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CP4-ES-2303 FRev. 2	**TITLE**: Borehole Logging	Page 1 of 16

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REVISION/CHANGE LOG

Revision/Change Letter	Description of Changes	Pages Affected	Date of Revision/Change
FR0	Initial bluesheeting	All	10-20-17
FR1	Non-intent revision to incorporate bluesheeting changes and to update to current format	All	11-28-17
FR1	Conducted periodic review, updated Required Review Date	All	1/7/2021
FR2	Inclusion of bedrock and revision of references to “sorting” as “grading.” Added hazard controls.	3, 5, 7, 10	5/9/2024

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1.0 PURPOSE AND SCOPE

1.1 Purpose

This procedure describes the guidelines for field description and documentation of subsurface conditions encountered during borehole drilling operations.

Borehole logging entails the description and classification of unconsolidated materials and bedrock retrieved from the borehole as drilling advances. The materials are incrementally classified using visual and manual methods of examination.

1.2 Scope

This procedure applies to the Paducah Gaseous Diffusion Plant Deactivation and Remediation (D&R) contractor employees and subcontractors that perform borehole logging at the Paducah U.S. Department of Energy Site.

2.0 REFERENCES

2.1 Use References

- CP3-WM-1037, *Generation and Temporary Storage of Waste Materials*
- CP4-ES-2700, *Logbooks and Data Forms*
- CP4-RP-1110, *Radiation Surveys*

2.2 Source References

- CP3-OP-0207, *Use of Procedures*
- Compton, R.R. 1962, *Manual of Field Geology, John Wiley & Sons Inc., New York, NY*
- United States Environmental Protection Agency. 1991, *Description and Sampling of Contaminated Soils, A Field Pocket Guide. Center for Environmental Research Information. Cincinnati, Ohio.*
- American Geological Institute (AGI) 1982, *AGI Data Sheets for Geology in the Field, Laboratory, and Office, compiled by R.V. Dietrich, J.T. Dutro Jr., and R.M. Foose, American Geological Institute, Falls Church, VA.*
- American Society for Testing Materials (ASTM), 2000, *Annual Book of ASTM Standards. Volume 04.08, Section 4, D-2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*
- Soil Test, Inc., 1975, *Munsell Soil Color Charts. Baltimore, MD.*
- JHA-10905, *Soil Sample Collection for Characterization*

3.0 COMMITMENTS

None

4.0 PRECAUTIONS AND LIMITATIONS

4.1 Precautions

- A Trenching/Excavation/Penetration (TEP) Permit will be obtained and underground utilities marked around sample locations prior to performing sampling exceeding 12 inches below grade per procedure CP3-EN-0227, *Trenching, Excavation, and Penetration Permit*.
- Personal protective equipment required by the JHA is used when handling borehole material.
- If there is a potential for chemical or debris to get into eyes, a portable eyewash must be within 10 seconds from the work area.
- Personnel shall be aware of the potential for chemical hazards in the area and shall evacuate the area and notify supervision if he or she suspects chemical exposure, such as: strange smell, vapor cloud, burning or itching sensation, spill or unknown liquid, broken lines or damage to equipment that may contain hazardous chemicals.

4.2 Limitations

None

5.0 PREREQUISITES

5.1 Review the task-specific Work Package (WP) for the sampling methods, equipment to be used, and the specific data to be collected.

5.2 Ensure PPE is available as required:

- Steel-toe boots
- High-visibility clothing (when working around roadways and heavy equipment)
- Apron if exposed to more than incidental amounts of soil/mud/water
- Face Shield when applicable.
- Cut-resistant, Leather and Nitrile Gloves when applicable.
- Safety Glasses w/ Side Shields (when applicable or posted)
- Ear Plugs (when applicable or posted)
- Hard-Hat as required (posted area/during rig work/when overhead hazards exist)
- Respiratory Protection if specified by Industrial Hygiene/RADCON
- Any additional controls or PPE specified by Industrial Hygiene and RADCON.

6.0 INSTRUCTIONS

6.1 General Requirements for Borehole Logging

Geologist

NOTE:

Appendix D, *Borehole Logbook Entry* provides an example of information gathered during borehole logging.

6.1.1 Record all observations and borehole information in a logbook according to CP4-ES-2700, *Logbooks and Data Forms*.

6.1.2 Record the following minimum information at each borehole site.

- Project Information Summary
- Percent Sample Recovery
- Depth Below Ground Surface

6.1.3 Record the following additional information as applicable to each specific site.

- Sampler Advance Information
- Field Radiological Scan Information
- Field Organic Vapor Readings
- Any information pertinent to the project.

6.2 Lithological Descriptions for Soil

NOTE:

When describing lithologies, it is useful to include references covering items such as the grain size, distribution, particle shape, degree of grading, and lithologic symbols.

6.2.1 Record basic soil lithologic data including, but **NOT** limited to, lithologic names, texture, composition, color, bedding, and lateral and vertical contacts.

6.2.2 Capitalize primary lithology in the description **and** make it the first entry.

6.2.3 Determine the predominant lithology or lithologies within the sample intervals using the grain-size classification guide (using this procedure or a guide provided for use in the field).

NOTES:

Predominantly coarse-grained materials are subclassified based on relative percentage of coarse- and fine-grained fractions, and whether the material is poorly or well graded. A poorly graded sand, for example, is a sand composed of particles of relatively uniform size, while a well-graded sand consists of a more or less uniform distribution of coarse to fine particle sizes.

Samples from split spoons and small-diameter core tools are **NOT** always representative of coarse-grained material. Be sure to check driller's log and soil cuttings for boulders, cobbles, gravels, etc., that were encountered during advancement of the boring and note their presence in the remarks section of the Borehole Log.

6.2.4 **If** the soil portion comprises more than 50 percent SAND and GRAVEL, **then** classify the sediment as coarse-grained material, SAND or GRAVEL, depending on which portion is greater, or **if** approximately 50-50, **then** SAND AND GRAVEL.

6.2.5 **If** the soil portion comprises more than 50 percent SILT and CLAY, **then** classify the sediment as fine-grained material, SILT or CLAY, depending on which portion is greater and include modifiers such as SANDY SILT, SILTY CLAY, etc., as appropriate.

NOTE:

Because of the difficulty in distinguishing between silt and clay, it is not necessary to provide the relative percentage of each.

6.2.6 Classify **both** organic and inorganic silt and clay particles too small to be seen macroscopically based on their relative percentages, as well as those of coarse-grained constituents (i.e., sands and gravels), to the nearest 5 percent (ASTM 2000).

NOTE:

Because of the fine size of clay and silt, physical properties other than grain size must be used as criteria for identification in the field. The dilatancy or "shaking test" may be used to distinguish between the fractions of clay and silt. In this test, a small amount of sediment is mixed with water to a very soft consistency in the palm of the protected hand. The back of the hand is then lightly tapped. **If** the sediment is silty, **then** water rises quickly to the surface of the mixture and gives it a glistening or shiny appearance.

6.2.7 Determine the property of plasticity that is characteristic of clays by performing the simple field test in Steps 6.2.8 and 6.2.9.

6.2.8 Roll a sample of moist sediment in the palm of the protected hand.

NOTE:

If the sample can be rolled into a long thin thread in the palm of the protected hand, **then** it contains a significant amount of clay.

6.2.9 Describe the plasticity of the sample based on the following acceptable terms.

- Non plastic
- Low plasticity
- Medium plasticity
- High plasticity

6.2.10 **If** the soil is "Fill Materials or Pavement" (i.e., any materials emplaced by man such as artificial fill, aggregate, concrete, pavement) occurring at the ground surface or encountered in the subsurface during borehole advancement, **then** describe the material in terms of the Unified Soil Classification System (USCS) in Appendix B, *Graphics and Symbols Explanation.*

6.2.11 Record a description indicating its depth below ground surface, as well as its color, composition, thickness, and any other distinguishing features.

NOTE:

The "Percentages of Secondary and Tertiary Lithologies" table provides a set of descriptive adjectives that shall be used to identify secondary and tertiary lithologies based on the estimated percent composition.

6.2.12 Estimate the percentages of secondary and tertiary lithologies.

6.2.13 **If** the sample contains mixed-grain sizes, **then** estimate the relative percentages of the sediment sizes within the sample using the following information.

"Percentages of Secondary and Tertiary Lithologies"

Description	Percent Composition
Trace (tr)	< 5%
Trace-little (tr-ltl)	5-11%
Little (ltl)	12-24%
Some (sm)	25-34%
"Y" ending	35-44% (e.g., silty sand)

NOTE:

The geologist may use abbreviated qualifying adjectives as presented in Appendix C, *Standard Abbreviations for Lithological Descriptions.*

6.2.14 Identify applicable secondary modifiers (e.g., density, grain size, grading, structural/textural features, bedding, laminations).

6.2.15 Determine the relative density for sand and gravel by using the "Standard Penetration Test for Density of Sand and Gravel" table when standard penetration test results are available (otherwise make an estimate), "Standard Penetration Test for Consistency of Clay and Silt" table, or the "Modified Consistency Test for Clay and Silt" table.

NOTE:

A 2-inch outside-diameter split spoon sampler is advanced through the soil with a 140 pound hammer free-falling 30 inches (or equivalent mechanical hammer) over a 2-foot interval. The number of hammer blows required to advance the sampler each 6-inches of its 2-foot length is recorded. The middle two blow counts are summed to calculate blows per foot (N).

6.2.16 Estimate the relative density of a sand or gravel, or the consistency of a clay or silt, by using the standard penetration test where an "N" value is used to correlate the soil density or consistency.

6.2.17 **When** available, use the "N" values from the standard penetration test described in the following table to describe soil density.

Standard Penetration Test for Density of Sand and Gravel

Term	"N" Blows
Very Loose	≤ 5
Loose	6-10
Medium Dense	11-30
Dense	31- 50
Very Dense	≥ 51

6.2.18 To describe soil consistency, use the terms provided in the "Standard Penetration Test for Consistency of Clay and Silt" table, using the standard penetration test with a standard split spoon sampler and drop hammer to determine what "N" value relates to the corresponding consistency, or **if** the standard penetration test information is **NOT** available, **then** use the "Modified Consistency Test for Clay and Silt" table for the modified consistency test.

Standard Penetration Test for Consistency of Clay and Silt

Term	"N" Blows
Very Soft	≤ 3
Soft	4-5
Medium Stiff	6-10
Stiff	11-15
Very Stiff	16-30
Hard	≥ 31

Modified Consistency Test for Clay and Silt

Description	Field Test
Very Soft	Exudes between fingers when squeezed in hand.
Soft	Can be molded by light finger pressure.
Medium Stiff	Can be molded by strong finger pressure.
Stiff	Cannot be molded by fingers; can be indented by thumb.
Very Stiff or Hard	Can be indented by thumb nail.

6.2.19 Determine the color of moist soil samples according to ASTM method D-2488-00.

6.2.20 Record the numerical color description obtained from a Munsell Soil Color Chart before the color description.

NOTE:

The description of particle angularity is applicable to the description of boulder, cobble, gravel, sand, and some components of the soil.

6.2.21 Determine the Angularity/Particle Shape (for coarse sand and larger materials, such as gravel) using the "Particle Shape" table.

Particle Shape

Term	Selection Criteria
Angular	Particles have sharp edges and relatively plane sides.

Subangular	Particles have relatively plane sides, 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.

6.2.22 Record any other relevant observations, such as moisture content, signs of contamination, cementation of particles, grading, bedding, contacts between strata, and nonconformities.

6.2.23 Determine moisture content and describe in the field logbook using one of the terms in the "Moisture Content" table.

Moisture Content

Term	Observed Condition
Dry	Absence of moisture, dusty, dry to touch.
Moist	Damp, but no visible water.
Wet	Visible free water, usually soil is below the water table.

6.2.24 **If** observed soil moisture is due to the presence of free product, **then** document the condition in the field logbook.

6.2.25 Determine structural features and describe in the field logbook.

6.2.26 **If** an intact sample of soil is collected using a soil sampler or coring tools, **then** describe any evident structural features as indicated below.

- Blocky - cohesive soil that can be broken down into small angular lumps, which resist further breakdown.
- Fissured - breaks along definite planes of fracture with little resistance to fracturing.
- Homogeneous - same color and appearance throughout.
- Laminated - alternating layers of varying material or colors with the layers less than 1/4 inch thick.
- Lensed - Inclusions of small pockets of different soils.
- Slickensided - fracture planes appear polished, glossy, and sometimes striated.
- Stratified - alternating layers of varying material or color with layers at least 1/4 inch thick.

6.2.27 Determine the grading of the soil **and** describe the distribution of particle sizes in the sand or gravel components by the "Distribution of Particle Sizes" table grading and sorting terminology:

Distribution of Particle Sizes

Grading	Sorting	Criteria
Well-graded	Poorly sorted	The material has a wide range of particle sizes with substantial amounts of intermediate particle sizes.
Poorly graded	Well sorted	The material consists primarily of one particle size.
Gap graded	NA	The material has a wide range of particle sizes with intermediate sizes obviously missing.

6.2.28 **If** coarse-grained fractions are present in the sample, **then** determine the following:

- Range of particle size (for sands only; e.g., fine- to medium-grained)
- Angularity (e.g., angular, sub-angular, sub-rounded, or rounded)
- Particle shape (only if flat, elongated, or flat and elongated)
- Approximate percentages of sand, gravel, cobbles, and/or boulders
- Maximum particle size (measured in inches along longest dimension)

6.2.29 **If** coarse- or fine-grained materials are present in the sample, **then** determine the following, as applicable:

- Soil type (e.g., colluvium, regolith)
- Type and relative percentage of lithologies observed (e.g., quartz, mica)
- Soil name (e.g., Bay Mud), if known
- Degree of grading (e.g., poorly graded, moderately well graded)
- Degree of cementation (i.e., weak, moderate, or strong)
- Stains (e.g., iron-oxide, hydrocarbon)
- Presence of iron or calcareous nodules
- Odor (e.g., organic, chemical)
- Percentage of roots or other organic material
- Plasticity

6.2.30 Once the information has been gathered for the sample, record the sample description in the field logbook.

NOTE:

Example:

A sample is visually examined in the field and is found to be comprised of approximately 55 percent medium-grained sand and 40 percent silt. The structure of the sample is massive and the color is yellowish brown. The sample is damp to moist, and the standard penetration test produced a penetration resistance (N) of 16. The description would be as follows: SILTY SAND (SM), 10YR5/6, Yellowish Brown, medium- grained, trace clay, moist, firm.

6.2.31 In order to maintain consistency, present the lithologic description in the following order

- MAJOR LITHOLOGY (USCS CLASSIFICATION SYMBOL) followed by secondary constituents that may include these: numerical color designation; name of color; grain size; grading; grain shape; other lithologic components; sedimentary structures/bedding; consistency or relative density; moisture; and other descriptive modifiers as necessary.

6.2.32 After core samples have been logged, place an index card indicating the borehole identification number and core depth adjacent to each core **and** photograph the cores as required by the task-specific WP.

6.2.33 Record the photograph numbers in the field logbook, as applicable.

6.2.34 **If** the borehole is abandoned after drilling operations are completed, **then** record the backfill and type of sealing material (e.g., bentonite pellets, high-solids bentonite grout, cement, cement-bentonite grout) along with the date of disposition in the field logbook.

6.2.35 Handle core samples after borehole logging (e.g., placing cores into core boxes, labeling top of core, etc.) according to the requirements in the task-specific WP.

7.0 ACCEPTANCE CRITERIA

None

8.0 POST PERFORMANCE WORK ACTIVITIES

8.1 As necessary, request survey of borehole logging equipment from radiological areas, in accordance with CP4-RP-1110, Radiation Surveys.

8.2 Manage waste generated during borehole logging activities according to CP3-WM-1037, *Generation and Temporary Storage of Waste Materials*.

8.3 Ensure field logbook entries are checked for technical adequacy and conformance to this procedure according to CP4-ES-2700, *Logbooks and Data Forms.*

9.0 RECORDS

9.1 Records Generated

The following records may be generated by this procedure:

- Field Logbook Entries
- Borehole Photographs

Forms are to be completed in accordance with CP3-OP-0024, Forms Control.

9.2 Records Disposition

The records are to be maintained in accordance with CP3-RD-0010, *Records Management Process*.

Appendix A – Acronyms/Definitions

ACRONYMS

AGI – American Geological Institute

ASTM – American Society for Testing and Materials

JHA – Job Hazard Analysis

USCS – Unified Soil Classification System

WP – Work Package

DEFINITIONS

Depth Below Ground Surface - The depth refers to the depth below the ground surface. All depths shall be recorded in feet. The scale of the log is determined by the depth column. The scale may be adjusted as needed by the logger for the best and most accurate representation of the data.

Lithology - The scientific study and description of rocks or soil, especially at the macroscopic level, in terms of color, texture, and composition.

Percent Sample Recovery - The recovery documents the amount of sample recovered per sample attempt. Split spoon sample recovery shall be recorded as the portion of sample recovered (in inches) out of the total 2-foot attempt and later converted to show percentage. **When** using a continuous core tool, indicate in the total length of core recovered and the length of interval sampled.

Project Information Summary – The project information summary portion of borehole logging contains general information. The project information summary may include project number, borehole number of drilling location, site location, drilling methods, total depth and diameter of borehole, start and completion dates, depth to static water, depth to first water encountered, angle, ground surface elevation, hammer weight/fall, and name of logger.

Sampler Advance Information - Blow counts provide a quantitative estimate of the mechanical properties for a particular sample interval. Each individual blow count refers to the number of hammer blows required to advance the split spoon 6 inches. The blow counts/core run is used to record the number of blows it takes to drive the split spoon sampler 6 inches or to exhibit the complete interval where a continuous core tool was advanced. Standard penetration test results are based on the use of a 140 pound hammer dropped a distance of 30 inches. Blow counts shall be recorded as a number for each 6-inch interval of the sampler and shall be recorded in groups of four (e.g., 6/10/10/16) where applicable.

Appendix B – Graphics and Symbols Explanation

UNIFIED SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (little or no fines)		GW	well-graded gravels, gravel - sand mixtures, little or no fines
				GP	poorly-graded gravels, gravel - sand mixtures, little or no fines
	more than 50% of coarse fraction retained on no. 4 sieve	GRAVELS WITH FINES (appreciable amount of fines)		GM	silty gravels, gravel - sand - silt mixtures
				GC	clayey gravels, gravel - sand - clay mixtures
more than 50% of material is largerthan no. 200 sieve size	SAND AND SANDY SOILS	CLEAN SANDS (little or no fines)		SW	well-graded sands, gravelly sands, little or no fines
				SP	poorly-graded sands, gravelly sand, little or no fines
	more than 50% of coarse fraction passing on no. 4 sieve	SANDS WITH FINES (appreciable amount of fines)		SM	silty sands, sand - silt mixtures
				SC	clayey sands, sand - clay mixtures
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
				CL	inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
				OL	organic silts and organic silty clays of low plasticity
more than 50% of material is smaller than no. 200 sieve size	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	inorganic silts, micaceous or diatomaceous fine sand or silty soils
				CH	inorganic clays of high plasticity
				OH	organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS				PT	peat, humus, swamp soils with high organic contents

NOTE: dual symbols are used to indicate borderline soil classifications

Appendix C – Standard Abbreviations for Lithological Descriptions

ABUND	Abundant	MIN	Minimum
APPROX	Approximately	MINL	Mineralized
BED	Bedding	MOD	Moderately
BL	Blue	MOTT	Mottled
BLDR/S	Boulder/s	NODS	Modules
BLK	Black	NUM	Numerous
BLSH	Bluish	OCC	Occasional/y
BP/S	Bedding Plane	OR	Orange
BR	Brown	ORSH	Orangish
BRSH	Brownish	ORG	Organics
C	Common	POSS	Possible/bly
CBL/S	Cobble/s	PROB	Probable/bly
CEM	Cement/ed	RD	Red
CHT/Y	Chert/y	RDSH	Reddish
CL/Y	Clay/ey	REF	Reference
CSG	Casing	RK	Rock
DK	Dark	RTS	Roots
ELEV	Elevation	SAT	Saturated
EST	Estimated	SCATT	Scattered
F	Fine	SD/Y	Sand/y
FE	Ferrous	SEV	Several
FOSS	Fossil/iferous	SL	Slightly
GR	Gray	SLT/Y	Silt/y
GRSH	Grayish	SM	Some
GRN	Green	SML	Small
GRNSH	Greenish	SPLS	Samples
GRND	Grained	ST	Stained
GVL/Y	Gravel/ly	STKS	Streaks
HD	Hard	STRAT	Stratified
HOR	Horizontally	T	Tan
LAM	Laminated	TRSL	Topsoil
LGT	Light	TR	Trace
LSE	Loose	V	Very
LTL	Little	VAR	Variable/bly
LYD	Layered	W	With
LYS	Layers	WD	Wood
LZ	Lenses	WEA	Weathered
M	Medium	WHT	White
MASS	Massive	WTR	Water
MATL	Material	YEL	Yellow
MAX	Maximum	YELSH	Yellowish
MIC	Micaceous	ZN/S	Zone/s

Appendix D – Borehole Logbook Entry (Example)