simplified references for the *required* soil and rock description, identification, and/or classification components presented in this Manual. References for *optional* descriptors do not appear on the legend sheets. To correctly interpret the LOTB, the reader must be familiar with this Manual.

There are three legend sheets, two predominantly for soil and the other for rock (Figures 5-3, 5-4 and 5-5).

The legend sheets define the format for the graphical presentation of a boring log and differentiate between the various borehole and sounding types. The legend sheets also present the symbols used to identify laboratory tests.

Figure 5-2
As-Built LOTB Title Block

GEOTECHNICAL SERVICES – DIVISION OF ENGINEERING SERVICES					
As-Built Log of Test Borings sheet is considered an informational document only. As such, the State of California registration seal with signature, license number and registration certificate expiration date confirm that is this a true and accurate copy of the original document. It does not attest to the accuracy or validity of the information contained in the original document. This drawing is available and presented only for the convenience of any bidder, contractor or other interested party.					
DIST.	COUNTY	ROUTE	POST MILES – TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
11	SD	15	10.00-15.00	249	250
REGISTERED ENGINEER – CIVIL			DATE		
MAIN STREET OVERCROSSING					
LOG OF TEST BORINGS 5 OF 6					
As-Built Vertical Datum:			Datum Conversion:		
NOTE: A COPY OF THIS LOG OF TEST BORINGS IS AVAILABLE AT OFFICE OF STRUCTURE MAINTENANCE AND INVESTIGATIONS, SACRAMENTO, CALIFORNIA				CU: 11 EA: 432563	BRIDGE NO. 57-3456

Figure 5-3

REFERENCE: CALTRANS SOIL & ROCK LOGGING, CLASSIFICATION, AND PRESENTATION MANUAL (2010)

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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REGISTERED PROFESSIONAL ENGINEER NO. EXP. CIVIL STATE OF CALIFORNIA

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.

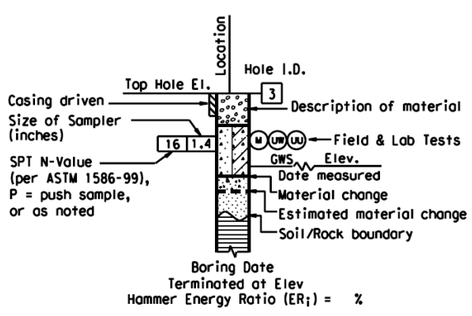
BOREHOLE IDENTIFICATION

Symbol	Hole Type	Description
Size	A	Auger Boring (hollow or solid stem bucket)
Size	R RW RC P	Rotary drilled boring (conventional) Rotary drilled with self-casing wire-line Rotary core with continuously-sampled, self-casing wire-line Rotary percussion boring (air)
Size	R	Rotary drilled diamond core
Size	HD HA	Hand driven (1-inch soil tube) Hand Auger
●	D	Dynamic Cone Penetration Boring
▲	CPT	Cone Penetration Test (ASTM D 5778)
[ ]	O	Other (note on LOTB)

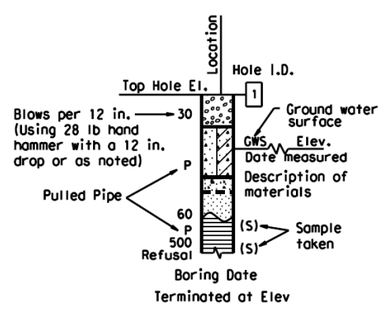
Note: Size in inches.

CONSISTENCY OF COHESIVE SOILS

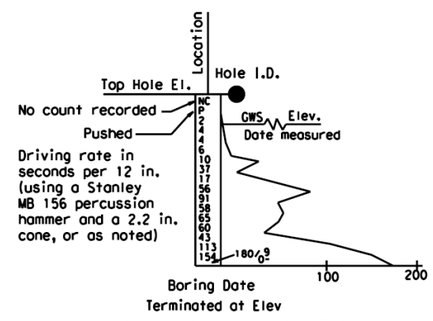
Description	Shear Strength (tsf)	Pocket Penetrometer Measurement, PP, (tsf)	Torvane Measurement, TV, (tsf)	Vane Shear Measurement, VS, (tsf)
Very Soft	Less than 0.12	Less than 0.25	Less than 0.12	Less than 0.12
Soft	0.12 - 0.25	0.25 - 0.5	0.12 - 0.25	0.12 - 0.25
Medium Stiff	0.25 - 0.5	0.5 - 1	0.25 - 0.5	0.25 - 0.5
Stiff	0.5 - 1	1 - 2	0.5 - 1	0.5 - 1
Very Stiff	1 - 2	2 - 4	1 - 2	1 - 2
Hard	Greater than 2	Greater than 4	Greater than 2	Greater than 2



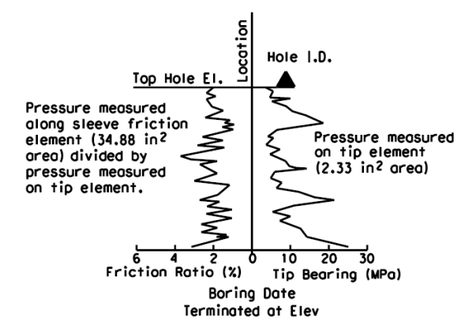
ROTARY BORING



HAND BORING



DYNAMIC CONE PENETRATION BORING



CONE PENETRATION TEST (CPT) BORING

ENGINEERING SERVICES	GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN DESIGN BRANCH	BRIDGE NO. / POST MILE	Project or Structure Name
FUNCTIONAL SUPERVISOR:	DRAWN BY: / CHECKED BY: / FIELD INVESTIGATION BY:				LOG OF TEST BORINGS

GS LOTB SOIL LEGEND — ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3 — CU EA — DISREGARD PRINTS BEARING EARLIER REVISION DATES — REVISION DATES — SHEET OF

legend soil 1of2.dgn 2/16/2010 8:15:47 AM

Figure 5-4

REFERENCE: CALTRANS SOIL & ROCK LOGGING, CLASSIFICATION, AND PRESENTATION MANUAL (2010)

GROUP SYMBOLS AND NAMES

Graphic/Symbol	Group Names	Graphic/Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND	CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
GP	Poorly-graded GRAVEL Poorly-graded GRAVEL with SAND		
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND	CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GP-GM	Poorly-graded GRAVEL with SILT Poorly-graded GRAVEL with SILT and SAND	ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
GP-GC	Poorly-graded GRAVEL with CLAY (or SILTY CLAY) Poorly-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GM	SILTY GRAVEL SILTY GRAVEL with SAND	OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND		
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND	OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL		
SP	Poorly-graded SAND Poorly-graded SAND with GRAVEL	CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL		
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
SP-SM	Poorly-graded SAND with SILT Poorly-graded SAND with SILT and GRAVEL		
SP-SC	Poorly-graded SAND with CLAY (or SILTY CLAY) Poorly-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
SM	SILTY SAND SILTY SAND with GRAVEL		
SC	CLAYEY SAND CLAYEY SAND with GRAVEL	OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY ORGANIC elastic SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL		
PT	PEAT	OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND
	COBBLES COBBLES and BOULDERS BOULDERS		

FIELD AND LABORATORY TESTING

- (C) Consolidation (ASTM D 2435)
- (CL) Collapse Potential (ASTM D 5333)
- (CP) Compaction Curve (CTM 216)
- (CR) Corrosivity Testing (CTM 643, CTM 422, CTM 417)
- (CU) Consolidated Undrained Trioxial (ASTM D 4767)
- (DS) Direct Shear (ASTM D 3080)
- (EI) Expansion Index (ASTM D 4829)
- (M) Moisture Content (ASTM D 2216)
- (OC) Organic Content-% (ASTM D 2974)
- (P) Permeability (CTM 220)
- (PA) Particle Size Analysis (ASTM D 422)
- (PI) Plasticity Index (AASHTO T 90) Liquid Limit (AASHTO T 89)
- (PL) Point Load Index (ASTM D 5731)
- (PM) Pressure Meter
- (R) R-Value (CTM 301)
- (SE) Sand Equivalent (CTM 217)
- (SG) Specific Gravity (AASHTO T 100)
- (SL) Shrinkage Limit (ASTM D 427)
- (SW) Swell Potential (ASTM D 4546)
- (UC) Unconfined Compression-Soil (ASTM D 2166) Unconfined Compression-Rock (ASTM D 2938)
- (UU) Unconsolidated Undrained Trioxial (ASTM D 2850)
- (UW) Unit Weight (ASTM D 4767)

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER NO. EXP. CIVIL STATE OF CALIFORNIA

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APPARENT DENSITY OF COHESIONLESS SOILS

Description	SPT N_{60} (Blows / 12 in.)
Very Loose	0 - 5
Loose	5 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	Greater than 50

MOISTURE

Description	Criteria
Dry	No discernable moisture
Moist	Moisture present, but no free water
Wet	Visible free water

PERCENT OR PROPORTION OF SOILS

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

PARTICLE SIZE

Description		Size (in.)
Boulder		Greater than 12
Cobble		3 - 12
Gravel	Coarse	3/4 - 3
	Fine	1/5 - 3/4
Sand	Coarse	1/16 - 1/5
	Medium	1/64 - 1/16
	Fine	1/300 - 1/64
Silt and Clay		Less than 1/300

ENGINEERING SERVICES — FUNCTIONAL SUPERVISOR: DRAWN BY: CHECKED BY:

GEOTECHNICAL SERVICES — FIELD INVESTIGATION BY:

STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN DESIGN BRANCH

BRIDGE NO. POST MILE

Project or Structure Name

LOG OF TEST BORINGS

GS LOTB SOIL LEGEND

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU EA

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES SHEET OF

Figure 5-5

REFERENCE: CALTRANS SOIL & ROCK LOGGING, CLASSIFICATION, AND PRESENTATION MANUAL (2010)

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

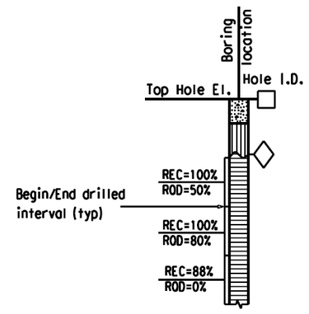
REGISTERED PROFESSIONAL ENGINEER NO. EXP. CIVIL STATE OF CALIFORNIA

PERCENT CORE RECOVERY (REC) & ROCK QUALITY DESIGNATION (RQD)

$$REC = \frac{\sum \text{Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100\%$$

$$RQD = \frac{\sum \text{Length of intact core pieces} \geq 4 \text{ in.}}{\text{Total length of core run (in.)}} \times 100\%$$

RQD* Indicates soundness criteria not met.



BEDDING SPACING

Description	Thickness / Spacing
Massive	Greater than 10 ft
Very Thickly Bedded	3 ft - 10 ft
Thickly Bedded	1 ft - 3 ft
Moderately Bedded	4 in. - 1 ft
Thinly Bedded	1 in. - 4 in.
Very Thinly Bedded	1/4 in. - 1 in.
Laminated	Less than 1/4 in.

LEGEND OF ROCK MATERIALS

- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

ROCK HARDNESS

Description	Criteria
Extremely Hard	Cannot be scratched with a pocketknife or sharp pick. Can only be chipped with repeated heavy hammer blows.
Very Hard	Cannot be scratched with a pocketknife or sharp pick. Breaks with repeated heavy hammer blows.
Hard	Can be scratched with a pocketknife or sharp pick with difficulty (heavy pressure). Breaks with heavy hammer blows.
Moderately Hard	Can be scratched with pocketknife or sharp pick with light or moderate pressure. Breaks with moderate hammer blows.
Moderately Soft	Can be grooved 1/16 in. deep with a pocketknife or sharp pick with moderate or heavy pressure. Breaks with light hammer blow or heavy manual pressure.
Soft	Can be grooved or gouged easily by a pocketknife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a pocketknife. Breaks with light manual pressure.

FRACTURE DENSITY

Description	Observed Fracture Density
Unfractured	No fractures.
Very Slightly Fractured	Core lengths greater than 3 ft.
Slightly Fractured	Core lengths mostly from 1 to 3 ft.
Moderately Fractured	Core lengths mostly from 4 in. to 1 ft.
Intensely Fractured	Core lengths mostly from 1 to 4 in.
Very Intensely Fractured	Mostly chips and fragments.

WEATHERING DESCRIPTORS FOR INTACT ROCK

Description	Diagnostic Features					General Characteristics
	Chemical Weathering-Discoloration and/or Oxidation		Mechanical Weathering-Grain Boundary Conditions (Disaggregation) Primarily for Granitics and Some Coarse-Grained Sediments	Texture and Leaching		
	Body of Rock	Fracture Surfaces		Texture	Leaching	
Fresh	No discoloration, not oxidized.	No discoloration or oxidation.	No separation, intact (tight).	No change	No leaching	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved	Minor leaching of some soluble minerals.	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty," feldspar crystals are "cloudy."	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in-situ disaggregation, see grain boundary conditions.	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitics are disaggregated.	Texture altered by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened.
Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay.		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes."

ENGINEERING SERVICES	GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN DESIGN BRANCH	BRIDGE NO. / POST MILE	Project or Structure Name
FUNCTIONAL SUPERVISOR:	DESIGNED BY: / CHECKED BY: / PREDESIGN INVESTIGATION BY:		CU EA		LOG OF TEST BORINGS

GS LOTB ROCK LEGEND

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES SHEET OF

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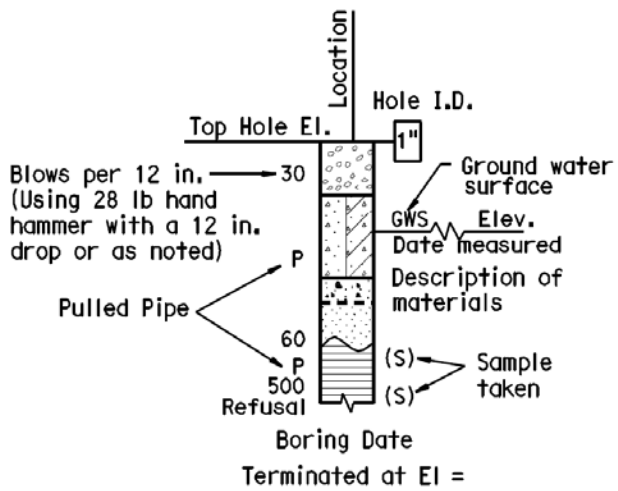
Four general hole-type formats are graphically presented as follows:

5.2.5.1 Hand Boring

Hand Driven (HD) (1-inch soil tube) and Hand Auger (HA) borings must be presented per Figure 5-6.

Figure 5-6

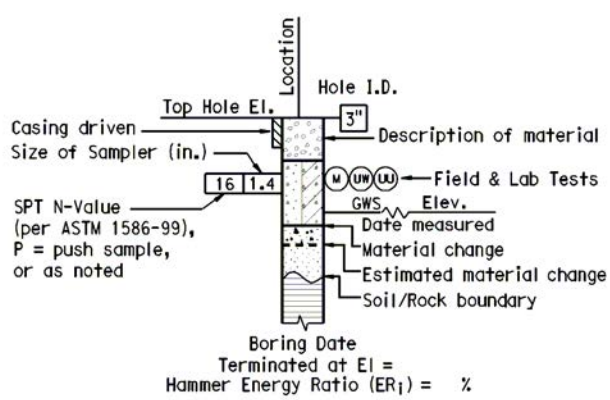


HAND BORING

5.2.5.2 Rotary Boring

Rotary Drilled Boring or Diamond Core (R), Rotary Percussion Boring (Air) (P), Auger Boring (A), must be presented per Figure 5-7.

Figure 5-7



ROTARY BORING

Changes in material with depth must be shown using the following terms and symbols (Figure 5-8):

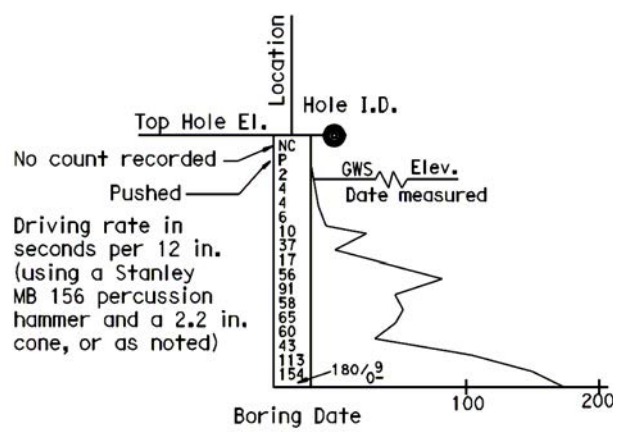
Figure 5-8
Definitions for changes in material

		Symbol
Material Change	Change in material is observed in the sample or core, and the location of change can be accurately measured.	
Estimated Material Change	Change in material cannot be accurately located because either the change is gradational or because of limitations in the drilling/sampling methods used.	
Soil/Rock Boundary	Material changes from soil characteristics to rock characteristics	

5.2.5.3 Dynamic Cone Penetration Boring

The Dynamic Cone Penetration Boring (D) must be presented per Figure 5-9.

Figure 5-9

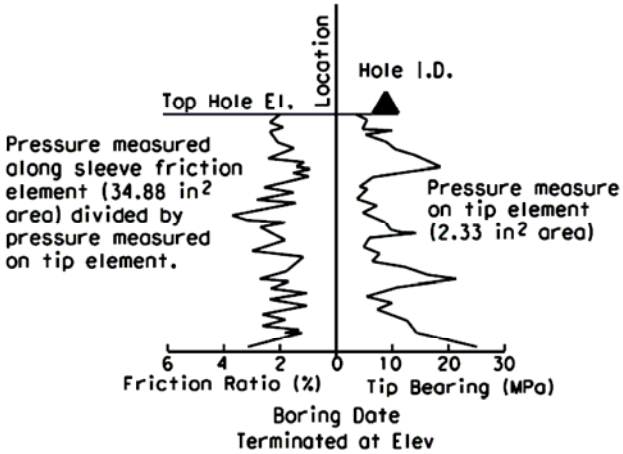


DYNAMIC CONE PENETRATION BORING

5.2.5.4 Cone Penetration Test (CPT) Boring

A Cone Penetration Test (CPT) boring must be presented using the following format:

Figure 5-10

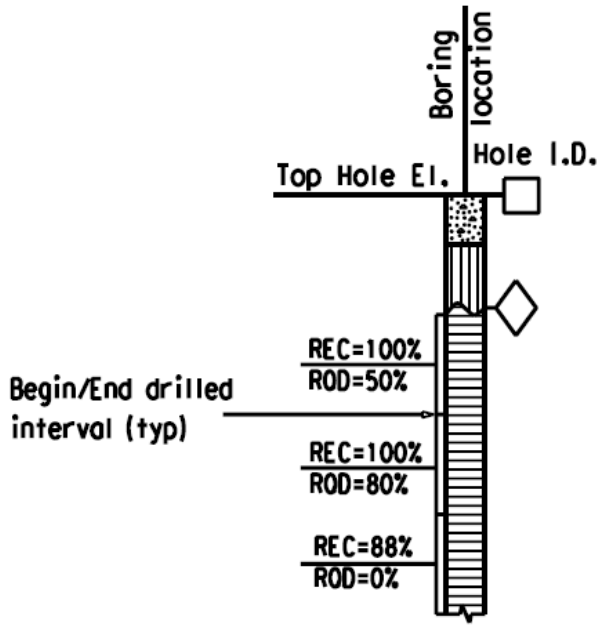


CONE PENETRATION TEST (CPT) BORING

5.2.5.5 Rock Coring

Rock coring logs must be presented using the following format:

Figure 5-11



5.2.5.6 Hole Type Symbols

Hole type is identified within the hole identification numbering convention (see Section 2.3) and symbolized on the LOTB as follows:

Figure 5-12

BOREHOLE IDENTIFICATION

Symbol	Hole Type	Description
Size	A	Auger Boring (hollow or solid stem bucket)
Size	R	Rotary drilled boring (conventional)
	RW	Rotary drilled with self-casing wire-line
	RC	Rotary core with continuously-sampled, self-casing wire-line
	P	Rotary percussion boring (air)
Size	R	Rotary drilled diamond core
Size	HD	Hand driven (1-inch soil tube)
	HA	Hand Auger
●	D	Dynamic Cone Penetration Boring
▲	CPT	Cone Penetration Test (ASTM D 5778)
[ ]	O	Other (note on LOTB)

Note: Size in inches.

5.2.5.7 Graphical Representation of Material Types

Soil Group Name and Group Symbol and Rock Type are shown on the LOTB as follows:

Figure 5-13

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GM	SILTY GRAVEL SILTY GRAVEL with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL
SP	Poorly graded SAND Poorly graded SAND with GRAVEL
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SM	SILTY SAND SILTY SAND with GRAVEL
SC	CLAYEY SAND CLAYEY SAND with GRAVEL
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL
PT	PEAT
	COBBLES COBBLES and BOULDERS BOULDERS

Graphic / Symbol	Group Names
CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND

ROCK GRAPHIC SYMBOLS

- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

5.3 Boring Records

Figure 5-14

LOGGED BY	BEGIN DATE	COMPLETION DATE	BOREHOLE LOCATION (Lat/Long or North/East and Datum)	HOLE ID
Tom Whitman	2-1-10	2-1-10	34° 0' 24.62" / -117° 7' 62.55" WGS 84	R-09-001
DRILLING CONTRACTOR: Caltrans			BOREHOLE LOCATION (Offset, Station, Line): 18.8' Rt Sta 100+30.2 C/L Rte 36	SURFACE ELEVATION: 10.0 ft NAVD 88
DRILLING METHOD: Rotary Wash			DRILL RIG: CS 2000 (track)	BOREHOLE DIAMETER: 3.8 in.
SAMPLER TYPE(S) AND SIZE(S) (ID): SPT (1.4"), CalMod (2"), HQ core			SPT HAMMER TYPE: Automatic	HAMMER EFFICIENCY, ERi: 90%
BOREHOLE BACKFILL AND COMPLETION: Neat cement grout backfill			GROUNDWATER READINGS: DURING DRILLING 12.0 ft; AFTER DRILLING (DATE) 12.0 ft on 2-1-10	TOTAL DEPTH OF BORING: 39.0 ft

ELEVATION (ft)	DEPTH (ft)	DESCRIPTION	Sample Location	Sample Number	Blows per 6 in.	Blows per foot	Recovery (%)	RQD (%)	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (tsf)	Drilling Method	Casing Depth	Remarks
	0	Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; little coarse and fine GRAVEL; trace fines; 10% IGNEOUS COBBLES, hard, 5-10", subrounded; (FILL).												
8.00	2													
	3			S01	2 2 2	4								
6.00	4													
4.00	6													
2.00	8													
	9	medium dense.		S02	4 4 4	8			5	105				PA
0.00	10													
	11	SANDY lean CLAY (CL); soft; dark bluish gray, moist; medium SAND; trace shell fragments; PP=0.35; (BAY MUD).												
-2.00	12													
	13													
-4.00	14			U03					22	100	PP=0.35			
	15													
-6.00	16													
	17													
-8.00	18													
	19	no shell fragments.		U04					20	100	PP=0.4 UU=0.45			PA, PI
-10.00	20													
	21													
-12.00	22													
	23													
-14.00	24	medium stiff; dark gray.		U05					20	101	PP=0.45 UU=0.55			PA, PI
	25													

(continued)

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Division of Engineering Services
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Office of Geotechnical Design - West

REPORT TITLE				HOLE ID
BORING RECORD				R-09-001
DIST. 01	COUNTY HUM	ROUTE 101	POSTMILE 10.5/11.2	EA 04-123321
PROJECT OR BRIDGE NAME: Rte 36/101 Interchange				
BRIDGE NUMBER 04-0873	PREPARED BY Tom Whitman		DATE 2-1-10	SHEET 1 of 2

Figure 5-14 (continued)

ELEVATION (ft)	DEPTH (ft)	Material Graphics	DESCRIPTION	Sample Location	Sample Number	Blows per 6 in.	Blows per foot	Recovery (%)	RQD (%)	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (tsf)	Drilling Method	Casing Depth	Remarks
	25		SANDY LEAN CLAY (CL) *(continued)*.												
-16.00	26														
	27														
-18.00	28		SEDIMENTARY ROCK (SHALE); dark bluish gray with orange mottling; intensely weathered.		S06	10 60/6"									
	29		Dark bluish gray; moderately to slightly weathered; medium strong; moderately soft; moderately fractured; UC=3600.		C07			90	60						
-20.00	30														
	31														
-22.00	32														
	33														
-24.00	34		Slightly fractured; UC=4100		C08			100	90						
	35														
-26.00	36														
	37														
-28.00	38														
	39		Bottom of borehole at 39.0 ft. Boring terminated at planned depth.												
-30.00	40														
	41		This Boring Record was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (2010)												
-32.00	42														
	43														
-34.00	44														
	45														
-36.00	46														
	47														
-38.00	48														
	49														
-40.00	50														
	51														
-42.00	52														
	53														
-44.00	54														
	55														

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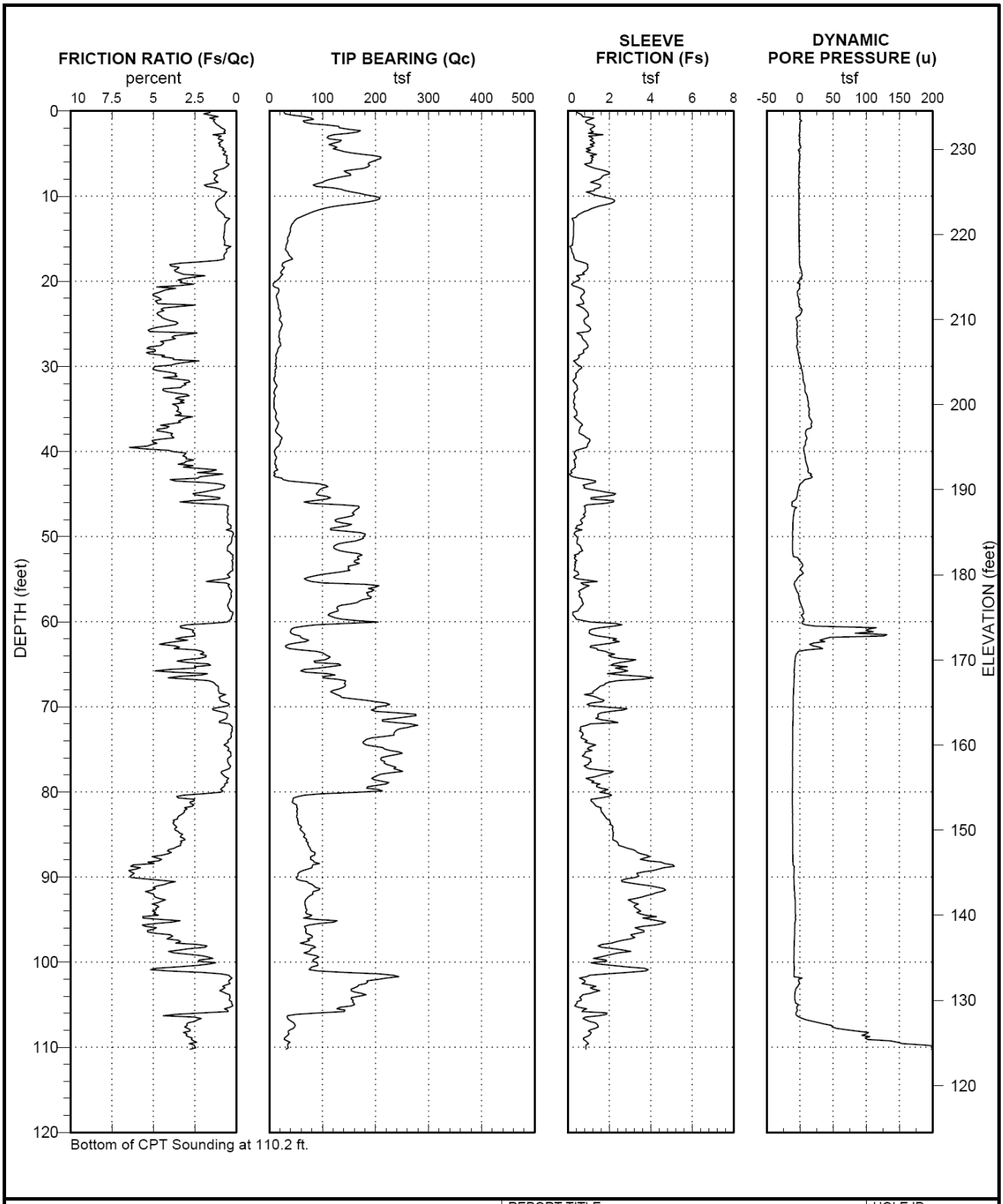
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - West

REPORT TITLE				HOLE ID
BORING RECORD				**R-09-001**
DIST. **01**	COUNTY **HUM**	ROUTE **101**	POSTMILE **10.5/11.2**	EA **04-123321**
PROJECT OR BRIDGE NAME **Rte 36/101 Interchange**				
BRIDGE NUMBER **04-0873**	PREPARED BY **Tom Whitman**		DATE **2-1-10**	SHEET **2 of 2**

Figure 5-15



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Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - West

REPORT TITLE				HOLE ID
BORING RECORD				CPT-09-003
DIST. 01	COUNTY HUM	ROUTE 101	POSTMILE 10.5/11.2	EA 04-123321
PROJECT OR BRIDGE NAME Rte 36/101 Interchange				
BRIDGE NUMBER 04-0873	PREPARED BY Tom Whitman		DATE 2-1-10	SHEET 1 of 1

5.3.1 Content and Characteristics of the BR

A Boring Record (BR) is presented as an attachment to a geotechnical report and:

- Presents a single borehole record or CPT sounding.
- Presents the borings to an elevation scale.
- Presents the type of drilling method used to perform the investigation, the type of sampling performed, and how the sampler was advanced.
- Presents the location and description, both graphical and written, of the types of soil and rock encountered within the borehole.
- Accommodates the presentation of select field and laboratory test results.
- Is optimized for printing on 8.5" x 11" sheets
- Is accompanied by BR Legend Sheets.

5.3.2 Notes on the BR

If the procedures of this manual were followed without exception, then the following note must appear on the first page of the BR:

"This Boring Record was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date)"

If an exception to the procedures of this manual has been approved and implemented, then the note must be modified to read:

"This Boring Record was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date) except as noted on the soil or rock legend or below"

Optional notes are left to the discretion of the geoprofessional and, if are specific to an elevation or depth, should be presented at the appropriate location in the "Remarks" column. These notes may include:

- Changes in drilling equipment
- Other drilling observations

Notes that are more general, such as a site observation, should be placed within the body of the geotechnical report.

5.3.3 Boring Record Format

The BR must be formatted in general conformance with Figures 5-14 and 5-15. The format and information presented in the header and footer sections should match the Figures.

The following information must be presented in the body:

- Elevation
- Material Graphic
- Description
- Sample Location
- Sample Number
- Blows per foot (if performed)
- Drilling Method

5.3.4 The Boring Record Legend Sheets

The soil and rock legend sheets are standard forms that provide convenient references for the *required* soil and rock description, identification, and/or classification components presented in this Manual. References for selected *optional* descriptors do not appear on the legend sheets; however, they are explained in this Manual. To correctly interpret the BR, the reader must be familiar with this Manual.

There are three legend sheets: two predominantly for soil and the other for rock, as shown in Figures 5-16, 5-17 and 5-18.

The legend sheets define the format for the graphical presentation of a boring log and differentiate among the various borehole and sounding types. The legend sheets also present the symbols used to identify laboratory tests.

Figure 5-16

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GM	SILTY GRAVEL SILTY GRAVEL with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL
SP	Poorly graded SAND Poorly graded SAND with GRAVEL
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SM	SILTY SAND SILTY SAND with GRAVEL
SC	CLAYEY SAND CLAYEY SAND with GRAVEL
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL
PT	PEAT
	COBBLES COBBLES and BOULDERS BOULDERS

Graphic / Symbol	Group Names
CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND

FIELD AND LABORATORY TESTING

C	Consolidation (ASTM D 2435)
CL	Collapse Potential (ASTM D 5333)
CP	Compaction Curve (CTM 216)
CR	Corrosion, Sulfates, Chlorides (CTM 643; CTM 417; CTM 422)
CU	Consolidated Undrained Triaxial (ASTM D 4767)
DS	Direct Shear (ASTM D 3080)
EI	Expansion Index (ASTM D 4829)
M	Moisture Content (ASTM D 2216)
OC	Organic Content (ASTM D 2974)
P	Permeability (CTM 220)
PA	Particle Size Analysis (ASTM D 422)
PI	Liquid Limit, Plastic Limit, Plasticity Index (AASHTO T 89, AASHTO T 90)
PL	Point Load Index (ASTM D 5731)
PM	Pressure Meter
R	R-Value (CTM 301)
SE	Sand Equivalent (CTM 217)
SG	Specific Gravity (AASHTO T 100)
SL	Shrinkage Limit (ASTM D 427)
SW	Swell Potential (ASTM D 4546)
UC	Unconfined Compression - Soil (ASTM D 2166) Unconfined Compression - Rock (ASTM D 2938)
UU	Unconsolidated Undrained Triaxial (ASTM D 2850)
UW	Unit Weight (ASTM D 4767)

SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT)
- Standard California Sampler
- Modified California Sampler
- Shelby Tube
- Piston Sampler
- NX Rock Core
- HQ Rock Core
- Bulk Sample
- Other (see remarks)

DRILLING METHOD SYMBOLS

- Auger Drilling
- Rotary Drilling
- Dynamic Cone or Hand Driven
- Diamond Core

WATER LEVEL SYMBOLS

- First Water Level Reading (during drilling)
- Static Water Level Reading (short-term)
- Static Water Level Reading (long-term)

REFERENCE Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).

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Division of Engineering Services
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REPORT TITLE				
BORING RECORD LEGEND				
DIST. 01	COUNTY HUM	ROUTE 101	POSTMILE 10.5/11.2	EA 04-123321
PROJECT OR BRIDGE NAME Rte 36/101 Interchange				
BRIDGE NUMBER 04-0873	PREPARED BY Tom Whitman		DATE 2-1-10	SHEET 1 of 3

Figure 5-17

CONSISTENCY OF COHESIVE SOILS				
Description	**Shear Strength (tsf)**	**Pocket Penetrometer, PP, Measurement (tsf)**	**Torvane, TV, Measurement (tsf)**	**Vane Shear, VS, Measurement (tsf)**
Very Soft	Less than 0.12	Less than 0.25	Less than 0.12	Less than 0.12
Soft	0.12 - 0.25	0.25 - 0.5	0.12 - 0.25	0.12 - 0.25
Medium Stiff	0.25 - 0.5	0.5 - 1	0.25 - 0.5	0.25 - 0.5
Stiff	0.5 - 1	1 - 2	0.5 - 1	0.5 - 1
Very Stiff	1 - 2	2 - 4	1 - 2	1 - 2
Hard	Greater than 2	Greater than 4	Greater than 2	Greater than 2

APPARENT DENSITY OF COHESIONLESS SOILS	
Description	**SPT N_{60} (blows / 12 inches)**
Very Loose	0 - 5
Loose	5 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	Greater than 50

MOISTURE	
Description	**Criteria**
Dry	No discernable moisture
Moist	Moisture present, but no free water
Wet	Visible free water

PERCENT OR PROPORTION OF SOILS	
Description	**Criteria**
Trace	Particles are present but estimated to be less than 5%
Few	5 - 10%
Little	15 - 25%
Some	30 - 45%
Mostly	50 - 100%

PARTICLE SIZE		
Description		**Size (in)**
Boulder		Greater than 12
Cobble		3 - 12
Gravel	Coarse	3/4 - 3
	Fine	1/5 - 3/4
Sand	Coarse	1/16 - 1/5
	Medium	1/64 - 1/16
	Fine	1/300 - 1/64
Silt and Clay		Less than 1/300

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.

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).

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REPORT TITLE				
BORING RECORD LEGEND				
DIST. 01	COUNTY HUM	ROUTE 101	POSTMILE 10.5/11.2	EA 04-123321
PROJECT OR BRIDGE NAME Rte 36/101 Interchange				
BRIDGE NUMBER 04-0873	PREPARED BY Tom Whitman		DATE 2-1-10	SHEET 2 of 3

Figure 5-18

LEGEND OF ROCK MATERIALS

- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

BEDDING SPACING

Description	Thickness/Spacing
Massive	Greater than 10 ft
Very Thickly Bedded	3 ft - 10 ft
Thickly Bedded	1 ft - 3 ft
Moderately Bedded	4 in - 1 ft
Thinly Bedded	1 in - 4 in
Very Thinly Bedded	1/4 in - 1 in
Laminated	Less than 1/4 in

WEATHERING DESCRIPTORS FOR INTACT ROCK

	Diagnostic Features					
	Chemical Weathering-Discoloration-Oxidation		Mechanical Weathering and Grain Boundary Conditions	Texture and Leaching		
Description	Body of Rock	Fracture Surfaces		Texture	Leaching	General Characteristics
Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No leaching	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull	Minor to complete discoloration or oxidation of most surfaces	No visible separation, intact (tight)	Preserved	Minor leaching of some soluble minerals	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty"; feldspar crystals are "cloudy"	All fracture surfaces are discolored or oxidized	Partial separation of boundaries visible	Generally preserved	Soluble minerals may be mostly leached	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, grain boundary conditions	All fracture surfaces are discolored or oxidized; surfaces friable	Partial separation, rock is friable; in semi-arid conditions, granitics are disaggregated	Texture altered by chemical disintegration (hydration, argillation)	Leaching of soluble minerals may be complete	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures or veinlets. Rock is significantly weakened.
Decomposed	Discolored of oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay		Complete separation of grain boundaries (disaggregated)	Resembles a soil; partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes".

PERCENT CORE RECOVERY (REC)

$$\frac{\Sigma \text{ Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100$$

ROCK QUALITY DESIGNATION (RQD)

$$\frac{\Sigma \text{ Length of intact core pieces} \geq 4 \text{ in.}}{\text{Total length of core run (in.)}} \times 100$$

RQD* indicates soundness criteria not met.

ROCK HARDNESS

Description	Criteria
Extremely Hard	Cannot be scratched with a pocketknife or sharp pick. Can only be chipped with repeated heavy hammer blows
Very Hard	Cannot be scratched with a pocketknife or sharp pick. Breaks with repeated heavy hammer blows.
Hard	Can be scratched with a pocketknife or sharp pick with difficulty (heavy pressure). Breaks with heavy hammer blows.
Moderately Hard	Can be scratched with a pocketknife or sharp pick with light or moderate pressure. Breaks with moderate hammer blows
Moderately Soft	Can be grooved 1/16 in. deep with a pocketknife or sharp pick with moderate or heavy pressure. Breaks with light hammer blow or heavy manual pressure.
Soft	Can be grooved or gouged easily with a pocketknife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a pocketknife. Breaks with light manual pressure.

FRACTURE DENSITY

Description	Observed Fracture Density
Unfractured	No fractures
Very Slightly Fractured	Core lengths greater than 3 ft.
Slightly Fractured	Core lengths mostly from 1 to 3 ft.
Moderately Fractured	Core lengths mostly 4 in. to 1 ft.
Intensely Fractured	Core lengths mostly from 1 to 4 in.
Very Intensely Fractured	Mostly chips and fragments.

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).

Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - West

REPORT TITLE				
BORING RECORD LEGEND				
DIST. 01	COUNTY HUM	ROUTE 101	POSTMILE 10.5/11.2	EA 04-123321
PROJECT OR BRIDGE NAME Rte 36/101 Interchange				
BRIDGE NUMBER 04-0873	PREPARED BY Tom Whitman		DATE 2-1-10	SHEET 3 of 3

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*The revision dates of all test methods referenced in this Manual are those dates current on the publishing date of this manual.

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Appendix A: Field Test Procedures

A.1 Pocket Penetrometer

The Pocket Penetrometer test is conducted using the following general instructions:

- To begin test, remove protective cap, push ring against body so that low side reads 0.
- Slowly insert piston until engraved mark is level with soil.
- Observe the reading in TSF (KG/SQ CM) using low side of ring, (side closest to the piston end): record reading and repeat.
- For weak soil, use 1" adapter foot, multiply reading by 0.0625.

A.2 Torvane

The Torvane test is conducted using the following general instructions:

- To start test, push indicator counter clockwise to zero stop.
- Select reasonably flat surface at least 1 inch in diameter.
- Using midsize vane, one division equals 1 TSF (1KG/SQ CM).
- One division using small and large vane equals respectively 2.5 and 0.2 TSF (KG/SQ CM).
- Press pocket vane shear tester into soil to depth of blade; maintain constant vertical pressure while turning knob clockwise at rate to develop failure within 5 to 10 seconds.
- After failure develops, release remaining spring tension slowly. Pointer will indicate maximum shear value until manually reset.

A.3 Dry Strength Test

Select enough material to mold into a ball about 1 inch diameter. Mold it until it has the consistency of putty, adding water if necessary. From the molded material, make at least three test specimen balls about 1⁄2 inch in diameter. Allow the test specimens to dry in air, sun, or by artificial means, as long as the temperature does not exceed 140°F. If the test specimen contains natural dry lumps, those that are about 1⁄2 inch in diameter may be used in place of the molded balls. Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in the table in Section 2.4.14. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

A.4 Dilatancy

Select enough material to mold into a ball about 1⁄2 inch diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in the table in Section 2.4.15. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

A.5 Toughness

After the dilatancy test, shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1⁄8 inch diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1⁄8 inch; this occurs when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the

lump crumbles. Note the toughness of the material during kneading. Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in the table in Section 2.4.16.

A.6 Jar Slake Index Test

The Slake Durability Test (ASTM D 4644) is the most rigorous test of slaking, however the Jar Slake Test is a simple, but less sensitive method used in the field or in the office to screen specimens for the Slake Durability test. A water filled jar and a watch are required. The steps are as follows:

- Immerse a fragment in enough water to cover it by ½ inch. It is best if the rock is oven dried. It has been reported that moist material is relatively insensitive to degradation in this test when compared with dry material.
- After immersion, observe the sample continuously for 10 minutes and carefully during the first 30 minutes. When a reaction occurs, it is often during the first 30 minutes. A final observation is made after 24 hours.

The condition of the piece is categorized (complete breakdown, partial breakdown, no change), as shown in the table in Section 2.5.14

A.7 Calcium Carbonate

Report the presence of calcium carbonate based on the sample reaction with dilute hydrochloric acid, and describe the reaction per Fig A.7-1.

Figure A.7-1 (from ASTM 2488)
Descriptors for calcium carbonate reaction

	Criteria
None	No visible reaction.
Weak	Some reaction, with bubbles forming slowly.
Strong	Violent reaction, with bubbles forming immediately.

A.8 Standard Penetration Test

The Standard Penetration Test (SPT) must be conducted according to the following two test methods:

- ASTM D 1586, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
- ASTM D 6066, Standard Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential

Blow counts (N) must be reported on the LOTB and BR as observed in the field without corrections.

Where,

N The sum of the hammer blows required to drive the sampler in the test interval from 0.5 to 1.5 ft below the cleanout depth.

Hammer efficiency must be shown on the LOTB and BR to allow the reader to determine N_{60}.

Where,

ER_i Hammer energy ratio

N_{60} Penetration resistance adjusted to a 60% drill rod energy ratio per ASTM D 6066:

$$N_{60} = N_{measured} \text{ X } (ER_i /60)$$

The following are examples of how to report various SPT measurements:

- Blow counts for each of the 6-inch increments must be recorded in the field, but not necessarily reported on the LOTB and BR. The 2nd and 3rd driving intervals must be summed and reported.

  For example:

  1st 6 in. interval: 10 blows

  2nd 6 in. interval: 15 blows

  3rd 6 in. interval: 18 blows

  N reported as “33”

- For partial increments, the depth of penetration must be reported to the nearest 1 inch, in addition to the number of blows.

  For example:

  1st 6 in. interval: 20 blows

  2nd 6 in. interval: 40 blows

  3rd 6 in. interval: 60 blows for 2 inches, then refusal

  N reported as "100/8-REF"

  -or-

  1st 6 in. interval: 20 blows

  2nd 6 in. interval: 40 blows

  3rd 6 in. interval: 50 blows for 2 inches

  N reported as "90/8"

  Refusal is defined as 10 blows with no discernable sampler advancement.

- If the seating interval (1st 6 in. interval) is not achieved, note refusal.

  For example:

  1st 6 in. interval: 50 blows for 2 inches, then refusal

  N reported as "REF"

- If the sampler sinks under its own weight without any hammer blows, then N is reported as "0"

- If a substantial change in material is encountered over the course of driving the sampler, the 2nd and 3rd driving intervals can be reported separately.

  For example:

  1st 6 in. interval: 10 blows

  2nd 6 in. interval: 20 blows

  3rd 6 in. interval: 60 blows for 3 inches,

  N reported as "20/6, 60/3"

A.9 Core Recovery (REC)

The core recovery value (REC), with few exceptions, provides an indication of the success of the coring operation in recovering the cored rock. Portions of the cored rock mass may not be recovered because the fluid used in the drilling operations washes away portions of the rock mass during the coring operation or the rotation of the core barrel traps and grinds away portions of the rock mass. Diminished core recovery can also be attributed to voids within the rock mass. Core recovery is expressed as a percentage.

$$\text{REC} = \frac{\Sigma\,(\text{Length of the recovered core pieces, inches})(100\%)}{\text{Total length of the core run, inches}}$$

A.10 Rock Quality Designation (RQD)

Rock Quality Designation is a measure of the fracturing in a rock mass as observed in a core specimen. A high value of RQD indicates few or widely spaced fractures. RQD is valid for core diameters from 1.4 to 3.35 inches. The RQD criteria are generally based on ASTM D 6032.

$$\text{RQD} = \frac{\Sigma\,(\text{Length of intact core pieces} \geq 4\ \text{inches})(100\%)}{\text{Total length of the core run, inches}}$$

The RQD denotes the percentage of sound intact rock retrieved from a borehole. All pieces of sound intact rock core equal to or greater than 4 inches long, including intensely weathered core that cannot be hand broken, are summed and divided by the total length of the core run. An intact core is any segment of core between two open, natural discontinuities.

For weaker or more intensely weathered rock that do not appear sound, RQD, if reported, must be determined and shown with an asterisk, e.g., RQD*=15%.

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